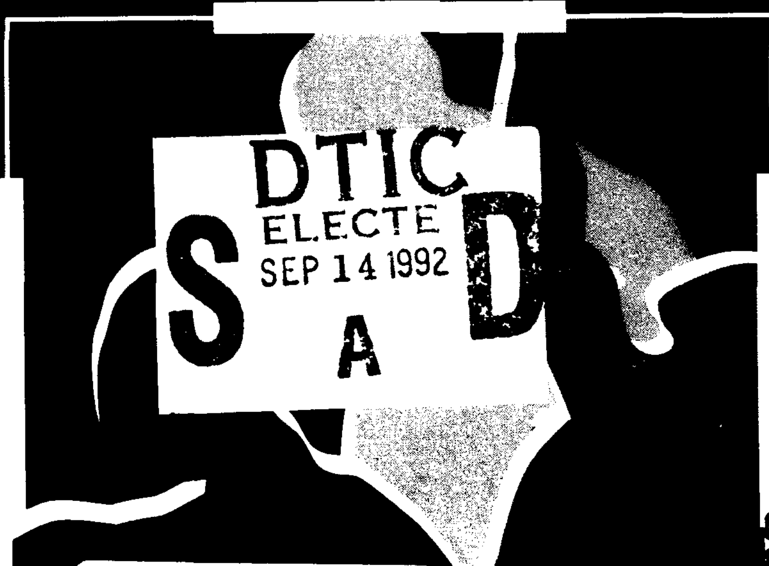
BODY COMPOSITION AND PHYSICAL PERFORMANCE



INSTITUTE OF MEDICINE

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COMMITTEE ON MILITARY NUTRITION RESEARCH: BODY COMPOSITION AND PHYSICAL PERFORMANCE

SPECIAL REPORT

BERNADETTE M. MARRIOTT
JUDITH GRUMSTRUP-SCOTT

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Bernadette M. Marriott and Judith Grumstrup-Scott, Editors

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The serpent has been a symbol of long life, healing, and knowledge among almost all cultures and religions since the beginning of recorded history. The image adopted as a logotype by the Institute of Medicine is based on a relief carving from ancient Greece, now held by the Staatlichemuseen in Berlin.

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Preface

This publication on body composition and physical performance is another from a series of workshops that have been sponsored by the Committee on Military Nutrition Research (CMNR, the Committee) of the Food and Nutrition Board, Institute of Medicine, National Academy of Sciences. Other workshops or mini-symposia have included such topics as nutrition and physical performance, cognitive testing methodology, and fluid replacement and heat stress. These workshops are a part of the response the CMNR provides to the Assistant Surgeon General of the U.S. Army (U.S. Army Medical Research and Development Command, Frederick, Maryland) to issues that are brought to the Committee through the Military Nutrition Division of the U.S. Army Institute of Environmental Medicine (USARIEM) at Natick, Massachusetts.

FOCUS OF THE REPORT

The relationship of body composition to performance of physical tasks is of major interest to the military. Not only is it important in the decisions of acceptance or rejection of recruits for military service, but it also has significant implications for the individual relating to retention and advancement while in the services. There are financial implications as well for the military services, due to the high cost of training replacements when individuals are discharged for failure to meet the established standards. The discharge of highly trained and experienced specialists has significant additional implications concerning unit readiness and performance.

The application of body composition standards in the military on a rational and equitable basis based on ethnicity, gender, and age is therefore an important issue. A perspective on the current outcome of the applications of height, weight, and body composition standards for entrance or retention in the military services was succinctly stated by James A. Vogel, Director, Occupational Health and Performance, USARIEM, in his introductory remarks to the workshop, which was held February 6, 1990 at the National Academy of Sciences, Washington, D.C.

> Every day potential new Army recruits are turned away at the recruiter's door for the reason of overweight or overfatness. Ironically, they often go next door to the Navy or Air Force recruiter where they are accepted. I am referring to young women who are unable to meet the Army's entry standard for body weight.
>
> An outsider might assume that the services have weight-fat standards to ensure that personnel can meet the physical demands of military service, that is, that they are performance driven. This may only be partially true. In the Army, at least, it is apparent that an important factor in the Army's fat standards is appearance. The Navy, on the other hand, has established health criteria as important for its body fat standards. Are appearance and health criteria compatible with physical performance criteria? These questions lead us to our goals for this workshop:
>
> 1. What is the relationship between body composition and physical performance in terms of the military's needs?
> 2. Can the service's needs in performance, appearance, and health be blended together in a body composition standard?
> 3. When the services already have performance standards (various fitness and occupational tests), do we also need a body composition standard?
>
> Those of us within the services who are dealing with weight and fat standards need to revisit this issue - at a theoretical and mechanistic level, at a practical or job task level, and at a population and policy level.
>
> We cannot look at this body composition issue in isolation. So in addressing our goals, we must consider them in the military context where other factors come into play.

The proceedings of this workshop are published here to provide a) a review of current knowledge on the relationship of body composition to physical performance, b) a discussion of the application of this data base to accession and retention standards in the military services, and c) an evaluation and recommendations for consideration by the military in relating body composition to physical performance. While the Committee on Military Nutrition Research recognizes that body composition, physical performance, and health status are closely linked to the amounts and types of foods ingested, a comprehensive discussion of nutrition as related to body composition and performance was deemed to be beyond the scope of this workshop. The CMNR has limited the report to a review of the scientific evidence relating physical performance to body weight and composition. It is anticipated that this information will aide the military in establishing body composition standards that are more appropriate to the task performance requirements of military personnel. In addition, the information from this workshop may be of more general interest to those civilians concerned with establishing physical testing criteria for jobs requiring minimum physical performance standards.

HISTORY OF THE COMMITTEE

The Committee on Military Nutrition Research (CMNR) was established in October, 1982 when the Assistant Surgeon General of the U.S. Army requested the Food and Nutrition Board (FNB), National Academy of Sciences, to establish a committee to advise on the need for and conduct of nutrition research and related issues for the U.S. Department of Defense. The overall tasks of the Committee are

- to identify nutritional factors that may critically influence the physical and mental performance of military personnel under all environmental extremes,
- to identify deficiencies in the existing database,
- to recommend research that would remedy these deficiencies,
- to recommend approaches for studying the relationship of diet to physical and mental performance, and
- to review and advise on standards for military feeding systems.

Within this context the CMNR was asked to focus on nutrient requirements for performance during combat missions rather than requirements for military personnel in garrison, because the latter were judged not to differ significantly from those of the civilian population.

Although the Committee membership has changed periodically, the disciplines represented have consistently included human nutrition, nutritional biochemistry, performance physiology, food science, and psychology. When issues have been presented to the CMNR by the Army that require broader expertise than what exists within the Committee, or for which the Committee would like additional information or opinions, workshops have been convened. These workshops provide additional state-of-the-art scientific information for the Committee to consider in their evaluation of the issues at hand.

COMMITTEE TASK AND PROCEDURES

In 1989, personnel from USARIEM raised the question with the CMNR of the relationship of body composition to physical performance. Of particular interest was the application of then current height-weight standards in recruitment and retention of military personnel to the performance of military tasks. Although the tasks of military personnel are increasingly diverse, the Army contends that all individuals need to maintain a certain level of physical fitness to preserve the combat readiness of the services in general. However, with the increasing diversity of military personnel in terms of gender, ethnicity, and age, there was a concern whether current standards were appropriate and were uniformly applied in recruitment and retention. The applicability of these standards to the mission requirements of the services was also questioned. The CMNR reviewed these issues and concluded that a workshop was needed to review the literature, provide additional information on military standards, provide the most current research findings from within the Army related to this issue, and hear interpretation of this issue from experts in related fields.

A small planning group was given the task of identifying the pertinent topics and the participants. This task force, comprised of Col. E. Wayne Askew and James A. Vogel of USARIEM and CMNR members Ed Horton, Richard Atkinson, Robert O. Nesheim, and FNB Staff Officer Susan Berkow, met at USARIEM in the fall of 1989 to plan the workshop. The workshop outline and participants were reviewed by the CMNR at its December 1989 meeting, and the workshop was held February 6, 1990, at the National Academy of Sciences in Washington, D.C.

The invited speakers were chosen for their specific expertise in the areas of body composition, performance, and obesity. They were asked to provide in-depth reviews of their area of expertise as it directly applied to a series of questions prepared by the CMNR and make recommendations on the issues. Speakers subsequently submitted written versions of their presentations.

The workshop format was a formal presentation by a speaker followed by questions and a brief discussion with Committee members and other participants. At the end of the presentations, a general discussion of the overall issues was held. The next day, the CMNR met in executive session to review the various issues, draw some tentative conclusions, and make assignments for draft reviews and summaries of specific topics by various Committee members. An initial summary paper discussing some of the issues was prepared by one of the Committee members, Joël Grinker, to aide the CMNR in focusing the draft recommendations (See Part III). A subcommittee composed of Joël Grinker, Richard Atkinson, and Richard Jansen worked separately and together using the authored papers and additional reference material to draft the summary and recommendations that were reviewed and approved by the CMNR.

The summary and recommendations of the CMNR are included as Part I, and the papers presented at the workshop are included as Part II of this book. Part I has been reviewed anonymously by an outside group with expertise in the topic area and experience in military issues. The authored papers in Part II and Joël A. Grinker's paper in Part III have undergone limited editorial change, have not been reviewed by the outside group, and represent the views of the individual authors.

ACKNOWLEDGMENTS

As Committee chair I wish to acknowledge the assistance of the FNB staff: Susan Berkow, who participated in planning and organizing the workshop prior to her leaving the FNB, Al Lazen, Ph.D., former acting director of the FNB for his considerable contribution acting as staff officer during the workshop and in the interim before Bernadette Marriott joined the FNB as program officer for the CMNR. Bernadette's strong technical assistance and organizational skills have been a major factor in pulling the proceedings together and bringing them to publication. I appreciate the extensive work of Joel Grinker in preparing the discussion paper that focused Committee discussion on essential areas of concern. I particularly want to acknowledge the major inputs by Richard Atkinson in drafting an initial review of the proceedings and Richard Jansen in bringing together the various sections provided by Committee members into a consistent format. The Committee is grateful for their joint effort in drafting, reviewing, and editing the summary, conclusions, and recommendations.

I also wish to acknowledge on behalf of the Committee, the assistance of James Vogel and others from his division at USARIEM and Col. Askew and his group at USARIEM. The insightful comments of Col. David Schnakenberg during the workshop were also useful to the Committee in summarizing the proceedings. Major Karl E. Friedl was particularly helpful in providing the Committee with current information on recent changes in Army regulations. The critiques of the reviewers, Cathie Woteki, and FNB CMNR liaison, Johanna Dwyer, provided helpful insight to the development of this final document. The editorial efforts of Judith Grumstrup-Scott are gratefully acknowledged. The Committee is also grateful to Vicki L. Friedl, History-Bibliographer, Mugar Library, Boston University, for her research and suggestions about reference styles for government documents. The assistance of Connie Rosemont, FNB research assistant, and Valerie Breen, CMNR project assistant, in word processing, editing, and proofreading this report is greatly appreciated.

Finally, I wish to acknowledge the individual and collective contributions of the Committee members. They represent a fine, unselfish example of busy professionals volunteering their limited time for the consideration of issues important to our national defense. I am stimulated by the expertise and dedication of this group as we work together on CMNR business.

ROBERT O. NESHEIM, *Chairman*
Committee on Military Nutrition Research (CMNR)

Contents

PART I

Overview

PART I CONSISTS OF TWO CHAPTERS. Chapter 1 provides the background for the report. It describes the task as presented to the Committee on Military Nutrition Research (CMNR) by the Department of Defense through the *U.S. Army Medical Research and Development Command, Frederick, Maryland* and its Grant Officer Representative from the Military Nutrition Division, U.S. Army Institute for Environmental Medicine (USARIEM). In developing the plans for the workshop and report, a task force of the CMNR, working with their military liaison, developed a specific set of questions on which the workshop and report are based. These questions are listed in Chapter 1 together with: an overview of the relevant areas of concern, the operational definitions of the pertinent terminology, a review of current military standards as they relate to accession and retention of personnel, and a summary of the committee's interpretation of the current scientific knowledge in these areas. Chapter 2 presents the committee's findings and conclusions. Chapter 2 also includes specific and general recommendations developed by the CMNR in response to the set of questions, presented in Chapter 1, that defined their task as a committee.

1

Introduction and Background

THE COMMITTEE'S TASK

The Committee on Military Nutrition Research (CMNR, the Committee) of the Food and Nutrition Board (FNB), Institute of Medicine (IOM), National Academy of Sciences (NAS), was asked by the Department of Defense to review and comment on the current physical criteria for recruitment and retention of personnel in the various military services. These criteria are largely based on direct measurement of height and weight, on indirect assessment of body composition, and on the subjective criteria of a trim military appearance. With the advent of a more diverse military population in terms of ethnic origins and increasing numbers of women, there was concern about the applicability of the existing standards to the diverse pool of volunteers.

The seven principal questions the CMNR was asked to address were:

1. Can or should physical performance assessments be used as criteria for establishing body composition standards in the services?
2. What is the relationship between body composition and performance?
3. The services currently use a maximal body fat standard. Should they also establish a minimum fat-free or lean body mass standard?
4. What factors should be considered in setting body composition standards?
5. Are performance and body composition standards redundant?
6. If performance criteria exist, are weight-fat standards needed?
7. How does one rationalize the different uses of body composition for performance, appearance, and health?

To assist the CMNR in responding to these questions, a workshop was convened on February 6–7, 1990, that included presentations from individuals familiar with or having expertise in current military recruitment and retention criteria, military task performance, body composition and physical performance, racial or ethnic differences in body composition, and gender differences in body composition and physical performance. The invited speakers discussed their presentations with Committee members at the workshop and submitted written reports. The Committee met after the workshop to discuss the issues raised and information provided. Committee members later reviewed the workshop presentations and drew on their own expertise and the scientific literature to develop the following summary, conclusions, and recommendations.

CURRENT PHYSICAL STANDARDS FOR ACCESSION AND RETENTION IN THE MILITARY

The rationale for physical standards for accession and retention in the military, according to Army regulation (AR) 600-9 is ". . . to insure that all personnel are able to meet the physical demands of their duties under combat conditions and present a trim military appearance at all times" (AR 600-9, 1986). Current physical standards place upper limits on body fat as assessed from anthropometric measurements, including height, weight, skinfold thicknesses, body diameter measurements, and body circumference measurements. Body composition in terms of body fat mass (BFM) and lean body mass (LBM) is calculated from these measurements. Anthropometric measurements are used because they are inexpensive to obtain, relatively easily learned, and adaptable to field conditions.

Accession Standards

For accession, personnel are initially screened by height and weight. Standard tables have been developed for ease of use by field commanders and recruitment staff to identify personnel who fall outside acceptable values of weight-for-height. These standards differ among the military services, based on the perceived needs of each service, and are included in Appendix A. If an individual is identified as not meeting acceptable standards of weight-for-height, an assessment of body composition by anthropometric techniques is performed. The formulas used for determining body composition also differ among the services (Appendix A). The Army uses a combination of height, weight, and circumferences of neck and waist in men and of height, weight, and circumferences of neck, forearm, wrist, and hips in women to calculate percent body fat. The rationale for these particular measurements is based on studies done at the U.S. Army Institute for Environmental Medicine (USARIEM) on 1,126 men and 266 women (Vogel et al., 1988). The Navy uses height, weight, and circumferences of neck and waist for men (Hodgdon and Beckett, 1984a), and height, weight and circumferences of neck, waist, and hips in women (Hodgdon and Beckett, 1984b). The Marines use measurements of height, weight, and neck circumference for men (Wright et al., 1981) and measurements of height, weight, flexed biceps, forearm, neck, waist, and thigh circumferences for women (Wright et al., 1980). The Air Force uses height, weight, and biceps measurements for men (Fuchs et al., 1978) and height, weight, and forearm measurements for women (Brennan, 1974).

Retention Standards

For retention, military personnel are evaluated on a regularly scheduled basis for height, weight, and/or body circumference and are required to perform a test of aerobic fitness (Appendix B). For the Army and Navy, the weight-height and body fatness standards for admission allow a greater degree of overweight than do the standards for retention. The rationale for this policy is that high levels of physical activity during basic training result in a loss of body fat and a gain in LBM in the overfat individuals. Thus military recruits can be accepted that exhibit higher body weight for their height than will subsequently be permitted by retention standards. For the U.S. Air Force and recently the U.S. Marine Corps[1] retention standards are also used for accession.

PROCEDURES USED BY THE MILITARY SERVICES FOR FAILURE TO MEET PHYSICAL OR PERFORMANCE STANDARDS

It is generally accepted that body weight 20 percent above the population standard of height for weight is obesity. Although the military services differ in their acceptable standards, all services have clearly stated weight control and physical fitness programs that are detailed in their retention standards (Appendix B). Typically, when individuals fail to meet the weight/height standard at the regularly scheduled evaluation, they are further assessed for body fat using anthropometric measurements. On the basis of these measurements and medical review, they are assigned to a program of diet and exercise for a specific time period that varies with each service. At set time inter-

[1]Effective June 1, 1992 the U.S. Marine Corps began using the height, weight, and body fat retention standards (Marine Corps Order 6100.10A with Change 1) for both retention and accession of personnel.

vals, the individual's progress is reviewed, and the weight control program is evaluated. For all services, there is a specific total time limit established for an individual to meet the requirement prior to final evaluation for separation. Individuals who do not lose sufficient weight or body fat are discharged from the service. Physical performance standards follow a similar procedure.

However, also of concern here is that individuals who do lose weight and meet the service retention standards are at high risk to regain this weight with advancing age. Numerous studies have documented an increase in body weight and percent body fat with increasing age (Borkan et al., 1983; Bray, 1976). There is also evidence that excessive body fat is not necessarily a lack of personal discipline as stated in AR 600-9 (1986) but a chronic disease of complex and multifactorial origins (Bray, 1976, 1978, 1989). A genetic component is involved (Bouchard et al., 1990; Stunkard et al., 1990), and some investigators (Keesey, 1980) believe there is a level of body weight that is defended from change under equilibrium conditions. According to this hypothesis, when individuals attempt to lose weight below a set level, body defense mechanisms come into play that limit the amount of weight lost unless there are major changes in lifestyle, eating, and exercise (Keesey, 1980; Keys et al., 1950). Studies in humans have shown that there is frequently minimal or no relationship between food intake and body fatness for individual people (Thomas et al., 1961).

METHODS FOR ASSESSING BODY COMPOSITION

Definition of Terms

Because a number of recent articles have reviewed methods for assessing human body composition (Buskirk, 1987; Heymsfield and Waki, 1991; Lukaski, 1987; Smalley et al., 1990), a detailed review of methodology will not be presented here. This section will begin with a brief review of the operational definitions used in this report, followed by an overview of methods for assessing body composition as directly applied to the military services.

Body composition, in the context of these proceedings, refers to the relative proportion of lean body mass (LBM) and body fat mass (BFM) within the body. LBM can further be subdivided into muscle mass, body water, and bone mass. These two approaches are commonly referred to as a two-compartment model (LBM and BFM) or a four-compartment model (BFM, muscle mass, body water and bone mass) for assessing body composition. Because the main concern of the military is LBM and BFM as related to performance, the two-compartment model is generally used by the services. However failure to account for differences in bone density can lead to systematic errors in measurements, so the two-compartment model must be used with caution when applied to an individual. Fat-free mass (FFM) refers to the portion of the body remaining after all fatty substances are extracted. For the purposes of this report, FFM will be used interchangeably with LBM.

Anthropometric Measurements

The most commonly used anthropometric assessments are height, weight, skinfold thicknesses, body diameter, and body circumference measurements. Numerous previous studies in the literature have used combinations of anthropometric measurements to estimate body fat. It is well recognized that there are problems with this approach. A major criticism of the use of anthropometric data to calculate body fat is that the formulas are based on population data, and when such formulas are used to calculate body fat of an individual, a significant error may result (Lukaski, 1987). In other words, the formula may have a small error when predicting body fat for a population but a greater error for predicting body fat for a given individual.

Another problem with anthropometric measures is observer error. Hodgdon (Chapter 4) discussed the difficulty of training military personnel to accurately measure skinfolds and body circumferences. After performing 150 trial skinfold measurements, only 24 percent of personnel were proficient. However, 68 percent of trainees had reached proficiency after only 45 measurements of body circumferences. In cross-validation studies, the standard errors for the formulas used by the different services ranged from 3.63 percent to 5.17 percent. Thus, based alone on errors in measurement and inherent individual differences, these data indicate that it would be possible to inappropriately target an individual for separation or to reject a new recruit. Due to these concerns, the military should consider the importance of validation of their measurements through multiple observations on each individual.

When measurements of height and weight are combined with measurements of waist and hip circumferences, a better assessment of long-term health risk may be obtained. Increasing evidence suggests that the deposition of fat in the abdominal area, particularly in the intraabdominal depots, is associated with a variety of diseases including hypertension, diabetes mellitus, hyperlipoproteinemias, and increased cardiovascular risk (NIH, 1989). Using these measurements to screen recruits at accession may help select individuals with lower long-term risk for health problems. Using them in older military personnel also may identify individuals, with or without obesity, who are at increased health risk, and who should receive special attention for weight or body fat reduction.

Densitometry

Densitometry has generally been considered the standard against which all other techniques for measuring body composition are compared. However, the formulas on which this method is based were calculated originally from carcass analysis of only seven individuals (Brozek et al., 1963; Forbes et al., 1953; Siri, 1956). In this procedure, which assumes the two compartments of LBM and BFM, the density or specific gravity of the body is measured by weighing the body in air and under water, with correction made for residual air in the lungs (Behnke et al., 1942; Keys and Brozek, 1953). The relative proportion of the two compartments is calculated, with assumptions made about the density of the two compartments. The density of the body fat is assumed to be constant. Although interstitial muscle fat has a slightly higher density than depot fat, this assumption does not usually lead to a significant error. Much more of a problem is the assumption of a density for LBM, because it can be quite variable depending on age, race, physical activity, gender, and possibly other variables, such as bone mass.

Underwater weighing has also not been well standardized. For example, the influence of age, gender, race, and ethnic group has not been evaluated. The relatively greater lean mass, particularly bone mass, that is present in many Blacks further adds to the inaccuracy of the formulas for this population. The Committee recognizes that underwater weighing could eventually be improved if the two-compartment model in present use applied densities for lean body mass that are specific for age, gender, and ethnicity.

As with the calculation of body composition from anthropometric data, underwater weighing measurements may have significant error. The technique requires special equipment and highly specialized training, which limit its use to specialized facilities. Expensive equipment and the time required to train technical staff, coupled with the fairly long time it takes to do a measurement of a single individual, precludes this technique from being useful for accession or retention screening of military personnel.

Bioelectric Impedance Analysis

The principle on which bioelectric impedance analysis (BIA) is based is that lean tissue conducts electricity better than does fat tissue. Electrodes are placed on the arms and legs, and a low-level current is run through the individual. Impedance—resistance to the flow of electricity—is measured, and the percent body fat is calculated by a formula (Segal et al., 1988). This technique has been standardized for several populations, but as with the techniques mentioned above, it is less accurate when used in a given individual. Some training is required to achieve reasonable reproducibility, and there is significant interobserver variation. The equipment is relatively inexpensive (about \$3,000–\$5,000), and thus impedance measurement would be feasible as a technique for screening for accession or retention of personnel. Segal et al. (1988) found that the accuracy of this method is not significantly better than the results achieved with anthropometric measurements, but Lukaski et al. (1985), and Kushner and Schoeller (1986) reported that BIA is superior. It would appear that BIA, particularly with the most modern equipment, is preferable to anthropometry. However, BIA as commonly used at present, does not give any information on regional fat distribution which may be of military interest and importance. More research is needed to validate this technique.

Options Requiring Major Equipment or Time

Several techniques described in the literature are more accurate than the techniques described above, but the expense of purchasing costly equipment or the time required to perform the measurements may not make their use feasible by the military services. These techniques include dual photon absorptiometry, neutron activation, whole body potassium 40 counting, electromagnetic conductance, and body water measurement by radioactive or stable isotopes. Advances in the development of multicompartmental chemical approaches to the determination of body composition in humans have recently been summarized by Heymsfield and Waki (1991). Most of these techniques would be of great research interest for validating simple measurements that can be used on a large scale in the military, but they are less practical for routine use. Of these methods, only dual photon absorptiometry has potential for routine use as a secondary measure of body composition by the military (see review in Chapter 10). Like many new techniques additional validation studies are needed. This equipment also requires a substantial financial investment and specially trained personnel to operate.

FACTORS THAT MAY INFLUENCE BODY COMPOSITION

Age

Many studies have documented an increase in body weight and percent body fat with increasing age, at least over the age range of active duty military personnel (Borkan et al., 1983; Bray, 1976). For the majority of people, LBM decreases with age and body fat increases with age, even if body weight does not change. This fact is recognized by the military's age-adjusted standards for body weight, body fatness, and performance. Alterations in body composition with age also exacerbate the problem of differences in accession versus retention standards for excess body weight and body fatness. The rationale for the difference between accession and retention standards in some branches of the military appears to be related to high levels of physical activity during basic training, which usually produce losses in body fat and gains in LBM. Obese individuals who do not lose sufficient weight or body fat are discharged from the service.

However, individuals who lose weight and meet the service retention standards may be at increased risk to regain this weight with advancing age, may encounter increasing difficulty in achieving the body fatness standards, and may consume more resources in the form of weight reduction programs or in administrative costs for separation from the service.

Gender

Women have a higher percentage of body fat than do men. Frisancho (1984) has documented the gender-related difference in body composition based on data from the National Health and Nutrition Examination Survey (NHANES) I and II. For individuals 25 to 54 years old of average frame, fiftieth percentile triceps skinfold thicknesses ranged from 11 to 15 mm for men and 19 to 30 mm for women depending on height and weight. The corresponding ranges for subscapular skinfold thicknesses were 13 to 18 mm for men and 12 to 29 mm for women. Lohman (1981) reviewed data on skinfolds and body density and the relationship to body fatness and concluded that skinfolds predict body density with standard errors of measurement close to that expected based on known biological and technical factors. Most of the error was associated with variance related to age and gender. The biological variation in predicting body fat from densitometry was estimated at 3.8 percent for the general population (Lohman, 1981). Based on densitometry, Smalley et al. (1990) reported that men and women averaged 20.9 ± 7.6 percent and 26.3 ± 9.4 percent body fat, respectively (n = 363). These results from the general U.S. population thus provide the rationale for current gender differences in body fat standards in the military services.

Race and Ethnic Group

The majority of studies evaluating body composition have been done in Caucasians. Many investigators have recognized that the methods currently used do not accurately predict body composition in Blacks, and their applicability to other racial and ethnic groups, such as Asians, Hispanics, and Native Americans is uncertain (Malina, 1971; Mueller et al., 1987; Mueller and Malina, 1987; Zillikens and Conway, 1990). A number of speakers at this workshop discussed the problems of measurement of body composition in racial and ethnic groups (see Chapters 6, 10, 11, and 13). There is general agreement that Blacks have relatively greater bone mineral mass, and there is some evidence that muscle mass may be different in Blacks and Caucasians (Cohn et al., 1977a,b; Hampton et al., 1966; Merz et al., 1956; Pollitzer and Anderson, 1989; Schutte et al., 1984; Seale, 1959; Trotter and Hixon, 1974; Zillikens and Conway, 1990). Formulas for calculating body composition that have been developed predominantly from Caucasians or even from mixed groups may not adequately predict body composition in racial and ethnic subgroups. The problem is further complicated by marked differences in body composition depending on socioeconomic status (Bray, 1976; Cohn, 1977a; Goldblatt et al., 1965). Some of the observed differences in body composition may also be explained by the fact that the socioeconomic status of Blacks on the average is lower than that of Whites. Evaluating differences in ethnic groups is also complicated because new immigrants have smaller stature and lower body weights than do later generations (see Chapter 13).

BODY WEIGHT, COMPOSITION, AND PHYSICAL PERFORMANCE

The rationale for current standards for body weight and body composition in the military is that these measures are correlated with performance of military duties, appearance, and overall health. In contrast to past standards, which were designed to exclude underweight or chronically ill individuals from active duty, the primary concern of the current standards is to address excess weight in the military population. Specifically, excess weight or body fatness is thought to impair military performance. Since 1960 and particularly since 1976, weight standards have been used to ensure that all personnel are able to meet the physical demands of their duties under combat conditions and to present a ". . . trim military appearance" (AR 600-9, 1986). The Army further states that excessive body weight ". . . denotes a lack of personal discipline, detracts from military appearance, and may indicate a poor state of health, physical fitness, or stamina" (AR 600-9, 1986). The relationship of body weight and composition to performance in the military is addressed below and a discussion of appearance standards follows.

Does Being Overweight Impair Military Performance?

Indicators of physical performance currently used by the military services are shown in Table 1-1. The relationship of body weight and various components of body composition to successful performance of these activities varies with the activity.

Running ability, sit-ups, and push-ups

In most tasks involving physical work, objects—including the body—must be moved through space. The greater the body weight in general, the more energy that must be expended simply to move the body (see Chapter 7). Cureton et al. (1978) (Chapter 5) used weight belts and shoulder harnesses to add weights to normal volunteers in good physical condition.

TABLE 1-1 Mandatory Physical Fitness Testing Retention Standards

	Army		Navy*		Marines†		Air Force‡		Coast Guard§	
Assessment	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Age Group (yr)	17-21		17-19		17-26		17-29		N/A	
Muscular Endurance										
Push-ups (reps/min)	42/2	18/2	38/2	18/2	—				—	—
Pull-ups	—	—			3			—	—	
Flexed arm hand	—	—	—		—	16	—	—	—	
Sit-ups	52	50	—		40	22	—			—
Curl-ups	—	—	45	40	—					—
Flexibility										
Sit reach (toes/1 sec)	—		P/F	P/F	—	—	—	—	—	
Cardiovascular (min sec)										
1.5-mile run	—	—	12:45	16:15	—	15:00	14:30	15:36		
2-mile run	15:54	18:54		—		—	—	—	—	—
3-mile run	—	—		—	28:00	—	—	—	—	—
Options										
500-yd swim	—	—	13:15	17:00		—	—		—	—
800-yd swim	20:00	21:00		—		—	—	—	—	—
6.2-mile bike	24:00	25:00		—	—	—	—	—	—	—
2.5-mile walk	34:00	37:00	—	—	—	—	—	—	—	—
3-mile walk	—	—	—		—	—	40:54	43:52	—	—
Additional Facts										
Point system	yes		yes		yes		no		no	
Semi-annual testing	yes		yes		yes		no		no	
Annual testing	no		no		no		yes		no	
Fitness rehab programs for failures	required		required		required		required		none	
Incentive system	yes		yes		yes		yes		no	
Promotion dependent	yes		yes		no		no		no	

*For Navy personnel, if an individual fails one category including body fat, then he or she fails the entire test. Points determine an individual's overall classification. Personnel are given three chances to pass. P/F = pass/fail.

†Marines must exceed the minimum standards in one or more categories to pass scoring standards.

‡For Air Force personnel the 1.5-mile run standards are based on age and gender.

§For Coast Guard personnel duty-dependent testing exists for boat crew and helicopter swim rescue personnel.

SOURCE: Adapted from Hale (1990).

These authors found with this added-weight model that with increased body weight there was a decrease in running performance. The changes in oxygen consumption and running time reported in Cureton's study were similar to those seen with cross-sectional studies done with volunteers with different body weights. These results suggest that an added-weight-based performance model used by Cureton et al. (1978) is valid.

Studies conducted by Vogel and Friedl, and separately by Harman and Frykman (see Chapters 6 and 7), also suggested that excess weight diminishes running performance and that, conversely, lower body weight is associated with relatively better running performance. Because sit-ups and push-ups involve lifting the body, these studies indicate that increased body weight is associated with lesser performance. Therefore, as supported by the work of Harman and Frykman (Chapter 7), smaller, lighter-weight individuals do well with these tasks of muscular strength and endurance.

Unfortunately, performance on the standard physical training (PT) test does not correlate well with measures of military performance, because there is little need for unloaded running, sit-ups, or push-ups in normal daily military activity. Although overweight individuals do relatively poorly and underweight individuals do relatively well on PT tests, the usefulness of these measures as a predictor of military performance is limited.

Load carrying ability and lifting

Unlike measures in the PT tests described above, load carrying ability and lifting have a more direct relationship to military performance. Harman and Frykman (Chapter 7) noted that moderately overweight individuals performed reasonably well in load carrying ability as assessed by 20-km marches with packs. In contrast, underweight individuals frequently underperformed. These authors noted that LBM was the best predictor of load carrying and lifting abilities, as discussed below. These authors also described studies of the ability to push loads and produce torque and concluded that underweight individuals perform relatively poorly on these tasks, while overweight individuals generally perform adequately, perhaps due to their relatively greater LBM. However, both load carrying and lifting ability, as well as performance during running, sit-ups, and push-ups, are impaired in significantly obese individuals.

RELATIONSHIP OF LEAN BODY MASS VERSUS BODY FATNESS TO PERFORMANCE OF PHYSICAL TASKS

As noted above, the compartments of the body may be divided into LBM and BFM. The standard measures of body weight and body mass index (weight/height^2) may give a misleading picture of actual body composition. Some of the speakers noted that being underweight and overfat is a problem that may be more significant than overweight as a predictor of poor military performance, which further emphasizes the importance of distinguishing overweight from overfatness. The data are quite clear that the best correlations of all aspects of physical performance are with LBM. Cureton (Chapter 5) found that exercise performance of fit, normal-weight individuals decreased with increasing weight added by a weight belt and shoulder harness. Their performance was similar to that of obese individuals of similar LBM, but greater body weight.

Harman and Frykman (see Chapter 7) discussed the relationship of LBM in a variety of tasks relevant to military performance. LBM was the best predictor of performance capability as assessed by maximal aerobic capacity, treadmill run time, and 12-minute run distance. These studies pointed out that body fatness was not a strong predictor of run time on an individual basis. Fatness was associated with longer load carrying time to cover a given distance, and LBM was associated with faster load carriage time. Thus, lean individuals with a small LBM, or obese individuals with a high body fatness, would be expected to do poorly on load carrying tests. These studies also found a low but positive correlation of percent body fat with lifting ability, probably because individuals with more fat tend to have greater LBM. As described above, LBM is positively associated with the ability to push, carry, and exert torque. LBM was a better predictor of performance ability with these tasks than was percent body fat. There was a weak trend for fatter people to push and exert torque better, probably because they could use their fat mass to generate momentum. Harman and Frykman (Chapter 7) concluded that minimum LBM standards may be more important to military performance than are maximum percentage body fat standards. They suggested that recruits should be required to meet standards for both minimum LBM and maximum percent body fat. They further suggested that recruits be required to pass physically demanding performance tests that closely simulate military tasks *before* entry into the service. Many police and fire departments currently require such tests before accession.

There is a lower level of physical performance for the average woman versus the average man, due in large part to the lower LBM and not to differences in body fat. Cureton (see Chapter 5) evaluated running performance in men versus women and found that most of the difference in performance could be explained by the differences in LBM, but there were also differences in energy efficiency during running. He stated that other investigators have not found this difference in running efficiency, so more research is needed to determine if all of the differences in performance between men and women can be explained on the basis of differences in LBM, or if there are more fundamental differences in muscle function.

In contrast to the findings above, Jones et al. (Chapter 9) found that increased body fatness had a weak but positive correlation with lower run times in women trainees. The explanation for this finding is not clear, but may relate to the greater LBM of the somewhat fatter women.

By having more stringent body fat standards for women, women inducted into military service are selected for performance abilities closer to those of men than to those typical of the average American woman. These less-fat women service personnel may be better able to carry out the tasks involved in normal military operations.

RELATIONSHIP OF BODY COMPOSITION AND INJURY

Jones et al. (1988) evaluated the association of fatness, fitness, and injury among U.S. Army trainees at Fort Jackson, South Carolina, in two studies in 1984 and 1988. Women trainees suffered significantly more injuries than did men (50 percent versus 27 percent). These injury rates, however, did not correlate with body fatness. In both men and women, there was instead a significant correlation of injury rate with body mass index (BMI). Individuals at the lowest quartile and the highest quartile of BMI had significantly greater injury rates than did individuals in the middle two quartiles. Jones also found that greater aerobic fitness, as measured by 1-mile and 2-mile runs, was strongly associated with a decreased risk of injury. However, he pointed out that despite the correlation between poor fitness and injury and between poor fitness and fatness, there was no correlation between fatness and injury.

Jones et al. (Chapter 9) speculated that women and men with a low BMI do not have sufficient muscle mass to endure vigorous physical training under the conditions present in military basic training programs. Again, this seems to suggest that the absolute amount of LBM is a critical factor and provides justification for assessment of LBM and physical performance ability in military recruits before accession.

RELATIONSHIP OF BODY COMPOSITION TO HEALTH

BMI is related to all causes of mortality and increased morbidity from specific diseases such as cardiovascular disease, hypertension, and diabetes mellitus. Bray (1989) reviewed a number of prospective and retrospective studies that included data on the effects of being overweight on health. Both general data from the American Cancer Society (Figure 1-1) and a study from Norway indicated that a minimum mortality was associated with a BMI between 22 to 25 kg/m^2 for both men and women. Bray concluded that fat distribution, particularly increased abdominal fat, was a more important risk factor than overweight for morbidity and mortality.

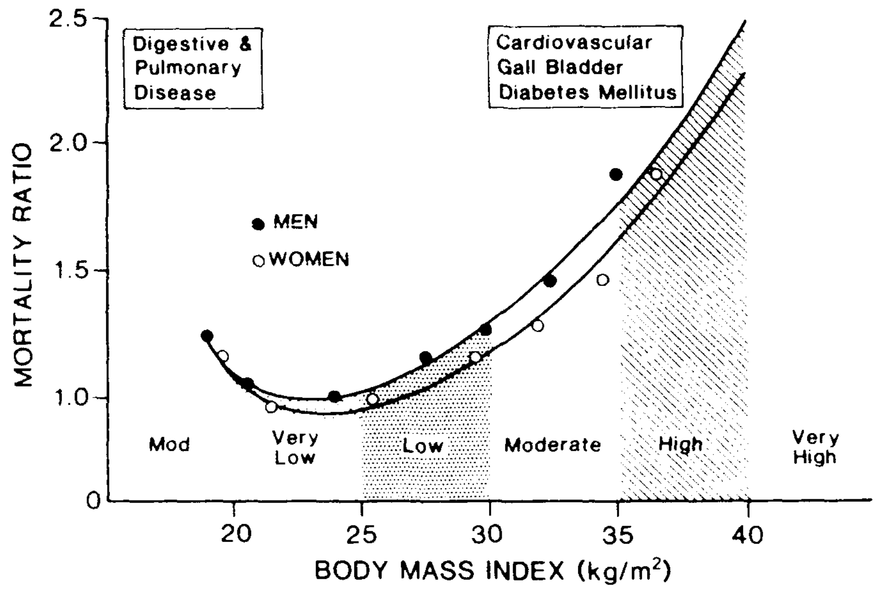

FIGURE 1-1 Mortality ratio and body mass index. Data from the American Cancer Society study have been plotted for men and women to show the relationship of body mass index to overall mortality. At a body mass index below 20 kg/m^2 and above 25 kg/m^2 there is an increase in relative mortality. The major causes for this increased mortality are listed along with a division of body mass index groupings into various levels of risk. [Adapted from Lew and Garfinkel (1979). Copyright 1976, George A. Bray, M.D. Used by permission.]

In particular, as shown in Figure 1-2, there is an increased risk of hypertension, gall bladder disease, and diabetes with increased abdominal fat. The percentage of the population affected increases with greater obesity. Given the high cost of obesity in terms of health risk, Bray recommended large-group behavior modification in the work place as the most cost-effective treatment for obesity.

Body fat distribution may be more important than total body weight or body fatness as a risk factor for several diseases including hypertension, diabetes, and cardiovascular disease. Increased abdominal fat, as assessed by a high waist-to-hip circumference ratio increases health risk for these diseases. Complicating these observations is the fact that body fat distribution differs among racial and ethnic groups (Cohn et al., 1977a,b; Hampton et al., 1966; Merz et al., 1956; Schutte et al., 1984; Seale, 1959; Trotter and Hixon, 1974; Zillikens and Conway, 1990). Few studies have addressed the health risks of different racial and ethnic groups with similar degrees of

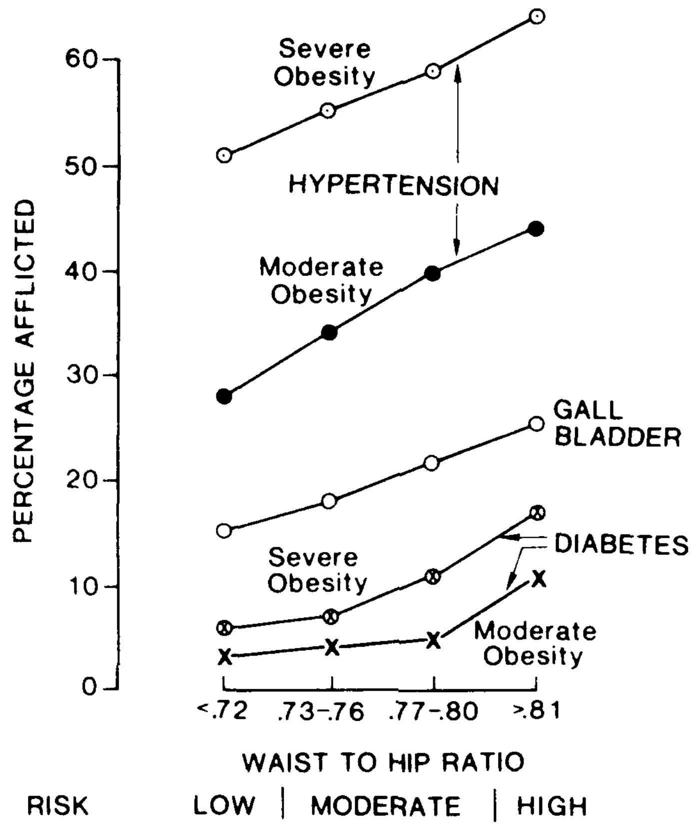

FIGURE 1-2 Relationship of the abdominal (waist) to gluteal (hips) circumference ratio to various risks of obesity. [Data from Blair et al. (1984). Copyright 1988, George A. Bray, M.D. Used by permission.]

abdominal overweight. Evaluation of ethnic group differences is complicated by the fact that new immigrants have a smaller stature and lower body weights than do later generations (see Chapter 13). Furthermore, some of the factors that are said to predict health risks are different among ethnic groups. Haffner et al. (1986) showed that increased abdominal fat, which is a major risk factor in Caucasians, does not carry the same risk for Hispanics. Stevens et al. (personal communication) have shown that a high waist/hip ratio is not associated with higher mortality in Black women studied in the Charleston Heart Study. Recent research (Dowling and Pi-Sunyer, 1990) also indicates ethnic variability of these risk factors. More research is needed in this area.

BODY COMPOSITION AND MILITARY APPEARANCE

Part of the rationale for a body composition (that is, body fat) standard in the military is that, according to AR 600-9 and similar statements from the other services, all personnel are to ". . . present a trim military appearance at all times" (AR 600-9, 1986). A "trim military appearance" is a subjective criterion that is difficult to define in any scientific sense. Currently, this determination is made by local commanders who are not provided with standardized criteria on which to base their decisions. Although there would be little trouble finding consensus among multiple observers on grossly obese or overweight personnel in terms of meeting an appearance standard, a direct generalizable relationship between body fat content and military appearance is not likely to be observed. Some overweight and overfat individuals "carry their weight better" than others depending on skeletal structure, body type, and body fat distribution. Some individuals who fail to meet the body composition standard may even be of normal weight but are overfat and have a lower LBM. Caution must therefore be exercised in making subjective assessments of a trim military appearance.

ASSESSING *BODY COMPOSITION FOR INDIVIDUALS WHO* FAIL TO MEET MILITARY STANDARDS

For individuals who fail to meet performance standards or subjective standards of trim military performance, appropriate therapy and administrative actions for weight reduction and weight control are warranted within military guidelines. Anthropometric techniques such as circumferences or skinfold measurements, currently in accordance with published procedures, should be used as the first assessment of body fat burden. Reliance on these data is appropriate where individuals agree and respond to a weight reduction program involving modest calorie restriction and moderately increased physical activity. However, more accurate and reliable techniques for assessing body fat burden should be used when any of the following conditions exist:

- the level of body fat burden is disputed,
- the individual routinely engages in heavy physical activity and/or participates in body building or physically demanding sports,
- the individual appears to be making a sincere effort to lose weight but shows little or no progress, or
- the individual resists or fails the appropriate weight loss program and is being separated from service.

The recommended techniques for measuring body fat under these circumstances include underwater weighing, body volume measurement, total body water measurement, or total potassium 40 (^{40}K) measurement, although these methods, as noted earlier, have limitations.

The procedures described above also are subject to some minor risk, which should be described to the patient. For some individuals, compliance with necessary conditions for underwater weighing is difficult or impossible because of an inherent fear of being submerged in water. Some individuals who suffer claustrophobia will be unable to comply with ^{40}K measurements. Others are likely to object to the administration of substances for total body water measures. It is recommended that informed consent be obtained before any of these procedures are performed to avoid possible legal action. However, refusal to participate should not interfere with administrative actions.

COMMENTS ON BODY COMPOSITION STANDARDS

The standards for weight and body fatness for accession and retention in the military services are significantly different for men and women. The standards recognize that women have a higher percent body fat than men; the Department of Defense standard levels of body fatness are 20 percent for men and 26 percent for women. However, criteria for accession and retention are not equal for men and women who have a level of fatness that exceeds the standards. For accession into the Army, 16 to 20 year old men can be approximately 37 percent above the medium-frame "desirable" weight from the 1959 Metropolitan Life Insurance Tables (see Appendix C), but 18 to 20 year old women can be only 6 percent above the medium-frame "desirable" weight. Differences in accession standards for men and women also exist for the Navy and Air Force. Retention standards for the Army are more strict for women. Although men aged 17 to 20 can be 14 percent over "desirable weight" to remain in the Army, women aged 17 to 20 can be only 5 percent ov - (see also Appendix B). Current weight criteria suggest that approximate. ?9 percent of women Army recruits are not acceptable for accession vers . only about 3 percent of men recruits (see Chapter 3).

As indicated earlier, women accepted into military service are selected for performance abilities that are closer to those of men than to those of the average American woman. These less-fat women in the services with a greater LBM may be better able to carry out the tasks involved in normal military operations. A second rationale for stricter criteria for women is the perception that women have more injuries due to increased body fat. This rationale may derive from the perception that overweight and increased body fat are associated with an increased risk of injury. However, Jones et al. (1988) conducted studies during basic training at Fort Jackson, South Carolina, and found no association between fatness and injury in either women or men. In both women and men, injuries were associated with both the highest and lowest BMI quartiles. These data suggest that low weight-for-height individuals are prone to injury and that individuals with heavier body weights, regardless of fatness, are prone to injury. Women suffered significantly more injuries than men (50.5 percent versus 27.4 percent). The reasons for this result are not clear, but Jones speculated that women and men with a low BMI do not have sufficient muscle mass to endure vigorous physical training under the conditions present in military basic training programs. Again, this finding seems to suggest that the absolute amount of LBM is a critical factor and provides justification for assessment of LBM and physical performance ability before accession.

The current body fat standard in the military appears to discriminate against women. The Services recognize that women have a higher percent body fat and allow for these differences between men and women. However, standards for women allow less excess over "ideal weight". These major differences in standards for men and women discriminate against women. Although female soldiers may be fatter in absolute terms than male soldiers, they are required to have a greater percent LBM in relationship to a gender-specific mean than are men soldiers. However, it is also true that the physical performance standards in the military discriminate against men in that higher performance levels are required for male soldiers than for female soldiers. As mentioned above, LBM correlates positively with physical performance, and therefore it is a better predictor of physical performance than is BFM, which has a weak negative correlation with performance. Paradoxically, fatter women may perform physical tasks better than less fat women because they have a higher LBM. The question of the appropriateness of current body fat standards for men and women in the military cannot be answered separately from the question of whether there should also be a minimum standard for LBM. These issues become of increasing importance as women move into more military occupation specialties as an outcome of the Persian Gulf War and societal trends.

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2

Conclusions and Recommendations

CONCLUSIONS

As stated in the Introduction, the Committee on Military Nutrition Research (CMNR) was asked to respond to seven specific questions dealing with the body weight and composition standards of the military. The committee's responses to these questions are as follows:

1. Can or should physical performance assessments be used as criteria for establishing body composition standards in the services?
Aerobic fitness, as assessed by the current physical training tests, is an appropriate indicator of physical fitness for military personnel. However, serious consideration should be given to developing job-related performance tests, such as lifting and carrying tasks, that are more closely related to actual military activities. These tests should be used to help develop body composition standards that are more closely related to physical performance of military tasks.

2. What is the relationship between body composition and performance?
Within the range of body composition exhibited by current military personnel, there is no consistent relationship between body fat content and physical performance. There is, however a direct relationship between physical performance as measured by tests of load carrying ability and lifting abilities and the amount of lean body mass.

3. The services currently use a maximal body fat standard. Should they also establish a minimum fat-free or lean body mass standard?
In view of the positive relationship between fat-free or lean body mass and physical performance, the military should seriously consider establishing a minimum standard for lean body (that is, fat-free) mass. There is doubt among the members of the CMNR as to whether the military should continue to employ a maximal body fat standard.

4. What factors should be considered in setting body composition standards?
A body composition standard in the military should be based primarily on ability to perform required physical tasks and secondarily on long-term health implications. A stronger rationale needs to be developed for basing the standard. This conclusion relates only to service-wide standards, not the more stringent standards required for particular military occupation specialties.

5. Are performance and body composition standards redundant?
If job-related performance standards were in place, a body composition standard would be unnecessary in relation to physical performance.

6. If performance criteria exist, are weight-fat standards needed?
Because body weight and composition have health implications entirely aside from the question of physical performance, such standards are desirable. Also, if the military determines that appearance is a sufficiently critical factor that it outweighs the cost of enforcing weight/fat standards, then appearance standards would be needed.

7. How does one rationalize the different uses of body composition for performance, appearance and health?
As stated above, body fatness is related to long-term health, and lean body mass is related to some aspects of physical performance. Appearance of different individuals at the same body weight and fat content can vary considerably depending on other factors. A stronger rationale for an appearance criterion and standards that define acceptable and unacceptable appearance needs to be developed.

RECOMMENDATIONS

On the basis of the papers presented by the invited speakers, discussion at the workshop, and subsequent committee deliberations, the Committee on Military Nutrition Research (CMNR) presents the following recommendations to the Army Medical Research and Development Command regarding body composition and physical performance as it relates to accession and retention standards for the military services:

- All services should develop job-related physical performance tests to use for accession into military service.

• The differences between accession and retention standards for body weight need reevaluation for all services.[1]

• An inequity exists in body composition standards for men and women. Accession and retention standards for body weight and body fatness in men and women should be reevaluated in the light of all factors discussed in this report.[1]

• The appropriateness of current body composition standards needs to be validated for the significant ethnic groups represented in the military services.

• A relationship between trim military appearance and military performance could not be identified. If the military determines that a trim military appearance is important, objective criteria should be developed to the extent possible for appearance evaluation.

• For individuals who face separation from the service for failing to meet body composition standards, it is suggested that the military identify a limited number of military centers that can perform more specific measurements of body composition (for example, dual photon densitometry, underwater weighing, and body water) and to which the individuals in question could be referred for further evaluation.

AREAS FOR FUTURE RESEARCH

The Committee on Military Nutrition Research (CMNR) suggests several areas for future research within the military related to body composition and physical performance. The CMNR believes that the military services, through its pool of volunteer personnel, have an excellent and often unique opportunity to generate statistics about nutrition, health, and well-being of service personnel that can be directly applied toward improved

[1]In April, 1991, Dr. J. A. Vogel and MAJ K. E. Friedl, Occupational Health and Performance Directorate, U.S. Army Research Institute of Environmental Medicine, presented a briefing and a proposal for revisions to Army Accession (AR 40-501) and Retention (AR 600-9) Standards to LTG Reno. These recommendations (See Appendix D) were approved at the briefing. As a result, on May 7, 1991 the Army retention standard (AR 600-9) was amended for women by increasing the allowable percent body fat standards by 2 percent body fat units for each age group as follows: 17-20 yr formerly 28 percent amended to 30 percent, 21-27 yr formerly 30 percent amended to 32 percent, 28-39 yr formerly 32 percent amended to 34 percent, 40+ yr formerly 34 percent amended to 36 percent. Changes to the Army Accession Standard (AR 40-501) as proposed went into effect on October 1, 1991. These changes result in the Army switching to a body fat standard for accession, reducing the accession standard for men to not exceed 4 percent body fat units over retention fat standards, and make the body fat accession standards for women the same as the newly revised retention standards (Appendix E).

health of military personnel and for the general U.S. population. Research on the following topics is recommended:

• the development of service-specific standard tests of military performance that more accurately reflect military activities;

• the relationship of body composition to military and physical performance among men and women, including consideration of the relationships of lean body mass, height, and physical performance;

• the relationship of body fat distribution and body composition to long-term health outcome in career military personnel, specific for race and gender; and

• the relationship of injuries to components of body composition (specifically bone density and lean body mass).

Two additional areas of research were not specifically mentioned in the task posed to the committee for this project; however, in view of the unique opportunities available for research within the military setting and afforded by its data bases, the CMNR recommends that the military conduct research in these areas to increase general knowledge related to body composition and physical performance:

• A retrospective study of the Medical Remedial Enlistment Program (MREP) data base to evaluate (a) long-term health status and performance of overweight recruits and overweight personnel in general, and (b) cost-benefit analyses of enrolling individuals who are overweight at the time of enlistment.

• The relationship of body composition to emotional and psychological factors in military units: (a) psychological effects of being overweight and underweight on individuals in a military setting; (b) psychological effects on unit morale of having overweight and underweight individuals present in the unit; and (c) an evaluation of officers' and noncommissioned officers' attitudes and possible biases toward the presence of overweight and underweight individuals in potential combat situations.

The Committee on Military Nutrition Research is pleased to participate with the Division of Military Nutrition, USARIEM, U.S. Army Medical Research and Development Command, in programs related to nutrition and health of American military personnel. The CMNR hopes this information will be useful and helpful for the Department of Defense in developing programs that continue to improve the lifetime health and well-being of service personnel.

PART II

Invited Papers

In Part II the expert papers that formed the basis for the development of the summary and recommendations presented in Part I are included in the order presented at the 1½ day workshop. Each speaker was asked to carefully review the literature in their own field of expertise as it related to the seven questions posed to the committee, make critical comments on the relevant research including their own work, and end with their individual recommendations. After the workshop, each author was given the opportunity to revise or add to their papers based on committee questions. The papers were then submitted in writing and used by the committee in the development of Part I. Although focused on the relationship of body composition to physical performance in the military services, these chapters also provide a state-of-the-art review of body composition and physical performance that is relevant for many settings and occupations.

Body Composition and Physical Performance 1992.
Pp. 31 55. Washington, D.C.
National Academy Press

3

Body Composition and Military Performance: Origins of the Army Standards

Karl E. Friedl

Excessive body fat connotes a lack of personal discipline, detracts from military appearance, [and] may indicate a poor state of health, physical fitness, or stamina.

(AR 600-9, 1986)

INTRODUCTION

The primary intent of physical standards in the military has always been to select soldiers best suited to the physical demands of military service. This standard has usually meant the selection of soldiers who at least looked as though they could carry loads and fight well. Currently, body fat standards are part of the U.S. Army's fitness emphasis to ensure that forces "possess the stamina and endurance to fight in extreme climatic and terrain environments" (Study of the Military Services Physical Fitness, 1981).

For most of the past century, weight-for-height has been a key physical discriminator of a recruit's fitness for military service, but until recently, these standards were used only to exclude underweight candidates. Weight-for-height standards were relevant when a sizable proportion of draftees and volunteers were malnourished, tuberculous, or had parasitic diseases; underweight was a good marker of such individuals who were clearly unsuited to the physical demands of the military. The need for height-weight standards has diminished as the importance of these diseases has diminished. In addition to advances in health care, improved nutrition over the past century has produced increases in the mean height, weight, and fat-free mass of soldiers (Table 3-1) (Karpinos, 1961). However, improved nutrition has also increased the importance of health risks at the other extreme of body size, with excessive fatness due to overnutrition. Although tuberculosis

TABLE 3-1 Comparison of Some Anthropometric Characteristics of Male Soldiers in 1864, 1919, 1946, and 1984

	Year of Study (*n*)*			
Anthropometric Characteristic	1864 (23,624)	1919 (99,449)	1946 (85,000)	1984 (869)
Height (inches)	67.2	67.7	68.4	68.6
Weight (pounds)	141.4	144.9	154.8	166.8
Age (years)	25.7	24.9	24.3	26.3
Neck girth (inches)	13.6	14.2	14.5	14.5
Chest girth (inches)	34.5	34.9	36.4†	35.5
Waist girth (inches)	31.5	31.4‡	31.3‡	32.7
Estimated body fat (percent)	16.9	15.7	14.4	17.3
Fat free mass (pounds)	117	122	133	138

NOTE: Relative body fat is estimated from mean values for height, neck, and waist, using the Army circumference method as published in AR 600-9 (AR 600-9, 1986). The value is based on hydrostatically determined body fat estimated in 1984 soldiers.

**n* = number of men in the study

†Chest circumference measurement did not specify expiration although it was the specified standard in the physical examination regulation in existence at the time; the other three values are for chest at expiration.

‡Measurement at natural waist adjusted upward by 1.66 cm, the mean difference between "natural waist" circumference and circumference at the umbilicus in 1984 soldiers; no adjustment was made for 1864 because measuring was done over clothing.

SOURCE: 1864: Gould (1869); 1919: Davenport and Love (1921); 1946: Randall (1947); 1984: Fitzgerald et al. (1986). Used by permission.

was a leading cause of death in the early 1900s, the leading cause of death in 1987 was heart disease (Surgeon General's Report on Nutrition and Health, 1988). Prompted by these health trends and the current national obsession with body fat and fitness, the principal target of physical standards in the Army has shifted from underweight to overfat soldiers. The use of these standards has also changed from simple entry selection criteria to standards that must be maintained throughout an Army career by appropriate nutrition and exercise.

The current U.S. Army Weight Control Program (AR 600-9, 1986) and the objectives of this regulation will be outlined here, as well as earlier policies and how the Army arrived at the current policy, standards, and method of assessment. From this historical review it will be evident that in the last decade, two important considerations have been dropped, possibly inadvertently, from the current standards: (1) the low-end standard (or strength testing) to emphasize the importance of an adequate fat-free mass and (2) the confidence interval built into these standards, based on the precision of the measurement methods and the relative strength of the relationship between body composition and the desired objective, retention of combat-ready soldiers.

THE CURRENT ARMY WEIGHT CONTROL PROGRAM: POLICY AND GOALS

All soldiers, regardless of rank, are weighed at 6-month intervals to demonstrate that they are below tabled height-weight limits (divided by gender and into four age categories). Soldiers exceeding these screening weight standards are assessed at the unit (company) level for body fat by an Army-developed circumference method, which is described below. If a soldier exceeds fat standards prescribed by gender and age, the unit commander must enter the individual in the U.S. Army Weight Control Program. The commander is required to provide motivational programs to the soldier, including nutrition education sessions and exercise programs. As additional incentive to achieve the standards, the soldier's records are flagged to prevent: reenlistment, assignment to command positions, favorable actions such as awards, and transfer to any professional schooling beyond initial entry training. A soldier who fails to make satisfactory progress toward weight or fat loss—determined as failure to achieve a 3- to 8-pound weight loss/month in 2 consecutive months—can be discharged from the Army under a separation action for failure to meet the weight-control standards. A medical evaluation is required for a soldier being considered for separation to ensure that the overfatness is not due to an underlying illness. A soldier is cleared from the program only by achieving the body fat standard by the Army circumference method. The upper limits of permissible body fat are shown in Table 3-2. Although personnel are held to these

TABLE 3-2 Upper Limits of Permissible Body Fat, U.S. Army, 1990*

	Percent Body Fat	
Age Range	Men	Women
17-20	20 percent	28 percent
21-27	22	30
28-39	24	32
> 40	26	34

*These limits were increased by 2% for women since this meeting was held. (See Chapter 2)

SOURCE: AR 600-9 (1986).

TABLE 3-3 Chronology of U.S. Army-Relevant Body Composition Studies and Policies

1863–1865	U.S. Sanitary Commission Study of Civil War soldiers. Detailed inquiry into soldier physique by B. A. Gould.
1875	Statistics compiled from physical examinations of approximately 500,000 Civil War recruits by J. H. Baxter.
1887	First U.S. Army height-weight standard tables.
1912	Medico-Actuarial Mortality Investigation.
1917–1919	Davenport and Love analyze physical examination data of 2.5 million World War I draftees (1917–1918) and anthropometry of 100,000 demobilizing soldiers.
1907–1928	Biometric study of U.S. Army officers. Analysis of annual health examination data over 20 years.
1943	Height-weight means of 465,000 World War II selectees collected and later tabulated by B. D. Karpinos (Office of the Surgeon General).
1946	Quartermaster Corps conducts an anthropometric study involving 66 body measurements of 105,062 men at six Army separation stations. Photographs of 39,376 of the men were somatotyped by Hooton.
1960	New maximum weight limits issued, tabled by age and by gender (Army Regulation 40-501).
1976	Army Physical Fitness and Weight Control Program regulation is released with new tables (AR 600-9).
1980	Review of military fitness is ordered by President Carter. This results in Department of Defense directive 1308.1 (June 1981), directing the use of body composition standards and a proactive emphasis on fitness and weight control.
1983	Revision of AR 600-9, issued as "The Army Weight Control Program", specified use of body composition standards with penalties for soldiers not meeting standards. Use of Durnin Womersley equations as interim method.
1984	Army Body Composition Project developed Army body fat equations by comparison to hydrostatic weights in Army men and women and collected information on fat relationship to fitness and military appearance.
1986	Revision of AR 600-9 detailed circumference-based methods of fat estimation.

standards, the regulation encourages all personnel to achieve the more stringent Department of Defense goal of 20 and 26 percent body fat for men and women.

The intended purpose of these standards, as stated in the current Army Regulation 600-9 (AR 600-9, 1986) is explicit. It is "to insure that all personnel:

(1) are able to meet the physical demands of their duties under combat conditions, [and]

(2) present a trim military appearance at all times."

The use of physical standards to ensure the combat readiness of the Army comes out of a long evolution (see Table 3-3).

THE DEVELOPMENT OF MILITARY ACCESSION STANDARDS

Physical Standards in Relation to the Demand for Soldiers

Some physical standards have changed easily with the need for soldiers, which suggests that what may be portrayed as a soldierly characteristic may not be solidly rooted in combat necessity. Height is an example. European monarchs prided themselves on their tall soldiers; it was also convenient to have men of about the same height for drill and ceremony. Some eugenicists claimed that criminals tended to be shorter than the rest of the population (Baxter, 1875), and a retired military surgeon proposed that physical characteristics could identify future heroes (Foster et al., 1967). Thus, the minimum height for U.S. soldiers was 66 inches early in the nineteenth century and has progressively lowered, with the least stringent requirements (no minimum height standard during part of the Civil War) coinciding with national emergencies when new recruits were in greater demand (Figure 3-1). The Romans also imposed height standards on their soldiers, and the usefulness of this selection standard was questioned even then. Vegetius Renatus, a military philosopher, suggested using a more subjective visual appraisal of potential recruits, noting that "when all these marks are found in a recruit, a little height may be dispensed with, as it is of much more importance that a soldier should be strong than that he should be tall" (Baxter, 1875). When health screening capabilities were less advanced, height standards served a health fitness screening purpose; for example, short stature could reflect disease and poor physical development. Thus, even after careful review of physical standards during World War II, men less than 60 inches in height were "nonacceptable" (U.S. Congress, 1944). Today, the best rationale for current height standards is practical: to limit the range of sizes for uniforms, protective ensembles, and workspace dimensions. However, when other reasons are dismissed, commanders argue from anecdotal experience that short soldiers simply cannot carry the same load as their average-height peers (Davenport and Love, 1921).

Early Scientific Investigations of Soldier Physique

More than a century ago, scientists such as Benjamin Gould recognized the importance of military anthropological studies. Gould was invited by the U.S. Sanitary Commission to perform an ambitious study on soldier physique with detailed demographic and anthropometric measurements on 23,785 soldiers studied at various Civil War camps, and with substudies on

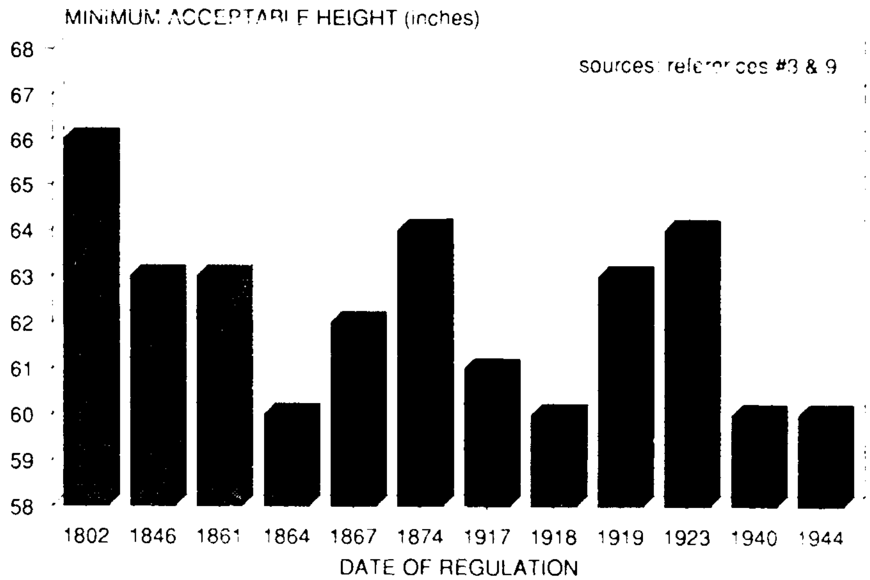

FIGURE 3-1 U.S. Army male standards for minimum acceptable heights, as they have changed with the demand for soldiers. SOURCES: Davenport and Love (1921); Foster et al. (1967).

captured rebels, Iroquois Indians, Black soldiers, and freed slaves (Gould, 1869). Although the study was curtailed by the Secretary of War, it successfully outlined some anthropometric relationships with respect to age, health, and strength among Civil War soldiers (see Figure 3-2).

Gould tested several proposed relationships between adult weight and height and concluded that the weight/height^2 formula of the Belgian scientist, Lambert A. J. Quetelet, was the most suitable. Current weight screening tables are based on Quetelet's index. Gould also discovered that mean weights did not change significantly in this study population after age 22. This trend was not readily apparent in subsequent studies, presumably because of reduced activity levels and improved nutrition, with consequent increases in weight and fatness becoming virtually inevitable with age. Weight was investigated in terms of height, chest size, age, health, race, service (Army versus Navy), length of service, pulse and respiration. Some of these latter investigations were influenced by the earlier work of John Hutchinson, who had pioneered studies of vital capacity and had also developed some of the first tables of "desirable" weight-for-height (ranging from 21.4 to 23.0 kg/m^2) for life insurance companies. In 1846, Hutchinson observed a loss of vital capacity with excess weight and concluded that individuals as little as 7 percent over his weight tables had a measurable reduction in vital

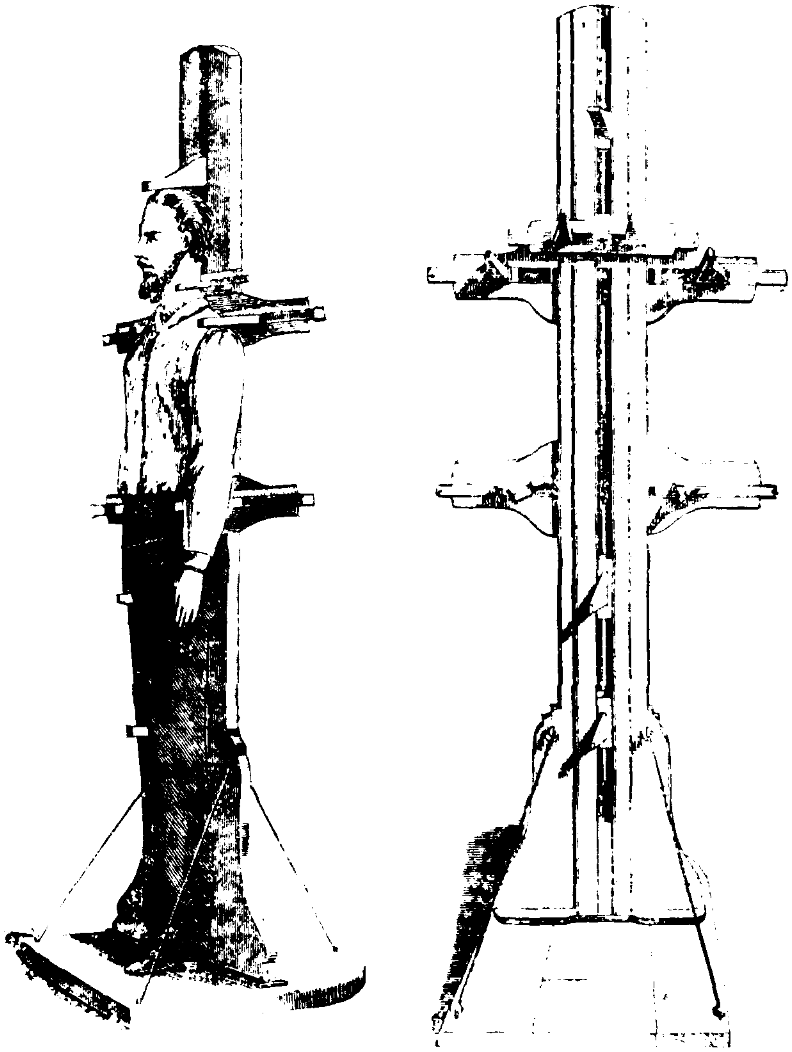

FIGURE 3-2 Dr. Gould's "andrometer", one of several devices designed for anthropometric and physiological data collection on Civil War soldiers. This device enabled rapid measurement of height, crotch height, lower leg length, and breadths of the neck, shoulders and pelvis. It was based on a device used by an Edinburgh tailor commissioned to manufacture uniforms for the English Army. SOURCE: Gould (1869).

capacity (Baxter, 1875). Unfortunately, Gould never completed these analyses or those from his intriguing strength measurements. For these studies a dynamometer was devised to measure something approximating deadlift performance: healthy White soldiers could lift an average of 330 pounds (n = 12,157), with a strength apex at 24.5 years of age. He found that the bigger men were the stronger soldiers, with mean lifting strength equal to *about* 2.25 to 2.5 *times* their body weight, although Iroquois Indians far surpassed all other subjects in this measure (Gould, 1869). Gould also warned about a significant bias that is still a problem for military data collected today: the data are limited because they pertain to only one gender and "to those ages, for that sex, in which the physical changes are least marked."

The ultimate report consisted of only a portion of what the Sanitary Commission had hoped to present as "an incidental contribution to military and anthropological knowledge." The National Academy of Sciences proposed to follow up on Gould's work with a study of World War I draftees, but the study was turned down by the War Department as inappropriate during the national emergency (Davenport and Love, 1921). No single study, quite as ambitious in scope, has since been attempted.

Standards of Physique in the Civil War: Eye of the Physician

At the time of the Civil War, general regulations specified that the surgeon would ascertain whether a draftee's "limbs are well formed and sufficiently muscular . . . his chest is ample and well formed, in due proportion to his height and with power of full expansion . . . whether the abdomen is well formed and not too protuberant . . ." (Baxter, 1875). Height and chest circumference measurements were to be considered, but only as part of the screening physician's subjective "estimate of the man's physical capacity." These regulations were influenced by standards imposed by European armies, such as the British and French, which involved minimum heights and chest circumferences. However, in those countries, the standards were administered by the recruiting officer in advance of any medical screening.

Weight was less consistently assessed during the Civil War but if used, it was by a screening physician to evaluate for underweight, not overweight (Ordronaux, 1863). Nevertheless, conscripts with notable obesity, such as one 51-inch man weighing 313 pounds, were exempted (Baxter, 1875). Colonel Jedidiah Baxter (1875) summarized the rationale for physical standards of his time:

> Weight is not a regulated quality in any code of laws governing the enlistment of recruits. The circumference of chest thought to be indispensable as an accompaniment to certain degrees of stature, is carefully laid down in the English regulations, but weight is not even mentioned. It is presumed

> that the matter is left to the discretion of the examining surgeon, with whom the decision as to the other qualities named might, it is thought, be also left with advantage. A due proportion in the weight is quite as essential in the soldier as a well-formed chest, and is of greater importance than lofty stature. In former times, when it was necessary to make use of a ramrod in loading a musket, men of a certain height were absolutely necessary for the service; but in these days of breech-loading arms, a man from 5 feet to 5 feet 4 inches in stature, and well proportioned in build and weight is, ceteris paribus, as serviceable a soldier as can be desired.

Thus, it was a physician's subjective assessment of a recruit's suitability to the demands of military service that determined Civil War selections, and this evaluation emphasized adequate weight, height, and chest size. The first U.S. Army table of weight-for-height was published later, in 1887 (Reed and Love, 1932).

Published Standards for Physician Guidance

By the time of the World War I call-up, the earlier physical standards were codified with specific guidance for examining physicians. Desirable weight-for-height standards were clearly specified, but men who were evidently vigorous and healthy were permitted a lower minimum weight (Table 3-4). *Below these absolute limits, men were classified as underweight,* which was usually grounds for rejection (Love and Davenport, 1919). Draftees were also rejected for deficient chest measurements as a reflection of not being "well developed and muscular." A man was considered unfit for military service if general examination proved him to be "undersized, underweight, undeveloped, pale and emaciated, poorly nourished with thin flabby muscles, or manifestly lacking in stamina and resistance to disease." In contrast, obese applicants were eliminated only for overt morbidity or if their weight was excessive for cavalry service (Foster et al., 1967). Thus,

> variations in weight above the standard are disqualifying if sufficient to constitute such obesity as to interfere actually or potentially with normal physical activity, as may be evidenced by high blood pressure, a beginning nephritis, breaking down of the arches of the feet, or other defects incident to such condition. No applicant will be accepted for Cavalry service whose weight is in excess of 180 pounds (AR 40-105, 1923).

In 1918, 2.6 percent of all candidates (approximately 75,000 men) were rejected for military service for being underweight; only 4,211 men were rejected for obesity and others classified as obese were still accepted for military service because "the variation was correctable with proper food and physical training" (Love and Davenport, 1920). Thus, obesity was functionally determined by the examining physician, and underweight was now defined by published height-weight tables.

TABLE 3-4 U.S. Army Standards for Weight and Chest Girth, 1917

Height (inches)	Standard Accepted Measurement: Weight (pounds)	Standard Accepted Measurement: Chest Circumference (inches)[‡]	Permissible Minimum Variation*: Weight (pounds)	Permissible Minimum Variation*: Chest Circumference (inches)[‡]
61	118	31	110	30
62	120	31	110	30
63	124	31	112	30
64	128	32	113	30
65	130	32	114	30
66	132	32 [illegible]	116	30 [illegible]
67	134	33	118	30 [illegible]
68	141	33 [illegible]	121	30 [illegible]
69	148	33 [illegible]	124	31
70	155	34	128	31 [illegible]
71	162	34 [illegible]	133	31 [illegible]
72	169	34 ¾	138	31 [illegible]
73	176	35 [illegible]	143	32 [illegible]
74	183	36 [illegible]	148	33 [illegible]
75	190	36 [illegible]	155	34 [illegible]
76	197	37 [illegible]	161	34 [illegible]
77	204	37 [illegible]	168	35 [illegible]
78	211	38 [illegible]	175	35 [illegible]

NOTE: A separate table for Filipinos included a lower range of heights.

* Variations from standard permissible when applicant is active, has firm muscles, and is vigorous and healthy.

‡ Chest girth at expiration.

SOURCE: Selective Service Regulations, Pt VIII (1917); later, AR 40-105 (1923), with only a change in range of permissible heights, beginning at 64 inches.

The minimum standards were also clearly rooted in health and minimum strength concerns. Love and Davenport (1920) noted that "common observation indicates that the Southern men have a tendency to lankiness, and this has often been attributed to infection with malaria, hookworm, and other parasites found prevailingly in the South." Taller men were also required to carry greater weight-for-height, with a linear 7 pound/inch increase above average height (approximately 68 inches) in the tabled values. This requirement may have reflected a bias against young tuberculous men. Pulmonary tuberculosis, if not readily evident, was screened by low weight. It was particularly suspected in tall persons (Davenport and Love, 1921) because tuberculous men averaged 1/2 inch more in height and 12 pounds less in weight (n = 10,701) compared to the average of healthy World War I registrants (Davenport and Love, 1921). Regardless of how it was established, this standard served to eliminate only the lowest-weight men.

WORLD WAR II HEIGHT-WEIGHT STANDARDS

The U.S. Army height-weight tables used for World War II draftees still contained no upper limit of body weight, only prescribing desirable standards and lower limits for weight and chest circumference (Foster et al., 1967). The previous standards were slightly modified, with chest circumferences set to regular 1/4 inch increments and ideal weight increased by 4 pounds/inch, above 64 inches in height (Table 3-5). The chest circumference standards were consistent with scientific data demonstrating this relationship between chest girth and height in over 250,000 20-21 year old Italian men (Frassetto, 1926). The "standard" values of weight were much closer to the "desirable" weights for 20-year-old men in the 1912 Medico-

TABLE 3-5 Standard and Minimum Measurements of Height, Weight, and Circumference of Chest, U.S. Army, 1940

	Standard Measurement		Minimum Measurement	
Height (inches)	Weight (pounds)	Chest Circumference (inches)*	Weight (pounds)	Chest Circumference (inches)*
60	116	31 1/4	105	28 3/4
61	119	31 1/2	107	29
62	122	31 3/4	109	29 1/4
63	125	32	111	29 1/2
64	128	32 1/4	113	29 3/4
65	132	32 1/2	115	30
66	136	32 3/4	117	30 1/4
67	140	33	121	30 1/2
68	144	33 1/4	125	30 3/4
69	148	33 1/2	129	31
70	152	33 3/4	133	31 1/4
71	156	34	137	31 1/2
72	160	34 1/4	141	31 3/4
73	164	34 1/2	145	32
74	168	34 3/4	149	32 1/4
75	172	35	153	32 1/2
76	176	35 1/4	157	32 3/4
77	180	35 1/2	161	33
78	184	35 3/4	165	33 1/4

*Chest circumference to be taken at expiration.
SOURCE: Mobilization Regulation 1-9 (1940).

Actuarial tables (Davenport, 1923), and minimum weights were set at roughly 90 percent of the desirable values at each height (Newman, 1952). Men were unacceptable for military service if they were less than 105 pounds in weight or if "overweight which is greatly out of proportion to the height . . . interferes with normal physical activity or with proper training." The latter category was still to be considered if, in the opinion of the examining physician, the variation was correctable with proper food and physical training (Foster et al., 1967).

A well-circulated legend claims that in the early 1940s, 17 out of 25 professional football players studied by the Navy physician Albert Behnke, were found unfit for military service because they were overweight (Welham and Behnke, 1942). This convenient example illustrates the possibilities for mismatch between overweight and overfat; this group was estimated to have a mean body fat of less than 10 percent, and by performance criteria these men would be expected to be combat-effective soldiers. They were not, in fact, likely to have been rejected. The 1940 mobilization regulations specified that men whose weight was greater than the standard weights for height would be classified 1-A "provided that the overweight is not so excessive as to interfere with military training." Welham and Behnke (1942) only suggested that "according to standard height-weight tables, these men *could* be classified as unfit for military service" based on the qualifier, "*if* an allowance of 15 percent above the average values in the tables is considered as the upper limit." They proposed instead that a body density of 1.060, corresponding to an estimate of about 17 percent body fat by the Siri equation (1961), be used as the discriminator for the rejection of the obese. Neither this theoretical nor their proposed standard was applied to draftees in World War II.

The first height-weight tables for women were created in a World War II regulation (AR 40-100, 1942). These tables which applied only to the U.S. Army Nurse Corps, broke down acceptable weights by age categories (in regular 5-year age intervals). It prescribed that "the permissible variation below the standard for age is 15 pounds, with the exception that no applicant will be accepted whose weight is less than 105 pounds" (Foster et al., 1967). It also hinted at an upper end of acceptable weight with the admonition that "the weight for each height for the age group 26 to 30 is the ideal one to maintain thereafter." The introduction of physical standards for women may have caused the demise of chest circumference and mobility standards.

After World War II, the preoccupation with underweight recruits remained. This emphasis was again clear in a study by the eugenicist Ernest Hooton who was contracted by the Army to somatotype 40,000 separatees and to establish common associations within their former military specialties. The large and fat extreme was not necessarily undesirable: a desirable combat soldier "type" could be both extremely fat and muscular, "a tremendously powerful and impressive man," in Hooton's words, ". . . types frequently seen in professional wrestlers and professional football linemen," while there was nothing good about a low-weight man, represented as either "thin, meagre, poorly muscled" types, or—if they had some body fat—as "well nourished weaklings" (Hooton, 1959). Thus, fatness was not an issue; the important discriminator for military performance was an adequate fat-free mass.

When the Army anthropologist, Russell Newman (1952), proposed the use of body fat to assess soldiers, he was still concerned with low-weight soldiers, not overweight soldiers:

> What are really needed are minimum standards based on lean body weight (obtainable through assessment of body fat). The standards obviously should exclude men with insufficient musculature satisfactorily to perform military tasks and not penalize men whose musculature is adequate but who are low in weight because they are low in fat.

This emphasis on underweight continued up to 1960. Obesity, in its lesser forms, was considered trainable and was not a reason for exemption.

Development of Current Accession Standards

In 1960, the standards applied to candidates for military service (accession standards) established minimum weights for height and—in 5-year age increments—maximum weights for height for men and women (AR 40-501, 1960). Outside of these limits, candidates were to be rejected for Army service. The source of these standards is uncertain, but they were quite liberal: upper limits for men were approximately 140 percent of the average weights tabulated by the U.S. Army Office of the Surgeon General for over 0.5 million Black and White World War II Selective Service registrants (Karpinos, 1958). At some point in the three dozen changes issued for this regulation, the tables were changed so that by 1983, the maximum weight limits for women had been lowered by 15 to 20 pounds from the 1960 tables (AR 40-501, 1983). This change made the tables for women considerably more restrictive relative to the national population and more stringent compared to the tables for men. These accession tables are the current basis of entry to the Army, although body fat assessment can now be performed at the Military Entrance Processing Station (MEPS) as a secondary criterion if a candidate exceeds tabled maximum values (U.S. Department of the Army, 1988).

Until the 1960s, body size standards pertained only to accessions. Obviously, there was no special concern that once in the Army, soldiers might become underweight, and if they did, then it was a medical problem. However, fitness levels could diminish. Thus, until 1976, body weight was a screening tool that excluded only the extremes of underweight and obesity (at least for men), while a separate regulation detailed physical fitness tests, which periodically assessed physical performance in active duty soldiers.

Combat readiness was the concern of President Theodore Roosevelt when he initiated an early version of the Army Physical Fitness Test for officers, known as the Annual Test Ride. He had observed "field officers who were physically unable to ride even a few miles at an increased gait," and he announced that it was "essential that field officers of the line of the Army should be at all times physically fit and able to perform the duties pertaining to their positions" (U.S. War Department, 1907a). The President's solution was explicit: he told the Secretary of War that "as I believe that such physical fitness can only be demonstrated by actual physical tests, I desire that you give the necessary directions . . .," and he outlined mandatory tests, such as "cavalry marches of not less than 30 miles per day for three days in succession, under conditions suitable to the making of forced marches in active field operations" (U.S. War Department, 1907b). He also wanted the names reported for any officers who fell out of these marches and directed that "appropriate action be taken in the cases of all officers found not qualified physically for active service." Specific tests of physical performance, such as the Annual Test Ride, were once useful in the Army; however, today's Army may be too diversified to routinely screen soldiers using realistic combat performance tests. The current U.S. Army Physical Fitness Test assesses primarily aerobic fitness with a 2-mile run test in addition to push-up and sit-up tests; these standards are for retention, not accession, and are more leniently enforced than body fat standards.

A physical test that assesses the principal demands of modern Army work—carrying and lifting capacity—has never been effectively used as a physical accession standard. One previous effort in this area failed because of policy considerations that rendered the standards meaningless. Extensive Army research resulted in the development of a dynamic lift device (MEPSCAT), which is currently installed in every MEPS (Myers et al., 1984; Teves et al., 1985). MEPSCAT was designed to screen soldiers being considered for occupational specialties that routinely require heavy lifting. It was shown, for example, that only 2 out of more than 200 women who were contracted for heavy lifting specialties as recruits could meet the minimum standards when screened by the device, and should have been redirected to other jobs (Teves et al., 1985). However, the standards now in place detect only a few of the weakest individuals and still do not prevent them from being routed to those specialties where their chances of injury and unsatisfactory performance are expected to be increased.

Thus, body weight and body fat standards are the only physical standards currently used that actually exclude or eliminate individuals for unsuitability on the basis of combat readiness (and military appearance). Body fat, however poor as a correlate of physical performance, is used as a surrogate measure of physical fitness because thin, lean soldiers *look* more physically fit than large, fat soldiers. This new emphasis on overweight and fatness began in 1976 when new retention standards were issued.

RETENTION STANDARDS IN THE MILITARY

Potbellies and the Army Weight Control Program

A significant revision of AR 600-9 (1976) combined the U.S. Army Physical Fitness and Weight Control Program regulations. This was a response to concern that Army personnel were becoming too sedentary and were not maintaining desired levels of physical fitness. Quite simply, the Army leadership felt that there were too many obese soldiers. The previous U.S. Army Weight Control Program (AR 632-1, 1972, classified under "Standards of Conduct and Fitness") was weak; it referred to the height-weight tables in the accession regulation (tables that were liberal for men) and recommended that soldiers exceeding these tables be put on a weight loss program. The new regulation, developed under the direction of General Bernard Rogers, established a new and separate set of maximum and minimum height-weight standards to be maintained by all active duty soldiers and added specific penalties for soldiers who were judged to be obese and did not satisfactorily change to achieve standards. The male upper limit was 27.5 kg/m^2 or 125 percent of the World War II male "standard" weights. This upper limit was, in turn, based on the "desirable" weights for men, age 20, in the 1912 Medico-Actuarial tables (Davenport, 1923), which represented average weight-for-height of the insured U.S. population at the turn of the century (Figure 3-3). The upper limit for women was 23.7 kg/m^2. Both of these new male and female standards for retention in the Army were considerably more stringent than the accession weight standards (AR 40-501, 1960) at that time. (A later change in the accession standards made accession and retention standards for women equally stringent).

The stated emphasis of this regulation was physical fitness: "It is essential to the readiness and combat-effectiveness of the Army that every soldier be physically fit regardless of age or duty assignment." Weight control and military appearance were given as related aspects of fitness. The two stated objectives of weight control were very similar to the most current ones: "(a) maintain the weight of all personnel at a level which is best suited to permit them to perform their duties in a peacetime or combat environment, and (b) present a smart soldierly appearance expected of a combat ready Army." However, the importance of appearance was specifically acknowledged in a remarkable paragraph:

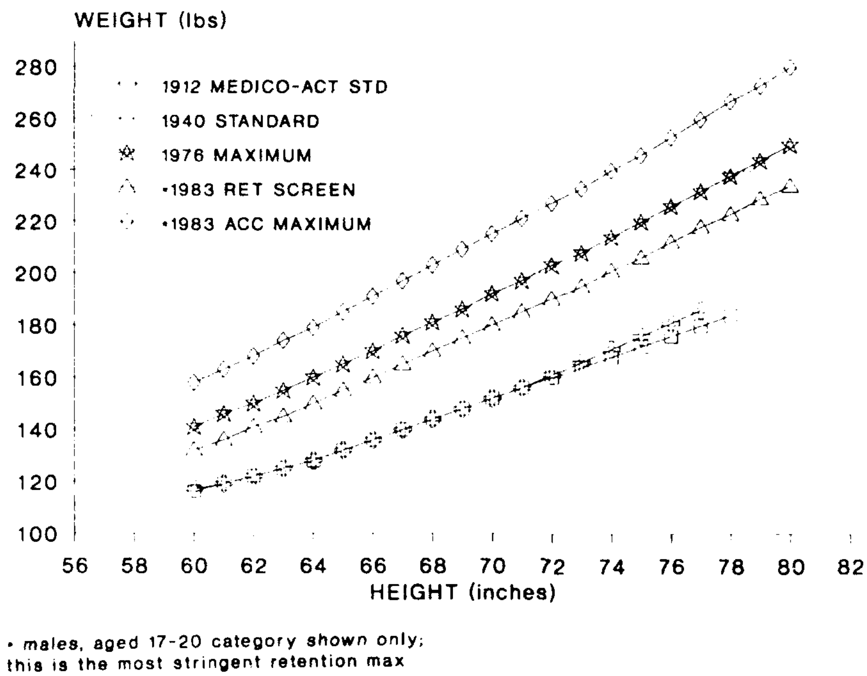

FIGURE 3-3 Evolution of U.S. Army weight-for-height tables for men.
NOTE: The "desirable" weights of the 1912 Medico-Actuarial tables, representing the mean values for insured men at age 20, formed the basis of the World War II "standard" weights. Even "evidently vigorous and healthy men" who fell below 90 percent of these weights were usually excluded from service. In 1976, General Rogers established a new maximum weight limit for active duty soldiers to observe (standards for retention in the Army); this was 125 percent of the World War II standard weights. This limit later became the screening weight standard for the 40-and-over age category in the new two-tiered U.S. Army Weight Control Program, with a secondary body fat assessment for the high-risk individuals. More stringent weight screens and body fat standards extend down to the youngest age category (17 to 20 years), illustrated here as the retention screen (triangle symbols). The current "accession" weight maximum, which determines entry into the Army, is also shown for this youngest age group (diamond symbols).

> The wearing of the Army uniform should be a matter of personal pride and satisfaction. Each soldier is a representative of the United States Government, and should have a physical configuration and posture when in uniform that is trim and smart. Waistlines that stretch the front of an otherwise well-fitting blouse or shirt, and "pot-bellies" detract from good military appearance. (AR 600-9, 1976)

Obesity was defined as excessive fat "implying excessive caloric intake or a sedentary existence or both, as causative factors" (AR 600-9, 1976). Much responsibility was placed on the commander to prevent this through early detection: "Particular attention must be directed to the general military appearance, physical condition, and the ability to perform assigned duties." Thus, obesity was an implied cause of poor military performance.

The firm weight standard, imposed to determine who needed to be screened for obesity, was followed with the proviso that maximum weights "were not to be utilized as the sole criterion for a classification as obese." It was acknowledged that "evaluation of the body build, muscular development, and bone structure" may be necessary to differentiate between overweight and obese. The specific guidance to the examining physician was that

> a view of the entire body should be taken, noting the proportions, symmetry of the various parts of the body, chest development, abdominal girth, and the condition and tone of the muscles. An overweight member, who is obviously active, of firm musculature, evidently vigorous and healthy, and who presents a satisfactory military appearance, should not be classified as obese. (AR 600-9, 1976)

These instructions read very much like those given to physicians who screened Civil War draftees a century before. As in all preceding regulations, this one called for the subjective determination by an Army physician—although now it was also the responsibility of unit commanders—to "identify and counsel all personnel who do not present a suitable military appearance or satisfactory level of physical fitness because of an obese/overweight condition." The regulation thus provided a safety margin between precise weight standards and the elimination of good soldiers from the Army.

Department of Defense Directive 1308.1 and the U.S. Army Body Fat Standards

In 1980, President Jimmy Carter, another health- and fitness-minded President, asked for an assessment of military physical fitness programs. A review was conducted by a panel of government scientists (Study of the Military Services Physical Fitness, 1981), and a Department of Defense (DOD) directive was issued based on their recommendations (DOD directive 1308.1, 1981). Included was a requirement that the services use body fat standards to assess obesity. It was directed that weight tables would still be used as a preliminary screen for retention standards, but the final determination would be based on a new objective body fat assessment procedure instead of the physician's assessment.

Obesity was defined by the panel as anything over 22 percent body fat for men and 29 percent for women. Desirable body fat figures were originally to be 15 percent for men and 23 percent for women. These values were based on a consensus by panel members who felt that the figures would require revision as a better understanding was gained of the relationship between health and body fat. Health concerns brought body fat assessment into the recommendations. However, health was construed to be a subset of military performance in terms of "man hours lost due to minor illnesses and lack of vigor." The panel's report (Study of the Military Services Physical Fitness, 1981) noted further that

> . . . to design our physical fitness programs in the military with the singular focus on health enhancement and long-range health care cost savings would be an error in . . . emphasis [since] the most fundamental goal of military physical fitness programs and research efforts must be that of making the personnel of the Services as fit for combat as possible . . . . The American people are supporting the defense establishment with the understanding that all our personnel are fit to fight and win.

In this way, the use of body fat for health screening became confused with military performance objectives; it was easy to transfer body fat to physical performance without hard data because of the pervasive notion that a soldier who looks fat cannot adequately perform military duties. Nevertheless, the DOD directive still indicated a health goal in the use of body fat standards and it noted that "standards shall be evaluated for consistency with health-fat relationships." The panel had relied heavily on the textbook of McArdle et al. (1981) for their recommendations (Study of the Military Services Physical Fitness, 1981). This text suggested 20 and 30 percent body fat for men and women as desirable goals for all purposes; these values included a statistical interval of 5 percent body fat units over the average fatness of fit young men (15 percent body fat) and women (approximately 25 percent body fat) (McArdle et al., 1981). The DOD directive that finally emerged recommended 20 and 26 percent body fat, with services "authorized to set more stringent standards." The panel apparently wanted to bring standards for women closer to the standards for men. These recommended standards were not based on health studies related to body fat, but rather on the mean values of fit individuals in the youngest adult category. Indeed, translating current body mass index health recommendations (Surgeon General's Report on Nutrition and Health, 1988) into body fat would set limits for young men and women at about 26 and 36 percent body fat, respectively.

The body fat standards in the DOD directive were construed to be recommended goals, and each service set their standards differently. The Army standards that were set revolve around the base value of 20 percent body fat for young men. They were established, in part, on the basis of

Army data on aerobic capacity of young male soldiers (Vogel et al., 1986), where a modest inflection point was inferred with lower maximal oxygen uptake above 20 percent body fat. The remainder of the standards were largely linked to this single value. Two percent body fat increments were included for increasing age, very roughly by decades (Table 3-2), to accommodate accepted but poorly quantified age-related changes in body composition. Standards for women were set at 8 percent body fat above those for men in each age category to account for gender-specific "essential" body fat. In retrospect, this 8 percent difference for women—another "consensus" value—may have been overly restrictive. Certainly, the DOD recommendation of 26 percent body fat was too restrictive even for the youngest women, because Army data which were available at that time demonstrated that the average body fat of young women entering the Army was closer to 28 percent.

This scheme for the standards also preserved the stringency of the previous 1976 standards, a consideration in setting the Army body fat standards. The 1976 maximum weights for men and women were assigned as the screening weights for age 40 (and over), and these appeared to suitably screen individuals who approached 26 percent (men) and 34 percent body fat (women). (Some adjustments were later made, with a 5 percent increase in all table weights for women.) This approach helped to establish upper limits of fatness for the oldest age category (Colonel D. D. Schnakenberg, personal communication). Body fat standards for the intermediate age categories were then arbitrarily interpolated between the 20 and 26 percent male body fat limits, with 8 percent added for women. Thus, the current Army body fat standards were adopted as best guesses of performance-related standards, with consideration given to existing weight standards. At the time these standards were required to be enacted, the 20 percent body fat standard for young men was a relatively soft relationship, and the other values were not based on any empirically determined performance relationships.

Attempts to empirically study the relationship of fatness to military performance in women are seriously hampered by the narrow range in body weights of accepted Army women. This limitation is a result of the accession weight standards, which are sufficiently stringent that they exclude 28.7 percent of otherwise qualified young U.S. women (Laurence, 1985, 1988). There is also little difference between accession and retention standards for women, so that substantially overfat women do not remain in the Army. Thus, studying Army women cannot provide enough information to determine if higher body fat limits could be compatible with female military performance. The male accession standards, by comparison, allow young men as much as a 40-pound margin over the screening weights for body fat (Figure 3-3). Thus, few men (3.0 percent) are excluded from joining the

Army (Laurence, 1988), even though some never achieve their fat standards and are later eliminated under provisions of the U.S. Army Weight Control Program regulation.

Attrition from the Army is one of the useful end points to test the validity of body fat standards. It captures, in effect, unsatisfactory military performance for all reasons. If applied to new recruits, it is not confused by separation for failure to meet the standards of the weight control program. It can be reasonably predicted that at some level of fatness, fitness is impaired enough to increase attrition of recruits from the Army. This assumption was originally suggested by M. T. Laurence (1988) who demonstrated higher attrition rates for individuals above 120 percent and below 80 percent of national mean weights. The upper end would correspond to men with a mean body fat of approximately 26 percent. Although there are few male Army recruits above this level, there is a trend toward higher attrition of male recruits with increasing fatness (Friedl et al., 1989). There is no such relationship apparent for women, presumably because of the even more restricted range of body fat. There is, however, a significantly higher attrition of women in the lower end of body mass index, which suggests that some minimum level of fat-free mass is important to success of women in the Army.

Development of Army Body Fat Equations

An Army study was conducted to establish population-specific body fat equations that could be used by soldiers to estimate body fat without special instruction and without costly equipment (Vogel et al., 1988). As an interim (1983–1986) method of body fat measurement, the Army adopted the Durnin-Womersley skinfold equations (Durnin and Womersley, 1974; AR 600-9, 1983). This method required the standardization of measurement procedures by trained medical personnel throughout the Army, using appropriate equipment (usually Lange calipers). Commanders were distressed by the difficulty of obtaining consistent, accurate skinfold measurements and by the jump in body fat that occurred between certain birthdays for the same sum of skinfold measurements (because of the organization of the table by age intervals). Accordingly, the new method was to use simple measurements and avoid the use of age. The DOD directive noted that this assessment was to be applied only to the high-risk (of obesity) group who failed an initial weight screen. A later amendment to the directive (DOD directive, 1308.1, 1987) also required the services to use a circumference-based method, developed by comparison to hydrostatic weight, which achieved a minimum correlation of 0.85 (neither population, sample size, nor standard error of the estimate were specified).

The Army circumference equations were developed from a study in 1984 and 1985 in which 38 anthropometric measurements were obtained from an ethnically diverse sample of Army personnel at Fort Hood, Texas and Carlisle Barracks, Pennsylvania, totalling 1,126 men and 266 women (Vogel et al., 1988). The male equation estimates percent body fat from the difference of the abdominal circumference (at the navel) and the neck circumference, and a height factor is deducted. The female equation uses hip circumference and body weight as components of fatness, with neck, wrist, and forearm circumference and height factors having a lowering effect on estimated percent body fat. Because this was a cross-sectional study, it did not validate the use of the equations to follow individuals over periods of weight loss or body composition change. In fact, there is some question about whether anthropometric equations, in general, can be accurately used to follow percent body fat change during weight loss, although they are routinely used this way. Because the development of these equations is discussed and critiqued elsewhere in this book, only a few points will be highlighted here.

The Army equations may be reasonably good predictors of total body fat in an ethnically diverse population, but this is difficult to evaluate using percent body fat estimated by hydrostatic weighing, because the latter is so greatly influenced by variations in bone density. There is also a problem in obtaining good hydrostatic weight measurements from nonswimmers who are uncomfortable with performing maximal exhalations under water; Black women were particularly overrepresented in the subpopulation of excluded hydrophobic subjects from the Army Body Composition Study (Vogel et al., 1988). The method of residual volume determination used in conjunction with hydrostatic weighing may also produce significant differences in estimated body fat, especially for men (Forsyth et al., 1988). Anthropometric methods may be more equitable than hydrostatic weighing across ethnic and gender groups, although this can only be established using another criterion method.

Because circumference measurements necessarily emphasize certain sites, the standards become, in effect, circumference standards instead of total body fat standards. Accordingly, soldiers are not allowed to pick and choose their method of body fat estimation; they are held to Army circumference standards. This is reasonable if it can be demonstrated that desired objectives are still achieved using this standard. In fact, the circumference at the navel is a good site selection for men (a) as a marker of fitness, because it is the primary fat storage site in overnourished and underexercising men; (b) as the single fat site most correlated with long-term health risk factors including reduction of HDL-cholesterol, reduced glucose tolerance, and directly with cardiovascular mortality; and (c) as the primary site of concern in appearance (the potbelly). It can also be shown from the data how abdominal circumference increases linearly (in proportion to hip circumference) with hydrostatically estimated percent body fat, although the strength of this relationship is less important if abdominal fat, not total fat, is the best discriminator of military performance objectives. Which site is ideal for women is less certain and there are more sites with more specific physiological roles to consider. Hip circumference appears to be one reasonable site as an indicator of fatness and fitness in healthy young women: as a primary site of fat deposition; and, with exercise, as a primary site of fat mobilization.

CONCLUSIONS

In the frontispiece to their book on human physique, Sheldon et al. (1940) showed photographs of three extremes of somatotype: an endomorph, who was characterized by pendulous fat deposits; a mesomorph, who looked well proportioned and muscular; and an ectomorph, who looked like a victim of anorexia nervosa. There can be little argument about which of these three types would make a suitable soldier. Without question, the massively obese endomorph would be unable to perform physically, would fail even the most subjectively lenient standards of military appearance, would likely encounter acute as well as long-term health problems as a direct consequence of excess fat, and would suffer miserably with work in even a moderately hot environment. At the other extreme of size, the ectomorph would be unable to carry a normal load on a standard road march task, would likely suffer health problems from extreme deficiency of muscle mass, and would be unable to effectively thermoregulate in a cold environment. The current Army body composition standards ignore the ectomorph, because this soldier is undetected by the height-weight screening tables, even when the soldier is so deficient in fat-free mass that relative body fat is high. This omission is a change from the earlier standards, which emphasized the exclusion of physically weak individuals who would have difficultly with basic soldier tasks. At the upper end, the endomorph is clearly excluded by current Army standards, as are many individuals who may even approach the mesomorph in appearance and physical capabilities. Thus, the second change from previous standards is that current body fat standards draw a precise line, without confidence intervals, for acceptable fatness; these standards take into account neither the strength of the association between body fat and military performance nor the reliability of the method of estimation. Previously, a physician made the final subjective determination that a soldier was unsuited to the Army because of his or her obesity, but this was subjective and had little impact on offenders of military appearance. Without this buffer, the arbitrary standards have had a major impact. Thus, it becomes more important to test and carefully adjust body composition standards to performance end points to ensure that good soldiers are not eliminated.

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4

Body Composition in the Military Services: Standards and Methods

James A. Hodgdon

BACKGROUND

This paper will discuss two topics: the development of standards for body composition in the U.S. Navy and the methods of body composition assessment in use by the military services today.

In 1981, the Department of Defense (DOD) issued directive 1308.1 (DOD directive 1308.1, 1981). Part of the policy expressed in that directive was that the "determining factor in deciding whether or not a service member is overweight is the member's percent body fat." (DOD Directive 1308.1, p. 2 Encl. 2, 1981). The military services were directed to determine body composition and fat standards consistent with the mission of the services.

The directive also indicated that there are three concerns relating to the need for establishing a weight control policy: first, body composition is an integral part of physical fitness and is, therefore, essential for maintaining combat readiness. This statement implies a relationship between fatness and military performance. Second, control of body fat (BF) is necessary to maintain appropriate military appearance. Third, control of BF is important in maintaining the general health and well-being of armed forces personnel.

The directive left the task of developing the most appropriate methodology for BF determination to the individual services. The directive required that fat measurement techniques must have a correlation coefficient of 0.75 or better with percent BF from underwater weighing. This coefficient has since been increased to 0.85. DOD percent BF goals were set at 20 percent BF for men and 26 percent BF for women.

BODY COMPOSITION STANDARDS

If body composition was presumed to affect military performance, military appearance, and general health and well-being, the basis for setting standards ought to lie with one of these three relationships. Below is the line of argument followed within the U.S. Navy to arrive at suitable standards for body composition.

Body Composition and Physical Performance

Performance on the U.S. Navy's biannual Physical Readiness Test (PRT) is taken to be an indicator of a sailor's readiness for combat. As an adjunct to setting standards for physical fitness and body composition, studies were carried out that investigated relationships between performance on the PRT items and performance of materials handling tasks. The Navy's PRT includes a body composition assessment, sit-reach distance, time for a 1.5-mile run, number of sit-ups performed in 2 minutes, and number of push-ups performed in 2 minutes. Work by Robertson and Trent (1985) at the Navy Personnel Research and Development Center showed that the majority of the physically demanding jobs performed by Navy personnel were materials handling tasks: lifting, carrying, and pulling, with the most common being carrying while walking (48 percent) and lifting without carrying (20 percent). Performance on such tasks might form a reasonable basis for setting standards for shipboard work.

Beckett and Hodgdon (1987) investigated associations between PRT items, body composition variables, and performance on two materials handling tasks. The two tasks were: the maximum weight of a box that could be lifted to elbow height (box-lift maximum weight) and the total distance a 34-kg box could be carried (box carry power) on alternate laps of a 51.4-m course during two 5-minute work bouts. The parameters of the carry task represented median values of the weight, distance, and timing of Robertson and Trent's survey of carry tasks performed aboard ship. Table 4-1 shows the correlations between PRT and body composition items, and performance on the lift and carry.

Table 4-1 shows percent BF to be only modestly correlated with these materials handling tasks. These modest correlations suggest that using relationships between these tasks and percent BF as the basis of setting percent BF standards would not be particularly fruitful. However, it might be noted that one of the body composition variables (fat-free mass [FFM]) is highly correlated with the box-lift maximum weight. In this study, FFM was also

TABLE 4-1 Correlations, U.S. Navy Physical Readiness Test Items, and Body Composition with Materials Handling Tasks*

	Box-Lift Maximum Weight	Box-Carry Power
Sit-reach distance	-0.21	0.01
Sit-ups in 2 minutes	-0.00	0.31
Push-ups in 2 minutes	0.63	0.56
1.5-mile run time	-0.34	-0.67
Percent fat (from circumferences)	-0.36	-0.43
Fat-free mass	0.84	0.44
Fat mass	0.08	-0.23

*n = 102 Navy personnel: 64 men and 38 women.
SOURCE: Beckett and Hodgdon (1987) by permission.

found to be highly correlated with other muscle strength measures. The possibility exists for using FFM as an approximation of overall strength in job assignment.

Body Composition and Appearance

The second stated reason for maintaining appropriate levels of BF is for proper military appearance. It is the Navy's policy that judgments about appearance are subjective and not necessarily strongly related to fatness. Current performance evaluation procedures allow for these subjective assessments, and they need not be anchored to other objective variables.

The soundness of this approach was recently tested by Hodgdon and colleagues (1990). A panel of 11 U.S. Army headquarters staff (5 women, 6 men; 6 officers, 5 enlisted; and including both Black and White members) rated the "military appearance" of 1,075 male and 251 female U.S. Army personnel dressed in Class A uniform. Physical characteristics of this population sample are provided in Table 4-2. A 5-point scale was used for the ratings. In this scale, a value of 1 was labeled "poor"; a value of 2, "fair"; a value of 3, "good"; a value of 4, "very good"; and a value of 5, "excellent". The raters were instructed to rate the "military appearance" of the soldier according to their own personal standards, and instructed to evaluate how the individual looked in uniform, not how the uniform looked. The personnel who were rated also had their percent BF determined from underwater weighing. The inter-rater reliability of the ratings was quite good (*alpha* = 0.86 for rating of men, 0.87 for rating of women). The results of the regression analysis to predict measured percent BF from the ratings of appearance

TABLE 4-2 Participant Characteristics in U.S. Army Personnel Appearance Study

	Males (n^* = 1,075)	Females (n = 251)
Height (cm)	175.1 ± 6.9	162.5 ± 6.2
Weight (kg)	77.1 ± 11.2	60.3 ± 8.1
Age (yrs)	30.1 ± 8.9	24.0 ± 57
Body Density (kg/l)	1.052 ± 0.015	1.036 ± 0.012
Body Fat Content (% body wt)	20.6 ± 6.9	28.0 ± 5.7
Fat-free Mass (kg)	60.9 ± 7.3	43.1 ± 4.8
Fat Mass (kg)	16.3 ± 7.1	17.1 ± 5.2
Appearance Rating in Uniform	3.31 ± 0.62†	3.21 ± 0.67‡

*n = number of subjects.
†n = 988.
‡n = 233.

are provided in Table 4-3. The correlation between appearance ratings and percent fat was modest: 0.53 for ratings of male personnel, and 0.46 for ratings of female personnel. The square of the correlation coefficient indicates the percent of the total variance in one variable accounted for by the other. Percent fat accounts for only 28 percent of the measured variance in appearance for men, only 22 percent for women. It does not appear from this study that percent BF, by itself, constitutes a reasonabl indicator of military appearance. Clearly, other factors play a role in such judgments.

Body Composition and Health

The DOD directive points out that one of the reasons for wanting to set BF standards is the maintenance of health and well-being of the service

TABLE 4-3 Prediction of Appearance from Percent Fat Scores in U.S. Army Personnel Appearance Study

Predictor	Regression Coefficient	Constant	R^*	R^2	SEE†
Males:					
Percent fat	-0.047	4.277	0.53	0.28	0.523
Females:					
Percent fat	-0.054	4.721	0.46	0.22	0.598

*R = multiple correlation coefficient.
†SEE = standard error of the estimate.

members. It is in the relationship between health and fatness that the Navy has anchored its body composition standards.

On February 11–13, 1985, the National Institutes of Health (NIH) Office of Medical Applications of Research; the National Institute of Arthritis, Diabetes, and Digestive and Kidney Diseases; and the National Heart, Lung, and Blood Institute convened a consensus development conference on the health implications of obesity (National Institutes of Health, 1985). The conferees determined that obesity is related to a significant impairment of health, particularly in terms of increased risk of diabetes, hypertension, coronary artery heart disease, and cancer. They also agreed that obesity could be defined as a weight-for-height 20 percent above the midpoint weight listed in the 1983 Metropolitan Life Insurance tables for the medium-frame individual (Metropolitan Life Insurance Company, 1984).

Armed with this definition, and the information that obesity could be considered a health risk, the following study determined whether or not these weight-for-height tables had any reasonable expression in percent BF. Using the Navy anthropometry data set, the regression between weight and height and percent BF was determined. Table 4-4 describes the data set used for development of the regressions.

The regressions that were developed were:

$$\text{Percent BF} = 0.464 \times \text{weight (kg)} - 0.411 \times \text{height (cm)} + 54.769$$
$$(R = 0.75,\ \text{SEE} = 5.33 \text{ percent BF}) \text{ for men,}$$

and

$$\text{Percent BF} = 0.638 \times \text{weight (kg)} - 0.409 \times \text{height (cm)} + 54.367$$
$$(R = 0.77,\ \text{SEE} = 4.54 \text{ percent BF}) \text{ for women,}$$

where R = multiple correlation coefficient and SEE = standard error of the estimate.

TABLE 4-4 Regression Sample Descriptions

	Men (n^* = 1,024)	Women (n = 340)
	Mean ± standard deviation	
Age (years)	31.9 ± 6.93	26.6 ± 5.29
Height (cm)	177.6 ± 6.96	164.5 ± 6.71
Weight (kg)	85.7 ± 14.45	62.2 ± 9.35
Percent fat (underwater weighing)	21.6 ± 8.07	26.8 ± 7.07

* n = number of subjects.

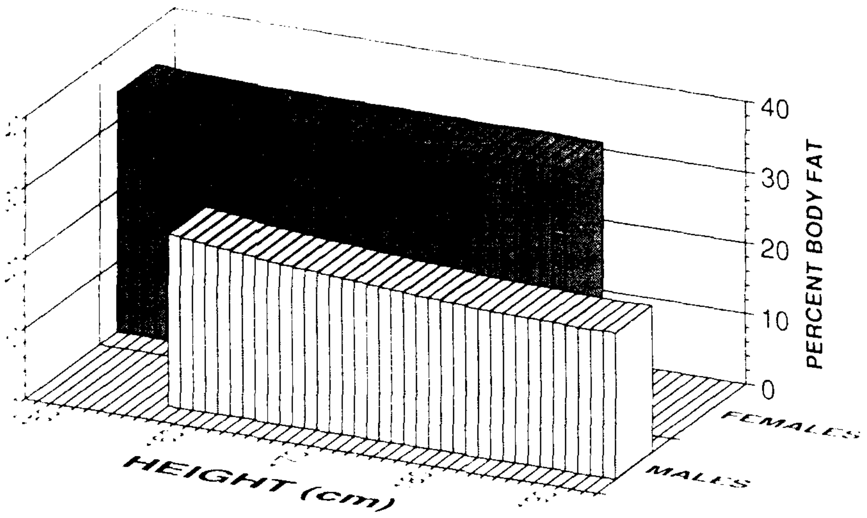

FIGURE 4-1 National Institutes of Health critical weights for each height expressed as percent fat.

Using these equations, we then determined the percent BF value associated with the NIH critical weights at each height for both men and women. The results are provided graphically in Figure 4-1. As can be seen from Figure 4-1, the "critical" percent BF values are rather constant across heights, especially the values for women. Mean values for critical percent BF across height were 22.0 ± 1.20 for men and 33.5 ± 0.18 for women.

Standards for percent BF for Navy personnel were derived from these mean values. The circumference equations used by the U.S. Navy to predict BF have standard errors of measurement of approximately 3.5 percent BF. It was decided that the standard for administrative action should be approximately one standard error above the critical percent BF to minimize the number of false positives for individuals exceeding the NIH obesity definition. The values of 26 percent BF for men and 36 percent BF for women were thus adopted. Any sailor or officer exceeding these limits for three successive administrations of the PRT is subject to administrative action. In addition, an "overfat" category was defined. Individuals exceeding values of 22 percent BF, if men, or 30 percent BF if women, are required to go on a fat reduction program. This approach allows remedial action on BF reduction to begin prior to exceeding the limits for admin-istrative action.

The finding that the NIH critical weights represent a relatively constant percent BF for men and women is intriguing, especially when one considers that those weights derive from the empirically determined Metropolitan Life Insurance Tables (Metropolitan LIfe Insurance Company, 1984). However, there is a paucity of data relating body composition variables themselves to mortality and morbidity outcomes. Such epidemiological studies need to be done.

In summary, the U.S. Navy, finding a lack of basis for setting body composition standards based on either performance or appearance, has chosen to base its standards on health considerations. The standards are derived from the NIH consensus definition of obesity.

BODY COMPOSITION MEASUREMENT

The criteria for selecting methods for assessment of body composition in the military were that the measures must be: usable easily in the field, able to be made reliably, and be valid indicators of fatness. It was also important that skill in measurement be relatively easily acquired. To meet these measurement technique requirements, all four services have adopted circumference measurements, often in conjunction with height and weight, as the basis for predicting percent BF.

Reliability and Trainability

In 1987, Mueller and Malina determined intra- and interexaminer reliabilities of skinfold and circumference measurements. They found both techniques to be quite reliable but circumferences to be more reliably measured than skinfold thicknesses (0.97 and 0.96 for circumference intra- and interexaminer reliabilities, respectively, and 0.94 and 0.92 for skinfold reliabilities).

In addition to being slightly more reliably made, circumference measurements appear to be more easily learned. J. H. Heaney and coworkers (Naval Health Research Center, San Diego, unpublished manuscript) investigated the time course for acquiring skill in circumference and skinfold thickness measurement. Thirty-eight active duty Navy personnel were provided six 1-hour training sessions during which they were trained and evaluated in skinfold measurements at two sites and circumference measurements at three sites. Heaney and coworkers found that after 75 skinfold measurements at each site (150 total measurements), only 24 percent of the study participants had reached proficiency in skinfold measurement. In contrast, 68 percent of the participants had reached proficiency after 45 circumference measurements at each site (135 total measurements). In this study, circumference measurement was clearly the more easily learned technique.

Equation Validity

Each of the services developed regression equations involving body circumference measurements, sometimes in conjunction with height or weight or both. The regression equations predict either body density, percent BF, or FFM. For the U.S. Army, Navy, and Marine Corps, the criterion measurement for equation development was either body density from underwater weighing or percent BF using the Siri (1961) equation to convert body density to percent BF. The U.S. Air Force equations use as a criterion measure FFM determined from tritiated water dilution or from body volume and weight (Allen, 1963). Tables 4-5a and 4-5b contain the equations and descriptive data from the equation development samples for the military services. Sample descriptors are shown as mean plus or minus standard deviation.

U.S. Army

The U.S. Army equations were developed by Vogel and coworkers (1988) at the U.S. Army Research Institute of Environmental Medicine on a large sample of Army personnel. The sample was not stratified to reflect distributions of demographic variables (for example, age, gender, race, job classification) within the Army population.

These equations are used in conjunction with weight-for-height tables that serve as an initial screening tool in detecting overfat. Current Army BF retention standards are based on age (AR 600-9, 1986). Standards for men are 20 percent BF for ages 16–20 years, 22 percent BF for ages 21–27 years, 24 percent BF for ages 28–39 years, and 26 percent BF for ages 40 years and older. Standards for women are 28 percent, 30 percent, 32 percent, and 34 percent BF respectively, for the same age groupings as the men.

U.S. Navy

The U.S. Navy equations were developed by Hodgdon and Beckett (1984a,b) at the Naval Health Research Center. Their large sample of U.S. Navy personnel was also nonstratified with respect to Navy demographics. Within the Navy every service member has his or her BF estimated twice each year using these equations (U.S. Department of the Navy, 1986a). There are no weight-for-height screening tables used. As noted above, the current retention standards are 26 percent BF for men and 36 percent BF for women, irrespective of age.

U.S. Marine Corps

The Marine Corps was the first service to use body composition estimation from circumferences. The Marine Corps equations were developed by Wright and coworkers (1980, 1981) of the Institute of Human Performance from data collected by Wright and Wilmore (1974) on Marine Corps personnel. The Marine Corps uses weight-for-height tables as the basis for

TABLE 4-5a Body Composition Equations for the Military Services

Equations
U.S. Army (Vogel et al., 1988)
Men
Percent fat = 76.5 × Log_{10} (abdomen II − neck) − 68.7 × Log_{10}(height) + 46.9
R = 0.82, SEE = 4.02
Women
Percent fat = 105.3 × Log_{10}(weight) − 0.200 × wrist − 0.533 × neck − 1.574 × forearm + 0.173 × hip − 0.515 × height − 35.6
R = 0.82, SEE = 3.60
U.S. Navy (Hodgdon and Beckett, 1984a,b)
Men
Density = −.191 × Log_{10}(abdomen II − neck) + 0.155 × Log_{10}(height) + 1.032
Percent fat = 100 × [(4.95/density) − 4.5]
R = 0.90, SEE = 3.52
Women
Density = −.350 × Log_{10}(abdomen I + hip + neck) + 0.221 × Log_{10}(height) + 1.296
Percent fat = 100 × [(4.95/density) − 4.5]
R = 0.85, SEE = 3.72
U.S. Marine Corps (Wright et al. 1980, 1981)
Men
Percent fat = 0.740 × abdomen II − 1.249 × neck + 40.985
R = 0.81, SEE = 3.67
Women
Percent fat = 1.051 × biceps − 1.522 × forearm − 0.879 × neck + 0.326 × abdomen II + 0.597 × thigh + 0.707
R = 0.73, SEE = 4.11
U.S. Air Force (Fuchs et al., 1978; Brennan, 1974)
Men
FFM = 0.018 × *flex-biceps*^{2} + 0.514 × *height* − 49.67
R = 0.84, SEE = 2.95 kg
Percent fat = 100 × (weight − FFM)/weight
Women
FFM = 1.619 × forearm + 0.311 × height − 47.76
R = 0.84, SEE = 2.29 kg
Percent fat = 100 × (weight − FFM)/weight

NOTE: Circumference measurements and height are in cm; FFM = fat-free mass; SEE = standard error of the estimate.

TABLE 4-5b Body Composition Development Data for the Military Services

Service	Gender	n*	Age (years)	Height (cm)	Weight (kg)	Percent Fat
				Mean ± standard deviation		
U.S. Army	Men	1,126	30.2 ± 8.9	175.0 ± 6.9	77.1 ± 11.3	26.6 ± 7.0
U.S. Army	Women	266	24.1 ± 4.5	162.6 ± 6.2	60.4 ± 8.2	28.0 ± 6.1
U.S. Navy	Men	602	31.9 ± 7.1	176.8 ± 7.0	84.3 ± 14.9	21.6 ± 8.1
U.S. Navy	Women	214	26.5 ± 5.2	164.5 ± 6.6	61.7 ± 9.3	27.0 ± 6.9
U.S. Marine Corps	Men	279	28.7 ± 8.2	177.1 ± 6.3	77.9 ± 9.8	16.5 ± 6.2
U.S. Marine Corps	Women	181	23.1 ± 5.9	164.3 ± 6.3	59.3 ± 6.7	23.1 ± 5.9
U.S. Air Force	Men	197	37.0 (19 – 57)†	—		20.3 (5.9 – 35.6)†
U.S. Air Force	Women	38	22.2(18 – 28)†	162.3(147.2 – 178.5)†	57.3(43.5 – 83.4)†	26.5(14.6 – 44.0)†

*n = number of subjects.
†Range.

weight control decisions (U.S. Department of the Navy, 1986b). If a Marine is overweight by the tables but does not appear to be fat, he or she may have a BF estimation done. If the individual's BF is less than the Marine Corps standards of 18 percent BF for men and 26 percent BF for women, a new maximum allowable weight is calculated and entered into the Marine's record.

U.S. Air Force

The U.S. Air Force body composition equation for men was developed by Fuchs and coworkers (1978) at the U.S. Air Force School of Aerospace Medicine. The equation for women was developed by Brennan (1974) as part of her master's work at the Incarnate Word College in San Antonio. Unlike the equations of the other services, the U.S. Air Force equations predict FFM. Also, the development sample for the women's equation contained some non-service personnel.

Like the Marine Corps, the U.S. Air Force has a weight-for-height standard (AFR 35-11, 1985). Individuals whose weight exceeds the standard will have their body composition determined. If they do not exceed the U.S. Air Force BF standards (20 percent BF for men less than 30 years of age, 26 percent BF for men older than 30 years; 28 percent BF for women less than 30 years, 34 percent BF for women older than 30 years), new maximum allowable weight can be assigned. Similarly, individuals whose weight does not exceed the standard, but who appear obese, can have a new allowable weight assigned based on BF measurement.

Cross-Validation

To provide a basis for comparing the performance of these equations on a general military population, each of the equations was cross-validated on the Navy anthropometric sample described in Table 4-2. If the equation did not predict percent BF directly, the equation output was converted to percent BF. Predicted percent BF was correlated with percent BF derived from underwater weighing using the Siri (1961) equation. Table 4-4 shows the results of this cross-validation. Note the U.S. Air Force equation for men is only cross-validated on a subset of the U.S. Navy sample. This is because flexed biceps measurements were only made on a few of the Navy subjects.

It is apparent from Table 4-4 that predicted BF was rather highly correlated with hydrostatic BF in all of the equations. More importantly, the standard errors of measurement seen here with these equations are comparable to those seen with other generalized equations in common use, including those using skinfolds (Durnin and Womersley, 1974; Jackson and Pollack, 1978; Jackson et al., 1980). Hodgdon and Beckett (1984a,b) and Wright et

TABLE 4-6 Cross-Validation of Military Equations, U.S. Navy Sample

	Correlation Coefficient	Mean Difference (percent fat)	Standard Error of Measurement (percent fat)
U.S. Army			
Men	0.89	3.15	3.73
Women	0.79	-0.17	4.39
U.S. Navy			
Men	0.89	0.02	3.63
Women	0.84	-0.17	3.82
U.S. Marine Corps			
Men	0.87	-0.75	4.05
Women	0.80	-2.88	4.25
U.S. Air Force			
Men*	0.74	2.67	5.17
Women	0.78	4.18	4.45

*Cross-validation on only 52 Navy subjects.

al. (1980) have already shown that generalized circumference and skinfold equations have similar validities when applied to these military population samples.

SUMMARY

Two major summary points can be made: first, there is admittedly a need to further validate the relationship between body composition and health outcomes. However, as evidenced by the studies presented here, it would appear at present that health considerations are the most rational scientific basis for setting body composition standards. Second, the military services have used standard techniques to derive equations to estimate relative BF from anthropometric measures: body circumferences, height, and weight. When applied to a general military population sample, these equations have validities and standard errors of measurement similar to other published, generalized anthropometric equations and would appear to be reasonable, useful estimators of body composition.

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5

Effects of Experimental Alterations in Excess Weight on Physiological Responses to Exercise and Physical Performance

Kirk J. Cureton

INTRODUCTION

There is little experimental data describing the effects of altered body composition on physical performance. This is because body composition is difficult and time-consuming to change in human volunteers. In the late 1970s, three studies were conducted that were designed to investigate the effects of experimental alterations in excess weight on physiological responses to exercise and on physical performance capabilities. The research objective was to use an experimental model to simulate the effects of different levels of body fatness in order to determine whether the cross-sectional data available describing relationships between percent body fat (BF) and physical performance reflected cause and effect.

EXCESS WEIGHT, AEROBIC CAPACITY AND RUNNING PERFORMANCE

The first study (Cureton et al., 1978) involved investigating the effects of experimental manipulation of excess weight on aerobic capacity and distance running performance. It was known from cross-sectional data that percent BF is inversely related to aerobic capacity ($\dot{V}_{O_2\,max}$) expressed relative to body weight (BW) and to distance running performance (Figure 5-1), but the magnitude of changes in $\dot{V}_{O_2\,max}$ and distance running performance that result from altered percent BF had not been established.

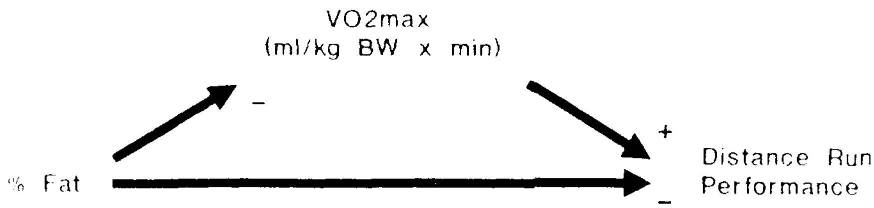

FIGURE 5-1 Diagram of relationships among percent body fat, $\dot{V}_{O_2max}$ (ml/kg body weight × minute) and distance run performance reported in cross-sectional studies.

Six recreational runners, four men and two women, 20 to 30 years of age, were used as subjects. They were relatively lean and had above average $\dot{V}_{O_2max}$ (ml per kg body weight per minute) (Table 5-1). Body composition was estimated from body density, which was determined using hydrostatic weighing. A maximal, graded, running treadmill test and the 12-minute run were administered under four added-weight (AW) conditions: 0, 5, 10, and 15 percent AW. Weight was added to the trunk of the subjects using a weight belt and shoulder harness.

During submaximal running on the treadmill at 188 meters per minute (7 miles/hour), addition of excess weight significantly and systematically increased ventilation, oxygen uptake in liters per minute, and heart rate but did not significantly alter the oxygen uptake expressed relative to the total weight carried (TW). This latter measure tended to decrease slightly (Table 5-2). During maximal running, addition of excess weight did not significantly affect ventilation, oxygen uptake in liters per minute, or heart rate but systematically decreased $\dot{V}_{O_2max}$ (ml/kg TW × minute), treadmill run time, and 12-minute run performance. Under the 15 percent AW condition, these three measures were reduced 6.9 ml/kg/minute (12 percent), 1.5 minutes (10 percent), and 277 meters (8 percent), respectively, compared to the normal weight condition (Table 5-3). The changes by individual subjects for $\dot{V}_{O_2max}$ (ml/kg TW × minute) and 12-minute run performance were very consistent (Figure 5-2). The average reductions in $\dot{V}_{O_2max}$ and 12-minute run distance per 1 percent added weight were 0.5 ml/kg TW × minute and 18 meters, respectively.

Comparison of the $\dot{V}_{O_2}$ (liters per minute) during submaximal and maximal running clearly indicated that the primary metabolic effects of addition of excess weight were to increase the energy requirement of running at submaximal speeds without affecting the absolute $\dot{V}_{O_2max}$ (Figure 5-3). Any submaximal speed of running therefore required a higher percentage of $\dot{V}_{O_2max}$, and $\dot{V}_{O_2max}$ was reached at a lower speed of running, which in turn, resulted in a reduction in treadmill time. The mechanism by which added

TABLE 5-1 Physical Characteristics of Subjects in Cureton and Coworkers (1978) Study

Subject	Gender	Age (years)	Height (cm)	Weight (kg)	Fat (%)	FFW (kg)	$\dot{V}_{O_2\,max}$ (ml/min × kg BW)	$\dot{V}_{O_2\,max}$ (ml/min × kg FFW)
1	M	27	191.5	72.1	7.1	67.0	62.2	67.6
2	M	29	183.7	79.4	11.8	70.0	57.5	65.4
3	M	25	168.3	60.1	7.6	56.3	58.4	62.2
4	M	30	181.9	64.2	10.9	57.2	56.1	62.3
5	F	26	169.5	60.1	19.9	48.1	47.7	58.4
6	F	20	163.7	53.2	21.6	41.7	49.9	63.3

NOTE: FFW = fat-free weight; BW = body weight.

SOURCE: K. J. Cureton, P. B. Sparling, B. W. Evans, S. M. Johnson, U. D. Kong, J. W. Purvis. Effect of experimental alterations in excess weight on aerobic capacity and distance running performance. Med. and Sci. Sports 10:194-199, 1978. © by The American College of Sports Medicine, by permission.

TABLE 5-2 Means ± SD and *F* Ratios for Physiological Variables Measured During Sub-Maximal Treadmill Running (7 mph) for the Four Added Weight (AW) Conditions

Variables	% AW 0	5	10	15	*F* Ratio
		n = 6			
V_E (l/min)	49.4 ± 5.0	51.4 ± 6.3	52.2 ± 3.1	54.5 ± 4.2	5.37*
$\dot{V}_{O_2}$ (l/min)	2.292 ± .317	2.350 ± .349	2.363 ± .327	2.515 ± .385	5.97†
$\dot{V}_{O_2}$ (ml/min × kg BW)	35.6 ± 2.3	36.1 ± 2.5	36.6 ± 2.7	38.7 ± 2.5	4.33*
$\dot{V}_{O_2}$ (ml/min × kg FFW)	40.8 ± 3.3	41.8 ± 3.7	42.1 ± 4.3	44.7 ± 3.5	5.78†
$\dot{V}_{O_2}$ (ml/min × kg TW)	35.6 ± 2.3	34.4 ± 2.5	33.3 ± 2.4	33.6 ± 2.2	3.05
Heart rate‡ (bpm)	150 ± 12	153 ± 9	155 ± 8	160 ± 12	7.20†
R	.94 ± .04	.94 ± .05	.96 ± .05	.95 ± .05	<1.00

NOTE: *n* = number of subjects; BW = body weight; FFW = fat-free weight; TW = total weight carried; *R* = respiratory exchange ratio: $\dot{V}_{O_2}$ (l/min) divided by $\dot{V}_{CO_2}$ (l/min).

*$p < .05$.

†$p < .01$.

‡Based on five subjects due to a technical difficulty with EKG recording on one subject.

SOURCE: K. J. Cureton, P. B. Sparling, B. W. Evans, S. M. Johnson, U. D. Kong, J. W. Purvis. Effect of experimental alterations in excess weight on aerobic capacity and distance running performance. Med. and Sci. Sports 10:194-199, 1978. © by The American College of Sports Medicine, by permission.

TABLE 5-3 Means ± SD and F Ratios for Physiological Variables Measured During Maximal Treadmill Running and 12-Minute Run Performance for the Four Added Weight (AW) Conditions

Variables	% AW 0	5	10	15	F Ratio
			$n = 6$		
V_E (l/min)	105.3 ± 19.3	106.4 ± 21.0	103.4 ± 21.8	106.9 ± 18.9	2.68
V_{O_2} (l/min)	3.605 ± .822	3.587 ± .837	3.537 ± .854	3.644 ± .776	3.47*
V_{O_2} (ml/min × kg BW)	55.3 ± 5.5	54.5 ± 5.5	54.1 ± 6.1	55.7 ± 5.4	2.08
V_{O_2} (ml/min × kg FFW)	63.2 ± 3.1	62.9 ± 3.3	61.9 ± 3.5	64.1 ± 3.3	3.48*
V_{O_2} (ml/min × kg TW)	55.3 ± 5.5	51.9 ± 5.2	49.1 ± 5.5	48.4 ± 4.7	48.11‡
Treadmill run time (min)	14.8 ± 2.3	14.3 ± 2.4	13.7 ± 2.2	13.2 ± 1.8	20.16‡
Heart rate (bpm)	194 ± 8	193 ± 9	193 ± 7	192 ± 8	<1.00
R	1.19 ± .04	1.20 ± .05	1.18 ± .06	1.20 ± .04	<1.00
12-minute run (m)	3230 ± 306	3104 ± 277	3043 ± 263	2953 ± 254	46.26‡

NOTE: n = number of subjects; BW = body weight; FFW = fat-free weight; TW = total weight carried; R = respiratory exchange ratio: V_{O_2} (l/min) divided by V_{CO_2} (l/min).

*$p < .05$.

‡$p < .01$.

SOURCE: K. J. Cureton, P. B. Sparling, B. W. Evans, S. M. Johnson, U. D. Kong, J. W. Purvis. Effect of experimental alterations in excess weight on aerobic capacity and distance running performance. Med. and Sci. Sports 10:194-199, 1978. © by The American College of Sports Medicine, by permission.

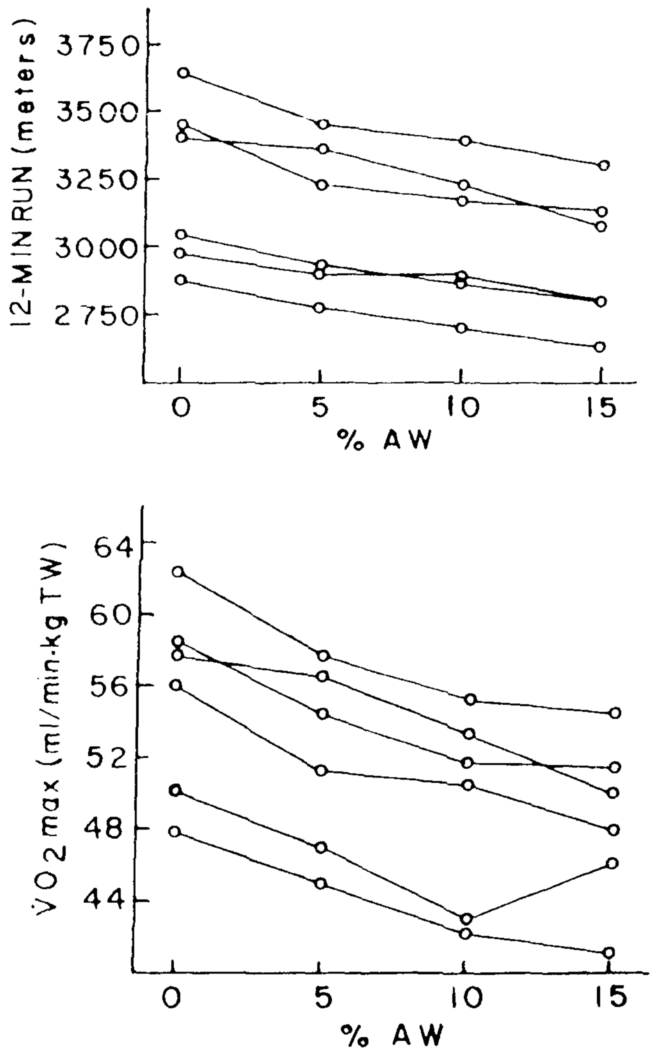

FIGURE 5-2 Individual values for the 12-minute run performance and $\dot{V}_{O_2\,max}$ (ml/kg total weight × minute) for the four added-weight conditions. SOURCE: Cureton et al. (1978) by permission.

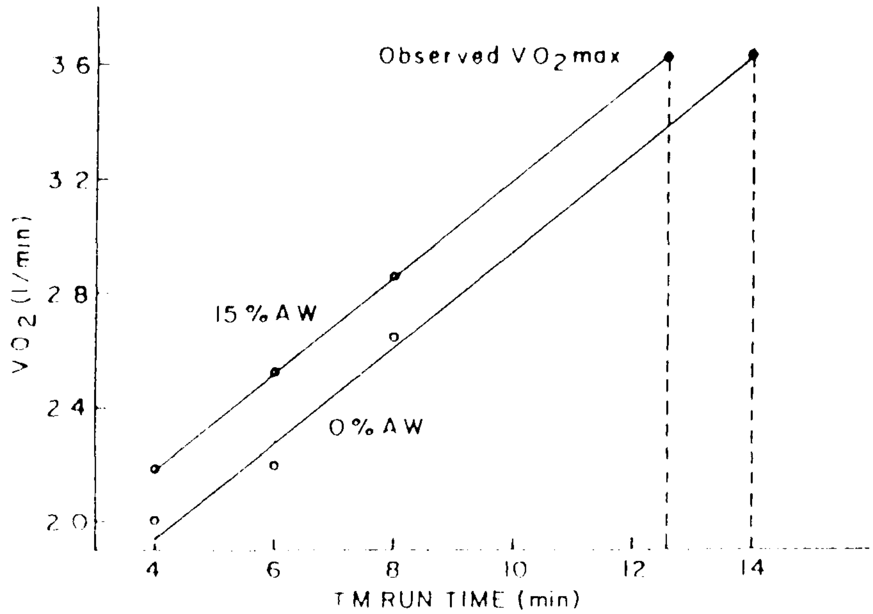

FIGURE 5-3 Treadmill (TM) run time estimated from mean submaximal and maximal $\dot{V}_{O_2}$ (liters per minute) values for the 0 percent and 15 percent added-weight (AW) conditions. SOURCE: Cureton et al. (1978) by permission.

weight affected the 12-minute run performance should have been the same, assuming an individual ran at the same fraction of the $\dot{V}_{O_2max}$ across AW conditions.

A measure of the total excess weight (EW) carried during the treadmill and track runs can be computed by adding the fat weight of each subject to the AW. This increases the dispersion of excess weight compared to that when just AW is considered and substantially strengthens the relationship of EW to $\dot{V}_{O_2max}$ (ml/kg TW × minute) and 12-minute run performance (Figure 5-4). The changes in run performance associated with the variation in percent BF closely paralleled the changes that resulted from added weight, which indicates that the relationship of percent BF to these measures was similar to the effects of added weight.

Based on the results of this study, it was concluded that (a) excess (fat) weight causally affects $\dot{V}_{O_2max}$ expressed relative to weight and distance running performance and (b) two alternate metabolic explanations can be given for the detrimental effect of excess weight on distance running performance. One explanation is that excess (fat) weight increases the energy requirement of submaximal exercise without affecting the absolute $\dot{V}_{O_2max}$.

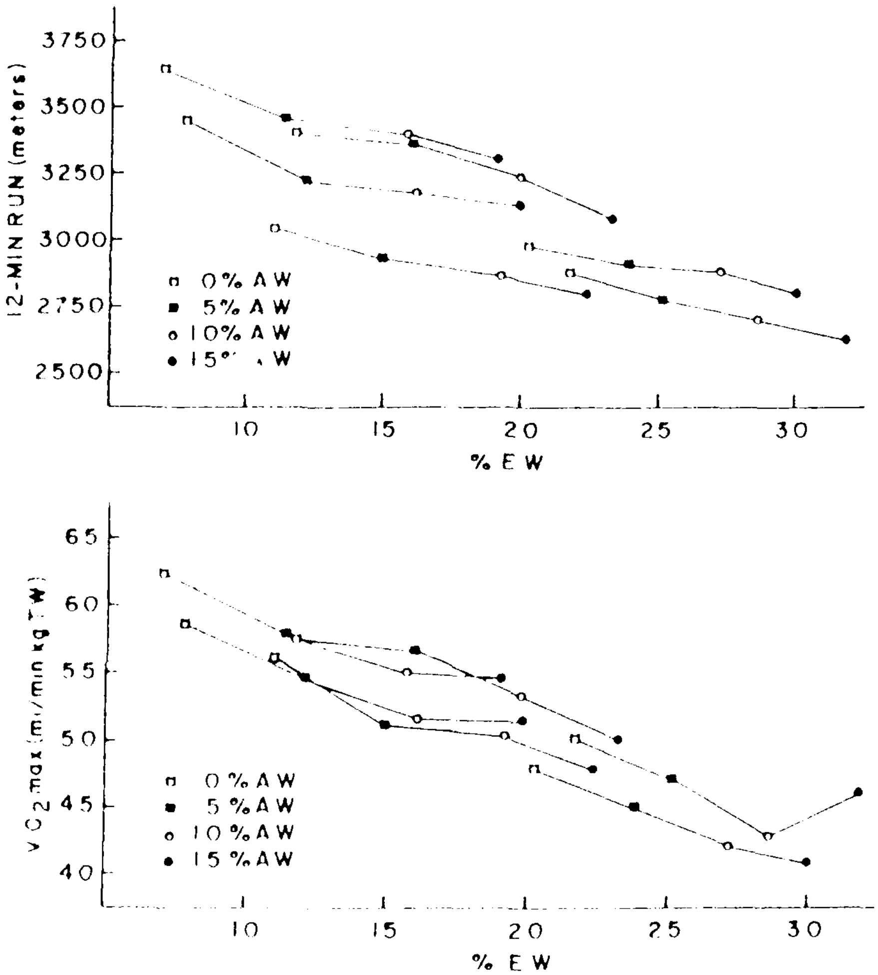

FIGURE 5.4 Relationships of percent excess weight (EW) to 12-minute run performance and $\dot{V}_{O_2}$ (ml/kg total weight × minute). AW = added weight. SOURCE: Cureton et al. (1978) by permission.

Therefore, running at any submaximal speed requires a higher percentage of $\dot{V}_{O_2max}$, and the pace that can be maintained for a given duration is reduced. An alternate explanation is that excess (fat) weight reduces the $\dot{V}_{O_2max}$ expressed relative to weight without affecting the oxygen requirement of submaximal running per unit weight. Therefore, as for the other explanation, the percentage of $\dot{V}_{O_2max}$ used during running at a submaximal speed is increased, and the pace that can be sustained for a given duration is reduced.

The primary limitation of the AW model is that weight was added to the trunk and not distributed over the limbs and trunk as would be the case for BF. Therefore, the effects of changes in BF might be underestimated by the AW model, because it is known that weight added to the limbs has a bigger effect on the energy requirement of submaximal exercise than weight added to the trunk. Another limitation of the model is that when body weight changes, fat is not the only tissue to change. Gains in BF are typically accompanied by gains in fat-free weight (FFW), and losses in BF are usually accompanied by losses in FFW (Forbes, 1987). Thus, acute changes in the fat-free component of the body that accompany weight loss or gain may have effects not accounted for by the model. The validity of the model is supported by data indicating that the increased oxygen required to walk at a given submaximal speed brought about by adding weight to the trunk using a backpack is the same as that produced by a similar weight gain produced by overeating (Hanson, 1973). A number of other studies have indicated that the oxygen required per unit weight carried to walk or run at a given speed is not related to whether some of the weight is carried externally using a weighted belt, vest, or backpack (Cureton and

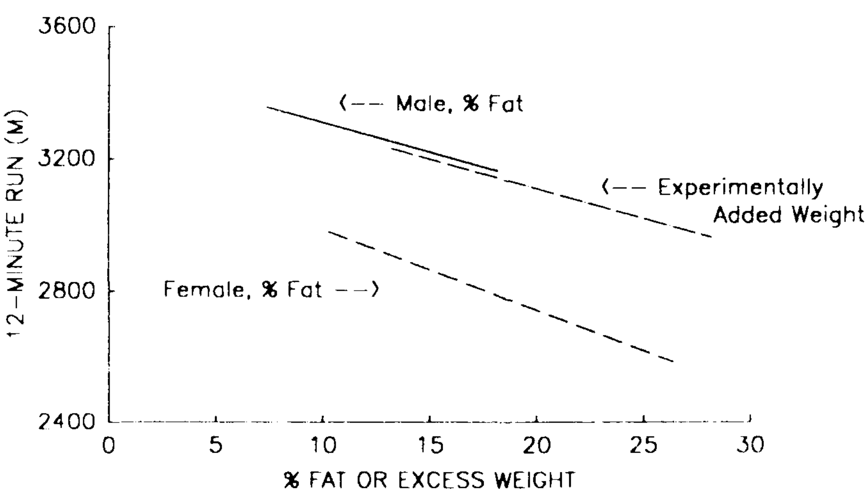

FIGURE 5-5 Comparison of regression lines describing the relationship between percent fat and 12-minute run performance in men and women to the regression line describing the effect of added weight on 12-minute run performance.

Sparling, 1980; Goldman and Lampietro, 1962; Hanson, 1973; Miller and Blyth, 1955).

To evaluate whether the effects of added weight were the same as the relationship of BF to performance in cross-sectional data, the regression lines relating percent BF to 12-minute run performance in 34 male and 34 female recreational runners (Sparling and Cureton, 1983) were compared to the regression line indicating the average effect of the AW in this study (Figure 5-5). The slopes of the regression lines were almost identical, which supports the validity of the model and the conclusion that the inverse relationship between BF and distance running performance reported in cross-sectional data is cause and effect.

RUNNING PERFORMANCE, METABOLIC RESPONSES AND GENDER DIFFERENCES

The second study also used the AW model (Cureton and Sparling, 1980). The purpose of this study was to investigate the extent to which differences between men and women in distance running performance and metabolic responses during running are due to the gender difference in percent BF. On the average, the percent BF of women is approximately 10 points higher than for men. Women also have lower average $\dot{V}_{O_2\,max}$ (ml/kg BW × minute) and poorer distance running performance (Figure 5-6). Of interest was the determination of the effect of experimentally eliminating the gender difference in percent BF (by adding excess weight to the men) and observing how much the gender differences in $\dot{V}_{O_2\,max}$ (ml/kg TW × minute) and 12-minute run performance were reduced.

The subjects for the study were 10 male and 10 female recreational runners who were matched on running mileage and competitive experience. The $\dot{V}_{O_2\,max}$ expressed relative to fat-free weight (FFW) of the groups was also not significantly different, which indicates that the men and women

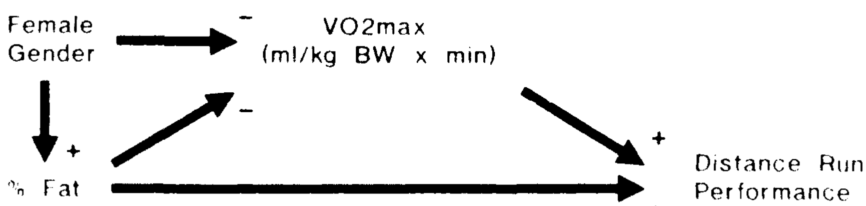

FIGURE 5-6 Diagram of the effects of gender on percent body fat, $\dot{V}_{O_2\,max}$ (ml/kg body weight × minute) and distance run performance based on comparative data in the literature.

TABLE 5-4 Physical Characteristics of the Subjects in Cureton and Sparling (1980) Study

Variable	Men (n* = 10)	Women (n = 10)
	mean ± standard deviation	
Age (years)	26.4 ± 4.9	25.8 ± 4.6
Height (cm)	178.7 ± 6.7	160.4 ± 6.9
Weight (kg)	70.8 ± 8.1	50.6 ± 8.1
Fat-free weight (kg)	62.0 ± 6.7	40.9 ± 6.3
Percent fat	11.4 ± 2.3	18.9 ± 4.0

*n = number of subjects.
SOURCE: Cureton and Sparling (1980) by permission.

had similar cardiorespiratory capacity. Both the men and women were relatively lean (Table 5-4). The measurements and procedures were the same as for the earlier study (Cureton et al., 1978). Women were measured only once with normal weight. The men were administered the graded treadmill and 12-minute run test twice, once under a normal-weight (NW) condition and once under an AW condition. The objective of the AW condition was to equate the mean percentage EW carried by the men and women. EW was defined as the sum of fat weight and added external weight. Each man was paired with a woman, and weight was added to the man such that his total percent EW was equal to the percent BF of the

TABLE 5-5 Means ± SD for Physiological Variables Measured During Maximal Treadmill Exercise and 12-Minute Run Performance

	Men (n = 10)		Women (n = 10)
Variable	Normal Weight	Added Weight	Normal Weight
V_E ($l \times min^{-1}$)	123.3 ± 14.5	120.5 ± 13.4	81.8 ± 13.5
V_{O_2} ($l \times min^{-1}$)	4.31 ± 0.44	4.40 ± 0.42	2.82 ± 0.49
V_{O_2} ($ml \times min^{-1} \times kg\ FFW^{-1}$)	69.8 ± 6.0	71.4 ± 7.2	68.9 ± 5.2
V_{O_2} ($ml \times min^{-1} \times kg\ TW^{-1}$)	61.7 ± 5.1	57.8 ± 5.9	55.7 ± 3.0
Heart rate ($b \times min^{-1}$)	187 ± 8	185 ± 8	185 ± 7
R	1.16 ± 0.05	1.12 ± 0.04	1.13 ± 0.06
Treadmill run time (min)	15.6 ± 1.4	14.4 ± 1.7	11.7 ± 0.9
12-Minute run (m)	3362 ± 226	3189 ± 243	2794 ± 156

NOTE: n = number of subjects; FW = fat-free weight; TW = total weight carried; R = respiratory exchange ratio: V_{O_2} (l/min) divided by V_{CO_2} (l/min).
SOURCE: Cureton and Sparling (1980) by permission.

Table 5-6 Means ± SD for Physiological Variables Measured During Submaximal Treadmill Running (7 mph)

	Men (n = 10)		Women (n = 10)
Variable	Normal Weight	Added Weight	Normal Weight
$\dot{V}_E$ ($l \times min^{-1}$)	53.4 ± 8.7	54.8 ± 12.1	46.3 ± 7.6
$\dot{V}_{O_2}$ ($l \times min^{-1}$)	2.63 ± 0.42	2.79 ± 0.51	2.05 ± 0.35
$\dot{V}_{O_2}$ ($ml \times min^{-1} \times kg\ FFW^{-1}$)	42.4 ± 3.7	44.8 ± 5.1	50.0 ± 3.1
$\dot{V}_{O_2}$ ($ml \times min^{-1} \times kg\ TW^{-1}$)	37.5 ± 3.7	36.3 ± 4.2	40.4 ± 2.1
Heart rate ($b \times min^{-1}$)	143 ± 6	149 ± 7	162 ± 9
R	0.91 + .04	0.89 ± 0.04	0.93 ± 0.04

NOTE: n = number of subjects; FFW = fat-free weight; TW = total weight carried; R = respiratory exchange ratio: $\dot{V}_{O_2}$ (l/min) divided by $\dot{V}_{CO_2}$ (l/min).

SOURCE: Cureton and Sparling (1980) by permission.

woman. Therefore, different percentages of EW were added to individual men, but the average percent EW added was equal to the mean gender difference in percent BF (7.5 percent).

The differences between the men and women during submaximal and maximal running, and on the 12-minute run, were similar to those reported in other studies (Tables 5-5 and 5-6). During running at submaximal speeds, men had higher absolute levels of ventilation and oxygen uptake, but women had higher heart rates and higher oxygen uptake values expressed relative to body weight (BW) or FFW. The higher $\dot{V}_{O_2}$ (ml/kg BW × minute) indicated that the women had poorer running economy than the men, which was an unexpected finding. Most studies of trained runners have reported no gender difference in running economy. The mean $\dot{V}_{O_2\,max}$ expressed in liters per minute and relative to body weight was significantly higher in the men, with the mean gender difference for $\dot{V}_{O_2\,max}$ (ml/kg BW × minute) being 6 ml/kg × minute (11 percent). $\dot{V}_{O_2\,max}$ expressed relative to FFW was not significantly different in the men and women, with the mean gender difference being 1.9 ml/kg × minute (2.8 percent). Mean treadmill run time was 4 minutes (34 percent) longer, and 12-minute run distance was 568 m (20 percent) greater in the men than in the women.

As expected, the effects of adding weight to the men were the same as in the first study. The $\dot{V}_{O_2}$ during running at submaximal speeds expressed in liters per minute or relative to fat-free weight was significantly increased, whereas the $\dot{V}_{O_2}$ expressed relative to the TW was reduced by a small amount. The mean increase of 2.4 ml in $\dot{V}_{O_2}$ (ml/kg FFW × minute) elimi-

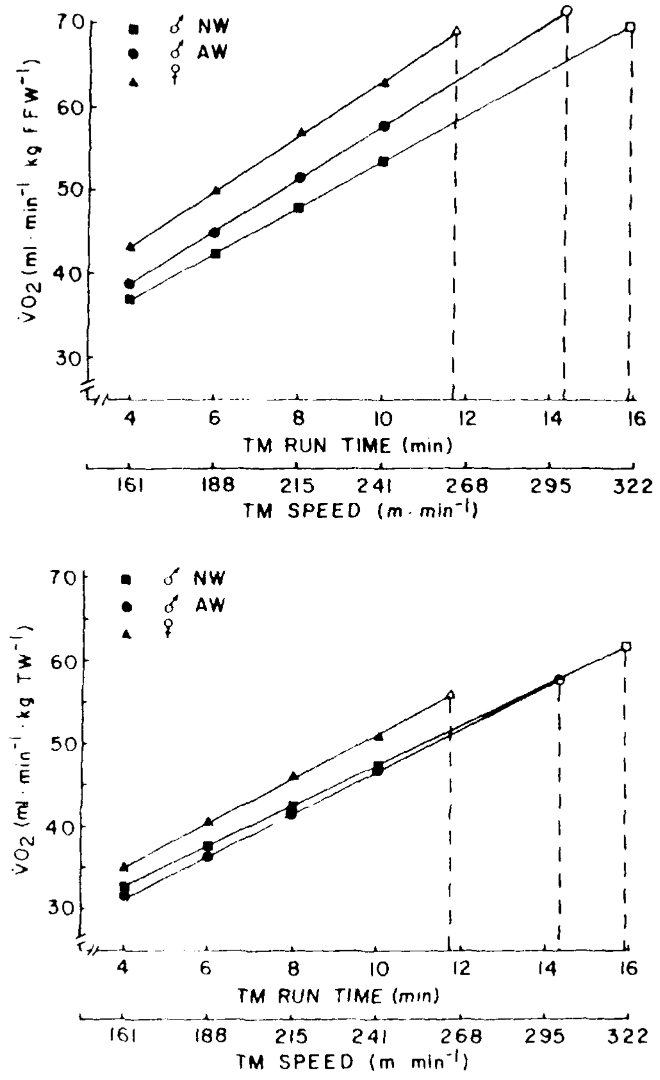

FIGURE 5-7 Mean submaximal and maximal $\dot{V}_{O_2}$ (ml/kg fat-free weight × minute) and $\dot{V}_{O_2}$ (ml/kg total weight × minute) values during running at various speeds during the treadmill test for women and men under the normal-weight (NW) and added-weight (AW) conditions. Linear regression lines are fitted to the four submaximal $\dot{V}_{O_2}$ values. Open symbols are observed $\dot{V}_{O_2 max}$ values. Broken vertical lines indicate mean treadmill run times. SOURCE: Cureton and Sparling (1980) by permission.

nated 32 percent of the gender difference for this variable. $\dot{V}_{O_2\,max}$ in liters per minute or expressed relative to FFW was not significantly affected by equating excess weight, but $\dot{V}_{O_2\,max}$ expressed relative to body weight was significantly reduced by an average of 3.9 ml, which reduced the mean gender difference by 65 percent. With excess weight equated in the groups of men and women, there was no significant difference between the men and women in $\dot{V}_{O_2\,max}$ expressed relative to TW or FFW, with mean differences being 2.1 ml (3.8 percent) and 2.5 ml (3.6 percent), respectively. Addition of weight to the men reduced the mean gender differences in

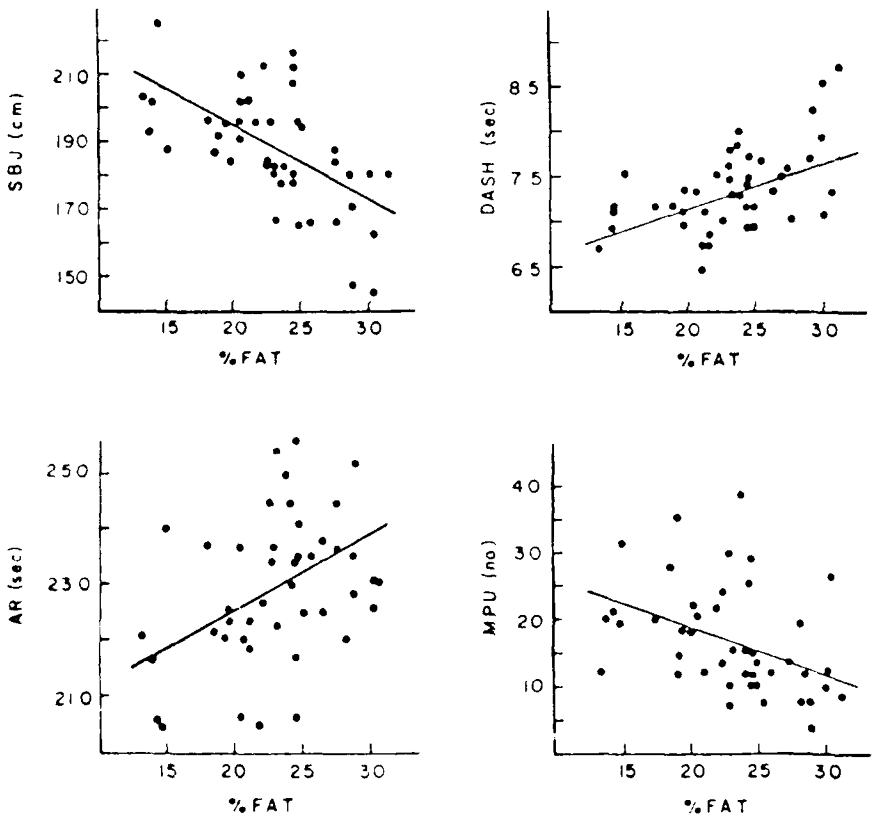

FIGURE 5-8. Scatter diagrams and linear regression lines predicting performances on the standing broad jump (SBJ), 50-yard dash (DASH), agility run (AR), and modified pull up (MPU) from percent body fat. SOURCE: Johnson (1978) by permission.

treadmill run time and 12-minute run distance by 1.2 minutes (32 percent) and 173 m (30 percent), respectively.

Examining the relationships among $\dot{V}_{O_2}$ expressed relative to FFW and TW during submaximal and maximal running, and treadmill run time (Figure 5-7) revealed that the mechanism through which EW contributed to the gender difference in treadmill run time could be explained in either of two complementary ways. First, the greater EW of women increases the energy required per kg of FFW to run at any given speed without affecting $\dot{V}_{O_2 max}$ (ml/kg FFW × minute). Thus, the percent $\dot{V}_{O_2 max}$ used at different speeds is increased, the pace that can be maintained for a given duration is less, and $\dot{V}_{O_2 max}$ is reached at a lower speed of running. Or second, the greater EW of women reduces the $\dot{V}_{O_2 max}$ expressed relative to BW without substantially affecting the $\dot{V}_{O_2}$ (ml/kg BW × minute) required to run at submaximal speeds. The percent $\dot{V}_{O_2 max}$ required to run at submaximal speeds is therefore increased with the same consequences as in the first explanation.

The conclusions from this experiment were, first, that the greater average gender-specific excess weight (fat) of women causes a portion of the gender differences in $\dot{V}_{O_2 max}$ (ml/kg BW × min) and distance running performance. About 65 percent of the gender difference in $\dot{V}_{O_2 max}$ (ml/kg BW × minute) and about 30 percent of the gender difference in distance running performance in the sample studied were eliminated by removing the gender difference in excess weight (BF). A greater percentage of the gender differences in treadmill time and distance running performance (probably closer to 65 percent) would have been eliminated if there had been no difference in running economy. And second, because the additional gender-specific BF of women is not eliminated by diet or physical training, it provides part of a biological justification for separate distance running performance standards and expectations for men and for women.

PHYSICAL PERFORMANCE, BODY FAT AND WOMEN ATHLETES

The third study (Johnson, 1978), in which the AW model was used, compared the physical performance changes associated with increased BF based on cross-sectional data with performance changes resulting from added external weight in women athletes. The relationships between percent BF, estimated from body density determined by underwater weighing, to four physical performance tests (50-yd dash, agility run, modified pull-up, and standing long jump) were determined in 14 women varsity athletes at the University of Georgia. A significant negative relationship between percent BF and each of the performances was found, although the correlations were not high, ranging from about 0.4 to 0.6 (Figure 5-8). Six subjects

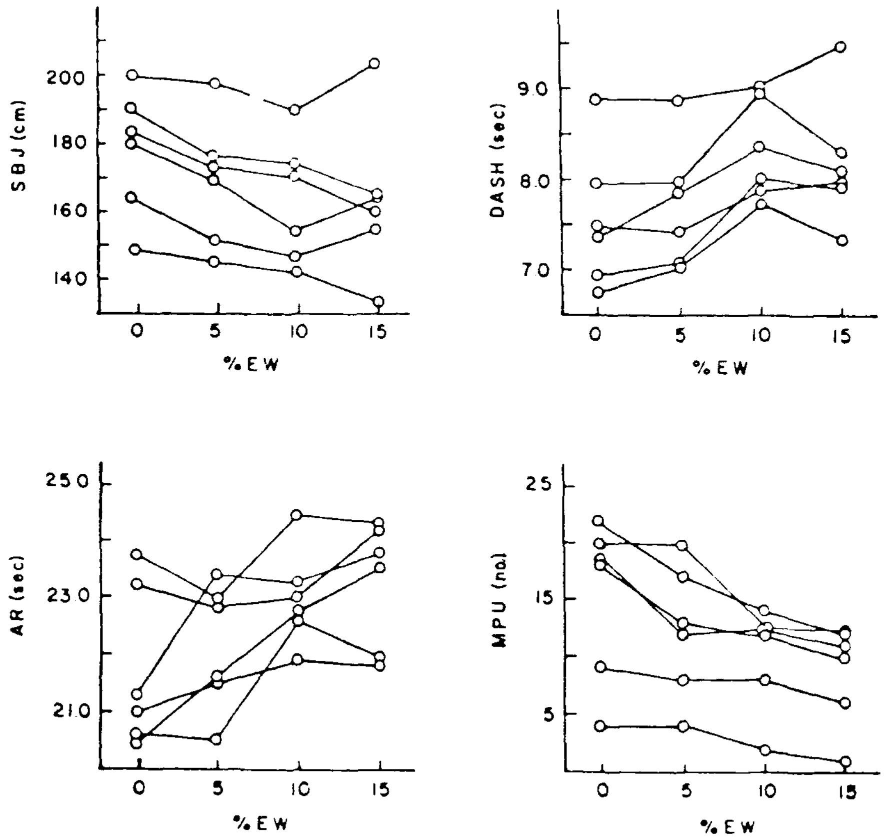

FIGURE 5-9 Individual values on the standing broad jump (SBJ), 50-yard dash (DASH), agility run (AR), and modified pull-up (MPU) for the four excess-weight conditions. SOURCE: Johnson (1978) by permission.

were selected at random from the 44, and the physical performance tests were readministered with 5, 10, and 15 percent AW. Performances on each of the tests decreased consistently and systematically with AW (Figure 5-9). The slopes of the regression lines relating percent BF to the performance scores based on the cross-sectional data were very similar to the regression lines indicating the average effect of the AW (Figure 5-10). Therefore, it was concluded that changes in performance associated with increased BF are similar to changes that result from AW. The results support the validity of the AW model for investigating the effects of differences in BF on performance and provide experimental data indicating that relationships be-

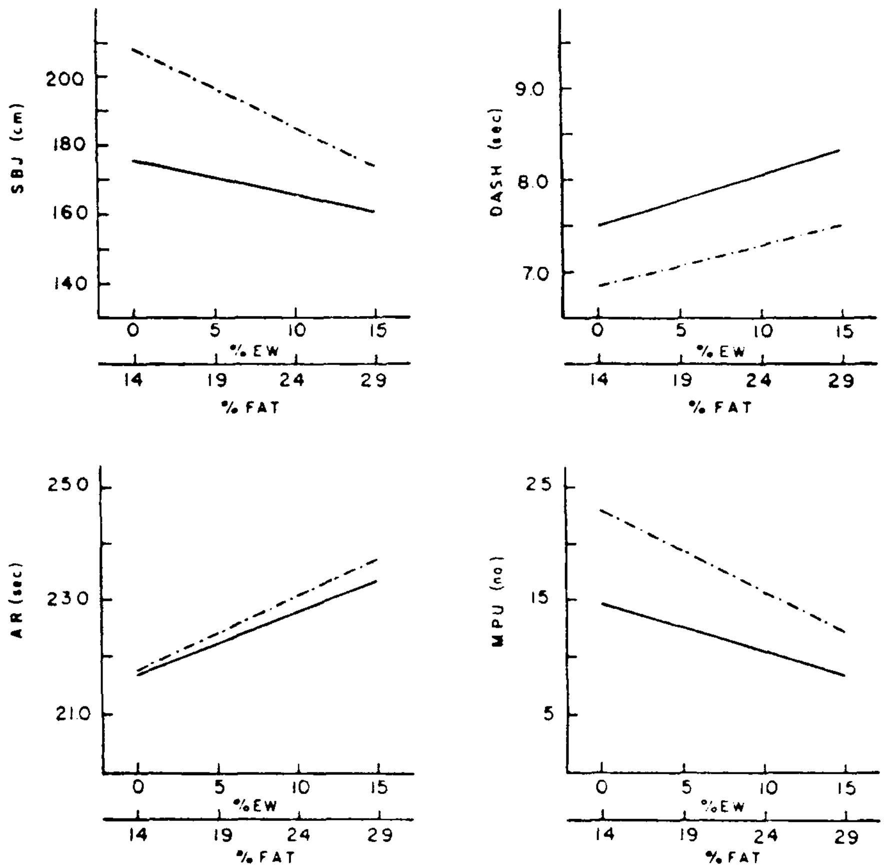

FIGURE 5-10 Comparison of regression lines predicting the standing broad jump (SBJ), 50-yard dash (DASH), agility run (AR), and modified pull-up (MPU) from percent body fat (—·—) and from percent excess weight (——). SOURCE: Johnson (1978) by permission.

tween percent BF and different types of physical performance that involve movement of the BW are cause and effect relationships.

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6

Army Data: Body Composition and Physical Capacity

James A. Vogel and Karl E. Friedl

INTRODUCTION

Body dimensions and body composition are known to influence the capacity for physical performance. Taller stature, for example, is associated with longer muscle length, which in turn is associated with proportionally greater muscle cross-sectional area and muscle mass (Astrand and Rodahl, 1986). The greater muscle area and mass of the taller individual is related to proportionally greater force development; for example, strength and aerobic capacity are proportional to the cube of height, with aerobic capacity also proportional to the two-thirds power of body weight (Astrand and Rodahl, 1986; Hebbelnick and Ross, 1974; see also Malina, 1975).

Body composition associations with exercise capacity are less well defined mathematically but nevertheless are quite evident. For example, it is apparent that there is a relationship between marathon running performance and a body type characterized by leanness and modest muscle mass, or between football defensive linemen and a large muscle mass and modest-to-high levels of body fat (BF). Thus in athletic performance, particularly in elite athletes, the influence of body dimensions and composition are readily evident (McArdle et al., 1985).

In contrast, the association of body composition with the capacity for occupational task performance has received little attention. One exception to this may be the military services who use on-the-job body weight or BF standards or both. At least in the case of the U.S. Army, these standards are said to be based in part on the requirements for physical job performance. In recent years the Army has become increasingly concerned with excess body weight and BF, although this concern appears to be focused as much on appearance as it is on performance. The relationship between military appearance and BF has been addressed earlier (Hodgdon et al., 1990).

Physical fitness or the capacity for physical performance is not a single entity but is composed of several components, each representing a separate source or pathway of energy for muscular activity. Although all energy for muscular contraction is derived initially from muscle, the size of these energy systems or fitness components are not equally influenced by the size of the muscle mass or the fat-free component. Likewise, the relatively metabolically inactive fat mass also does not influence these fitness components in similar ways. Therefore our consideration of body composition on physical performance must differentiate between these components of fitness capacity.

The purpose of this report is to address the relationship of the two major components of body composition—fat and fat-free mass (FFM)—with the major components of physical performance capacity—aerobic power and strength—and present new data on these relationships in a large Army population. Emphasis is placed on how these relationships might be used to establish BF standards for the U.S. Army.

DESIGN AND METHODS

The data presented here were collected as part of a larger project to validate BF standards based on objective criteria, including physical performance. Measurements were made on an unselected population of soldiers at Fort Hood, Texas, and Carlisle Barracks, Pennsylvania. The sample obtained at Carlisle Barracks, which provided most of the 40+ age group, consisted of students from the Army War College who were likely to be more physically fit relative to the rest of the sample. The total sample consisted of 1,126 men and 265 women. Age and racial distributions of the sample are given in Table 6-1.

Body composition was determined from hydrostatic weighing (Fitzgerald et al., 1987; Goldman and Buskirk, 1961) using the Siri equation (Siri, 1961) to estimate BF from density; residual lung volume was measured by oxygen dilution (Wilmore et al., 1980). Aerobic capacity was assessed as maximal oxygen uptake ($\dot{V}_{O_2\,max}$) determined from a treadmill progressive running procedure (Maksud and Coutts, 1971) that measured oxygen uptake by the open circuit procedure with Douglas bags, and maximal lift capacity (MLC) by an incremental maximal lifting test to a height of 152 cm (McDaniel et al., 1983). Scores on two items of the U.S. Army's physical

TABLE 6-1 Distribution of Sample by Gender, Age and Racial Grouping

	Men (n* = 1,126)			Women (n = 265)		
Age Group	White	Black	Hispanic	White	Black	Hispanic
17-20	102	40	13	38	14	6
21-27	203	117	51	80	67	8
28-39	167	80	52	33	13	4
40+	228	14	59	2	—	—
Total	700	251	175	153	94	18

*n = number of subjects

fitness test (2-mile run and sit-ups) were also collected by self-report. A preliminary description of this study was previously reported (Fitzgerald et al., 1986).

RESULTS

Body Composition and Performance Capacity Related to Age

The U.S. Army's BF standards are established according to age, using arbitrary age groupings set some years ago. Table 6-2 presents the mean plus or minus standard deviation (± SD) of the body composition variables, and Table 6-3 presents the corresponding values for performance variables for these established age groups. In this sample, percent BF and fat mass of men increased with age across all age groups while FFM was stable. Women's BF was not different between the first two age groups (17 to 20 and 21 to 27 years) but did increase in the third age grouping (28 to 39 years).

Maximal oxygen uptake decreased through the first three age groups in men, on an absolute basis, relative to body weight and relative to fat-free weight. In women, the decrease was clearly evident only on a body weight basis. Two-mile run time followed the same pattern as $V_{O_2\,max}$ (per kg body weight). MLC also decreased as a function of increasing age in men, most prominently when expressed relative to body weight, but it was largely unaffected by age in the women's sample.

Performance Capacity in Relation to Body Composition

Figures 6-1 and 6-2 illustrate contrasting expressions of aerobic and strength capacity in their relationship to BF and FFM in men. The same

TABLE 6-2 Body Composition Variables by Gender and Age Groupings, Mean ± SD

	Age Group (years) 17–20	21–27	28–39	40	Total
Men	(n* = 165)	(n = 402)	(n = 341)	(n = 269)	(n = 1,177)
Body mass (kg)	73.2 ± 9.2	73.3 ± 10.7	79.1 ± 12.7	81.1 ± 9.8	77.1 ± 11.4
Body fat (kg)	11.6 ± 5.5	12.8 ± 6.3	17.6 ± 7.6	18.9 ± 5.6	15.4 ± 7.1
Fat-free mass (kg)	61.7 ± 6.5	61.5 ± 7.5	61.7 ± 8.1	62.2 ± 6.7	61.7 ± 7.4
Body fat (%)	15.4 ± 5.9	16.7 ± 6.7	21.6 ± 7.0	23.1 ± 5.3	19.4 ± 7.0
Women	(n = 68)	(n = 173)	(n = 60)	(n = 2)	(n = 303)
Body mass (kg)	59.7 ± 7.3	59.8 ± 8.4	63.4 ± 9.0	—	60.5 ± 8.4
Body fat (kg)	16.0 ± 4.6	15.5 ± 5.2	18.9 ± 6.3	—	16.3 ± 5.5
Fat-free mass (kg)	44.0 ± 4.4	44.3 ± 5.2	44.6 ± 5.2	—	44.3 ± 5.1
Body fat (%)	26.3 ± 5.3	25.4 ± 6.0	29.2 ± 7.0	—	26.4 ± 6.2

*n = number of subjects

TABLE 6-3 Performance Variables by Gender and Age Groupings, Mean ± SD

	Age Group (years) 17–20	21–27	28–39	40	Total
Men	(n = 128)	(n = 337)	(n = 276)	(n = 223)	(n = 964)
$\dot{V}_{O_2 \max}$ (l/min)	3.77 ± .43	3.69 ± .48	3.57 ± .46	3.75 ± .49	3.69 ± .47
$\dot{V}_{O_2 \max}$ (ml/kg BW/min)	51.9 ± 4.5	50.1 ± 5.8	45.1 ± 5.7	46.0 ± 6.5	48.0 ± 6.3
$\dot{V}_{O_2 \max}$ (ml/kg FFM/min)	62.4 ± 5.2	61.3 ± 5.8	58.1 ± 5.7	61.5 ± 5.5	60.5 ± 6.0
2-mi run (min)	14.0 ± 1.6	14.4 ± 1.8	15.8 ± 2.0	16.0 ± 2.0	15.1 ± 2.0
	(n = 139)	(n = 361)	(n = 275)	(n = 22)	(n = 803)
MLC (kg)	61.3 ± 11.7	61.0 ± 12.0	56.6 ± 11.0	53.0 ± 8.3	59.2 ± 11.8
MLC (kg/kg BW)	.843 ± .139	.825 ± .140	.720 ± .134	.656 ± .094	.786 ± .148
MLC (kg/kg FFM)	1.01 ± .153	1.01 ± .160	.298 ± .141	.895 ± .098	.976 ± .156
Sit-ups (#)	59 ± 10	57 ± 11	50 ± 12	43 ± 17	52 ± 14
Women	(n = 51)	(n = 140)	(n = 45)	...	(n = 236)
$\dot{V}_{O_2 \max}$ (l/min)	2.46 ± .31	2.34 ± .30	2.41 ± .37	...	2.38 ± .32
$\dot{V}_{O_2 \max}$ (ml/kg BW/min)	41.2 ± 5.3	39.6 ± 3.8	38.0 ± 5.4	...	39.7 ± 4.6
$\dot{V}_{O_2 \max}$ (ml/kg FFM/min)	57.1 ± 5.9	54.3 ± 4.8	55.1 ± 5.0		55.1 ± 5.2
2-mi run (min)	17.2 ± 2.4	18.0 ± 2.0	18.4 ± 3.0	...	17.9 ± 2.4
	(n = 54)	(n = 143)	(n = 46)		(n = 244)
MLC (kg)	30.4 ± 8.1	29.3 ± 4.8	30.3 ± 7.2		29.7 ± 6.2
MLC (kg/kg BW)	.512 ± .141	.500 ± .089	.486 ± .144	...	.499 ± .114
MLC (kg/kg FFM)	.706 ± .183	.684 ± .109	.671 ± .077	...	.685 ± .12
Sit-ups (#)	55 ± 12	52 ± 12	43 ± 11		51 ± 13

NOTE: n = sumber of subjects; BW = body weight; FFM = fat-free mass; MLC = maximal lift capacity.

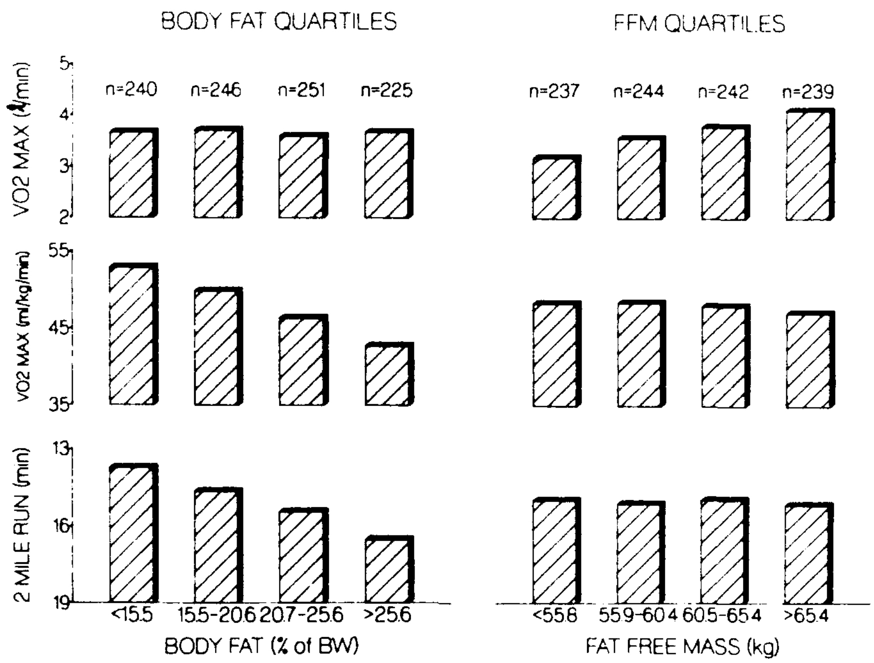

FIGURE 6-1 Relationship between aerobic fitness and body fat, and fat-free mass, by quartiles in men.

patterns exist for women. Figure 6-1 illustrates that absolute aerobic capacity (maximal oxygen uptake in liters per minute) is not related to the percent BF (metabolically inactive tissue) but instead is related to the amount of FFM or, more specifically, to the amount of oxygen-consuming muscle mass. Relative $\dot{V}_{O_2 max}$ (per kg of body weight), which is typically used in expressing aerobic fitness, is related to BF because increasing fat increases the denominator and thereby lowers the $\dot{V}_{O_2 max}$ value. This relationship corresponds to the physiological situation where the capacity for body propulsion is decreased as BF or non-energy-producing tissue ("dead weight") increases. This is also reflected in a similar association with the 2-mile run times. For this reason $\dot{V}_{O_2 max}$ is expressed relative to body weight when referring to the capacity of moving the body as in running.

Figure 6-2 illustrates that absolute lifting capacity is unrelated to BF but directly related to FFM in men. Absolute lifting capacity is the appropriate measure in relationship to actual job task performance. Relative lift capacity (kg lift per kg of body weight) changes with percent BF because of the changing denominator. The performance of sit-ups is related to changes in BF, not FFM, apparently due to the mechanical interference of the fat. Similar results were observed in the women.

These two primary associations, relative $\dot{V}_{O_2 max}$ with percent BF, and absolute MLC with FFM, are shown in further detail for men and women in scatter plots in Figures 6-3 and 6-4. The observed correlations in each case are substantial, indicating that BF and FFM account for approximately one-third of the variability in aerobic capacity and MLC, respectively.

Relationship to Fitness Standards

Although a stated purpose of the U.S. Army's BF standards is to ensure adequate physical performance capacity (U.S. Army, 1986), the standards were not actually based on performance requirements (passing scores on the Army's physical fitness test) when they were initially established and implemented in 1982 (Friedl et al., 1989). Therefore, the data presented here were used in a retrospective fashion to determine how well the BF standards did in fact correspond to the physical fitness standards. Two analyses were carried out.

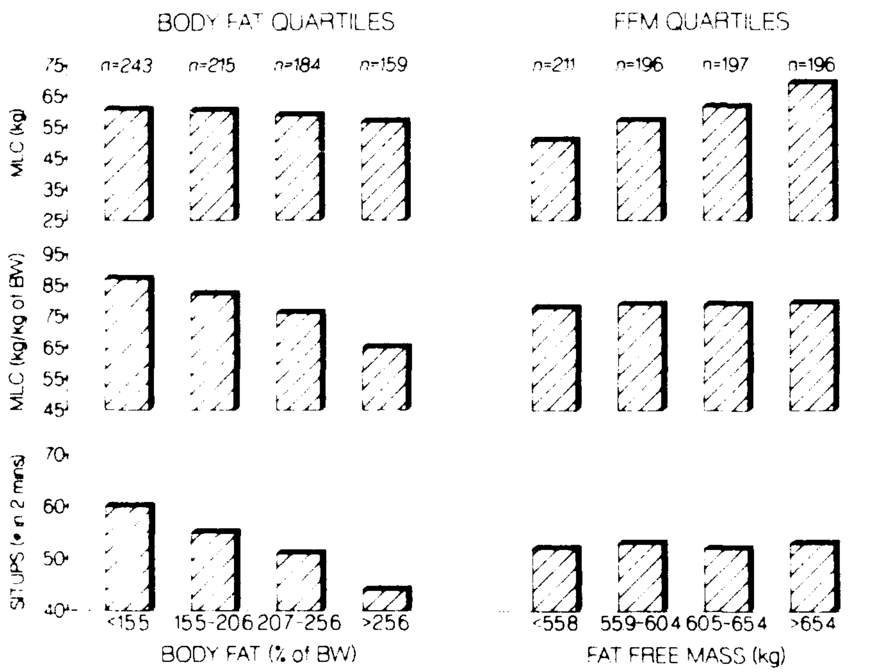

FIGURE 6-2 Relationship between maximal lift capacity (MLC) and body fat, and fat free mass, by quartiles in men.

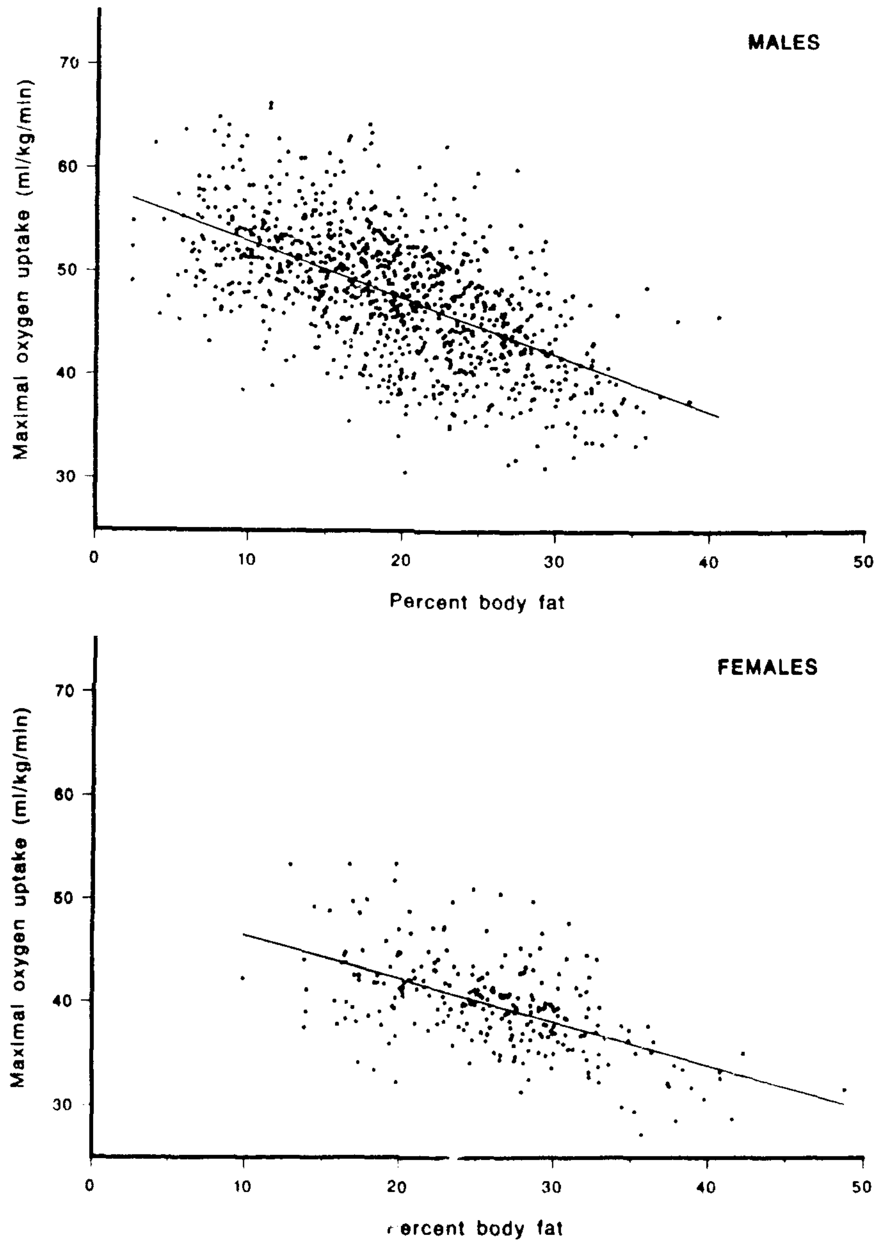

FIGURE 6-3 *A*. Scatter plot illustrating the relationship between $\dot{V}_{O_2\,max}$ and percent body fat in men. $\dot{V}_{O_2\,max}$ = 58.254 − .544 percent body fat; r = −.60; Standard Error of the Estimate (SEE) = 5.02. *B*. Scatter plot illustrating the relationship between $\dot{V}_{O_2\,max}$ and percent body fat in women. $\dot{V}_{O_2\,max}$ = 50.637 − .422 percent body fat; r = −.55; SEE = 3.77.

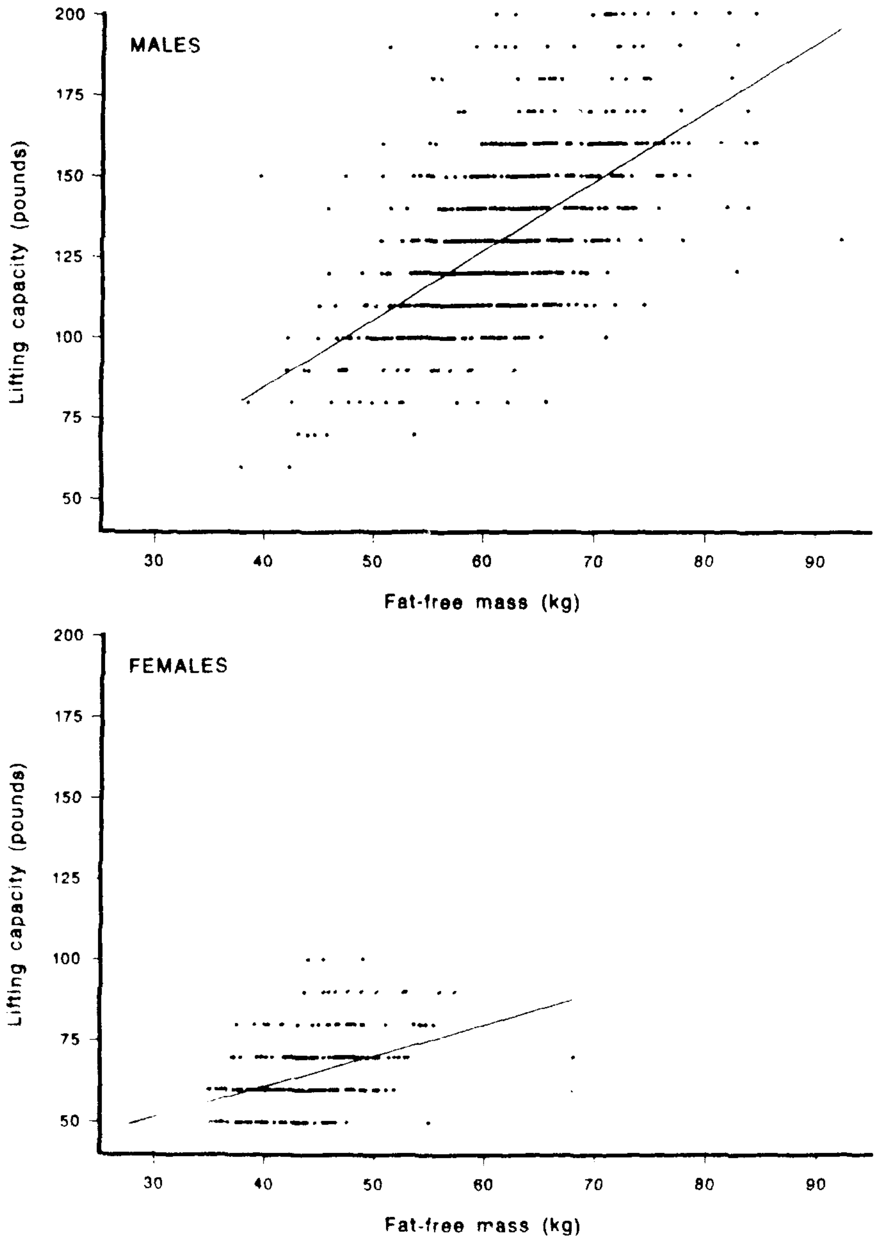

FIGURE 6-4. Scatter plots illustrating the relationship between maximal lift capacity (MLC) *and fat-free* mass (FFM) *A* in men (MLC = .502 + 2.107 FFM; r = .62, Standard Error of the Estimate (SEE) = 20.55) and *B* in women (MLC = 23.158 + .945 FFM, r = .38, SEE = 11.75).

The first analysis was preliminary in nature and determined in a general fashion whether aerobic fitness corresponded to the fat standard by matching those physically *fit* versus those *unfit* against those meeting and those not meeting the fat standard. This was done with the use of a 2 × 2 contingency table plot (Figure 6-5). A $\dot{V}_{O_2max}$ of 45 ml/kg body weight/minute was used as a cutoff point to represent being aerobically fit. This was an initial attempt to determine if the fat standards were in general agreement with the fitness standards by computing the number of correct and incorrect matches. There were 74 percent correct classifications for men and 84 percent correct matches for women.

This initial attempt to validate fat standards based on a single level of aerobic fitness did not take into account the actual fitness test scores (2-mile run times) and their adjustment by age. The second analysis (Friedl and Vogel, in press) plotted the passing (minimum) 2-mile run time equivalent to $\dot{V}_{O_2max}$ on a histogram of $\dot{V}_{O_2max}$ versus percent BF. In this case, the BF value used was that determined by the U.S. Army's circumference measurement procedure as actually applied to soldiers in their units. The procedure was derived from and validated against hydrostatic weighing (Vogel et al., 1988). An example of such a plot for the youngest male age group is shown in Figure 6-6, which identifies the percent BF that corresponds to the 2-mile run score requirement. The figure shows a very good correspondence between the aerobic fitness requirement and the BF standard that had been previously established for this age group, 20 percent BF. The correspondence of these points for all age groups in men is shown in Table 6-4.

	FIT*	UNFIT*
WITHIN FAT STANDARD	Match	No Match
EXCEED FAT STANDARD	No Match	Match

*Refers to cut point of 45 ml VO2max

FIGURE 6-5 2 × 2 contingency table for validating body fat standards against aerobic performance by determining the percent of correct matches.

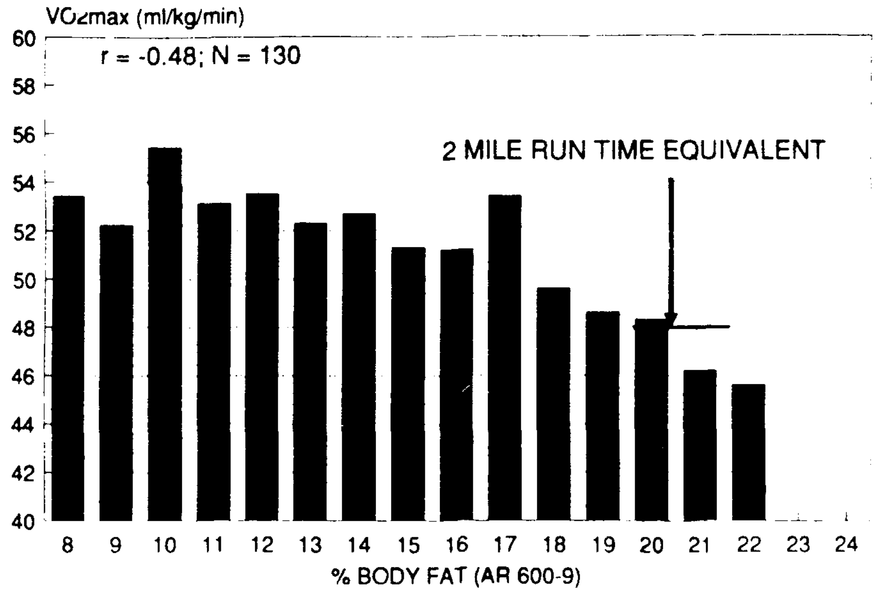

FIGURE 6-6 Histogram of $\dot{V}_{O_2 max}$ (per kg body weight) versus percent body fat (by anthropometric equations) showing the minimum 2-mile run test score equivalent for 17- to 20-year old men. SOURCE: J.A. Hodgdon, P. I. Fitzgerald, and J. A. Vogel. 1990. Relationships between body fat and appearance ratings of U.S. soldiers. Technical Report No. 12-90. U.S. Army Research Institute of Environmental Medicine, Natick, Mass.

Thus for men, the established BF standard agrees with the percent BF found in this population for the passing 2-mile run score for the two youngest age groups, which makes up a large share of the U.S. Army, but not for the two older groups. This result suggests that a more liberal BF standard is compatible with the aerobic fitness requirements in these older male groups. It is unlikely, however, that a more liberal BF standard would be acceptable for appearance criterion.

Such an analysis for women is not possible due to the limited size of the sample. In general, the relationship between BF and aerobic fitness is more flat in women than in men, which indicates a weaker relationship (Friedl et al., 1989, Friedl and Vogel, in press).

Another issue is whether the other component of fitness, strength capacity, should be related to a body composition standard, that is, a minimal acceptable level of FFM. Although the relationship between FFM and absolute strength or lifting capacity has been shown (Figure 6-4), the practical problem is what measures should be used to represent strength fitness in a

TABLE 6-4 Correspondence between Aerobic Fitness Requirement (2-Mile Run Time) and Established Body Fat Standard by Age Group in Men

Fitness Age Group	2-Mile Standard (min)	$\dot{V}_{O_2\,max}$ Equivalent (ml/kg/min)	Body Fat Correspondence (%)	Body Fat Standard (%)
17–21	15:54	46.4	20	20
22–26	16:36	44.9	22	22
32–36	18:00	39.4	27	24
42–46	19:06	35.7	28	26

NOTE: Age groups for fitness and body fat are not identical.

field fitness test. The current U.S. Army fitness test for strength or strength endurance is sit-ups and push-ups. Neither of these items are correlated with any actual Army tasks, such as lifting (Meyers et al., 1984). Thus in attempting to identify a minimal FFM standard, appropriate test item measures of strength would first need to be identified that are suitable for the Army's fitness test battery.

DISCUSSION

The data presented here show a moderate relationship between both aerobic and strength capacity with certain body composition components in a heterogenous population. These relationships are explained by the physiological fact that greater muscle mass will produce greater muscular strength or lift capacity, as well as maximal oxygen uptake, while greater fat mass will increase the required relative amount of oxygen uptake to propel the body that has more dead weight to propel.

These relationships are important in the military and other occupational settings for two reasons: (1) to set body composition standards that will support the level of physical performance capacity that is required and (2) to appropriately express fitness capacity tailored to different occupational activities. In regard to the former, it might be argued that if one displays adequate fitness capacity (passes the fitness test) or can successfully perform the physical demands of his or her job, then a body composition standard is unnecessary. However, a body composition standard (that is, a minimum requirement) at least for BF, is added insurance for achieving the desired level of fitness. Because fitness tests are not perfect measures of capacity, nor is fitness capacity a perfect indicator of job performance ability, a BF standard, in this case percent BF, would be an additional indication of adequate level of physical activity and capacity for a particular level of desired physical performance. Furthermore, even with an adequate capacity level, an inappropriately high BF may be a risk factor for musculoskeletal and heat-related injuries. This risk, along with the added relationships between BF and appearance or health, at least in the military and public safety arenas, seems to justify the desirability of body composition standards in addition to fitness standards.

With respect to the appropriate expressions of physical capacity, body composition is important when contrasting fitness capacities between genders or between individuals of different body size or stature. In such cases, differences in exercise capacity may be largely accounted for simply by differences in body weight, BF, or muscle mass. In comparing strength capacity of men and women, absolute force is a more appropriate expression relative to job performance, while strength (force) per unit of FFM would be advantageous when evaluating the response to a training program or comparing the contractile "quality" of muscle.

$\dot{V}_{O_2\,max}$ expressed in liters per minute, uncorrected for body or muscle mass, provides a measure of the total amount of aerobic power that the body can produce and is positively related to the absolute quantity of muscle present (Buskirk and Taylor, 1957; Welch et al., 1958). For the same level of training and fat mass, muscular individuals are likely to outperform less muscled individuals when significant amounts of external weight are carried or backpacked. This difference is due to the proportionally smaller "dead weight" being carried by the more muscular individual. The greater the external load, the more appropriate is the use of the expression of absolute aerobic capacity ($\dot{V}_{O_2\,max}$ in liters per minute) as compared to minimal or no-load conditions where $\dot{V}_{O_2\,max}$ adjusted by body weight is more useful.

A final comment is appropriate regarding the question of whether BF content alone is a good indicator of aerobic fitness (Parrish and Gustin, 1986; Slack et al., 1985). Direct measures of aerobic capacity ($\dot{V}_{O_2\,max}$) or aerobic performance (for example, 2-mile run for time) will always be preferable to indirect indications such as BF when assessing an individual's ability to carry out aerobic tasks if there are no measurement constraints. The fact that percent BF is correlated rather well with $\dot{V}_{O_2\,max}$ (an r of about 0.6) suggests that there may be limited applications where fat content could be used as a screening device or indicator of relative fitness in population studies. It is inappropriate as an estimate of aerobic fitness in groups homogenous in terms of fitness or fatness, in highly fit individuals, or in following changes in fitness of individuals during training.

In sum, physical capacity, in the context of occupational task performance, is related to body composition in a heterogenous population, with BF accounting for about one-third of the variability seen in aerobic capacity and FFM accounting for one-third of the variability in muscle endurance/

lifting capacity. The expression of physical capacity, whether uncorrected for body size or composition, depends on the physical activity or comparison of concern. BF content can also be used in some circumstances as an indicator of aerobic fitness. The U.S. Army's BF standards for men correspond to the aerobic standards in the younger age groups but deviate in the older groups due apparently to the influence of an appearance criterion.

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7

The Relationship of Body Size and Composition to the Performance of Physically Demanding Military Tasks

Everett A. Harman and Peter N. Frykman

INTRODUCTION

The most common physically demanding tasks in the U.S. Army are lifting and carrying (including load carriage). Typical military lifting tasks include loading artillery shells, lifting supplies onto and removing them from trucks, moving construction components, and assembling or disassembling heavy equipment. Most lifts involve raising an object from the ground to between waist and shoulder height. Carrying is usually associated with lifting. A soldier is generally expected to lift objects weighing as much as 50 kg single-handedly, with heavier objects lifted by more than one individual. Most of the objects lifted do not have handles. In heavy lifting jobs, 85- to 200-pound objects may be lifted and carried up to 200 yards by a single individual. Packs in excess of 100 pounds and other heavy loads may be lifted and carried for several miles (Myers et al., 1983; U.S. Army, 1978).

Unfortunately, large numbers of recruits have left the military because of failure to cope with physically demanding military training and work. Some enlisted personnel have been unable to carry out their jobs or have become injured while lifting or carrying heavy equipment and supplies (Myers et al., 1983). An important question one must ask is whether military screening tests are effective in excluding from service individuals likely to be either ineffective in performing their assigned tasks, or prone to injury due to physical weakness.

Aside from the standard physician's examination, the main physical screening tool for entry into the U.S. Army is a table of maximal body weight-for-height (accession standard AR 40-501) (K. E. Friedl, U.S. Army Research Institute of Environmental Medicine, unpublished data). Excessive body weight-for-height is used to infer obesity. The Army physical fitness test, which is based on age-specific standards for push-ups, sit-ups and 2-mile run time is not an entry screening test and is not administered until after the start of basic training. A lifting test on a stack-type weight machine is administered to potential recruits to help advise them whether they might have difficulty performing physically demanding jobs, but it is never used to exclude anyone from a military occupational specialty.

Associations Among Body Fat, Load Carriage Ability, and Running Performance

A sound theoretical basis exists for believing that excess body fat (BF) is detrimental to performance. Adipose tissue mainly serves the purpose of energy storage. It is noncontractile and cannot assist in force generation. Yet it has mass and weight, which increases the force-generation requirements of the muscles for support of body segments against gravity and to overcome inertia during acceleration (Boileau and Lohman, 1977). According to Newton's second law, force equals mass times acceleration, so that acceleration equals force divided by mass (Meriam, 1978).

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$
$$\text{Acceleration} = \text{Force} / \text{Mass} \qquad (1)$$

For an individual with a given amount of muscle tissue and force-generation capability, fat deposits increase the mass and thus the weight and inertia of body segments. Table 7-1, based on calculations using equation 1, shows that for a given amount of force applied to an object, a 10 percent

TABLE 7-1 Loss in Acceleration with Increase in Mass Given a Fixed Force

Increase in Mass (%)	Decrease in Acceleration (%)
10	9
20	17
30	23
40	29

increase in the object's mass reduces acceleration by 9 percent. A 20 percent increase in mass reduces acceleration by 17 percent, and so on. BF then reduces the rate at which the body can be accelerated, as when speed or direction are rapidly changed.

For endurance activities, where rate of energy production is a limiting factor, fat weight is detrimental because the work performed in raising an object to a given height is proportional to its weight, and energy required is directly related to work performed. The body's center of mass is raised repeatedly during locomotion. From a simplified point of view the net power output during running equals body weight times the vertical center of mass travel per stride divided by the time per stride. Increasing either body weight or the vertical travel of the center of mass raises the power requirement. Also, with all else being equal, a more rapid stride frequency—which results in a shorter stride time in which the work of raising the body is performed—increases power output. Because sustainable maximal power output is limited by one's anaerobic threshold, when an individual's body is fatter, it cannot be raised and lowered as frequently as when it is leaner, unless it is raised a shorter distance per stride. All else being equal, the lowering of either stride frequency or vertical center of mass travel (and thereby stride length) reduces running speed.

There is considerable evidence that fat weight can diminish running performance. Cureton et al. (1978) performed experiments in which they added weight to the trunks of runners to simulate the effects of fat weight. It was found that the added weight systematically and significantly decreased $\dot{V}_{O_2 max}$ expressed relative to body weight (which included the added mass) but did not decrease absolute $\dot{V}_{O_2 max}$ nor $\dot{V}_{O_2 max}$ relative to lean body weight. The added weight decreased endurance time on a treadmill, the speed of which was increased every 2 minutes, and shortened maximal distance run in 12 minutes. Fifteen percent added weight decreased the speed of the 12-minute run by 8.6 percent. The experiment showed a negative effect on running performance attributable to excess weight alone, independent of any change in cardiovascular capacity. In a similar experiment, Cureton and Sparling (1980) placed weights on each male subject to simulate the percent BF of a paired women subject. The weighting reduced men-women differences by about one-third for both treadmill run time and 12-minute run distance, and by two-thirds for $\dot{V}_{O_2 max}$ relative to total running weight.

Based on significant correlations of percent BF with both time required to run a fixed distance and distance covered in a fixed amount of time, studies have shown that fatter individuals tend not to perform as well in unloaded running as do leaner individuals. Table 7-2 shows correlations[1]

[1] Pearson product moment correlations (Ferguson, 1976) were used throughout.

TABLE 7-2 Correlations of Percent Body Fat with Run Performance

Study	Run	*n**	Gender	Male *r*†	Female *r*
K. E. Friedl (U.S. Army Res. Environ. Med., unpublished)	2 miles	1048	M	-0.36	
		846	F		-0.12
M. Knapik (U.S. Army Res. Environ. Med., unpublished)	2 miles	81	M	-0.38	
Mello et al. (1984)	2 miles	44	M	0.60	
		17	F		-0.35
Harman et al. (1988)	2 miles	32	M	-0.46	
Myers et al. (1983)	2 miles	751	M	-0.21	
		450	F		-0.19
Cureton et al. (1979)	12 minutes	55	M	0.30	
		55	F		-0.22
Fitzgerald et al. (1986)	2 miles	1001	M	-0.47	
	2 miles	253	F		-0.31

**n* = number of subjects.

†*r* = Pearson product-moment correlation coefficient; negative *r* means fatter subjects ran slower.

between percent fat and running performance for several reported studies. It can be seen that the relationship between percent BF and running performance is not strong. However, all of the studies showed some detrimental effect of percent BF on running performance.

Women in the Army show a weaker relationship between percent BF and running performance than do men. One reason might be that the women show less variation in percent BF, so that other factors such as cardiovascular status, skeletal proportion, and motivation can exert greater influence.

The relatively weak association between percent BF and 2-mile run time indicates that an individual's running ability cannot be well predicted by fatness. There are many fatter individuals who can run faster than leaner ones and many lean individuals who do not run as fast as expected.

Despite the fact that the 2-mile run is part of the semiannual physical fitness test that soldiers must take, there is little evidence that unloaded running ability relates to military performance. Running more than a mile without a load is a task rarely demanded of a soldier. One might assume that a soldier who can run better without a load can run better with one as well. This may not be the case. In experiments in which the performances of both load carriage and unloaded distance running have been assessed. Knapik (U.S. Army Research Institute of Environmental Medicine, unpublished data) found a correlation of only 0.16 between the 2-mile run time and 20-km load carriage time, while Kraemer et al. (1987) found a 0.63 correlation between 2-mile run times with and without a load. One reason for the higher correlation among Kraemer's subjects was that both run and load carriage were conducted over the same distance and course. The 20-km distance is much more typical of military marches and normally involves considerably more walking than running.

Why is the association between performances in load carriage and running not stronger? The answer seems to be that it takes a different body type to carry loads well than to be a good runner. Table 7-3 shows the typical body build of competitive middle- to long-distance runners (McArdle et al., 1986). It can be seen that they are slight of build and lean. Elite runners are even more slightly built and linear than very good runners, as shown by Bale et al.'s (1985, 1986) measurements of both men and women distance athletes. Tanaka and Matsuura (1982) showed that simple anthropometric measures of linearity and leanness account for as much variance in running ability as do $V_{O_2 max}$ and cardiac output combined.

Not only is the leaner individual favored in unloaded distance running, but so is the smaller individual who carries less muscle tissue. In their text on work physiology, Astrand and Rodahl (1986) extensively discussed the effects of body size on performance, that was based on an earlier exposition by Hill (1950). They explained why larger people, even if lean, could not be expected to run distances as effectively as smaller people. Their argument was based on the way the various body dimensions change as body size changes. Table 7-4 shows how some selected dimensions change with height if body proportions remain constant. Because areas are two-dimensional, they are related to the square of height. Volume is three-dimensional and thus related to height cubed. Flow rates are related to the square of height, while frequency and acceleration are inversely related to height. The derivations of these relationships are outside the scope of this paper.

TABLE 7-3 Typical Body Measurements of Marathon and Middle Distance Runners

Height	176 cm (5'9")
Weight	63 kg (139 lbs)
Percent fat	5 percent
Lean body weight	60 kg (132 lbs)

TABLE 7-4 Various Dimensions as Functions of Height (H)

Segment length	H
Muscle cross-sectional area	H^2
Body mass	H^3
Skin surface area	H^2
Flow rate	H^2
Frequency	1/H
Acceleration	1/H

Assuming constant body proportions, oxygen requirement is related to body mass, which is in turn proportional to height cubed. Oxygen transport depends on cardiac output, which is a flow rate proportional to height squared. Thus as body size increases, oxygen requirement increases faster than does the ability to transport oxygen. It is for this reason that Astrand proposed measuring aerobic fitness in terms of ml × $kg^{-2/3}$ × $minute^{-1}$ rather than the conventional ml × kg^{-1} × $minute^{-1}$, which favors the smaller body. Maximal oxygen uptake in absolute terms increases with body weight but, expressed relative to body mass, decreases with body weight. As a function of body mass raised to the two-thirds power, it remains constant over a wide range of body weights. It must be made clear however, that oxygen uptake expressed in the standard ml × kg^{-1} × $minute^{-1}$ is closely related to distance running performance. Correlation of 0.91 for men and 0.89 for women between running performance and rate of oxygen uptake expressed relative to body mass enabled Mello et al. (1988a) to develop equations that effectively predict relative oxygen uptake from 2-mile run time. Thus, using Astrand and Rodahl's (1986) recommended $kg^{2/3}$ for equating aerobic fitness of people of different sizes might indicate one's fitness relative to similar-sized individuals. It doesn't however, alter the fact that smaller people are more likely to run faster over middle to long distances.

Law (Burfoot, 1990) developed tables, based on 5,000 10-km performances and over 7,000 marathon performances from the 1987 Marine Corps Marathon, to compare both men and women of differing body weight. Table 7-5 shows the ninety-ninth, ninetieth, seventy-fifth and fiftieth percentile performance times for the mens' 10-km run. It can be seen that at each percentile, the larger runners were considerably slower. For example, the ninety-ninth percentile 10-km run time was almost 10 minutes slower for men over 195 pounds than for those under 155 pounds. Astrand and Rodahl's (1986) theory is supported in that the times in the table are close to those calculated if oxygen uptake in liters per minute increases with the two-thirds power of body mass, and running speed is proportional to oxygen uptake in ml × kg^{-1} × $minute^{-1}$.

TABLE 7-5 Times in Minutes for the 10-kilometer Run Referenced by Percentile and Body Weight

Percentile	Body Weight (lbs)			
	<155	155-174	175-194	195+
	Minutes:seconds			
99	29:50	33:39	36:54	39:29
90	35:10	39:24	42:49	45:37
75	39:13	42:56	45:57	48:18
50	44:06	47:03	49:44	53:14

Load carriage ability is not well predicted by unloaded running, because although a slight body build is well adapted to unloaded running, it is not well adapted to load carriage, particularly as loads become heavy. Larger people tend to have greater lean body mass (LBM) which helps to support and move the load carried. Table 7-6 shows correlations of LBM with both height and body weight. It can be seen that, for both men and women, LBM is well related to total body weight, at least for a young, military population.

Association of Lean Body Mass with Military Performance

Table 7-7 shows correlations of load carriage performance with LBM and percent BF. It can be seen that fatness is associated with slower load carriage. Higher LBM is associated with faster load carriage. The correla-

TABLE 7-6 Correlations of Lean Body Mass with Height and Weight

Study	Height		Weight	
	Men	Women	Men	Women
		r*		
Teves et al (1985)	0.60	0.75	0.91	0.88
Harman et al (1988)	0.68		0.85	
Myers et al (1983)	0.62	0.72	0.91	0.89
Fitzgerald et al (1986)	0.63	0.69	0.79	0.76

*r = Pearson product moment correlation coefficient (see tables that follow)

TABLE 7-7 Correlations of Load Carriage Performance with Lean Body Mass and Percent Body Fat in Male Subjects

Study	Distance	Load (kg)	LBM r^*	Percent Fat r
Mello et al. (1988b)	2 km	46	0.54	0.00
	4 km	46	0.39	0.38
	8 km	46	0.45	0.48
	12 km	46	0.55	0.29
Knapik (U.S. Army Res. Inst. Environ. Med., unpublished)	20 km	46	0.26	0.65
Dziados et al. (1987)	10 miles	18	0.30	0.15

*r = Pearson product-moment correlation coefficient; correlations mean higher lean body mass = faster times; higher percent body fat = slower times.

tions are stronger for LBM than for percent BF. It thus may be more important to screen potential recruits for LBM than for percent BF.

Added evidence as to the importance of LBM for performance of military tasks is the positive relationship between LBM and lifting ability. Table 7-8 shows correlations of lifting performance with LBM and percent BF. It is clear that LBM is an important factor in lifting, much more so than percent BF. The low but positive correlations of percent BF with lifting ability suggest a weak trend for fatter people to lift more effectively, probably because individuals with more fat tend to have greater LBM. Table 7-9 shows the weak but positive association among men between LBM and fatness. However, the Myers et al. (1983) data suggest that the trend declines or even disappears with training, probably as the fatter men lose weight. Figure 7-1, from the work of K. E. Friedl (unpublished) shows that men above the BF standard lose body weight, while those below the BF standard gain body weight during basic training. Overall, men gain about 2.5 kg of LBM during basic training, while losing 1 to 2 percent fat. Women also gain about 2.5 kg of LBM in basic training, but there is disagreement as to whether they gain or lose in percent body fat (K. E. Friedl, unpublished; Myers at al., 1983; Teves et al., 1985).

The weaker correlations for women than for men between lean body weight and lifting ability might be related to lack of experience among women with lifting, which results in greater variability in technique. It should also be noted that the correlations listed for the Myers et al. (1983)

TABLE 7-8 Correlations of Lifting Performance with Lean Body Mass (LBM) and Percent Body Fat

		Men		Women	
Study	Lift Type	LBM r*	Percent Fat r	LBM r	Percent Fat r
Teves et al. (1985)	Maximal	0.45	0.06	0.26	0.10
Sharp et al.	Repetitive[1]	0.68	0.25	–	–
(unpublished)	Maximal	0.48	0.15	–	–
Myers et al. (1983)	Maximal	0.64	0.26	0.45	0.03

*r = Pearson product moment correlation coefficient; positive correlations mean: higher lean body mass = better lifting; higher percent body fat = better lifting.
[1]Maximal number of lifts with 90 pounds in 10 minutes.

study are before basic training. Yet the correlations between LBM and lifting ability stayed quite constant through both basic training and advanced individual training. The relationship between LBM and lifting ability for women actually strengthened after training, probably due to practice with lifting, which lessened variability in technique. In contrast, correlations of lifting ability with percent BF dropped to about zero after basic training for both men and women, and remained there through advanced individual training. Thus, percent BF of the working soldier appears to be unrelated to lifting ability.

In addition to being positively associated with load carriage and lifting, LBM is related to other military task performances. Table 7-10 shows that LBM tended to be positively associated with the ability to push, carry and

TABLE 7-9 Correlations of Percent Body Fat with Lean Body Mass

Study	Men	Women
	r*	
Teves et al. (1985)	.12	.15
Myers et al. (1983)		
before basic training	.36	.11
after basic training	.11	.09
after AIT[1]	.09	.06

*r = Pearson product moment correlation coefficient
[1]AIT = advanced individual training

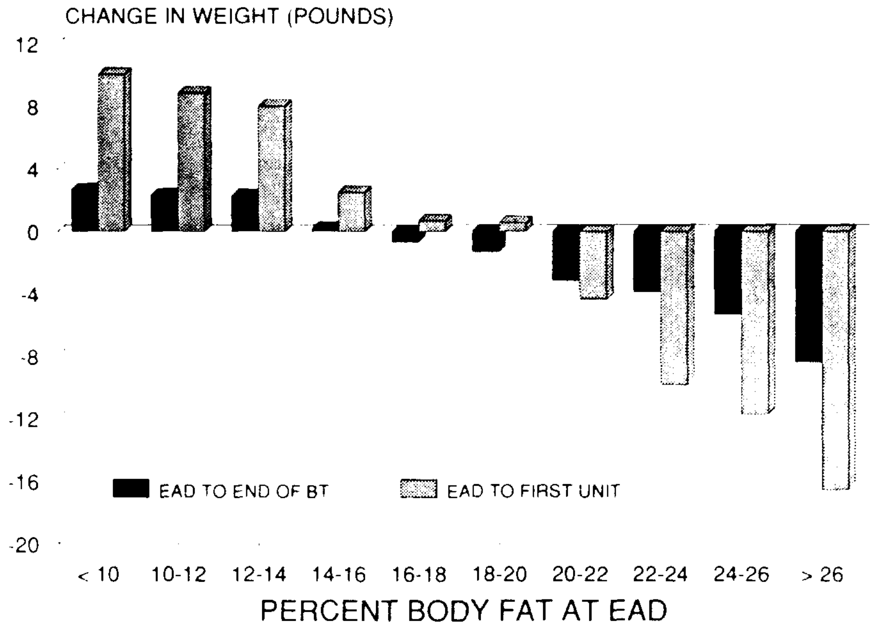

FIGURE 7-1 Change in body weight of military men from entry to active duty (EAD) to the end of basic training (BT) and assignment to first unit.

exert torque. As observed for lifting, lean body mass was a better indicator of performance ability than was percent BF. There was a weak trend for fatter people to push and exert torque better, probably because they could use their fat mass to generate momentum (Myers et al., 1983).

Discussion and Conclusions

Where does all this lead? Fat weight clearly impairs distance running ability, but distance running is rarely required of soldiers. The performances of common physically demanding military tasks, including load carriage, lifting, pushing, and exerting torque, are more closely related to LBM than to percent BF. There is even a weak trend for body fatness to improve performance in lifting, pushing, and torque exertion.

The evidence presented suggests that minimum LBM standards may be more important to military performance than are maximum percentage BF standards. Perhaps recruits should be required to meet standards for both minimum LBM and maximum percent BF.

Another alternative is to eliminate BF standards completely in favor of performance tests. Despite the consistent trend for LBM to be associated with lifting and load carriage ability, the correlation coefficients are fair at best. Thus, depending on their stringency, body composition standards could exclude many potential recruits capable of effectively performing military jobs well and grant entry to many individuals physically incapable of satisfactorily performing their military jobs.

In contrast to the Army, many police and fire departments only accept applicants who pass physically demanding performance tests that closely simulate job tasks. Advantages of this approach include

• actual performance is tested, rather than performance by inference.

• recruits who pass physically demanding performance tests might be less likely to be injured after enlistment, saving the Army medical and lost workforce costs.

• attrition might be reduced because potential applicants not physically or psychologically prepared for the demands of military duty are less likely to be able to train themselves to pass physically demanding performance tests.

• such testing would not necessarily lower the rate of recruit acceptance. It might help to select applicants more suited to their jobs and less likely to prematurely leave the military.

In addition, it does not appear that the existing Army physical fitness (PT) test would be effective for entry screening. Table 7-11 shows some of the minimal existing data relating physical fitness test scores to lifting and load carriage, the two most common physically demanding Army tasks. Of the three studies listed, the correlations from Myers et al. (1983) are based on the largest number of subjects and indicate only a weak positive association between number of push-ups and maximal lifting ability. The correla-

TABLE 7-10 Correlations of Performance with Percent Body Fat and Lean Body Mass (LBM) after Advanced Individual Training

	Percent Fat		Lean Body Mass	
Task	Men	Women	Men	Women
		r*		
Weight pushed	.20	.17	.52	.37
Torque	.18	.14	.35	.30
Push work	.09	.10	.23	.26
Carry work	.03	.17	.27	.02

*r = correlation coefficient; positive correlations mean: higher percent body fat = better performance; higher lean body mass = better performance.

TABLE 7-11 Correlations of Army Physical Fitness Test (PT) Scores with Lifting and Load Carriage Performance

Study	Lifting Men	Lifting Women	Load Carriage Men	Load Carriage Women
		r^*		
J. Knapik (U.S. Army Res. Inst. Med., unpublished) (n = 89 males)				
push-ups	—	—	0.09	—
sit-ups	—	—	0.19	—
2-mile run	—	—	0.16	—
Myers et al. (1983) (n = 751 males, 450 females)				
push-ups	0.24	0.32	—	—
sit-ups	0.06	0.24	—	—
2-mile run	−0.06	−0.14	—	—
Harman et al. (1988) (n = 32 males)				
2-mile run	−0.37	—	—	—

*r = correlation coefficient; positive correlations mean: better PT score = better lifting or load carriage

tions of 2-mile run performance with lifting show no association in the Myers et al. (1983) data and weak association in the Harman et al. (1988) report, where the negative correlation indicates some tendency for the better runners to lift less effectively. This is not surprising given the tendency for greater LBM to be detrimental to running ability but salutary to lifting ability. The J. Knapik data (unpublished) also show little relationship between the physical fitness test scores and load carriage ability.

There are obvious reasons, in addition to the differences between loaded and unloaded running abilities already discussed, why the PT tests do not effectively predict military task performance. The first relates to Astrand and Rodahl's (1986) discussion of body size. Assuming constant body shape, body weight increases with the cube of height, while strength, which reflects muscle cross sectional area (Ikai and Fukanaga, 1968; Ryushi and Fukanaga, 1986), is proportional to the square of height. Because muscle strength does not keep pace with increasing body mass, larger individuals are at a disadvantage in manipulating their own bodies. Thus, smaller people can more easily perform push-ups and sit-ups but cannot lift as much because the greater absolute strength of larger muscles can be effectively applied to the manipulation of objects external to the body, as in lifting.

An additional reason why push-up, sit-up, and 2-mile run scores are not strongly associated with military task performance relates to the concept of strength specificity, which holds that the more dissimilar two exercises are, the less their performances can be expected to be associated. The movements involved in push-ups and sit-ups are quite dissimilar to those involved in lifting and load carriage. The development of new physical fitness tests more specifically related to military tasks would require careful analysis and experimentation.

There are many different jobs in the U.S. Army, yet all soldiers must meet the same age- and gender-specific standards for BF and physical fitness. Because the Army is already dealing with great diversity and complexity in other areas, perhaps it can also deal with a limited number of different physical standards for different jobs. Tough standards could be applied to combat units and physically demanding occupational specialties. More lenient standards for non-physically demanding jobs could help avoid excluding fatter or weaker individuals who might have skills and abilities of potential benefit to the Army.

The U.S. Army should clearly define its reasons for having body composition standards. This report has shown that the existing standards are not well related to military task performance. If performance is the main reason for having standards, then new standards should be developed. If appearance is an important consideration, then psychological studies should be undertaken to determine how the appearance of fatness affects military morale and interpersonal relations. If health is the critical factor, then epidemiologic studies should be given priority. Identification of the problem is the most important step in finding its solution.

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8

New Approaches to Body Composition Evaluation and Some Relationships to Dynamic Muscular Strength

Frank I. Katch

NEW APPROACHES TO BODY COMPOSITION EVALUATION

Estimating Excess Body Fat From Changes in Abdominal Girth

A new method has been devised for determining changes in percent body fat (BF) based on the difference between an initial value for abdominal girth (AG) and a calculated "target" AG based on a desired level of percent BF (Katch et al., 1989). The new method differs from traditional approaches, such as fatfold and girth-generated regression analysis based on densitometry (' Kson and Pollock, 1978; Katch and McArdle, 1973; Pollock et al., 197 Wilmore and Behnke, 1968, 1969, 1970), bioelectrical impedance (Deurenberg et al., 1990; Segal et al., 1985), and other indirect appraisal procedures (Borkan et al., 1985; Lukaski, 1987) that first estimate percent BF, and then the individual attempts to achieve a desired change in body mass or composition. With these different methodologies, especially the fatfold technique, accuracy is often attenuated due to statistical factors related to validity (Katch and Katch, 1980), particularly the choice of measurement sites. Nevertheless, the use of regression equations for a one-time assessment has provided important quantitative information. However, using the same regression equation for pre and post-testing will produce unacceptable estimates of changes in percent BF (Barrows and Snook, 1987). In contrast, the new approach is based on a different strategy than the previous methods. With the new approach, the question is asked: How much does the abdominal girth need to be reduced to achieve a desired percent BF?

Development of the new method had its roots in clinical experience with subjects who altered their body composition dramatically during different regimens of exercise and caloric restriction. But it was Behnke (1963, 1969) who first detailed quantitatively that two abdominal girths (natural waist and umbilicus) showed the greatest absolute changes with body mass loss in relation to 11 other trunk and extremity sites. There is also good experimental evidence that increases in total BF result in proportional increases in abdominal fat (Kvist et al., 1986). Thus, it seemed logical that changes in percent BF could coincide with reductions in excess AG, or that reducing excess AG should coincide with proportionate reductions in percent BF. The proposed method is based on the difference between an initial value for AG and a target AG that corresponds to a "desired" percent BF.

Calculation of Excess Abdominal Girth

Excess AG is measured with a calibrated anthropometric cloth tape at the natural waist or the abdomen at the level of the umbilicus. A two-step procedure is required to calculate excess AG for an individual. Step 1 requires the development of constants based on the source data for subsequent application in Step 2.

- Step 1. The calculation of excess AG is based on large-scale anthropometric surveys in the military. For men, these included soldiers (White and Churchill, 1971) (Table 8-1) and U.S. Army aviators (Churchill et al., 1971) (Table 8-2), and for women, U.S. Air Force women (Clauser et al., 1972) (Table 8-3). From these data, a target AG was computed as the product of F (kg of body mass per meters [m] of stature) and a constant Q. This constant was calculated as the ratio of AG at a predetermined value for percent BF to F ($Q = AG/F$). From Table 8-1, for example, Q = 12.36 at the fiftieth percentile (Q = 78.9/6.381).

With the data sets from the military, it was necessary to estimate body composition because such criterion measures were not included in the surveys, or they were limited to a small subsample of the data (Clauser et al., 1972). For the soldiers and aviators, fat-free mass (FFM) was computed by the anthropometric method of Wilmore and Behnke (1968), and for U.S. Air Force women, percent BF was derived from a surface area equation that included triceps, subscapular, and supra-iliac fatfolds (Katch et al., 1979) and the variable F (square root of the quantity body mass in kg divided by stature in meters) (Behnke and Wilmore, 1974).

TABLE 8-1 Source Data for 6,682 U.S. Army Soldiers

	Percentile						
	1	5	25	50	75	95	99
Age (years)	17.4	18.6	19.6	20.0	23.0	31.5	43
Mass (kg)	52.7	57.4	64.8	71.0	78.4	91.7	103
*F**	5.497	5.737	6.096	6.381	6.705	7.251	7.685
Percent fat†	0.4	3.8	8.0	11.1	14.9	19.1	24.4
Abdomen (cm)	66.3	69.7	74.5	78.9	84.7	95.9	105.6
Q‡	12.06	12.15	12.22	12.36	12.63	13.23	13.74
Target girth§ (cm)	[illegible]	75.9	80.7	84.4	88.7	95.9	101.7

**F* = (body mass [kg]/height [m]). Median height used in calculations for each percentile was 1.744 m.

†The percent fat value for percentiles 1 and 5 are severe underestimations based on the anthropometric estimation technique and should be interpreted with caution. At the twenty-fifth percentile and greater, there is little under- or overestimation using the prediction methodology.

‡Q = Abdomen (cm)/*F*.

§Target girth = $F \times 13.23$.

For example, for a group of men (or an individual) with an AG of 89.7 cm, body mass of 85.5 kg, and stature of 1.876 m, the quotient *F* is (85.5/1.876) = 6.751. This value is then multiplied by the Q value at the desired percent BF (13.23 at the ninety-fifth percentile that corresponds to a desired percent BF of 19.1 percent; Table 8-1) to yield a target AG of 84.4 cm.

TABLE 8-2 Source Data for 1,482 U.S. Army Aviators

	Percentile						
	1	5	25	50	75	95	99
Age (years)	19.6	20.7	22.2	24.5	28.7	37.5	44.3
Mass (kg)	55.8	60.4	69.9	77.3	84.9	95.9	104.3
*F**	5.653	5.882	6.327	6.654	6.973	7.411	7.729
Percent fat	5.8	7.1	13.7	17.2	20.8	23.7	26.2
Abdomen (cm)	70.8	73.5	80.9	86.9	92.9	101.7	108.9
Q†	12.52	12.50	12.78	13.06	13.33	13.72	14.09
Target girth‡ (cm)	74.8	78.4	84.4	88.0	92.9	98.0	102.3

**F* = (body mass [kg]/height [m]). A median height of 1.746 m was used in calculations for each of the percentile distributions.

†Q = Abdomen (cm)/*F*.

‡Target girth (cm) = $F \times 13.23$.

TABLE 8-3 Source Data for 1,357 U.S. Air Force Enlisted Women

	Percentile						
	1	5	25	50	75	95	99
Age (years)	18.0	18.2	19.0	19.9	21.3	25.6	40.4
Mass (kg)	43.7	46.0	52.1	56.7	61.2	68.5	76.1
F[*]	5.200	5.335	5.678	5.923	6.154	6.511	6.862
Q[†]	11.06	11.15	11.15	11.19	11.31	11.60	11.89
Q[‡]	13.67	13.93	14.12	14.25	14.41	14.74	15.10
Percent fat	14.2	17.2	24.2	28.6	32.2	37.1	42.6
Waist (cm)	57.7	59.5	63.3	66.3	69.6	75.5	81.6
Abdomen extension (cm)	71.1	74.3	80.2	84.4	88.7	96.0	103.6
Target girth[§] (cm)	74.1	76.0	80.9	84.4	87.7	92.8	97.8

*F = (body mass [kg]/height [m]). Height at the fiftieth percentile was 1.616 m, which was used for each of the percentile distributions. The sample was Caucasian (*n* = 1,216), Black (*n* = 131), and other (*n* = 10).

†Q = Waist (cm)/F.

‡Q = Abdomen extension (cm)/F.

§Target girth (cm) = F × 14.25

• Step 2. Excess AG is computed as the measured AG (89.7 cm in the above example) minus the target AG at the fiftieth percentile of 84.4 cm from Step 1. The 5.3 cm difference (89.7 cm minus 84.4 cm) is the excess AG. The objective is straightforward: try to attain the target AG that corresponds to the desired percent BF. In this example, the predetermined, desired level for percent BF was chosen as 19.1 percent.

An important consideration with the new approach is to decide on the target or desired level of percent BF. If different percentile values are used for percent BF, then different Q values must be applied in Step 1.

The AG Method During Body Mass Loss by Exercise Plus Diet

Table 8-4 shows the application of the AG method to four obese men and four obese women who reduced their body mass by an average of 20.5 kg in experiments that involved 1 hour daily of cycling and walk-jog exercises over a 6-month period coupled with mild dietary restriction (Katch and Katch, 1984).

The results of the analyses based on densitometry to estimate percent BF and anthropometry to measure the change in AG (ΔAG) were remarkable for this relatively small sample of subjects. For the men and women of the same age, change in body mass (ΔBM) divided by ΔAG was almost identical for the first two tests (1.08 for men and 1.09 for women). These

TABLE 8-4 Application During Weight Reduction in Obese Men and Women

Test No.	Mass	F	$F \times Q$	AG	$AG - (F \times Q)/AG$	Percent BF	Mass/AG*
			Subject 1: man, age 58 years, height 1.844 m				
1	85.5	6.809	90.1	95.5	5.7	27.3	
2	78.1	6.508	86.1	88.6	2.9	19.9	1.07
3	74.6	6.360	84.1	83.8	0.4	18.0	0.734
4	74.9	6.373	84.3	85.2	1.0	16.0	0.21
			Subject 2: man, age 28 years, height 1.772 m				
1	88.1	7.051	93.3	100.4	7.1	22.5	
2	80.6	6.744	89.2	93.3	4.4	18.4	1.06
3	75.9	6.545	86.6	89.4	3.1	14.8	1.22
			Subject 3: m[illegible] [illegible]e 52 years, height 1.784 m				
1	90.5	7.122	[illegible]	96.1	2.0	22.8	
2	82.2	6.788	[illegible]	87.9	2.2	17.6	1.01
3	79.1	6.659	88.1	84.8	3.9	16.1	1.00
4	78.3	6.625	87.6	84.2	4.0	14.0	1.23
			Subject 4: man, age 46 years, height 1.790 m				
1	131.2	8.561	122.1	132.2	7.6	39.2	
2	94.[illegible]	7.281	103.8	99.7	4.1	27.1	1.17
			Subject 5: woman, age 29 years, height 1.702 m				
1	117.8	8.319	118.6	111.3	6.6	45.8	
2	87.1	7.154	102.0	102.2	0.2	35.7	3.37
			Subject 6: woman, age 41 years, height 1.680 m				
1	83.3	7.042	100.4	104.4	3.8	42.1	
2	65.7	6.254	89.2	89.1	0.1	28.9	1.15
			Subject 7: woman, age 37 years, height 1.591 m				
1	93.6	7.670	109.4	107.6	1.7	43.8	
2	71.9	6.722	95.9	88.2	8.7	35.6	1.12
			Subject 8: woman, age 35 years, height 1.625 m				
1	93.8	7.598	108.3	127.8	15.3	48.5	
2	71.2	6.619	94.4	105.5	10.5	35.7	1.01

NOTE: F = (body mass [kg] [illegible] height [m]) [illegible]; Q = a constant; AG = abdominal girth; BF = body fat.

*Ratio of change in mass to change in AG for Test 1 versus Test 2, 2 versus 3, 3 versus 4.

ratios indicated that the basic assumptions of the current analyses were valid because a ratio of 1.00 would signify a precise correspondence between ΔBM and ΔAG. Both groups reduced nearly the same amount in their AG (men, 13.7 percent; women, 14.6 percent); the women, however, reduced their percent BF to a greater extent (11.0 percent BF units) compared to the men (7.9 percent BF units). This difference probably occurred because the women had a higher initial percent BF (45.0 percent by densitometry) compared to the men (29.7 percent). The women also lost 5.5 kg more body mass than did the men.

An important consideration is the extent of agreement between the measured AG and the predicted AG using $F \times Q$ at the desired percent BF. For the initial measurements, the correspondence between the measured and target AG would not be congruent because the subjects were all obese. However, as they begin to reduce body mass, percent BF, and AG, the relationship between the target and measured AG should converge. Inspection of the individual data indicated that this did occur during Tests 1 and 2 except for Subjects 3 and 7. Male Subjects 1 and 2 were model subjects to illustrate the continued decline of the measured minus predicted AG as time progressed. For the first two tests, the percent changes in AG for the group, expressed as $(AG$ minus $F \times Q)/AG$, decreased in the predicted pattern (men from 5.6 percent to 3.4 percent; women from 6.9 percent to 4.9 percent). For Subjects 1 and 3 who were measured 4 times, there was a slight increase in the percent changes in AG, probably because there were no further decreases in BM or AG, and they achieved their target AG and desired percent BF. This also was true for Subjects 2 and 6. For the latter, her target and measured AG coincided at just about the desired level for percent BF. For the remaining subjects, there were discrepancies between the target and measured AG. Although the measured AG actually became smaller than the target AG, percent BF remained above the desired levels defined by the gender-specific Q values. Either there were small errors in the AG measurements, or the group Q values need refinement.

The AG Method During Body Mass Loss by Diet Only

Recent data made available by A. Weltman at the University of Virginia at Charlottesville shows the application of the AG method in 6 obese men and 19 women who participated in a controlled liquid-diet weight loss program. Table 8-5 shows the changes in body composition for the women and men. The salient features include changes in BM and two AGs (umbilicus and waist girths). For women, the value for Q at the fiftieth percentile for the waist girth is 11.19 (Table 8-3). The men reduced BM more than the women (24.2 kg versus 19.3 kg), as well as waist and umbilicus girths, percent BF, and absolute fat mass. Of interest are the nearly similar gender

TABLE 8-5 Changes in the Body Composition of 19 Obese Women and 6 Obese Men on a Reducing Diet

	Women				Men			
Variable	Pre Mean	SD	Post Mean	SD	Pre Mean	SD	Post Mean	SD
Body mass (kg)	92.4	8.40	73.1	6.67	114.9	13.6	90.7	24.2
Waist girth (Ab_1) (cm)	95.7	10.09	80.4	8.68	114.6	8.67	94.4	6.87
Umbilicus girth (Ab_2) (cm)	111.1	10.70	94.8	8.68	120.8	9.54	99.9	5.05
Body fat, %	45.3	4.06	35.4	5.04	37.0	4.14	26.7	3.65
Fat mass, kg	42.2	6.61	26.0	5.41	42.7	8.40	24.3	4.61
F	7.529	6.697		7.998		7.106		
$F \times Q$ (Ab_1)	84.3		74.9					
$F \times Q$ (Ab_2)	107.3		95.4		98.9		87.8	
Excess abdominal girth (AG)	3.8		5.5		21.9		12.1	
Mass/AG_1			1.26				1.20	
Mass/AG_2			1.18				1.16	

NOTE: For women, age = 38.1 years (SD = 11.3), height = 163.0 cm (SD = 6.86); for men, age = 43.1 years (SD = 13.9), height = 179.6 cm (SD = 8.03). F = (mass [kg]/height [m])$^{0.5}$; for women, Q = 11.19 for Ab_1 and Q = 14.25 for Ab_2 (fiftieth percentile for military data in Table 8-3); for men, Q = 12.36 *for* Ab_2 *(fiftieth percentile for military data in Table 8-1)*; Excess AG = $F \times Q$ minus measured AG; Mass/AG = ΔBM/ΔAG. Body fat was estimated from densitometry with correction for residual volume.

SOURCE: Data courtesy of A. Weltman, Department of Physical Education, Exercise Physiology Lab, University of Virginia, Charlottesville, Virginia, 1991. Used by permission.

$\Delta BM/\Delta AG$. For women, the $\Delta BM/\Delta AG_1$ is 1.26, and the $\Delta BM/\Delta AG_2$ is 1.18. For men, the $\Delta BM/\Delta AG_1$ is 1.20, and the $\Delta BM/\Delta AG_2$ is 1.16. Such results provide additional corroborative evidence for the close correspondence between mean ΔBM relative to mean AG ($\Delta BM/\Delta AG$). However, a different pattern emerges when the $\Delta BM/\Delta AG$ is computed for individuals.

Figure 8-1 shows the results of the simple regression analysis (with 90 percent confidence bands) for the $\Delta BM/\Delta AG$ for 19 women (top) and 6 men (bottom). The important result is that for men and women, the association is strongest between change in waist girth (abd_1) and change in BM (r^2 =.74 for abd_1, and r^2 = .88 for abd_1). While the results for $\Delta BM/\Delta AG_1$ for men is encouraging, the sample size is really too small for meaningful interpretations, and more data are required for confirmation. What can be stated with some confidence at this point is that the change in fat content

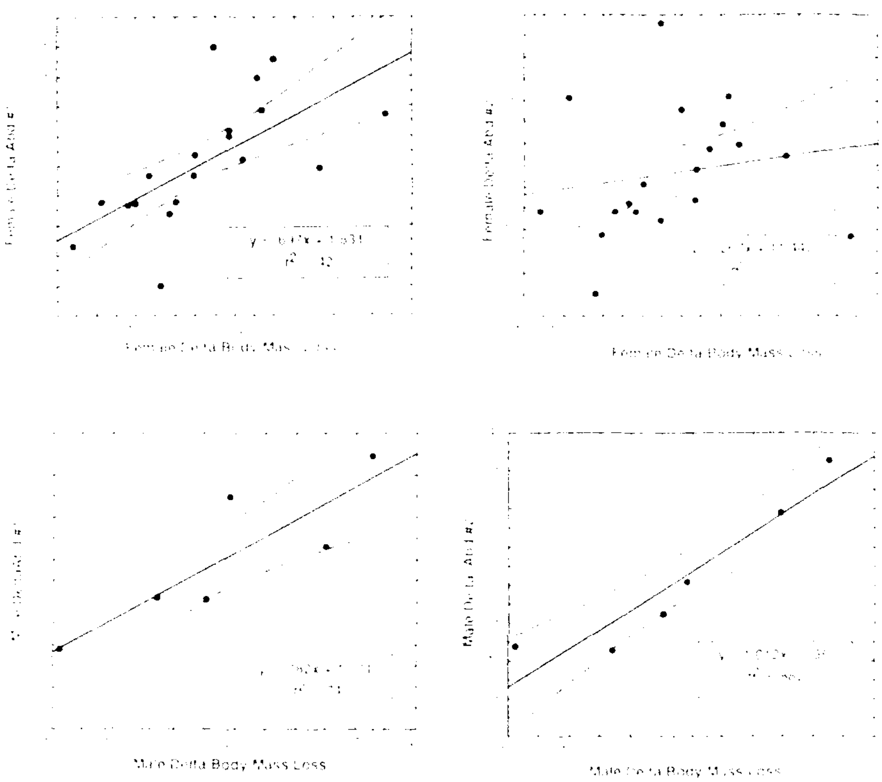

FIGURE 8.1. Regression analysis for the change in two abdominal girths plotted as a function of change in body mass for female (top) and male (bottom) subjects. The 90 percent confidence bands are shown for the slope of the regression line.

at the abdominal site as measured by change in AG parallels, in general, the overall change in BM that occurs due to caloric restriction plus exercise or by caloric restriction alone.

The main requirement in future experiments should be to secure large samples (as in the military anthropometric studies) and include subjects of diverse body composition. A large data base that includes complimentary anthropometric data and a criterion measure of BF would permit a more accurate determination of the Q constants used in Step 1 for different levels of BF. It would also be desirable to secure anthropometric data and criterion BF measures during BM loss. These data would allow for the validation of the Q constants with changes in body composition.

In summary, the objective for individuals who need to reduce their percent BF would be to try and attain a target AG. If excess girth is not too large, attainment of the target AG should coincide with an a priori determined level of percent BF. However, if the excess AG is considerable, then the target AG becomes a "first approximation" with BM loss, and a further body composition evaluation is required to ensure congruence with the desired percent BF. If individuals can reduce their excess AG by bringing their AG in line with the target AG, their percent BF should coincide with the desired level of BF. The latter, however, is difficult to ascertain because one must define what in fact is normal or acceptable percent BF in relationship to age. This problem is further influenced by such factors as physical condition (varying from sedentary to very physically active) and race.

THE BODY PROFILE: AN ENHANCEMENT OF THE SOMATOGRAM

The concept of the somatogram (SOM) was established by Behnke et al. (1959) to describe body shape expressed in percentage deviation units from reference standards developed from military and civilian large-scale anthropometric surveys (Hertzburg et al., 1963; O'Brien and Shelton, 1941; Welham and Behnke, 1942). The basis of the SOM is the translation between a squared matrix of 12 girths and the previously described body size module F (square root of the quantity body mass in kg divided by stature in decimeters)[1] into a graphic description of the percentage deviations from the reference standard.

To construct the SOM, each of 12 girths (g) are divided by their proportionality constants (k) to obtain a deviation (d) score ($d = g/k$). The k constant is computed as g/D, where D equals the sum of the g values divided by 100. The SOM presents the percentage deviation of each d quotient from D. This graphic approach has been used to show changes in body size during growth and development (Huenemann et al., 1974; Katch, 1985a), to depict progressive changes in overall body shape with aging (Behnke, 1963, 1969), and to describe gender differences in athletic groups (Behnke, 1963, 1968; Katch, 1985b; Katch and Katch, 1984). The SOM approach has now been enhanced, and the technique is referred to as the body profile, or more specifically, the ponderal SOM (P_{SOM}) (Katch et al., 1987).

The SOM analysis did not permit translation of girth size into a volume or weight entity that relates to the body as a whole. The original SOM also did not differentiate between muscular and nonmuscular areas of the body;

[1]Note that for the SOM concept, stature in decimeters replaces stature in meters in the calculation of F.

thus, nonmuscular girths such as the abdomen and hips were integrated with muscular parts such as the flexed biceps, thigh, and calf. Because the deviation of each d from D is based on the matrix of girths, each g is in fact related to itself because it is part of D. Although this discrepancy is probably of minor importance to the graphic representation of body shape, it still does not permit a clear-cut separation of the muscular and nonmuscular components.

The body profile is an extension of the SOM. Girth measures are converted to ponderal equivalent weight values. The matrix of girths can be separated into muscular and nonmuscular components and compared as mass equivalents. In this paper, the P_{SOM} is presented for a world champion male body builder where there is excessive muscular development, especially in the biceps, chest, and shoulders.

Original Somatogram Calculations

The left side of Table 8-6 lists the measurements and k constants for the reference man and woman (Behnke et al., 1978). To calculate SOM, each girth (g) is divided by k to obtain a ratio referred to as d ($d = g/k$). The reference value is then computed as D, where D is the sum of the girths ($D = \Sigma$ girths) divided by the sum of the k values (Σ k = 100). The graphic representation of body shape is a plot of the percentage deviation of each d from D (percent deviation = $[d - D]/D$). If an individual's measurements conformed precisely to the reference values, there would be no deviations, and the SOM would plot as a vertical line. An example of a SOM for a 40-year-old man is shown in the left side of Figure 8-2. For a biceps of 40.2 cm and $D = 6.771(\Sigma\ 11\ g/100)$, d for the biceps is 7.60 ($d = 40.2/5.29$), where 5.29 is the k(biceps) value for the reference man listed in Table 8-6. Expressed as a deviation from D, d(biceps) is 12.2 percent larger ([7.600 minus 6.771]/6.771) multiplied by 100, and is plotted on the somatogram as +12.2 to the right of the zero axis. The d values for the other girths are plotted in a similar fashion.

Ponderal Somatogram Calculation

The right side of Table 8-6 lists the constants to calculate the P_{SOM}. There are two components: (1) ponderal equivalent muscular component (PE_{M}), which includes the shoulder, chest, biceps, forearm, thigh, and calf, and (2) ponderal equivalent nonmuscular component (PE_{NM}), which includes two AG measures and their average, as well as hips, knee, wrist, and ankle.

The constants for the individual girths are calculated from the data of the reference man and woman as $k = g/F$, where g = individual girth in cm,

TABLE 8-6 Measurements and Proportionality Constants for the Reference Man and Woman, and Conversion of Anthropometric Girths into Ponderal Equivalents

	Original Somatogram*				Ponderal Somatogram†	
Variable	Reference Man Girth	k	Reference Woman Girth	k	Reference Man k	Reference Woman k
					Muscular component (PE_M)‡	
Shoulders	110.8	18.47	97.4	17.51	55.40	52.59
Chest	91.8	15.30	82.5	14.85	45.90	44.55
Biceps	31.7	5.29	26.7	4.80	15.85	14.42
Forearm	26.9	4.47	23.1	4.15	13.45	12.47
Thigh	54.8	9.13	55.8	10.03	27.40	30.13
Calf	35.8	5.97	34.1	6.13	17.90	18.41
Total					175.90	172.57
					Non-muscular component (PE_{NM})§	
Abdomen 1	77.0	12.84	65.6	11.83	38.50	35.42
Abdomen 2	79.8	13.30	77.8	13.95	39.90	42.00
Abdomen average	78.4	13.07	71.7	12.90	39.20	38.71
Hips	93.4	15.57	94.2	16.93	46.70	50.86
Knee	36.6	6.10	34.9	6.27	18.30	18.84
Wrist	17.3	2.88	15.2	2.73	8.65	8.21
Ankle	22.5	3.75	20.6	3.70	11.25	11.12
Total	600	100	556	100	124.10	127.74

NOTE: For the reference man, mean age = 21.0 years, median weight = 69.6 kg, median stature = 17.40 dm, and F = 2.000. For the reference woman, mean age = 21 years, median weight = 56.2 kg, median stature = 16.38 dm, and F = 1.852.

*Original data from Behnke et al. (1959).

†Original data from Behnke et al. (1963) as modified in Katch et al. (1987).

‡Ponderal equivalent muscular component.

§Ponderal equivalent nonmuscular component.

and F = the square root of the reference man and woman median weight in kg divided by reference man and woman median stature in dm. For the reference man, the value for F is 2.000; for the reference woman F is 1.852 (Behnke et al., 1978).

The ponderal equivalent (PE), expressed in kg for each girth, is computed as the square of the quotient g/k multiplied by stature in dm. For

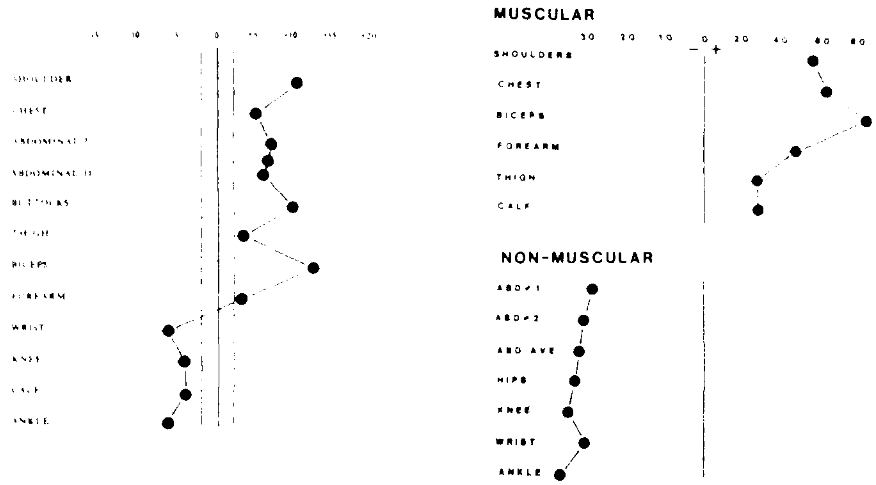

FIGURE 8-2 *Left.* Original somatogram (SOM). There is no distinction between muscular and nonmuscular components. Scores within a range of +2 percentage deviations from the zero reference line are considered to be within normal limits of variation compared with the reference man and woman standards. *Right.* Ponderal somatogram (P_{SOM}) for a 35-year-old world champion body builder with extraordinary upper body development. The largest deviations are 88.6 percent for the biceps, 62.8 percent for the chest, and 58.8 percent for the shoulders.

example, the PE for the shoulders for the reference man is $(g/k)^2$ multiplied by stature or $(110.8/55.4)^2 \times 17.4 = 69.6$ kg. For the reference man, the PE values for all of the girths are identical to the reference median weight of 69.6 kg; the same is true for the reference woman. All of the PE values for the girths are identical to the reference woman median weight of 56.2 kg. For the reference models, the deviations of each PE from their respective standards are necessarily zero because there is no deviation from group symmetry (the reference values represent the standard).

A unique aspect of the P_{SOM} is the calculation of the *d* values. In the original SOM, it was not possible to separate the muscular from the nonmuscular girths because *D* was calculated as the sum of all the girths/100. Thus, a particular *d* value was related to the sum of the girths that included that particular girth.

This complication is avoided in the P_{SOM} by comparing the PE_M girth values with the average of the PE_{NM} values, and vice versa. There will not be exact numerical equivalency between the total $(cm/k)^2$ multiplied by stature and the average of the PE values because of differences in proportionality between the reference man and woman, and among individuals or groups of individuals. For the P_{SOM} in Figure 8-2, the specific k values were from the P_{SOM} listed in Table 8-6.

In summary, the original Behnke SOM to quantify body shape is a valid approach (Sinning and Moore, 1989) for partitioning a matrix of girths into PE_M and PE_{NM} components that can be related to the body as a whole. In male body builders, for example, excess muscular development appears to predominate in the biceps without compensatory hypertrophy in the lower limbs. Even at the extremes, which includes the massively obese as well as diminutive and large adolescents (Katch et al., 1987), there appears to be a fundamental, intrinsic association between an individual's body weight and the squared matrix of girths multiplied by stature. Such relationships have useful clinical and research applications for the study of obesity and its relationship to growth and development, as well as various facets of human performance. The next section explores some of these relationships to muscular strength.

SOME RELATIONSHIPS TO DYNAMIC MUSCULAR STRENGTH

Traditional views suggest that an individual's body size is directly related to muscular strength. However, there are conflicting data concerning the relationships among muscular strength and various measures of body size, including limb dimensional characteristics. Some studies report correlations of r = .61 to .96 among strength and body size and limb dimensions (Clarkson et al., 1982; Ikai and Fukunaga, 1968; Nygaard et al., 1983; Sale et al., 1987; Schantz et al., 1983; Tappen, 1950; Tsunoda et al., 1985; Young et al., 1982). It is likely, however, that these correlations are spuriously inflated because subsets of samples are included that combined men with women and trained with untrained subjects of different ages. In contrast, other studies report correlations of r = –0.25 to 0.52 among body size variables and muscular strength (Cureton, 1947; Ergen et al., 1983; Katch and Michael, 1973; Smith and Royce, 1963; Watson and O'Donovan, 1977). Such results suggest that additional factors, such as muscle fiber type, neural control of force production, and biomechanical alignment of muscles and joint levers, help to explain a greater proportion of the variance in strength.

In a recent study (Hortobagyi et al., 1990), the relationship was examined between individual differences in muscular strength versus body size, body shape, limb volume, muscle plus bone cross-sectional area, and the P_{SOM}. This study was done with two homogeneous groups using a statistical approach that avoided the confounding influence of individual differences in age, gender, and training status.

Experimental Procedures

The subjects were 42 Caucasian men from physical activity classes at the University of Massachusetts. Two different test protocols were used to assess muscular strength:

- Bench press (BP) and squat (SQ) were measured with an isokinetic dynamometer during three sets of two repetitions for BP and three sets of three repetitions for SQ. There was a 1-minute rest between each set, and approximately a 3-second pause between repetitions.
- BP and knee extension (KE) were measured with a hydraulic dynamometer. Subjects performed one set of five continuous repetitions for the seated BP and right KE. Based on the strength scores, subjects were placed into high strength (HS) and low strength (LS) groups by converting each of the four measures of strength into Z-scores that were then averaged and ranked. The Z-score procedure was used to characterize muscular "strength" as an overall component without weighting of the strength measures.

Anthropometric Assessment

The measurements included six fatfolds, 11 girths, and two segment lengths.

Calculations

Muscle plus bone cross-sectional area for the biceps ($MCSA_{Bi}$) was calculated as:

$$MCSA_{Bi} = \pi\,(r - [BiFF + TrFF]/4)^2\,, \qquad [1]$$

where r is the radius of the upper arm calculated from biceps girth, $BiFF$ is biceps fatfold, and $TrFF$ is triceps fatfold.

Muscle plus bone cross-sectional area for the thigh ($MCSA_{Thi}$) was estimated as:

$$MCSA_{Thi} = \pi\,(r - [ThFF]/2)^2\,, \qquad [2]$$

where r is radius of the thigh and $ThFF$ is thigh fatfold.

The volume of the upper arm and thigh was estimated as:

$$\text{Volume} = \pi h/3\ \ (R^2/2\pi + r^2/2\pi + Rr), \qquad [3]$$

where h is the length of the upper arm or thigh in cm, R is upper arm or thigh girth, and r is elbow or knee girth.

FFM (fat-free mass) was predicted by the method of Wilmore and Behnke (1969), where FFM = 1.08*BM* + 44.6 – 0.74 (*AG*); *BM* is body mass in kg, and *AG* is abdominal girth (umbilicus) in cm. Body shape was described by the P_{SOM} outlined in the previous section.

For the statistics, a priori and postmortem sample size estimations using Cohen's Case 2 formula with an alpha level of 0.05 and power of 0.80 required a minimum sample size of 12 subjects per group. The a priori effect size was a 25 percent difference between HS and LS in muscular strength. The final sample size ($n = 21$ per group) was nearly twice that required.

Between-group differences for single pairs of variables were evaluated with a two-tailed independent *t*-test. A one-way multivariate analysis of variance (MANOVA) was used to compute the differences between the two groups in the overall P_{SOM} and pairs of various dependent variables. If the Hotelling's T^2 value was significant, a two-tailed independent *t*-test was used for pairwise contrasts with an adjusted confidence level. Pearson product-moment correlations were computed among selected variables, and the differences in correlations between the groups were compared by *z*-transformation.

Results

As expected, HS had significantly greater strength for isokinetic SQ (21.1 percent), BP (23.3 percent), hydraulic BP (16.7 percent), and hydraulic KE (24.2 percent).

Anthropometry

There were no significant differences between HS and LS for age (1.5 percent), stature (2.2 percent), or sum of six fatfolds. In contrast, there were significant differences between HS and LS in BM (6.9 percent; $p < 0.05$), FFM (6.6 percent; $p < 0.01$), and 11 girths. For the girths, applying the pairwise follow-up, 7 of the 11 girths were significantly larger for HS, including the shoulders (3 percent), chest (4.4 percent; $p < 0.05$), biceps (5.6 percent), forearm (5.9 percent), knees (4.5 percent; $p < 0.05$), wrists (4.0 percent; $p < 0.001$), ankles (7.7 percent; $p < 0.01$), and sum of 11 girths (3.6 percent ; $p < 0.01$). There were no significant differences in thigh or calf girths (~3.0 percent).

There were differences between HS and LS in thigh volume (13.2 percent; $p < 0.01$) and upper arm volume (7.2 percent; $p < 0.05$). HS had a 14.8 percent greater $MCSA_{Bi}$ ($p < 0.001$) and 13.8 percent greater $MCSA_{Thi}$ than LS ($p < 0.05$). The mean values for thigh length were significantly different between HS (41.7 cm) and LS (39.9 cm), but not for upper arm length (17.9 cm for HS versus 18.3 cm for LS).

There were significant differences in the P_{SOM} between HS and LS. The sum of the muscular components (shoulders, chest, biceps, forearm, thigh, calf) was also significantly larger by 2.8 percent for HS. In addition, the sum of the five nonmuscular components (abdomen, hips, knee, wrist, ankle) was significantly larger by 10.1 percent for HS.

The percent deviations for the PE_M from the PE_{NM} for P_{SOM} varied from 0.4 percent (thigh) to 12.3 percent (biceps) for the PE_M for LS, to minus 1.8 to 16.0 percent for HS. The deviations of the PE_{NM} from PE_M ranged from minus 11.7 to 2.2 percent for LS, and minus 8.9 to minus 1.8 percent for HS. None of the between-group comparisons were significant.

Correlations

Table 8-7 presents the intercorrelations between strength, BM, FFM, fatfolds, limb volume, and limb CSA for the total sample and the two subsamples. For HS and LS, all of the r values were less than $r = 0.56$. There were no significant differences in any of the r values between HS and LS. The observed r values between BM and the four measures of strength averaged $r = 0.23$ ($p > 0.05$) for HS and LS; they did not increase significantly and were not significantly higher after applying the Guilford correction for restriction of range ($r_c = 0.30$; $p > 0.05$). The r values between limb volume and the strength measures averaged $r = 0.31$ and $r_c = 0.41$ ($p > 0.05$). The corresponding r values for estimated FFM versus strength were $r = 0.27$ and $r_c = 0.34$ ($p > 0.05$). Similarly, low correlations were obtained for the comparisons of MCSA versus strength ($r = 0.43$ and $r_c = 0.59$; $p < 0.05$), and for the sum of six fatfolds versus strength ($r = 0.27$ versus $r_c = 0.36$; $p > 0.05$). Thus, the observed r values between strength and anthropometry averaged $r = 0.30$, and the average corrected r values increased slightly to only $r_c = 0.40$ ($p > 0.05$).

It was postulated that subjects classified as high and low strength would shed light on the relationship between size and strength. In the studies where the average r between estimates of strength and BM and estimates of strength and muscle size exceeded $r \geq 0.80$, it is likely that these r values were spuriously inflated due to at least five factors:

- large individual variations in body size and physique among comparison groups,
- combining men and women in the salient comparisons,
- mingling trained and untrained subjects,
- pooling young and old subjects in the data analyses, and

TABLE 8-7 Correlations (r) and the Correlations Corrected for Restriction of Range (r_c) Between Strength and Body Size and Segment Size for the Low- (n = 21) and High-Strength (n = 21) Groups, and for the Total Sample (n = 42)

	Body Mass		Volume		FFM		MCSA		Σ6 Fatfolds	
	r	r_c	r	r_c	r	r_c	r	r_c	r	r_c
Isokinetic bench press										
Low strength	-0.15	-0.21	0.22	0.39	-0.03	0.04	0.41*	0.52*	-0.41	-0.55*
High strength	0.23	0.24	-0.17	0.05	0.24	0.25	0.35	0.36	-0.12	-0.13
Total	0.23		0.17		0.37*		0.58*		0.21	
Isokinetic squat										
Low strength	-0.33	0.41	-0.10	-0.36	-0.30	-0.38	-0.10*	-0.52*	-0.27	-0.34
High strength	0.33	0.42*	0.27	0.28	0.56*	0.70*	0.28	0.39	-0.38	-0.48*
Total	0.18		0.44		0.33*		0.42		0.24	
Hydraulic bench press										
Low strength	-0.24	-0.33	0.50*	0.67*	-0.20	0.28	0.52*	0.69*	-0.52*	-0.70*
High strength	0.11	0.12	-0.31	-0.34	0.22	0.24	0.45*	0.48*	-0.24	-0.26
Total	0.15		0.23		0.31*		0.67*		-0.29	
Hydraulic knee extension										
Low strength	0.25	0.34	0.27	0.36	0.27	0.36	0.49*	0.61*	0.09	0.12
High strength	0.47*	0.59*	0.54*	0.67*	0.31	0.40	0.41	0.52*	0.13	0.17
Total	0.47*		0.75*		0.43*		0.64*		0.29	

*$p < 0.05$

• using the mean value to correlate strength and body size for nine different sport groups, rather than using the data of individuals for each group.

Thus, the moderate to high r values were probably generated because of a "range of talent" effect in body size and physique, gender, training status, and age. In studies that used more homogeneous samples, lower r values averaging $r \leq 0.60$ were reported between strength, BM, and FFM in men and women. The low r values observed in the present study support these latter findings.

In the present data, the r values were all low between BM and muscular strength regardless of strength level ($r = 0.29$ for HS, and $r = -0.12$ for LS) or between estimated FFM and strength ($r = 0.33$ for HS, and $r = -0.07$ for LS; Table 8-7). There also was no improvement in the r values when arm or leg strength was related to muscle CSA (average $r = 0.38$ for HS, and $r = 0.27$ for LS) or to segmental volume ($r = 0.12$ for HS, and $r = 0.27$ for LS).

Additional comparisons between HS and LS revealed some interesting findings. For the girth comparisons between the groups, 7 of 11 girths were significantly larger for HS than LS (range 3.0 to 7.7 percent). Also, thigh and calf girth did not differ significantly between HS and LS, but the non-muscular knee and ankle girths of the lower body did. Perhaps HS subjects had a propensity for upper body development that produced the significantly larger muscular upper body components.

The relationship among the P_{SOM} and the various expressions of muscular strength revealed that the PE (ponderal equivalents) for HS and LS showed identical patterns; that is, the same sites for girths and PE were different between HS and LS. Such data support the intrinsic validity of P_{SOM}.

In summary, the present data illustrate the relative independence of individual differences in strength and measures of anthropometry and body composition. Thus, other factors must be responsible for explaining the approximately 21 percent difference in muscular strength between HS and LS. Large individuals were not superior in overall muscular strength compared to their counterparts of smaller body size and shape. Such differences in strength cannot be explained by individual differences in girths, fatfolds, CSA, segmental volume, or P_{SOM}. The present conclusions may not apply to groups of highly trained individuals with extreme muscular development and strength. Factors other than muscle size alone, for example, neural and/or muscle and joint mechanical properties, may play at least an equally important role in explaining individual differences in muscular strength.

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9

Associations Among Body Composition, Physical Fitness, and Injury in Men and Women Army Trainees

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INTRODUCTION

Policies regulating the body composition of men and women in the military service are a matter of ongoing interest to the U.S. Army. Body composition is considered to be a component of a soldier's physical fitness, and in the Army's view, obesity is associated with being unfit and "unsoldierly." This association is important because physical fitness is an essential component of military readiness for combat. To be prepared for its combat mission, the Army attempts to select individuals with the fitness and stamina to endure the rigors of Army training and combat. Simply selecting fit men and women is not adequate, however, because physical training is necessary to both develop and maintain the fitness of soldiers. For physical training to be effective, however, it must overload cardiovascular and musculoskeletal systems. This overloading entails a risk of musculoskeletal injury. Thus an understanding of the interactions among body composition, physical fitness, training, and injuries is an essential foundation for policies governing both body composition and physical fitness.

In the following background material, the links between body composition and physical fitness made in Army regulations and policy will be reviewed, and components of physical fitness deemed to be essential to the Army's mission will be enumerated. The assumption that body composition reflects an individual's physical fitness will be explored. Also, the interactions between fitness, training, and injuries will be examined. Following this background material, the results of two recent Army studies will be presented.

Individuals with a wide range in body fat (BF) volunteer to join the Army annually, but not all are accepted for service. Because the Army is concerned about the fitness of enlistees, some volunteers are medically disqualified solely on the basis of their height and weight before entering the service, the presumption being that they are not physically fit enough to be enlisted (Friedl, chapter 3). Army standards for medical fitness are set forth in Army Regulation (AR) 40-501 (1987), which contains tables of acceptable heights and weights for enlistment in the Army. On the basis of these height-weight standards, only about 5 percent of eligible men in the United States would be excluded from service in the Army. In contrast, over 30 percent of otherwise eligible women would be excluded (Friedl et al. 1989).

In addition to height-weight standards, the Army also has a weight control program that defines acceptable percentages of BF for individuals who fail to meet the height-weight standards after enlistment (Army Regulation 600-9; U.S. Army, 1986). The two primary stated purposes of the Army weight control program are to ensure that soldiers are adequately physically fit to accomplish their combat mission and that they present "a trim military appearance."

Because of its demand for physically fit soldiers, the Army has a program of physical fitness, which is defined in Army Regulation 350-15 (AR 350-15; U.S. Army, 1989). The objectives of this program are to enhance combat readiness by developing and maintaining high levels of physical fitness in all soldiers as measured by cardiorespiratory and muscular endurance, muscle strength, flexibility, anaerobic performance, competitive spirit, self-discipline, and BF composition. The emphasis on physical fitness in both the selection and retention process seems appropriate because soldiers must have enough stamina and strength to perform a wide variety of physically demanding tasks such as marching with loads, digging fox holes, scaling walls, and loading artillery shells.

Physical fitness and appropriate body composition are achieved and maintained through physical training. The Army's program of physical fitness training is described in *Army Field Manual 21-20* (FM 21-20; U.S. Department of the Army, 1985). The manual lists five components of fitness the program strives to develop:

- cardiorespiratory endurance;
- strength;
- muscle endurance;
- flexibility; and
- body composition, which includes lean body mass and fat mass and which is affected by the other components of fitness.

Army doctrine links physical fitness, weight control, body composition, and physical training. Regulations regarding physical fitness and training indicate that body composition is simply a subcomponent of fitness (U.S. Department of the Army, 1985, 1989). Even the weight control regulation (AR 600-9) states that its primary objective is physical fitness. For this reason, before policies on the issue are decided, it is important to assess the degree to which body composition influences the other components of physical fitness.

Injuries are another important consideration. Soldiers disabled by injury are less able to perform their regular duties even if they are otherwise highly physically fit. In a sense, injury-prone soldiers are less physically fit than those who are able to continuously perform their duties. Training- and activity-related injuries are a matter of concern to the military not only because they limit the function of individual soldiers, but because they impinge on the combat readiness of entire units when their incidence is even moderately high.

Existing data indicate that the incidence of training-related injuries is high especially during basic training (Bensel and Kish, 1983; Cowan et al., 1988; Jones et al., 1988; Kowal, 1980). One report (Tomlinson et al., 1987) indicates that training-related injury rates are high among active duty soldiers as well. The majority of these injuries are overuse conditions of the lower extremities, which arise directly from Army training or sports activities that the Army encourages (Jones, 1983; Tomlinson et al., 1987). Historical data also indicate that musculoskeletal injuries similar to those seen in training are a common cause of morbidity even during wartime (Reister, 1975).

In exploring body composition as an indicator of fitness, it is important to examine the relationship of body composition not only to components of fitness listed in the Army fitness and training documents but also to injury. Scientific literature on the interrelationships among body composition, physical fitness, training, and injury will be explored next. In these studies body composition is measured by either percent BF or body mass index (BMI).

It is well accepted by both military (Jette et al., 1990; Vogel and Friedl, chapter 6) and civilian (Buskirk and Taylor, 1957; Cureton et al., 1979; Miller and Blyth, 1955) authorities that increased BF is associated with decreased weight-bearing endurance performance. Also, performance of other physical activities and exercises are negatively affected by higher levels of BF (Cureton et al., 1979; Jette et al., 1990; Vogel and Friedl, chapter 6). Despite their significance, the correlations between percent BF or BMI and other measures of physical fitness are low. Body composition explains only 5 to 30 percent of the variance in endurance performance measured by maximum oxygen uptake or timed run distance and even less of other factors, such as sit-ups, push-ups, or vertical jumps (Cureton et al., 1979; Jette et al., 1990; Vogel and Friedl, in press).

It is also well established that there is a dose response relationship between increased training volume and increased risk of injury (Koplan et al., 1985; Powell et al., 1986). Several studies have documented that higher amounts of training—especially higher running mileage—are associated with higher injury rates (Blair et al., 1987; Koplan et al., 1982; Macera et al., 1989a,b; Marti et al., 1988; Pollock et al., 1977). With the exception of volume of training, other risk factors for injury associated with physical training have not been clearly established.

Physical fitness and body composition are suspected to affect the risks of injury during physical activity for civilians and military personnel (Bensel, 1976; Cowan et al., 1988; Jones, 1983; Koplan et al., 1985; Macera et al., 1989a), but the exact nature of that relationship has not been clearly established. Another possible risk factor of importance to the military that may be associated with both fitness and body composition is gender. During basic training the incidence of injury for women has consistently been higher than that for men (Bensel and Kish, 1983; Kowal, 1980), but civilian studies have not identified gender as a risk factor (Koplan et al., 1982; Macera et al., 1989a,b).

TWO ARMY STUDIES OF BODY COMPOSITION, FITNESS, AND INJURY

Rational decisions regarding Army policy on fitness, fatness, and training are best made when based on data from military populations. As a foundation for decision making, this paper will examine data from two epidemiologic studies of male and female Army trainees that were conducted by the U.S. Army Research Institute of Environmental Medicine and that provide further insight into the following areas:

- the relationship of percent BF and BMI with physical fitness and their relative importance as predictors of physical fitness in male and female Army trainees;
- the degree of association of percent BF and BMI with risks of training-related injuries in men and women;
- the degree of association between physical fitness and risks of injury in men and women;
- the degree of association between past physical activity or training and current risks of injury;
- the relative importance of different parameters of body composition, physical fitness, and physical training (activity) on risks of injury using a multivariate model; and
- the implications of the above determinations for screening, selecting, and training military personnel.

Methods

The two studies described below were prospective follow-up studies of initial entry trainees. Both were conducted at Fort Jackson, South Carolina. One was completed in 1984 and the other in 1988, and both followed trainees through the full course of the 8-week basic training cycle.

Subjects

In 1984 potential volunteers were all trainees coming to the Fort Jackson reception station on one weekend. Ninety-nine percent volunteered to participate. In 1988 volunteers were solicited from all women being processed at the Fort Jackson reception station during 1 month. Male volunteers were recruited from men destined to be assigned to companies in the same battalions as the female volunteers during the same 1-month period. The volunteer rate from the second group in 1988 was 92 percent in this group.

The 1984 data are from a population of 310 trainees (124 men and 186 women). The 1988 data are from three training battalions, a total of 2,245 trainees (1,349 men and 896 women). Because not all trainees in either study were able to take all portions of the testing due to scheduling conflicts or assignment to other duties, the number of subjects was not identical in all portions of the analysis. Also, roughly 5 percent of men and 7 percent of women trainees were lost from follow-up due to discharge from the Army or transfer to another unit. Both studies were conducted in two phases: a prescreening phase, which consisted of a series of body composition and physical fitness measures along with a questionnaire, and a follow-up phase, which included a medical records review.

Both studies used a similar series of prescreening measures including height, weight, percent body fat (BF), body mass index (BMI), a health and fitness questionnaire, and Army physical fitness test results. Prescreening measures were made on all individuals over a period of 1 or 2 days, with the exception of physical fitness tests. Prior to screening, trainees were informed of the nature of the study. Those who volunteered signed a consent form, immediately after which they were screened and given the questionnaire. Follow-up consisted of medical records review and documentation of training.

Prescreening Measures

At Fort Jackson in 1984, BF was estimated from four skinfold measurements using the equations of Durnin and Womersley (1974). For the 1988 study, circumference measures were used to estimate percent BF (separate sites and equations for men and women as specified in Army Regulation 600-9; U.S. Army, 1986). BMI for both men and women was calculated as weight divided by height squared.

Physical fitness was assessed with the Army physical fitness test, which was taken within the first 3 days of the onset of basic training. Measures taken were 1-mile run or 2-mile run times and the number of sit-ups and push-ups performed in a 2-minute time period. Entire units (companies) ran either a 1- or a 2-mile "diagnostic fitness" test.

At Fort Jackson in 1984, past physical activity and sports participation were assessed by a questionnaire delivered to groups of 50 or more recruits. Each question was read aloud by trained personnel. The primary question to assess physical activity level prior to entering the Army was: How active are you compared to others of your age and sex? Subjects were asked to rate their activity on a 4-point scale from inactive to very active. A similar question was validated by Washburn et al. (1987).

Total kcals of energy expended in leisure time recreational and sports activities per week were estimated from questionnaire data. Study participants were asked to check activities they had done in the last year on a list of common activities. For each activity checked they were asked to list how many days per week on average they performed the activity and how many minutes per performance. The average number of performances per week was multiplied by the average number of minutes per performance a subject reported doing an activity in the last 6 months. The number of kcals per week was attained by multiplying minutes per week by an estimate of the average number of kcals expended in a specified activity per minute. All estimates were then summed for each individual. The question was modeled after the Minnesota Leisure Time Physical Activity questionnaire (Taylor, 1978).

The 1984 questionnaire also queried trainees about their prior athletic status (nonathlete = 1, recreational athlete = 2, nonschool team or intramural athlete = 3, and varsity athlete = 4). The usual energy intensity (kcals expended per minute) of the trainees' leisure time and sports activity was also estimated by the investigators and rated on a four point scale (1 = sedentary, 2 = low, 3 = moderate, and 4 = high). A more extensive questionnaire was delivered at Fort Jackson in 1988; the analyzed results are not yet available.

Medical Follow-up

Medical follow-up was achieved by a periodic 100 percent medical record review of every chart of every study participant. In 1984 a single records review was conducted during the last week of training. In 1988 records were reviewed every 2 to 3 weeks. An injury was defined as a sick-call visit to a troop medical clinic for a musculoskeletal complaint that received an injury diagnosis by a medical caretaker, usually a physician's assistant or a physician.

Physical Training

Physical training was assessed by scrutinizing company training schedules and verbal reports from company cadre in 1984. In 1988 daily training logs were also used to document training.

Physical training for companies of men or women trainees for a specific year was similar. In 1984 trainees ran and performed calisthenics 4 to 6 days per week. Men generally started running 1 mile and progressively increased the distance of runs by about 0.5 mile per run each week up to 3 miles per run. On occasion they may have run 4 or 5 miles at a time near the end of the training cycle. Women began running distances of 0.5 mile per run and progressed in distance 0.5 mile per week up to 3 miles per run. At Fort Jackson in 1988, trainees ran only 3 times per week; otherwise routine physical training was fairly similar to that in 1984. Both years, each company of trainees was required to complete a 5- to 10-mile road march while carrying a light load (20 to 25 pounds [lbs]) in the middle of the training cycle and another 8- to 12-mile march at the end of the cycle with a heavier load (40 to 45 lbs). Every company also conducted training and ran a time trial on an obstacle course and a confidence course.

Analysis

Pearson product-moment correlation coefficients were calculated to describe the relationship between continuous variables such as percent BF, BMI, and physical fitness measurements (that is, run times and numbers of sit-ups and push-ups). Also, to determine whether endurance performance (run times) of trainees at different points along the spectrum of percent BF and BMI was different, trainees were divided into quintiles (five roughly equal-sized groups) on the basis of BF measures and weight-height ratios (BMI). The mean run times of men and women in successive groups by percent BF or BMI were compared to each other for significance using a one-way analysis of variance (ANOVA). For significant ANOVAs, significant between-group differences were identified using a least significant difference post hoc test.

A stepwise multiple regression model was developed to predict mile run times for men and women from other physical measurements and questionnaire data at Fort Jackson in 1984. Changes in R^2 values from the stepwise regression output were interpreted as indicators of the amount of variance in endurance performance explained by successive predictors stepping into the equations. The point estimate of the significance of B coefficients for each successive predictor variable are reported as p values in the text. The significance of F scores are also reported for the successive steps in the models for both men and women.

Risks of injury were calculated as the cumulative incidence (percent) of trainees incurring one or more training-related injuries during the 8-week basic training cycle. Relative risks (percent injured in contrast group divided by percent injured in referent group) were used to compare the incidence of injury in groups possessing different supposed risk factors or exposed to different levels of a risk factor. Significance of contrasted risks was tested with simple chi-square tests or partitioned chi-squares. Mantel-Haenszel chi-squares for linear trends were used when a trend was suspected on inspection of the data.

To compare the risks of individuals exhibiting different levels of a continuous risk factor such as percent BF or mile run time, subjects were divided into successive quartiles (four roughly equal-sized groups) or quintiles (five nearly equal-sized groups) of risk based on their measured value of the variable of interest. For the 1984 data, trainees were placed into quartiles of risk based on continuous measured variables because the sample size lacked power to demonstrate differences between smaller-sized groups. Trainees in the 1988 study were divided into quintiles to obtain a clearer picture of trends and because the sample size was large enough to support more divisions without sacrificing power.

In both studies for all potential risk factors examined, a referent level of risk was chosen, and each other level was compared to it. Referent levels were usually the lowest level of risk observed or the level believed to have the lowest risk based on other knowledge. Relative risks were calculated for each contrast. For the 1984 data, 90 percent confidence intervals are reported in the tables below because this was a hypothesis-generating study, and we did not want to fail to recognize a possible significant association due to lack of power secondary to a small sample size. For 1988 data, both 90 and 95 percent confidence intervals are reported in the tables below. Point estimates of significance (p values) are reported in the text when appropriate.

To control for the influence of body composition and physical fitness on the risks of injury for women compared to men, Mantel-Haenszel chi-squares stratified on percent BF and mile run times, respectively, were performed. Finally, a stepwise logistic regression was also performed to determine the most important factors contributing to the risk of injury in a model where the effects of multiple factors were controlled for simultaneously.

Results

The mean physical characteristics and physical fitness test results for men and women trainees in 1984 and 1988 are listed in Table 9-1. Comparisons of the descriptive characteristics and fitness of men in 1984 and 1988 indicate that they were very similar in age, height, weight, percent BF, and BMI, but in 1988 they appeared to be slightly less fit; the same was true for women. Comparing men and women, the men were taller, heavier, and had higher BMIs than women in both 1984 and 1988, while women had higher percentages of BF. In both years, men ran faster and performed more push-

TABLE 9-1 Mean Descriptive Characteristics and Physical Fitness Test Results of Men and Women Army Trainees at Fort Jackson, South Carolina, in 1984 and 1988

	Men			Women		
Variable	*n*	Mean	(SD)	*n*	Mean	(SD)
			1984			
Age (years)	124	20.2	(2.7)	186	21.2	(3.6)*
Height (cm)	123	175.2	(6.6)	186	163.3	(6.6)*
Weight (kg)	124	73.6	(11.9)	186	58.7	(5.8)*
Body mass index (weight/height²)	123	24.3	(3.1)	186	22.4	(2.0)*
Body fat (%)	124	16.9	(4.9)	186	25.2	(9.4)*
1-Mile run (minutes)	79	7.2	(1.0)	140	9.7	(1.4)*
Sit-ups (no.)	98	54.5	(13.8)	163	39.7	(11.9)*
Push-ups (no.)	97	31.0	(9.3)	138	12.4	(9.9)*
			1988			
Age (years)	1,056	20.1	(3.3)	921	20.2	(3.5)*
Height (cm)	1,053	175.2	(7.1)	895	162.0	(6.5)*
Weight (kg)	1,053	75.7	(12.2)	895	58.3	(6.5)*
Body mass index (weight/height²)	1,053	24.6	(3.6)	895	22.2	(2.0)*
Body fat (%)	1,053	16.1	(5.8)	895	26.8	(3.0)*
1-Mile run (minutes)	756	7.6	(0.9)	541	10.3	(1.8)*
2-Mile run (minutes)	593	16.4	(2.2)	355	20.3	(2.3)*
Sit-ups (no.)	1,357	44.3	(12.2)	902	33.9	(13.8)*
Push-ups (no.)	1,357	30.5	(12.9)	792	10.3	(7.3)*

*Difference between men and women significant at $p < .05$.

ups and sit-ups than women. Cutoff points for quartiles and quintiles of percent BF, BMI, and run times are listed in Table 9-2 for 1984 and Table 9-3 for 1988.

Correlation of percent BF and Body Mass Index

The correlation between percent BF by skinfolds and BMI among men trainees in 1984 was .81 ($p < .000$), and the correlation between BF by circumferences and BMI in 1988 was .84 ($p < .000$). For women trainees in 1984, the correlation between body fat by skinfolds and BMI was .64, while in 1988 the correlation of body fat by circumferences and BMI was .86.

TABLE 9-2 Body Composition and Fitness Variable Medians, Quartile Cutoff Points, and Ranges for Men and Women Army Trainees at Fort Jackson, South Carolina, 1984

Variable	Median*	Quartile	Cutoff Point	Range
		Men		
Percent body fat	16.6	Q1	13.1	7–29
		Q3	20.6	
Body mass index (kg/m^2)	23.7	Q1	22.1	19–31
		Q3	26.5	
1-Mile run (minutes)	7.0	Q1	6.4	5.9–11.5
		Q3	7.7	
Sit-ups	52	Q1	46.8	16–99
		Q3	64.0	
Push-ups	31	Q1	26.5	4–53
		Q3	36.0	
		Women		
Percent body fat	25.1	Q1	22.4	14–37
		Q3	.4	
Body mass index (kg/m^2)	22.5	Q1	21.1	18–27
		Q3	23.6	
1-Mile run (minutes)	9.8	Q1	9.0	6.0–16.3
		Q3	10.4	
Sit-ups	51	Q1	30.0	6–66
		Q3	46.0	
Push-ups	11	Q1	5.0	1–30
		Q3	17.0	

*Median = Q2

TABLE 9-3 Body Composition and Fitness Variable Medians, Quintile Cutoff Points, and Ranges for Men and Women Army Trainees at Fort Jackson, South Carolina, 1988

Variable	Median	Quintile	Cutoff Point	Range
		Men		
Percent body fat	15.4	Q1	10.98	2.13–36.12
		Q2	14.00	
		Q3	17.38	
		Q4	21.50	
Body mass index (kg/m^2)	24.3	Q1	21.38	17.22–34.32
		Q2	23.34	
		Q3	25.14	
		Q4	28.07	
1-Mile run (minutes)	7.5	Q1	6.83	5.5–10.9
		Q2	7.27	
		Q3	7.73	
		Q4	8.38	
2-Mile run (minutes)	16.4	Q1	14.60	11.4–26.0
		Q2	15.67	
		Q3	16.56	
		Q4	17.83	
Sit-ups	45	Q1	34	2–85
		Q2	41	
		Q3	47	
		Q4	54	
Push ups	29	Q1	19	1–87
		Q2	26	
		Q3	32	
		Q4	40	
		Women		
Percent body fat	27.00	Q1	23.50	15.8–42.6
		Q2	25.86	
		Q3	27.90	
		Q4	30.10	
Body mass index (kg/m^2)	22.4	Q1	20.27	16.36–27.20
		Q2	21.79	
		Q3	22.97	
		Q4	24.11	
1-Mile run (minutes)	10.0	Q1	8.94	5.6–19.3
		Q2	9.72	
		Q3	10.41	
		Q4	11.50	

continued on next page

TABLE 9-3 *Continued*

Variable	Median	Quintile	Cutoff Point	Range
2-Mile run (minutes)	20.4	Q1	18.50	13.9–29.8
		Q2	19.71	
		Q3	20.81	
		Q4	21.98	
Sit-ups	34	Q1	23	1–92
		Q2	31	
		Q3	37	
		Q4	45	
Push-ups	9	Q1	4	1–52
		Q2	7	
		Q3	11	
		Q4	16	

Past Activity Level and Body Composition

On entry to the Army in 1984, the least active men were also the fattest. For men trainees, a trend was observed of decreasing average percentage BF (assessed by skinfolds) with increasing self-reported activity level prior to entry. Percent BF decreased from 20.7 percent for the least active group to 19.5 percent for the average group, to 16.2 percent for the next, and 15.5 percent for the most active. The extreme groups (inactive versus very active) were significantly different ($p < .05$). For women in 1984, however, there was no apparent association between activity levels prior to entry to the service and percent BF. The percent BF of women varied from 24.3 percent BF for the least active group, to 26.8 percent for the average groups, to 24.7 percent for the next group, to 23.9 percent for the most active group.

Body Composition and Physical Performance

Positive correlations between percent BF and mile run times and between BMI and mile run times were observed among both men (Table 9-4) and women (Table 9-5) in 1984 and 1988. Results indicate that for both men and women, as percent BF and BMI increase, run times become slower. The magnitude of the correlations between body composition measures and endurance performance and their degree of significance was greater for men than women in both years. For men, roughly 7 to 28 percent of the variance in mile run times can be explained by percent BF, while only 1 to 3 percent of the variance among women's times can be explained on this basis.

TABLE 9-4 Correlations of Percent Body Fat (BF) and Body Mass Index (BMI) with Entry Level Physical Fitness, and Correlations of Run Times With Sit-ups and Push-ups, Men Army Trainees, Fort Jackson, South Carolina

Correlation	*r*	*p*	*n*
		1984	
Percent BF with:			
1-Mile run	.27	.009	77
Sit-ups	17	.051	97
Push-ups	.11	.057	96
BMI with:			
1-Mile run	.18	.069	76
Sit-ups	.17	.336	96
Push-ups	.02	.407	95
1-Mile run time with:			
Sit ups	47	.000	77
Push ups	23	.000	76
		1988	
Percent BF with:			
1 Mile run	53	.000	525
2-Mile run	.36	.000	376
Sit-ups	-.18	.000	907
Push-ups	-.29	.000	912
BMI with:			
1-Mile run	.42	000	525
2-Mile run	36	.000	376
Sit-ups	.19	.000	907
Push-ups	.04	.291	912
1-Mile run time with:			
Sit-ups	-.41	.000	756
Push-ups	.29	.000	751
2-Mile run time with:			
Sit-ups	.31	.000	589
Push ups	-.30	.000	591

Negative correlations were noted between percent BF and numbers of sit-ups and push-ups. These data indicate that successively "fatter" men and women trainees on average perform fewer sit-ups and push-ups. Although the correlations between body fat and sit-ups and push-ups were significant for both men and women in both years, the magnitude of correlations were generally lower than for percent BF and run times. Although

TABLE 9-5 Correlations of Percent Body Fat (BF) and Body Mass Index (BMI) with Entry Level Physical Fitness, and Correlations of Run Times With Sit-ups and Push-ups, Women Army Trainees, Fort Jackson, South Carolina

Correlation	*r*	*p*	*n*
	1984		
Percent BF with:			
1-Mile run	.12	.075	135
Sit-ups	.14	.035	158
Push-ups	-.02	.410	133
BMI with:			
1-Mile run	.00	.478	135
Sit-ups	-.02	.393	158
Push-ups	-.10	.116	133
1-Mile run time with:			
Sit-ups	.24	.002	133
Push-ups	.01	.445	109
	1988		
Percent BF with:			
1-Mile run	.16	.004	339
2-Mile run	.12	.022	342
Sit-ups	.11	.000	605
Push-ups	.18	.003	686
BMI with:			
1-Mile run	.13	.017	339
2-Mile run	.09	.079	342
Sit-ups	.03	.405	686
Push-ups	.08	.041	606
1-Mile run time with:			
Sit-ups	.23	.000	536
Push-ups	.26	.000	467
2-Mile run time with:			
Sit-ups	.22	.000	353
Push-ups	.21	.000	314

the direction of correlations of BMI with sit-ups and push-ups was also negative, their magnitude was small (less than $r = 0.2$).

Tables 9-6 and 9-7 show mean run times for men and women for different quintiles of BF and BMI. Mean run times increased significantly with successively higher levels of BF above the third quintile for men. The leanest men ran 1 mile in an average 7.1 minutes compared to 8.4 minutes

TABLE 9-6 Mean Run Times by Quintile of Percent Body Fat (BF) and Body Mass Index (BMI) for Men Army Trainees, Fort Jackson, South Carolina, 1988

				Significantly different from			
Variable	Mean	SD	*n*	Q1	Q2	Q3	Q4
			1-Mile Run				
BF quintile							
Q1 lean	7.1	0.74	87				
Q2	7.2	0.71	117				
Q3	7.4	0.75	111	*			
Q4	7.8	0.84	108	*	*	*	
Q5 fat	8.4	0.93	102	*	*	*	*
			2-Mile Run				
BF quintile							
Q1 lean	15.8	1.74	100				
Q2	15.6	1.85	70				
Q3	15.8	1.51	71				
Q4	17.1	2.16	72	*	*	*	
Q5 fat	17.9	2.53	63	*	*	*	*
			1-Mile Run				
BMI quintile							
Q1 low	7.2	0.80	106				
Q2	7.3	0.76	84				
Q3	7.4	0.80	112				
Q4	7.6	0.81	121	*	*	*	
Q5 high	8.4	0.99	102	*	*	*	*
			2-Mile Run				
BMI quintile							
Q1 low	15.6	1.81	78				
Q2	15.8	1.60	94				
Q3	16.3	2.03	74	*			
Q4	16.7	2.30	65	*	*		
Q5 high	17.8	2.38	65	*	*	*	*

*Significantly different at $p < .05$ by least significant difference.

for the fattest quintile ($p < .05$). Among women, only the highest percent BF (fifth quintile) was significantly different from the others. Women with the lowest percentages of BF ran the mile in a mean time of 10.4 minutes compared to 11.2 minutes for the fattest ($p < .05$). The relationship and trends in time for the 2-mile run versus quintile of percent BF for men and women, respectively, are similar to those seen for the 1 mile.

Patterns of relationship of quintile of BMI and mean run times for men

TABLE 9-7 Mean Run Times by Quintile of Percent Body Fat (BF) and Body Mass Index (BMI) for Women Army Trainees, Fort Jackson, South Carolina, 1988

				Significantly different from			
Variable	Mean	SD	*n*	Q1	Q2	Q3	Q4
			1-Mile Run				
BF quintile							
Q1 lean	10.4	1.84	73				
Q2	10.2	1.60	74				
Q3	10.5	1.81	59				
Q4	10.6	1.91	63				
Q5 fat	11.2	2.17	70	*	*	*	*
			2-Mile Run				
BF quintile							
Q1 lean	20.0	2.11	66				
Q2	19.8	2.18	68				
Q3	20.3	2.48	76				
Q4	20.4	2.32	70				
Q5 fat	20.9	2.09	62	*	*		
			1-Mile Run				
BMI quintile							
Q1 low	10.3	1.81	70				
Q2	10.4	1.88	76				
Q3	10.5	1.89	66				
Q4	10.4	1.76	66				
Q5 high	11.2	2.06	61	*	*	*	*
			2-Mile Run				
BMI quintile							
Q1 low	20.3	2.40	62				
Q2	19.7	2.12	60				
Q3	20.0	2.42	74				
Q4	20.6	2.47	74	*			
Q5 high	20.8	2.06	73	*	*		

*Significantly different at $p < .05$ by least significant difference.

and women were virtually identical to those for BF. Men and women in the lowest quintiles of BMI ran significantly faster than those in the highest quintiles.

Prediction of Endurance Performance

Because of the importance of aerobic fitness to the Army's mission, an exploratory model was devised to predict endurance performance (mile run times) using data from the pilot study at Fort Jackson in 1984. Potential predictor variables for both men and women were:

- Age (years)
- Height (*HT*, cm)
- Body fat (*BF*, %)
- Sit-ups (*SU*, number)
- Push-ups (*PU*, number)
- Total calories (*TCAL*, total kcals/week)
- Activity level (*ACT*: 1 = inactive, 4 = very active)
- Athletic status (*ATHS*: 1 = nonathlete, 4 = varsity)
- Intensity (*INT*: 1 = sedentary, 4 = high)

Predictor variables entered the model in stepwise fashion in order of importance.

The final predictive regression equation for men trainees using the above variables was:

$$\text{Mile time (minutes)} = -.019(SU) + .055(BF) - .227(ACT) - .142(INT) + 8.47.$$

Sit-ups (p = .004) entered the equation first, explaining 20 percent of the variance in mile times. Percent *BF* (p = .009) entered the equation next, which explains an additional 11 percent of the variance in times. Following percent *BF*, activity level (p = .04) stepped in, contributing another 4 percent to the explanatory power of the equation. The last predictor to enter the model was the intensity of the trainee's past recreational and sports activities (p = .13), accounting for another 2 percent of the variance in run times for men. The final multiple regression model explained 37 percent of the variance in endurance performance of men trainees as measured by run times ($p < .000$). Multiple regression coefficients (R) increased with each step from .45 to .56 to .60 to .62. All steps were significant at $p < .009$.

For women the endurance performance predictive equation was:

$$\text{Mile time (minutes)} = -.39(ACT) - .038(HT) - .018(SU) + .045(BF) - .22(ATH) + 16.9.$$

The trainees' self-assessed activity level (p = .004) entered the model first, and explained 15 percent of the variance in mile times for women. Height stepped into the equation next, contributing an additional 9 percent to the explanatory ability of the model. Number of sit-ups (p = .07) followed height into the model, which boosted the explained variance 4 percent more. Percent *BF* (p = .08) entered the model for women fourth, contributing 3 percent to the explained variance in run times. The last variable to enter the model was athletic status (p = .13), which accounted for 2 percent of the explained variance. The multiple regression model explained 33 percent of the apparent variance in the run times of women trainees ($p < .000$). The multiple regression coefficients (R) for successive steps in the model increased from .39 to .49 to .53 to .56 to .57. All steps were significant at $p < .0009$.

Injuries

At Fort Jackson in 1984 over the course of the 8-week basic training cycle, significantly more women suffered training-related injuries than men: 50.5 percent of women compared to 27.4 percent of men, with a risk ratio of 1.84 ($p < 0.000$). In 1988 during the 8 weeks of basic training, 43.5 percent of women were injured, and only 27.2 percent of men experienced an injury, a risk ratio of 1.61 ($p < 0.000$). In 1984, over 90 percent of all musculoskeletal complaints for both men and women were due to lower extremity injuries, and in 1988 about 85 percent of the injuries of men and women were lower extremity training-related injuries, such as stress fractures, patellofemoral syndrome, achilles tendonitis, and ankle sprains.

Body Composition and Injury

Tables 9-8 and 9-9 display the risks of injury for men by quartile (1984) and quintile (1988) of percent BF. For men in both 1984 and 1988, a higher incidence of injury was evident among the fattest quartiles and quintiles of trainees. In 1988 the fattest three quintiles of men were at significantly greater risk than the leanest two, 25.3 versus 20.7 (risk ratio = 1.2, $p = .05$). Tables 9-10 and 9-11 show the risks of injury by quartile (1984) and quintile (1988) of percent BF for women. There were no significant differences in risk to women by percent BF in 1984. In 1988, contrary to what was observed for men, the incidence of injury for the leanest two quintiles of women was greater than the third and fourth quintiles: 42.4 percent compared to 33.8 percent (risk ratio of 1.3, $p = .05$).

The risk of injury by quartiles or quintiles of BMI is shown for men in Tables 9-8 and 9-9 and for women in Tables 9-10 and 9-11. The relationship between BMI for men and women in 1984 appeared as if it might be bimodal, with both the lowest and highest quartiles at greater risk of injury than the middle groups. For men in 1984 the risk of injury for the lowest quartile of BMI was 35.5 percent versus 18.0 percent for the middle two quartiles, a risk ratio of 2.00 ($p = .11$). For the highest quartile versus the middle two, the risk ratio was 38.7 percent to 18.0 percent (risk ratio = 2.15, $p = .03$). For women in 1984 the pattern of association of BMI with risk of injury was similar to that of men. The risk for the lowest quartile of women was 55.6 percent compared to 38.3 percent for the third quartile (risk ratio = 1.45, $p = .09$). The risk of the highest quartile of women trainees was 63.0 percent versus 38.3 percent for the third quartile, with a risk ratio of 1.65 ($p = .02$).

TABLE 9-8 Risk of Musculoskeletal Injury by Quartile of Percent Body Fat, Body Mass Index, and Mile Run Time for Men Army Trainees, Fort Jackson, South Carolina, 1984

Variable	Risk (%)	Relative Risk (versus baseline)	n	Confidence Interval (90%)
		Percent body fat		
Q1 lean	27.3	1.29	33	(0.62–2.65)
Q2	26.7	1.26	30	(0.60–2.64)
Q3	21.2*	1.00	33	—
Q4 fat	35.7	1.68	28	(0.84–3.36)
Total			123	
		Body mass index		
Q1 low	35.5	2.06	31	(0.94–4.48)
Q2	18.8	1.10	32	(0.44–2.68)
Q3	17.2*	1.00	29	—
Q4 high	38.7	2.25	31	(1.04–4.83)†
Total			124	
		Run time		
Q1 fast	14.3	1.43	21	(0.35–5.86)
Q2	10.0*	1.00	20	—
Q3	26.3	2.63	19	(0.74–9.30)
Q4 slow	42.1	4.21	19	(1.28–13.83)†
Total			79	

*Referent level (denominator for risk ratio).
†$p < .1$.

This bimodal relationship of BMI with injury risk was not clearly evident at Fort Jackson in 1988. Although the extremes of the distribution of BMI did tend to have a higher incidence of injury than middle quintiles (see Table 9-9 for men and Table 9-11 for women), no significant difference in risk between quintiles of BMI was identified among men trainees. For women in 1988 the extreme quintiles of BMI were at the greatest apparent risk, but only the lowest two quintiles were in significantly greater jeopardy, 42.5 percent risk, compared to the fourth quintile, which had the lowest risk: 30.7 percent (risk ratio = 1.3, $p = .01$).

Physical Fitness and Injury

The relationship between physical fitness and injury is more pronounced and more directional than that for body composition and injury. A significant association between low aerobic fitness (endurance) as measured by mile run times and elevated risk of injury for both men (p for trend = .02)

TABLE 9-9 Risk of Musculoskeletal Injury by Quintile of Percent Body Fat, Body Mass Index, and Run Time for Men Army Trainees, Fort Jackson, South Carolina, 1988

Variable	Risk (%)	Relative Risk (versus baseline)	n	Confidence Interval (90%/95%)
		Percent body fat		
Q1 lean	22.4	1.18	210	(0.86–1.62/0.81–1.72)
Q2	19.0*	1.00	211	—
Q3	25.6	1.35	211	(1.00–1.82/0.94–1.93)‡
Q4	23.2	1.23	211	(0.90–1.67/0.85–1.77)
Q5 fat	27.6	1.46	210	(1.09–1.96/1.03–2.07)†
Total			1,053	
		Body mass index		
Q1 low	23.3	1.12	210	(0.83–1.51/0.78–1.60)
Q2	25.6	1.23	211	(0.92–1.64/0.87–1.74)
Q3	20.9*	1.00	211	—
Q4	23.2	1.11	211	(0.82–1.51/0.78–1.60)
Q5 high	24.8	1.19	210	(0.88–1.60/0.83–1.69)
Total			1,053	
		Run time		
Q1 fast	23.5	1.03	277	(0.80–1.33/0.76–1.40)
Q2	22.8*	1.00	268	—
Q3	29.2	1.28	267	(1.01–1.63/0.96–1.71)‡
Q4	26.7	1.17	270	(0.91–1.50/0.87–1.57)
Q5 slow	34.1	1.50	267	(1.19–1.88/1.14–1.97)§
Total			1,349	

*Referent level (denominator for risk ratio).
†$p < .05$.
‡$p < .1$.
§$p < .01$

and women (p for trend = .03) was seen in 1984 (see Table 9-8 for men and Table 9-10 for women). The slowest two quartiles of men had a higher risk of injury than the fastest two: 34 percent versus 12 percent, a risk ratio of 2.8 (p = .03). For women trainees, a similarly significant association was observed between mile times and risk of injury. The slowest two quartiles of women had a higher risk of injury, 59 percent, versus 35 percent for the fastest two quartiles (risk ratio = 1.7, p = .01).

At Fort Jackson in 1988, a trend similar to those observed in 1984 was noted between run times and risk of injury among men trainees (see Table 9-9 for men and Table 9-11 for women). The slowest three quintiles of men trainees had a combined average incidence of injury of 30 percent compared to 23.1 percent for the fastest two, a risk ratio of 1.3 (p = .005). A signifi-

TABLE 9-10 Risk of Musculoskeletal Injury by Quartile of Percent Body Fat, Body Mass Index, and Mile Run Time for Women Army Trainees, Fort Jackson, South Carolina, 1984

Variable	Risk (%)	Relative Risk (versus baseline)	n	Confidence Interval (90%)
		Percent body fat		
Q1 lean	41.3	0.78	46	(0.54–1.12)
Q2	61.7	1.16	46	(0.86–1.56)
Q3	53.2*	1.00	47	—
Q4 fat	45.7	0.86	46	(0.61–1.21)
Total			186	
		Body mass index		
Q1 low	55.6	1.45	45	(1.00–2.11)†
Q2	45.8	1.20	48	(0.80–1.78)
Q3	38.3*	1.00	47	—
Q4 high	63.0	1.64	46	(1.15–2.35)†
Total			186	
		Run time		
Q1 fast	36.3	1.08	36	(0.64–1.84)
Q2	33.3*	1.00	36	—
Q3	57.1	1.71	35	(1.09–2.71)†
Q4 slow	60.6	1.82	33	(1.16–2.86)†
Total			140	

*Referent level (denominator for risk ratio).
†$p < .1$.

cant linear trend between slower run time and higher risk of injury was also identified (p =.003). The association between run times and injury risk was not so distinct for women in 1988. The risk ratio of the slowest two quintiles was contrasted with the fastest three, yielding a risk ratio of 1.2 (p = .02).

When the 1988 run time data for men trainees and lower extremity injuries only was examined for associations, an even more pronounced trend of increasing injury risk with slower run time was observed (Mantel-Haenszel chi-square for trend, p = .0006). Risks for men descended from 30.3 percent for the slowest quintile to 23.7 percent, to 24.7 percent, to 18.3 percent, and slightly up to 19.3 percent. There was also a stronger relationship between quintiles of run time and risk of injury for women trainees in 1988 when only lower extremity injuries were analyzed (Mantel-Haenszel chi-square for trend, p = .08). Risks for women for successive quintiles of run time for slowest to fastest went from 38.5 percent to 48.6 percent, then down to 37.9 percent for two quintiles and down to 34.1 percent.

TABLE 9-11 Risk of Musculoskeletal Injury by Quintile of Percent Body Fat, Body Mass Index, and Run Time for Women Army Trainees, Fort Jackson, South Carolina, 1988

Variable	Risk (%)	Relative Risk (versus baseline)	*n*	Confidence Interval (90%/95%)
		Percent body fat		
Q1 lean	44.8	1.32	181	(1.06–1.64/1.02–1.71)†
Q2	39.8	1.16	176	(0.92–1.48/0.88–1.52)
Q3	33.9*	1.00	183	—
Q4	34.1	1.01	176	(0.79–1.28/0.75–1.34)
Q5 fat	39.6	1.15	177	(0.91–1.45/0.88–1.51)
Total			893	
		Body mass index		
Q1 low	43.6	1.42	179	(1.13–1.78/1.08–1.86)†
Q2	41.3	1.35	179	(1.07–1.70/1.02–1.78)†
Q3	38.[illegible]	1.24	179	(0.97–1.57/0.93–1.65)
Q4	3[illegible].7*	1.00	179	—
Q5 high	37.4	1.22	179	(0.96–1.55/0.91–1.63)
Total			895	
		Run time		
Q1 fast	41.7	1.08	180	(0.87–1.33/0.84–1.39)
Q2	4[illegible].6	1.06	178	(0.86–1.31/0.83–1.37)
Q3	3[illegible].7*	1.00	181	—
Q4	[illegible].6	1.39	179	(1.15–1.68/1.11–1.74)‡
Q5 slow	4[illegible].3	1.12	178	(0.91–1.38/0.87–1.43)
Total			896	

*Referent level (denominator for risk ratio).
†$p < .05$.
‡$p < .01$.

Physical Activity and Injury

In 1984 a stepwise trend of decreasing risk with increasing activity level was evident for men (Table 9-12). Risks decreased from 43 percent for the least active group to 17 percent for the most active (p for trend = .06). Comparing the risks of the average and inactive groups with the active and very active groups, the risk ratio is 1.6 (36.4 percent/22.5 percent, $p = .09$). For women there did not appear to be an association between physical activity and risk of training-related injuries (Table 9-12).

Gender, Physical Fitness and Risk of Injury

The crude relative risk of injury for women compared to men at Fort Jackson in 1984 was 1.8 (50.5 percent/27.2 percent, $p < .000$). When risks

TABLE 9-12 Association of Self-Assessed Activity Level of Men and Women Trainees Prior to Entering the Army with Risk of Injury, Fort Jackson, South Carolina, 1984

Activity Level	Risk (%)	Relative Risk (versus baseline)	*n*	Confidence Interval (90%)
		Men		
Very active	17.2*	1.00	29	—
Active	25.5	1.48	51	(0.68–3.21)
Average	35.1	2.04	37	(0.95–4.37)
Not very active	42.9	2.49	7	(0.93–6.63)
Total			124	
		Women		
Very active	48.5*	1.00	33	—
Active	52.2	1.08	69	(0.84–1.31)
Average	48.4	1.00	64	(0.56–0.96)
Not very active	55.0	1.14	20	(0.57–1.21)
Total			186	

*Referent level (denominator for risk ratio).

for women versus men were stratified by level of fitness (mile run times) so that women were compared to men of the same degree of fitness, there was no difference in risk between genders, and the overall risk ratio was .98 (Mantel-Haenszel chi-square = 0.00, p = 1.00; Table 9-13). When risks were stratified on percent BF, the risk ratio remained unchanged at 1.8, which indicates that BF did not affect the risk of injury. Stratification on several other factors, including age, race, sit-ups, and push-ups, did not affect the magnitude of the risk ratio.

Two logistic regression models were also created to determine the importance of various risk factors for injury. The variables included in the first model were: gender, age, race, athletic status, self-assessed activity level, height, weight, percent BF, push-ups, and sit-ups. In this regression, without fitness/run time included, the only factor that stepped into the model was gender, with an estimated odds ratio for women versus men of 2.5 (p = .005). The second model created was identical except that mile run time was included as a variable. In this second model, gender did not approach the significance required to enter the model, but mile run time did, with an estimated odds ratio for slow versus fast of 3.5 (p = .001). Percent BF did not approach the required Fs for entry into either model, nor did any other variable. Again when a measure of physical fitness was a candidate for entry into the stepwise model, gender differences disappeared, and

TABLE 9-13 Risk of Injury for Women Versus Men Army Trainees by Tertiles* of Mile Run Time, Fort Jackson, South Carolina, 1984

Run Time Tertile*	Risk of Injury (%)† Women	Men	Risk Ratio	Confidence Interval (95%)
1	20.0% (2/10)	17.5% (11/63)	1.1	(.3–4.5)
2	37.3% (22/59)	46.7% (7/15)	0.8	(.4–1.5)
3	57.7% (47/71)	0.0% (0/1)	—	-

NOTE: Mantel-Haenszel summary risk ratio = .98 (.4 – 2.3); Mantel-Haenszel chi-square = 0.00, $p = 1.00$.)

*Tertiles were: T1 = 5.9 – 7.9 minutes, T2 = 7.9 – 9.7 minutes; T3 = > 9.7 minutes.

†Percent risk = injured/(injured + not injured).

endurance as measured by run times was the best predictor of training-related injuries.

Discussion

These two studies at Fort Jackson provided a unique opportunity to prospectively examine the relationships among body composition, physical fitness, and injury in men and women. The assemblage of basic trainees at an Army reception station for several days prior to the onset of basic training permitted the collection of baseline data from direct physical measurements and questionnaires. Access to medical records of this young, healthy population provided an opportunity that would be rare outside the military. Also, the records represent all health care received, because basic trainees do not have access to any other health care system. A final unique aspect of this study was that, unlike most epidemiologic studies of this nature on civilian sports and exercise populations, all individuals in the study were engaged in similar types and amounts of physical training and other daily activities.

Many of the results of this study, such as the correlation between increasing percent BF and decreasing endurance performance, were similar to those reported by previous investigators. Other findings, such as the association between lower levels of physical fitness and higher risks of injury, were unique. These singular findings may be explained by characteristics of this study design that were different from previous studies of this nature.

Results of this study have important implications for the military and physically active civilian populations.

Correlation Between Body Composition and Physical Fitness

Because an underlying assumption of Army policy is that fatter soldiers are less fit, it was deemed important to examine that premise. Others have found significant correlations between measures of BF and fitness. Vogel and Friedl (chapter 6) found a significant correlation (r = −.48) between percent BF and maximum oxygen uptake for men. In another recent study, Jette et al. (1990) reported correlations between BMI and estimated maximum oxygen uptake of −.41 for men and −.54 for women. Cureton et al. (1979) found negative correlations between percent BF and run times of men and women of −.30 and −.22, respectively. The findings presented here were parallel to those; significant positive correlations were observed between percent BF and 1- or 2-mile run times of .27 to .53 for men, but only .12 to .16 for women, which indicates that fatter men and women run slower.

In this study, correlations between BMI and run times were also significant and positive but of lower magnitude than for percent BF. This lower correlation probably occurred because BMI is only a surrogate measure of percent BF, and it is the inert fat tissue that detracts from weight-bearing endurance performance. BMI accounted for only 65 to 70 percent of the variance in percent BF among men trainees and between 40 and 70 percent of the variance for women trainees.

Negative correlations between BMI and number of sit-ups performed in 1-minute intervals have been reported by Jette et al. (1990): r = −.24 and r = −.15 for men and women, respectively. In this study, negative correlations were found between percent BF and number of sit-ups in 2 minutes of −.17 to −.29 for men and −.12 to −.14 for women. Jette et al. (1990) also observed negative correlations between BMI and push-ups with r = −.22 for both men and women. Correlations in this study between percent BF and push-ups for men ranged from −.17 to −.29, and those for women ranged from −.02 to −.18. Correlations between BMI and sit-ups and push-ups were lower than for percent BF and these calisthenics.

In general, the correlations between measures of BF and either push-ups or sit-ups were lower than for those with weight-bearing endurance performance such as running. These lower correlations with BF are attributed to the fact that individuals must lift only a portion of their body weight against gravity to perform push-ups and sit-ups, but they must lift their entire body weight, including the fat, to run.

To further understand the degree and significance of changes in run times as level of BF increases, these changes were analyzed for successive quintiles of BF in 1988. Significant differences in run times were found between successive quintiles of percent BF among men, but only between the extreme quintiles of BF, the fattest and the lower ones, among women. This finding suggests that in this study, percent BF is not as good a discriminator of fitness for women as for men. Vogel and Friedl (chapter 6) found significant decreases in run time between quartiles of active-duty men and women soldiers with successively higher percentages of BF.

As an aside, the relative run times of women may not be as strongly affected by increases in percent BF because the relative range of fatness for women is less than for men. The range of fatness for women is from 16 to 34 percent, a relative difference of 2.3 between extremes, while for men the range is 2 to 30 percent, a 15-fold difference (Friedl et al., 1989). For this reason, percent BF provides less discriminating power for women.

The consistency and significance of the correlation between measures of BF and endurance performance are important to the military because current regulations and policy assume such a relationship. Also, the stronger correlations between measures of percent BF and physical fitness (that is, run times, sit-ups, and push-ups) than between BMI and fitness have important implications for the military. Stronger correlations with percent BF suggest that using BF standards rather than BMI or height-weight tables as criteria for enlistment and retention would provide a better indicator of recruit and soldier fitness—not to mention a better measure of body composition.

Predicting Endurance

Because of the universal requirement for soldiers to march and carry loads, models were developed to predict the endurance performance of men and women. A multiple regression model was used to determine the relative importance of multiple factors suspected of contributing to weight-bearing endurance as measured by 1-mile run times. For both men and women, the same 10 potential predictors of physical performance were candidate variables for the models: age, height, weight, percent BF, sit-ups, push-ups, total leisure-time, kcals per week, self-assessed activity level, level of sports participation, and aerobic intensity of usual leisure-time activities. Four variables contributed to the final model for men, and five variables contributed to the final model for women.

In the men's endurance prediction model, percent BF stepped into the equation second—explaining 11 percent of the variance in run times—behind sit-ups, which explained 19 percent of the variance. For the women's model, percent BF stepped into the equation fourth—behind self-assessed activity, height, and sit-ups—explaining only 3 percent of the variance in the run times of women trainees. Activity level was important in both models and explained more of the variance in endurance (15 percent) among women than any other variable.

Results of this modeling suggest several things. First the regression models coupled with the lower correlations between percent BF and run times for women reported above suggest that percent BF is not as good an indicator of fitness for women as it is for men. Second, the models for predicting endurance performance suggest that in addition to percent BF, other simple measures—such as sit-ups—during the selection process might contribute significantly to the Army's ability to recruit fit soldiers. Although it might be difficult to use questions on self-assessed activity like those in this study in the context of recruiting soldiers, it is clear that past activity is an important factor in the prediction of fitness.

Risks of Injury

Previous studies have reported the incidence of musculoskeletal complaints ranging from 42 to 54 percent for women Army trainees and 23 to 26 percent for men (Bensel and Kish, 1983; Jones, 1983; Kowal, 1980). The cumulative incidence of injuries among trainees in this study was 51 percent for women and 27 percent for men, and the data here suggest that risks of injury have been relatively stable over almost a decade.

Association Between Body Composition and Risk of Injury

Few studies have examined the association of percent BF and BMI with the risk of training-related injuries, and no studies have systematically looked at the relationship of BF and weight-bearing training injuries. A few studies of runners have examined the relationship of BMI to injuries (Blair et al., 1987; Macera et al., 1989b; Marti et al., 1988). No association between BMI and injury was reported for men or women runners in a study by Macera et al. (1989b), while Blair et al. (1987) reported a slight but significant positive correlation ($r = .1$) between BMI and risk of injury among runners. More consistent with the findings here is Marti et al.'s (1988) report of a bimodal distribution of injuries among men runners, in which the groups with the highest and lowest BMIs in a population of distance runners suffered the highest incidence of injuries. Macera et al. (1989a) in a prospective study of exercising adults reported that a high BMI at baseline was a risk factor for men but not for women.

During this study in 1984 it was felt that the relationships between percent BF or BMI and risk of injury both might be bimodal. The hypothesis was that men and women of more "average" BF, those in the middle groups, would be at lower risk of injury than those at the high and low extremes. For this reason, the middle quartiles and quintiles of body fat and BMI were chosen as the referent level for contrasting risks.

It now appears, at least among this sample of men and women Army trainees, that the patterns of risk are different for men and women. The univariate analysis suggests that the men trainees with the highest percentages of BF are at greatest risk of injury. Certainly this was true in 1988 when the men trainees in the highest quintile of BF were at 1.5 times greater risk than the lower ones. In contrast, it appears that women with the lowest percentages of BF are at greater risk than those of average percent BF as seen in 1988, when the women with the lowest body fats were at 1.3 times greater risk than those women in the middle.

With BMI, the distribution of risk of injury appears to be bimodal. However, the only significant association for men occurred in 1984 when the trainees with the highest BMI were at 2.1 times greater risk of injury than those of average BMI. For women, the only significant associations occurred in 1988. At that time, women with both the highest and lowest BMI were at 1.5 and 1.6 times greater risk, respectively, than the more "average" referent group.

Assuming that this observation is correct—that the fattest and highest BMI men and the leanest and lowest BMI women represent the tails of the distribution of BF at greatest risk of injury—then a plausible explanation for these findings is necessary. It may be that the men trainees with the highest BF were at greater risk than their peers because they were carrying so much extra weight as fat—fat that would not only contribute to greater fatigue at any given level of weight-bearing performance, but also would impose an additional stress on the musculoskeletal system. Paradoxically, it may be that the least fat women trainees were at greater risk for the converse reason: too little lean body mass. Perhaps women with low percentages of BF who are still relatively fat compared to men may not have enough lean body mass to support their total body weight without undue stress.

In any case, distinct and consistent patterns of relationship between percent BF or BMI and risk of injury are not evident. Some of this lack of correspondence at least for percent BF may be attributable to different techniques of measurement used in 1984 and 1988: skinfolds versus circumferences, respectively. Also, the apparently different pattern of association between BF and injury for men and women in this study may hypothetically be due to the fact that the Army height-weight selection standards artificially truncate the distribution of percent BF among women trainees. The height-weight standards effectively exclude 30 percent of eligible women but only 5 percent of men (Friedl et al., 1989). Regardless of what accounts for the differences between men and women, the current upper limits of height-weight are not effectively excluding the women at greatest risk of injury.

Association of Physical Fitness with Risk of Injury

The association between physical fitness and risk of injury in this study is more consistent for both men and women than the association with BF. In fact, as the stratified and logistic regression analyses suggest, endurance or weight-bearing fitness was the factor most strongly associated with risk of injury. Men and women in this study with the least endurance—that is, the slowest run times—were at greatest risk of injury. The slowest men were at 1.4 to 2.8 times greater risk than their slower counterparts, and the slower women were at 1.3 to 1.8 times greater risk.

Other authors have not reported such a relationship between fitness and injury. In fact, most report an increase in risk of training injuries for the most fit individuals (Blair et al., 1987; Macera et al., 1989b; Marti et al., 1988). Blair et al. (1987) and Marti et al. (1988) both reported a positive association between high levels of fitness and high risks of injury on univariate analysis that disappeared when the amount of training (miles run) was accounted for in a multivariate analysis. This result suggests that in these studies the relationship between fitness and injury was confounded by the association of fitness with greater amounts of training.

Studies by others on the relationship of physical fitness to injury primarily investigated runners of different fitness levels who ran for different numbers of miles at various intensities (Blair et al., 1987; Koplan et al., 1982; Macera et al., 1989b; Marti et al., 1988). In this study, men and women within companies (150 to 250 trainees)—and to some extent across companies—ran, marched, and exercised similar amounts and at similar intensities, intensities that were dictated by the group and Army policy rather than individual predilections. Thus this study provided controls for confounding due to varied volume and intensity of training, which other studies have not.

It is not surprising that a measure of weight-bearing fitness is associated with injury among Army trainees. The single most common physical stress during basic training results from weight-bearing physical training, a stress that is secondary to running, drill and ceremony, marching to and from training sites, and road marching with loads. Even when not training, weight-bearing musculoskeletal stress is unavoidable. Walking is usually the only mode of transportation to and from the mess hall and other sites during available leisure time. The more aerobically fit trainees are under less physiological stress at any given activity level and may also have more prior exposure to musculoskeletal stress thus decreasing their risk of injury. Whatever the underlying reason, the data here suggest that a measure of endurance fitness might provide additional information to assist in identifying injury-prone Army volunteers.

Association of Physical Activity and Risk of Injury

It is well known that higher volumes (amounts) of training are associated with higher risks of injuries among runners (Koplan et al., 1985; Powell et al., 1986). But data from this study demonstrate that risks of injuries among men trainees at Fort Jackson in 1984 decreased in a stepwise fashion as self-reported levels of prior physical activity increased, and sedentary men trainees were more than twice as likely to suffer training injuries. This finding is similar to that from a study of marine recruits (Gardner et al., 1988) in which a highly significant trend was observed of decreasing incidence of stress fractures with increasing self-reported activity levels. These data suggest that for men recruits higher prior physical activity levels may protect against current injury when they are engaged in a uniform training program, and are performing the same amounts of exercise as individuals with less prior exposure to the stress of vigorous physical activity. Other studies have looked at runners all of whom ran different distances, in which case the "dose" or volume of running was the primary risk factor (Blair et al., 1987; Koplan et al., 1982; Macera et al., 1989b; Marti et al., 1988).

Gender, Physical Fitness, and Risk of Injury

In the studies reported here, women were injured significantly more often than men, between 1.6 and 1.8 times more often. This finding is in agreement with those of previous Army studies of basic trainees (Bensel and Kish, 1983; Kowal, 1980) but is not consistent with civilian studies (Koplan et al., 1982; Macera et al., 1989a,b). The primary risks during Army basic training are lower extremity injuries associated with weight-bearing activities such as running and marching. Also, the pattern and distribution of these injuries is similar to that for civilian runners and joggers (Jones 1983). Despite these apparent similarities of trainee activity and injuries to those of civilian runners and joggers, civilian studies have not found women to be at higher risk (Koplan et al., 1982; Macera et al., 1989b, Powell et al., 1986).

Powell et al. (1986) concluded that "gender per se does not appear to be an important risk factor for injuries." Macera and her colleagues (1989a,b) have shown in both civilian runners and in exercising adults that gender is not a risk factor for injury. Also, Koplan et al. (1982) found no differences in risk of running injuries between men and women.

Selection bias could account for these contradictory findings between military and civilian studies. Koplan et al. (1985) indicated that civilian studies of physical activity, fitness, and related injury suffer from selection bias. These studies (Koplan et al., 1982; Macera et al., 1989b; Powell et al., 1986) are biased in that the populations studied include only individuals who were fit enough to tolerate routine vigorous training and had not quit due to injury or for other reasons. If women were actually at greater risk of injury, what would be expected is that fewer women would be represented in the populations studied since women on average are less physically fit than men (Table 9-1, Vogel et al., 1986). In fact this is what is found. In all the cited studies of runners (Koplan et al., 1982; Macera et al., 1989b) and exercise participants (Macera et al., 1989a), the number of women in the population examined were only 16 to 23 percent that of men.

If the hypothesis that only men and women who are fit enough to survive training remain in the population of routine exercisers is true, then we might expect that the injury rates among men and women of the same high fitness levels would be similar. The results of the study of Army trainees in 1984 support such a conclusion. Although the crude risks of injury were higher for women, when risks of injury were stratified on run times (physical fitness), differences in risk between women and men disappeared, and the risk ratio approached 1. Also, with the logistic regression model, gender remained the predominant and only significant risk factor for injury with an odds ratio of 2.5 ($p < .0005$) until mile run time was entered as a potential predictor, whereupon gender ceased to even approach significance as a risk factor. Run time (aerobic fitness) replaced gender as the sole and best predictor of injury (odds ratio = 3.5, $p < .0001$).

The possible implications of this finding are important for the Army, the other military services, and possibly civilian exercise enthusiasts and medical practitioners for two reasons. First, it suggests that low levels of aerobic fitness or some related factor are a primary risk factor for musculoskeletal injuries associated with military and possibly other vigorous weight-bearing training activities such as running. Second, it indicates that gender per se is not the major risk factor that a crude analysis of military training injury data might imply, and that low physical fitness may be the underlying predisposing factor.

Conclusion

In general, men enter the Army with lower percentages of BF than women and are able to perform more sit-ups and push-ups and run faster than women. They also suffer fewer injuries than women because of their relatively higher levels of endurance and possibly other associated factors.

Data from this study suggest that measures of percent BF are not as good at predicting physical fitness for women as they are for men. For both men and women, physical fitness as measured by even simple techniques such as sit-ups in combination with BF is a better predictor of other types of fitness such as mile run times or other forms of weight-bearing endurance than percent BF alone. Furthermore, higher percentages of BF for men are associated with increased risk of injury, but for women they are not. Physical fitness is a better predictor of injury than BF or gender. Therefore, if physical fitness and freedom from injury are important to the Army, it would make sen_ to at least include some simple measure of fitness in the screening process for prospective enlistees.

Several important conclusions can be made from this study and also the process of analysis. A few multivariate analyses can be much more informative than numerous univariate analyses. Although univariate analyses are the foundation of multivariate approaches such as those used here, they are not a substitute for more complex models. More information generated from larger populations and yielding more powerful multivariate models is needed. With these models, the Army should be able to predict injuries and also such factors as career success or discharge. This information could provide the Army with a rational foundation from which to select and retain men and women who are most likely to possess the combination of fitness, fatness, and freedom from injury that is desired for military readiness.

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10

Body Composition, Morbidity, and Mortality

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INTRODUCTION

Relationships among body composition and morbidity and mortality are complicated by several factors, including the accuracy and reliability of methods of measuring body composition and the effects of age, gender, race, genetic, environmental (for example, altitude, climate), and behavioral (for example, diet, smoking) factors. In discussing measures of body composition, it is helpful to distinguish *criterion* from *prediction* methods, and *direct measures* from *indirect estimates*. Criterion methods measure physical properties, chemical or anatomical constituents that are either direct measures of well-defined components (for example, total body water from deuterium dilution space), or they can be used to calculate indirect estimates of other components of body composition (for example, percent body fat [BF] from total body water). Prediction methods are generally based on measurements of less specific aspects of the body, such as circumferences, skinfold thicknesses, or bioelectric impedance. These variables must be used in equations that are calibrated against values from criterion methods. In the selection of criterion or prediction methods, consideration should be given as to what aspect of body composition is to be related to a disease.

METHODS OF MEASURING BODY COMPOSITION

Underwater weighing, from which body density is derived, continues to be considered the "gold standard" among the indirect criterion methods of estimating body composition, despite long-standing recognition of its limitations (Siri, 1961). Other indirect criterion methods include potassium 40 counting, total body water from tritium or deuterium dilution, and total body carbon from neutron activation. In addition to technical errors of measurement, which are considered to be random, these methods may be subject to nonrandom and/or systematic errors due to deviations of individuals from the assumed proportionality values for body composition associated with age, gender, race, and other factors. These errors can distort as well as attenuate associations with morbidity or mortality.

In addition to technical errors of measurement, methods of predicting body composition also contain sampling errors, as well as errors associated with the limitations of the criterion method selected for calibration. The most commonly used prediction methods at present employ anthropometry and bioelectric impedance. Equations for predicting fat-free mass (FFM) and total BF using anthropometric and bioelectric variables have been developed for young or middle-aged adults, many of which may be appropriate for use with military personnel (Barillas-Mury et al., 1987; Baumgartner et al., 1989; Chumlea et al., 1988; Hodgdon and Fitzgerald, 1987; Lukaski et al., 1985; Lukaski and Bolonchuk, 1987; Segal et al., 1985; Zillikens and Conway, 1987). However, most of these prediction equations have not been cross-validated properly to determine their accuracy when applied to populations other than the ones used in development (Guo et al., 1989).

Methods such as neutron activation, computed tomography (CT), dual photon absorptiometry (DPA), and magnetic resonance imaging (MRI) are invasive or require cumbersome, expensive equipment and specialized personnel. As a partial result of these problems, reported reference data for these measures of body composition and their associations with risk factors are limited. CT and MRI are most useful as methods of regional body composition analysis and are among the only methods currently available for quantifying amounts of intraabdominal adipose tissue for which there may be considerable risk for several endocrine and metabolic diseases (Baumgartner et al., 1987; Kvist et al., 1986; Larsson et al., 1984). In contrast to CT, MRI does not involve exposure to ionizing radiation and is associated with little risk. MRI spectroscopic techniques can provide important information regarding the chemical composition as well as anatomical distribution of muscle and fat.

Photon absorptiometry is an accurate method of quantifying bone mineral density and for estimating total body mineral and skeletal mass. Accurate estimates of bone mineral density and total body bone mineral are needed to adjust equations for estimating BF from body density. The current equations are subject to systematic errors since they assume that bone density and the proportion of FFM that is bone are constants, despite evidence for their variability with factors including gender, ethnicity, and age (Lohman, 1986). Presently, there is a paucity of information on bone density for non-White individuals. DPA has the capability of directly estimating soft tissue composition for the whole body or body segments. The recent development of dual-energy x-ray absorptiometry (DEXA) with whole body scanning at relatively low cost may make this an important criterion method for body composition in the future (Mazess et al., 1984).

There are many methods of measuring body composition, and the choice depends upon the experimental setting. Briefly, in a field setting one is generally limited to anthropometry, that is, skinfolds and circumferences, possibly some limited d sitometry equipment, body water estimates depending on access to a laboratory for analysis, and more recently bioelectric impedance. All of these methods can have large measurement errors or limited specificity depending on the sample studied. For example, in young adults, the present gold standard of underwater weighing is estimated to have at best, a minimum residual error of 2.5 percent for estimates of percent BF (Behnke and Wilmore, 1974). This error, however, is likely to be greater in most settings because the accuracy of underwater weighing depends on the performance of the subject and the quality of the equipment. The use of an easily accessible water tank and a stable seat or platform suspended from load cells rather than spring scales will improve performance and accuracy of underwater weighing. If validated, DEXA could be the method of choice in the future, because it can provide both regional and whole body estimates of fat, lean mass, and bone mass at a relatively low cost. Because DEXA is passive and involves very low exposure to ionizing radiation, it is appropriate for repeated observations.

ACCURACY OF MEASUREMENTS

Body composition can be measured with increasingly greater accuracy than in the past. However, we are still hampered by the way measurement values are converted into amounts of bone, muscle, and fat. A major concern in this area is the validity of the assumptions underlying estimates of body composition. To date, most studies of body composition have used the simple two-compartment model or Siri's equation (1961). This equation divides the body into fat and FFM on the basis of body density from underwater weighing. Siri's equation is based on the assumptions that the densities of fat and FFM are 0.9 g/ml and 1.10 g/ml, respectively (Pace and Rathburn, 1945). The density of fat varies little among individuals across age, but the density of FFM can vary substantially among individuals depending on the relative proportions of its constituents, mainly water, protein, and osseous and nonosseous mineral and the age of the person (Lohman, 1986). A variation of plus or minus 0.02 g/ml away from the assumed value of 1.10 g/ml for the density of FFM can translate into an error of plus or minus 5 percent BF for an individual with a body density of 1.05 g/ml. These errors can be compounded due to reported greater variations in body water amount and bone mineral content among individuals with differences in age, race, and gender, which affect body density. Also, individuals who are physically fit tend to have higher bone mineral content and as a result, may have artificially low percent BF values when calculated using Siri's equation.

USING A FOUR-COMPARTMENT MODEL FOR STUDIES OF BODY COMPOSITION

The problems of estimating body composition can be improved by using a four-compartment model, which is now considered necessary for studies determining body composition. The equation for this model is as follows:

$$1/D = F/\mathrm{df} + TBW/\mathrm{dw} + B/\mathrm{db} + C,$$

where $1/D$ is the sum of the volumes (fractions of weight/density) for fat (F), total body water (TBW), total bone mineral (B) and protein plus small amounts of nonosseous mineral and glycogen (C).

In comparison to the two-compartment model, the volume of FFM is broken into three constituents: water, bone mineral, and protein. Other nonosseous minerals and carbohydrates that are only a small fraction of FFM (about 1.5 percent in young adults) are lumped together with the protein fraction. Water is the largest fraction of the fat-free body and is assumed to be about 73 percent of the fat-free volume in young adults. However, studies show that this percentage is somewhat higher in women and increases with levels of adiposity (Noppa et al., 1980; Pierson et al., 1982; Steen et al., 1977, 1979). An increase in the amount of water will decrease the overall density of the FFM, but an increase in bone mineral content will increase the density. The fraction of FFM composed of protein, nonosseous mineral, and carbohydrate is assumed to be relatively constant, but because of changes in these body tissues, such as an increase in connective tissue with age, and possible gender and racial differences, this assumption may be questionable. Before this model can be applied widely, however, it is necessary to establish the amount of difference among gender and racial groups that exists in the densities of the body components. Without this information, estimates or predictions of body composition will be subject to significant errors of unknown magnitude when applied to unrepresentative samples. Thus, our knowledge of body composition is limited when applied to women or members of non-White racial or ethnic groups.

ASSOCIATIONS AMONG BODY COMPOSITION, DISEASE AND DEATH

Bone

Until recently, bone has been the largest unknown in body composition due to our inability to quantify it accurately and noninvasively. The associations among bone and disease or death are not ones that usually affect individuals in the age range of most military personnel. With the use of DEXA, however, the potential exists for identifying young adults with low or falling amounts of bone mineral content or bone density who are at risk for osteoporosis or fractures due to physical stress in their military occupational specialty.

Fat-Free Mass

Differences between individuals in the quantity and quality of FFM result in variations in physical ability and performance. However, there is little or no information that associates FFM with disease or death except for the changes that occur during weight loss or in association with eating disorders. With greater numbers of women in the military, the incidence of eating disorders and dieting problems could be expected to increase. These problems can be associated with potentially harmful losses of FFM in some individuals. Individuals who gain FFM or attempt to lose BF should be made aware that changes in FFM are accompanied by concurrent and corresponding changes in adipose tissue. The link in these changes may be due to the extragonadol aromatization of androgens to estrogens in muscle as well as adipose tissue (Segal et al., 1987).

Excess Adipose Tissue

The vast majority of the associations among body composition and morbidity and mortality relate to excess adipose tissue or fat. The main impact of these associations tends to be on the cardiovascular system, although the effects on an individual can be modified or compounded by environmental and genetic factors. Fat or lipid is a pervasive component of the body, but in regard to morbidity and mortality, it can be viewed more in terms of amounts and distribution of adipose tissue and of the concentrations of various lipid molecules in the blood. High concentrations of total cholesterol, triglycerides, and the low-density lipoproteins are significantly associated with the occurrence of cardiovascular disease and increased risk of death due to myocardial infarction or stroke (Angel and Roncari, 1978; Bray, 1987; Hubert et al., 1983).

Adipose tissue is either subcutaneous or internal. The location of the tissue may be associated with the type of lipid stored, the metabolic activity of the tissue, the size and number of adipocytes, its response to diet and age, and its ease of measurement (Bray, 1987; Kaplan, 1989). The amounts and distribution of subcutaneous and internal adipose tissue are related to an individual's risk for cardiovascular disease, diabetes mellitus, hypertension, and some forms of cancer (Haines et al., 1987; Kaplan, 1989; Larsson et al., 1984; Selby et al., 1989; Shimokata et al., 1989; Sparrow et al., 1986). Many of these associations are confounded by the effects of smoking, diet, levels of physical activity, and genetic susceptibility.

Measuring Body Fat

The simplest measure of BF is weight. Individuals with above normal weights for their age and stature tend to have greater than normal levels of BF either in absolute amounts or in the percentage of the body that is fat (percent BF). These individuals are considered overweight and obese, but there can also be individuals who are overweight and not obese and individuals who are not overweight but are obese. Other convenient measures or indices of obesity are weight over stature squared or the body mass index (BMI), skinfold thicknesses, and ratios of body circumferences. There are numerous reports of the statistical relationships between body weight, relative weight, skinfold thicknesses, weight for stature, or the BMI and risk for cardiovascular disease. In most of these analyses, the data have come from large population studies such as Framingham, the first and second National Health and Nutrition Examination Surveys and several large insurance industry studies (Donahue et al., 1987; Hubert et al., 1983; Keys, 1989; Neser et al., 1986; Selby et al., 1989). All of these indices, however, do not have the same relationships with risk for disease or death. There is still some controversy depending on the measurement used, on the person's age, and on smoking habits. Those individuals with extreme levels of BMI are at risk, and those individuals with significant weight gains are at increased risk. Recently, Segal and coworkers (1987) reported that weight and BMI are not as important for the individual as it would appear. Weight and BMI are useful measures to describe levels of obesity indirectly in large samples, but for the individual, the amount and distribution of total BF is independently related to cardiovascular disease risk factors (Segal et al., 1987).

Distribution of Body Fat in Adults

Vague (1956) first reported that in adults the pattern of adipose tissue distribution differed by gender and that the masculine distribution was more closely related to endocrine and metabolic diseases. In the early 1980s, these facts were noticed again by Kissebah and coworkers (1982) who related the adipose tissue distribution or the waist-hip ratio to levels of cardiovascular risk. This ratio attempts to describe an individual with a large waist circumference compared to a small hip circumference, that is, the masculine type, with the converse consisting of large hips to a small waist, or the feminine type. The masculine type or centripetal form tends to be produced by large deposits of internal adipose tissue, while the feminine type is due to large deposits of subcutaneous adipose tissue. This simple difference between internal and subcutaneous adipose tissue deposits is also related to differing levels of risk. The masculine or centripetal pattern is strongly associated with increased glucose intolerance resulting in non-insulin-dependent diabetes, heart disease, hypertension, and stroke and an increased risk for premature mortality (Bray, 1987; Donahue et al., 1987; Haines et al., 1987; Larsson et al., 1984; Seidell et al., 1985; Selby et al., 1989). Individuals with the masculine pattern tend to have increased concentrations of saturated fat within the internal adipose tissue deposits, higher triglycerides, and lower high-density lipoprotein (HDL) cholesterol blood levels regardless of their gender (Baumgartner et al., 1987; Kaplan, 1989; Leclerc et al., 1983; Sedgwick et al., 1984; Segal et al., 1987; Wing et al., 1989). It has also been observed that smokers, even though they may be thin, have a greater waist-to-hip ratio than do nonsmokers who may have higher body weights. Upon the cessation of smoking, the body configurations of the smokers tend to move toward that of the feminine pattern with a smaller waist-to-hip ratio (Shimokata et al., 1989).

The primary problem with the use of the waist-hip ratio has been in measuring the circumferences at accepted locations. Much of the literature is confusing because someone's waist measurement is someone else's hip measurement. If the ratio is to be used, suitable landmarks for the measurements need to be identified and adhered to strenuously. Fortunately, the association between waist circumference and internal adipose deposits has been confirmed by computed tomography (Baumgartner et al., 1988; Kvist et al., 1986). The increased availability of MRI combined with spectrographic analysis will provide further detail about the amounts and chemical content of internal adipose tissue. Thus, it appears that one of the major problems of BF and disease is primarily one of the deposition of internal adipose tissue. Upper body, centripetal, or masculine type of adipose tissue deposition is the major contributor to the risk of overweight or obesity. With weight reduction, and corresponding decreases in the amounts of internal adipose tissue, many of the risks for cardiovascular disease are reduced accordingly.

Much of the work relating fat patterning and risk for disease has involved White women. There are only a few studies of men or Blacks except what has been reported from the national health surveys. There are possible ethnic or racial differences in the levels of thresholds for risk or in the patterning of adipose tissue. These differences are being explored in Mexican-Americans where the waist-hip ratio is the preferred measure, but skinfold thickness ratios may be significant (Haffner et al., 1986, 1987; Reichley et al., 1987). Because of the diverse ethnic background of U.S. military personnel, the use of any single criterion for risk should be discussed carefully.

SUMMARY

Body composition is an interdependent, multifaceted quantity. It is not yet possible to describe and quantify the tissues in the body with consistent levels of accuracy. It is hopeful that in the near future this goal will be attained in laboratory settings, but clinical or field procedures may remain relatively inaccurate and subject dependent. One can, however, determine when the distribution of tissues in the body's composition shifts toward a greater-than-normal level of fat or adipose tissue. In an individual with such a condition, the risk for disease and early death increases, but the magnitude of the shift relative to the threshold for the increased risk is affected by the age, gender, race, and living habits of the individual. Some of this change may be a normal manifestation of age, but it is evident that increased amounts of internal adipose tissue in the abdomen put one at the greatest health risk.

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11

Critique of the Military's Approach to Body Composition Assessment and Evaluation

Henry C. Lukaski

There are many reasons for assessment and evaluation of body composition of military personnel. One purpose is to provide objective standards for recruitment and retention of personnel. Other purposes include the maintenance of appropriate physical appearance, optimal performance under combat conditions and health. Thus, body composition assessment and evaluation are important and necessary to meet the duties and responsibilities of the Armed Forces.

APPROACHES

Because of the large numbers of military personnel that require body composition assessment, any approach must acknowledge and balance the factors of practicality, reliability and accuracy of measurements, time requirements, and skill required by the test administrator. These constraints led to the use of weight-for-height tables. Currently, each branch of the Armed Forces uses gender-specific weight-for-height tables both for recruitment and retention. Interestingly, the target values are different for recruitment and retention, except for the U.S. Air Force (Table 11-1). Whether these discrepancies reflect true differences in requirements for physical demands or historical precedent is unknown.

If an individual fails to meet the weight-for-height guidelines, an evaluation of body composition is performed by using either body circumference

TABLE 11-1 Weight Standards for Recruitment and Retention of a 70-Inch Man in the U.S. Armed Services

	Body Weight (lb)		
	Recruitment	Retention	Difference
Army	215	192	23
Navy	215	192	23
Marine Corps	211	194	17
Air Force	194	192	2

SOURCE: Adapted from U.S. Department of Defense (1981).

measurements (AR 600-9, 1986; Hodgdon and Beckett, 1984a,b; Vogel et al., 1988; Wright et al., 1981) or the combination of skinfold thicknesses and body circumference measurements (Clark, 1976). Each of these anthropometric approaches relies on regression equations to predict percent body fat (BF). As shown in Table 11-2, similar variables (neck and abdominal circumferences) are found in the currently used equations.

The estimated percent BF values are then compared to BF standards to determine whether an individual has excess BF. The U.S. Army BF standards are presented in Table 11-3. More stringent Department of Defense

TABLE 11-2 Variables Used to Predict Body Composition of U.S. Military Personnel

Source	Gender of Sample	Variables
U.S. Air Force		
Clark (1976)	Men	Lengths of humerus, radius, acromion, iliac crest, patella and tibia, circumferences of flexed biceps, forearm, chest, waist, buttocks, thigh, and calf, skinfold thickness at triceps, scapula, supra iliac crest, and calf; and fat density multiplied by number of limbs measured
U.S. Navy		
Wright et al. (1981)	Men	Neck and abdominal circumferences
U.S. Navy		
Hodgdon and Beckett (1984a,b)	Men	Neck and abdominal circumferences, height
	Women	Neck, abdominal and hip circumferences; height
U.S. Army		
Vogel et al. (1988)	Men and Women	Neck and abdominal circumferences; height

TABLE 11-3 Maximum Allowable Percent Body Fat Standards in the U.S. Army

	Age Group (years)			
	17–20	21–27	28–39	≥40
Men	20	22	24	26
Women	28	30	32	34

SOURCE: Adapted from AR 600-9 (1986).

guidelines indicate goals of 20 percent BF for men and 26 percent BF for women (AR 600-9, 1986).

DISCUSSION

The military program of body composition assessment and evaluation is ambitious and very challenging. Any critique of the current program needs to address issues that are philosophical and technical.

It is unclear from the available literature whether the military body composition program intends to establish norms and standards for the individual or for the armed forces as a whole. With the current system of weight-for-height tables, body circumference measurements, and an allowable increase of 2 percent BF standards per decade of age, it appears that population assessment methods are used for screening, and individual standards are used for evaluation. Thus, the basis for establishing the percent BF norms needs detailed examination and probably revision.

Weight-for-height tables have gained considerable use by the civilian American population. To generate national weight standards requires information on a large group of individuals. One approach was to use data on weight and height from the insurance industry (Society of Actuaries, 1959, 1980a,b). Although these surveys supply data on weight and height for nearly 5 million people, they suffer from the extreme bias of self-selection. A second data base has been generated by the National Center for Health Statistics (Abraham et al., 1983), which developed weight standards for height by plotting the normal distribution of weight-for-height. This distribution was arbitrarily divided into overweight and severely overweight. Overweight was defined as those persons exceeding the eighty-fifth percentile of weight-for-height and used as a reference the weights of men and women between 20 and 29 years of age. Severely overweight was considered as greater than the ninety-fifth percentile. The major drawback of this approach is that the standard may change as the weight distribution of the population changes.

Weight-for-height standards can also be based on the lowest overall risk to health. For example, the minimal death rate in several prospective studies was associated with a body mass index (BMI) of 22 to 25 kg/m^2; also, the BMI associated with the lowest risk of death increased with age (Andres, 1985). A World Health Organization (1987) group suggested that a BMI range of 20 to 30 kg/m^2 was associated with a modest risk of mortality.

Another approach to defining healthy weights was taken by a Canadian review group (Health Promotion Directorate, 1988). They labeled as "good weights for most people" the body weights associated with a BMI of 20 to 25 kg/m^2. Individuals with a BMI of less than 20 kg/m^2, as well as those with a BMI of 25 to 27 kg/m^2, were considered to have an increased health risk.

Currently available weight-for-height tables do not take into account ethnic or racial differences, morbidity, and mortality in the distribution of weight-for-height. Efforts are in progress to develop race-specific weight-for-height data distributions for Black, Hispanic, and Asian Americans using the limited data available.

The bases for the derivation and application of weight-for-height tables in the military need examination. What criteria have been used to establish the tables currently in use? If the tables were constructed from statistical analyses assuming normally distributed weight-for-height data and by using arbitrary cutoff points, the ranges of acceptable weights are biased by changes in the secular distribution of weight-for-height. Furthermore, these estimates may not include any consideration of the criteria of health, ethnicity, or performance.

The current weight-for-height standards differ for recruitment and retention. The differences are large (see Table 11-1) and represent unrealistic goals for weight loss, independent of body composition change, that are attainable during recruit training. It is reasonable to suggest that these differences be resolved.

Any attempt to revise weight-for-height tables for military use needs to include such factors as gender, ethnicity, performance, appearance, and health. Realistic consideration of attainable changes in body weight and body composition during recruit training should be included in deriving weight estimates for recruitment and retention of military personnel.

Evidence from the military application of anthropometric approaches to predict densitometrically determined body composition variables indicates that models for predicting percent BF by using either skinfolds and body circumferences (Clark, 1976) or neck and abdominal circumferences (Hodgdon and Beckett, 1984a,b; Vogel et al., 1988) yield biased estimates of body composition. That is, the equations overpredict body fatness for the lean individuals and underpredict fatness for the obese. This bias or error may be attributed to either errors in the biological assumptions associated with the densitometric and/or anthropometric methods, technical errors of the measurements or a combination of these two factors.

One critical issue for establishing normative standards for the military is ethnic or racial differences in body composition. There is accumulating evidence that distinct differences exist in body composition both within and among ethnic groups, and these observations indicate the need for race-specific standards. To date, this approach has not been adopted, but it appears to be necessary for the development and validation of useful body composition prediction equations.

The potential impact of the problem of ethnic or racial differences in body composition is magnified by the use of inadequate reference and candidate measurements of body composition. Currently, underwater weighing or hydrodensitometry is the reference method used in body composition surveys of military personnel to develop anthropometric models. This approach uses the two-compartment model to assess BF content (Lukaski, 1987). Unfortunately, bone mineral density or content is an unmeasured variable that has the potential to significantly bias the BF estimate. Bone mineral density, which has been shown to be greater in Blacks than in Caucasians (Cohn et al., 1977), greater in men than women (Cohn et al., 1977), and possibly reduced in Asians, has not been measured in any of the previous surveys. Using extrapolations from data on children (Lohman et al., 1984), the estimate of this error can be as high as 5 percent. Thus, failure to correct body density measurements for individual differences in bone mineral density can result in overestimates of BF.

With regard to the densitometric equipment used in previous surveys, investigators should modify existing apparatus to perform measurements of residual lung volume while the volunteer is immersed in the water. It is well established that conditions such as obesity are associated with a significant reduction in lung compliance and reduced pulmonary ventilatory capacity (Bray et al., 1977). The principal ventilatory variable that is reduced is the expiratory residual volume, whether expressed as a whole number or as a fraction of the vital capacity (Bartlett and Buskirk, 1983). Because this impairment appears to be a continuum over the range of body fatness from lean to obese, it would be prudent to measure residual lung volume rather than estimate it using standard equations or tables. Failure to do so may result in an overestimation of body volume, an underestimation of body density and an overestimation of BF (Lukaski, unpublished observations).

The selection of appropriate anthropometric measurements (body circumferences and bone diameters) and skinfold thickness sites is a challenging process. However, the availability of a current reference manual (Lohman et al., 1988) should be useful. Nevertheless, an important issue is the biological basis for using skinfold thicknesses and anthropometric measurements.

Although measurements of bone diameters, limb circumferences, and skinfold thicknesses have been used to derive prediction models for estimating body density and percent BF, this approach has generally been limited by population-specific prediction models (Lukaski, 1987). This point was recently reinforced by the findings of Hodgdon and Beckett (1984a,b) and Vogel et al. (1988) with military groups.

The limitation of using skinfold thicknesses to predict BF is found in the basic assumptions of this approach. It is generally assumed that the subcutaneous adipose tissue reflects a constant proportion of the total body adipose tissue and hence fat. Also, the sites selected for measurement represent the average thickness of the adipose tissue and thus are the best predictors of BF. Neither of these assumptions has been validated (Lukaski, 1987). Furthermore, the validity of such assumptions is dubious because of the extremes in distribution of body adipose tissue in the population.

In addition to the theoretical limitations of using skinfold thicknesses to predict BF, there also exist some practical concerns. The within- and between-observer variability in determining skinfold thickness can be greater than 5 percent (Burkinshaw et al., 1973; Jackson et al., 1978). Thus, trained and certified specialists are required. In addition, most prediction equations based on skinfold thicknesses are population specific (Edwards, 1951; Jackson, 1984; Lukaski, 1987). These factors limit the use of skinfold thickness measurements for precisely and accurately estimating body composition in the heterogeneous military population.

In contrast to the interobserver error in skinfold thickness measurements, the measurement of body circumferences is more reliable (Lohman et al., 1988). Unfortunately, this approach still suffers from population specificity in the development of prediction equations.

Statistical approaches for the development of prediction models need some consideration. Using power analysis to assess sample sizes for various racial groups based on estimates of both technical errors of the instrumentation and biological variability in the chemical composition of the fat-free mass (FFM) would enhance the probability of developing valid prediction equations. Furthermore, stepwise multiple regression analysis and factor analysis are needed to describe the most important predictor variables in the model.

An appropriate design for cross-validation of the candidate model is also needed. It is necessary to develop the prediction equation in one sample and then to cross-validate it in an independent sample. This approach has been used in previous cross-validation trials of equations derived in military personnel (Hodgdon and Beckett, 1984a,b; Vogel et al., 1988).

TABLE 11-4 Variability Estimates for Prediction Models and Cross-Validation Trials for Estimation of Percent Body Fat in U.S. Military Groups

Source	Sex of Sample	Standard Error of the Estimate (percent body fat) Model	Validation
Hodgdon and Beckett (1984a,b)	Men	3.52	2.7*
	Women	3.72	4.36*
Vogel et al. (1988)	Men	4.02	3.7*
	Women	3.60	4.4

*Statistically significant ($p \leq 0.05$) difference between predicted and measured values.

Another statistical analysis that would be appropriate is a determination of the directional bias of the error relative to the magnitude of the measured and predicted variable. This approach for cross-validation of values whose accuracy is unknown was proposed by Bland and Altman (1986). It involves the graphical representation of the residual scores plotted against the mean of the measured and predicted values. This is the appropriate statistical approach for cross-validation of the derived model.

The variability of the distribution of the relationship between measured and predicted percent BF values from the military trials using neck and abdominal circumference measurements and height is summarized in Table 11-4. It is clear that the standard errors of the estimate of percent BF are quite large and exceed the theoretical precision of the densitometric method (Lohman, 1981). These data indicate that the models are adequate for assessments of percent BF in population groups but are inadequate for individuals.

CONCLUSIONS AND RECOMMENDATIONS

Presently, the available anthropometric equations for estimating percent BF in the U.S. military are not valid for assessing body composition of individuals. This conclusion may be due to technical errors in the densitometric method, differences in the chemical composition of the fat-free body, the lack of specificity of the anthropometric measurements used in the prediction model, or a combination of these factors.

In retrospect, the major limitation of using regression equations to predict human body composition is the reliance on a mathematical equation derived in one group to predict a variable in another individual who may be a member of another group. This approach is susceptible to factors that can adversely influence its validity for estimating body composition of the individual. If factors such as ethnic differences in the bone density and BF distribution can be assessed and improvements in the technical measurement of the body can be made, perhaps an improved and more sensitive assessment and evaluation of body composition in the military population can be achieved.

These difficulties can be addressed and controlled by the following recommendations.

- Use current and technically accurate methods and equipment for densitometry and anthropometry.
- Use a multicompartmental model of body composition, and include measurements of bone mineral density (regional and total body) to correct apparent whole body density obtained by underwater weighing.
- Use appropriate statistical methods to determine appropriate sample sizes for model development and cross-validation. Calculations for sample sizes need to include estimates of technical and biological variability of measurements.
- Use stepwise multiple regression analysis and factor analysis to develop the prediction model.
- Establish the need or lack of need for race-specific prediction models.
- Ascertain the validity of the model or models to determine change in body composition after weight loss.
- Establish practical and valid criteria for implementing the new model(s) in the U.S. military environment.

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12

Body Composition and Performance in Relation to Environment

Roy J. Shephard

DEFINITION OF OBESITY

Clinicians commonly define obesity as a body mass that exceeds the actuarial "ideal" value by a specified margin such as 10 or 15 pounds (5 to 7 kg). However, this is not an entirely appropriate basis of assessment from an ergonomic point of view. First, the goal of the clinician when diagnosing obesity is to detect an increased vulnerability to chronic disease (Table 12-1). Thus, groups such as the Society of Actuaries (1959) have expressed the mortality from a variety of chronic conditions and diseases as a percentage of the "standard" mortality values observed in subjects of the same age and sex who had an "ideal" body mass relative to their height. Notice that a substantial increase of vulnerability develops only when there is a major excess of body mass (and by inference a major excess of body fat). Moreover, loss of production from morbid obesity and the resultant chronic disorders has a relatively minor impact upon the performance in the young adults of a military labor force. In contrast to the threshold of fatness required for a clinical diagnosis of obesity, most aspects of occupational performance tend to be continuous functions of body composition. Furthermore, the energy cost of most tasks depends not only on total body mass, but also on the nature of this mass (muscle or fat) and—if the person is burdened by an excess of fat—on its distribution (deep or superficial).

A possible method for defining body fatness is to compare hydrostatic estimates of body fat content with those observed in a person of ideal body

TABLE 12-1 Mortality of Obese Subjects, Classified by Condition or Disease, and Expressed as a Percentage of Standard Values for Subjects of the Same Gender, Aged 15 to 69 years.

	Percent of Standard Values of Mortality of Matched Controls			
	Men		Women	
	Excess Weight		Excess Weight	
Condition	≥ +24 kg	≥ +33 kg	≥ +28 kg	≥ +37kg
Diabetes	179	385	270	242
Cerebrovascular disease	136	183	143	142
Heart/circulation	131	155	175	178
Pneumonia/flu	128	193	148	110
Digestive diseases	147	197	140	200
Kidney diseases	146	230	93	122
Accident/homicide	109	126	85	98
Suicide	71	104	47	
All causes	12.	145	130	138

SOURCE: Based on data of the Society of Actuaries (1959). Previously published and reprinted by permission of Greenwood Publishing Group, Inc., Westport, CT, from Physiology and Biochemistry of Exercise by Roy J. Shephard (1982).

mass. One study of military recruits arbitrarily set the upper limit of ideal values at 14 percent body fat in men (Amor, 1978), although the same author's data apparently suggested that 16.8 percent fat would correspond with the upper limit of the actuarial ideal body mass. Taking the 14 percent ideal figure for the men, and the 18 percent ideal body fat for the women, this would imply respective ideal fat masses of 10 and 11 kg in the two genders. Applying the clinical criterion of obesity, those men with a 5 kg excess of fat (the obese) would have 21 percent or more fat, and the women would have 27 percent or more fat. Some 50 percent of the male soldiers studied by Amor (1978) exceeded the actuarial ideal of body mass. The proportion of those who exceeded his arbitrary criterion of obesity (18 percent of body mass in men) increased with age (Table 12-2) but was unrelated to the physical demands of employment (Table 12-3). Those whom he classified as obese nevertheless tended to have a poor maximal oxygen transport, particularly if this was expressed in ml/kg × minute (Table 12-4). Thus, for military purposes an obesity threshold of 18 percent fat in men and perhaps 24 percent fat in women seems preferable to the clinical criteria of 21 percent and 27 percent fat in the two genders.

A second potential method of identifying the obese is to measure skin-

TABLE 12-2 Relation of Chronological Age of Military Personnel to Obesity in the British Army

Age in Years (*n*)*	Percentage Obese (> 18 percent body fat)
17–19 (702)	32
20–24 (1,190)	39
25–29 (805)	46
30–34 (255)	56
35–39 (118)	62

*(*n*) = number of personnel surveyed.
SOURCE: Amor (1978).

fold thicknesses, again comparing the actual readings with the values observed in a person meeting actuarial standards of ideal body mass (Shephard, 1982). Average readings are about 10 mm in a male and 14 mm in a woman of ideal mass. Assuming that a double fold of the skin per se accounts for 4 mm of the total skinfold reading (Shephard, 1991), there is a superficial layer of some 5,400 cm^3 of fat in the ideal man with a body surface of 1.8 m^2 (4.8 kg of fat, assuming a density of 0.9) and 8,000 cm^3 of fat in the ideal woman with a body surface of 1.6 m^2 (7.2 kg of fat). Assuming also a 50 percent increase of subcutaneous fat in a person who is clinically obese, the clinical threshold of obesity would be an average skinfold reading of 13 mm in a man and 19 mm in a woman. However, if the military threshold of obesity were to be set at the ideal body mass,

TABLE 12-3 Relation of Job Intensity to Prevalence of Obesity among Militar Personnel in the British Army

Job Intensity (*n*)*	Percentage Obese (>18 percent fat)
Sedentary (353)	53
Light (1,389)	42
Moderate (1,269)	38
Heavy (59)	51

*(*n*) = number of personnel surveyed.
SOURCE: Amor (1978)

TABLE 12-4 Relation of Percentage of Body Fat to Percentage of British Army Personnel with Poor Aerobic Fitness

Body Fat Percent (*n*)*	Percentage with Poor Aerobic Fitness (maximal oxygen intake <35 ml/kg × min)
<10 (154)	2
10–14 (728)	5
14–18 (912)	9
18–22 (642)	21
22–26 (390)	32
>26 (244)	51

* (*n*) = number of personnel surveyed.
SOURCE: Amor (1978).

as proposed by Amor (1978), the ceiling of militarily acceptable skinfold reading would average about 11 mm in a man and 14 mm in a woman.

In summary, the standards for judging obesity in military personnel should be more rigorous than those adopted for clinical purposes; both body fat (limits of 18 percent in men and 24 percent in women) and skinfold readings (limits of 11 mm in men and 14 mm in women) should correspond to those observed in a person of ideal body mass.

PERFORMANCE IN COMFORTABLE CLIMATES

Physical Performance

Physical performance may be classified simply into endurance activities, well exemplified by prolonged marching with a backpack, and lifting tasks that are commonly the limiting factor in the front-line employment of military personnel (for example, the ability to lift a mass of 36 kg from the ground to a height of 110 cm; Nottrodt and Celentano, 1984). The metabolic load imposed by any given task reflects the sum of resting metabolism plus the energy cost of the required activity (Shephard, 1974).

Resting Metabolism

Because of the effects of body surface upon heat loss, resting metabolism is a power function of body mass M (Shephard, 1982):

$$V_{O_2} = (M)^{0.75}$$

However, a large part of the fat cell is occupied by metabolically inert stored triglyceride. Thus, the resting metabolism per unit of body mass is greater in a muscular than in a fat individual. Obesity also affects respiration through mass loading of the chest: the obese person shows decreases of lung volume, chest wall, and lung compliance that can precipitate a classical Pickwickian syndrome of hypercapnia and hypoxia (Burwell et al., 1956). In partial compensation for the added respiratory work, the respiratory centers of the obese individual may show an increased sensitivity to hypoxia (Burki and Baker, 1984) and in moderate but not in severe obesity there is an increased sensitivity to carbon dioxide (Emirgil and Sobel, 1973; Nishibayashi et al., 1987).

Endurance Activities

Givoni and Goldman (1971) and Pandolf et al. (1977) developed various equations for the prediction of the energy cost of marching in fit young recruits. In general, these authors found that the metabolic cost is a linear function of body mass and the mass of any backpack that is being carried. Thus, a heavier person will spend more energy when marching, regardless of whether the added body mass is attributable to muscle or fat. If the normal expectation is that a 70-kg recruit will carry 30 kg of equipment, then a person who is 10 kg heavier will immediately have a 10 percent handicap of endurance performance (Givoni and Goldman, 1971).

If the added burden is muscle, a heavy person may show some compensatory increase in their absolute maximal oxygen transport, and because the active muscles are stronger, it may also be possible for the individual concerned to operate at close to their maximal oxygen intake for a sustained period, so that their endurance performance may approach that of a lighter person. However, if the extra body mass is fat, there is certainly no compensatory development of maximal oxygen intake; indeed, oxygen transport is often poorer than in a lighter person, so that endurance performance is at least correspondingly limited. In moderate obesity, there is no change of mechanical efficiency, so that the oxygen cost of walking per kg of body mass is unchanged. However, if the obesity is extreme, a combination of heavier limbs, awkward or impeded body movements, and increased respiratory loading may give rise to a low mechanical efficiency, with a further restriction of potential performance (Dempsey et al., 1966).

Lifting and Carrying

The current Canadian military requirement is that recruits be able to lift 18 kg regularly and 36 kg occasionally to shoulder height (Nottrodt and Celentano, 1984). The load normally lifted is thus about 20 percent of body mass, and if objects are to be picked up from the ground, the resultant displacement of body mass is a major fraction of the overall task. Brown

(1966) suggested that the oxygen cost of most occupational tasks could be described by an equation of the type

$$\dot{V}_{O_2} = A + B(M)^n$$

where A and B are constants, and M is body mass raised to an exponent n that varied from 0.75 to 1.0. Godin and Shephard (1973) suggested that there might be merit in a three-term equation of the type:

$$\dot{V}_{O_2} = A + B(M)^{0.75} + C(M)^n$$

where A, B, and C are constants, M is body mass, and n is an exponent varying from 0.1 to 0.2 in very light arm work to near 1.0 in heavy physical tasks involving displacement of much of the body mass. The second term in this last equation distinguishes the influence of body mass on resting metabolism, a particular advantage in situations where a heavy, muscular person is performing relatively light industrial work.

Another consideration is that the obese person is often characterized by insulin resistance and difficulty in mobilizing fatty acids (Pacy et al., 1986; Scheen et al., 1983). If an endurance task must be sustained for a long period, the function of such an individual may be impaired by a depletion of glycogen reserves.

With a lifting task, the factor limiting performance is usually muscular strength rather than maximal oxygen intake; thus, if body mass is increased, it becomes critical whether the added load is due to muscle that can provide a compensating increase of strength or to fat, which merely increases the overall mass of the system.

Underwater Activity

Underwater activity is a special case where it is an advantage to be somewhat obese, both from the viewpoint of thermal insulation and also because of the resultant increase in buoyancy. Heavy, muscular individuals often have substantial difficulty swimming over long distances, because they must exert much greater effort to remain afloat, and a less horizontal leg position also decreases the mechanical efficiency of their swimming (Shephard et al., 1973). However, the person who lacks a normal amount of body fat can compensate for this handicap by keeping the lungs relatively well filled with air while swimming.

Size Problems

A final consideration is that many military work stations, such as aircraft cockpits, tanks, or submarines, have limited space for the human operator. A grossly obese person may be handicapped when working in such a situation because body size exceeds the available clearances.

Poor Health

Minor sickness and absenteeism are common sources of poor performance in all kinds of occupation. Among government employees, 10 of 220 working days are commonly lost through absenteeism each year, and an unpredictable need for well-trained replacements adds some 8 percent to payroll costs (Shephard, 1986). Given the well-recognized actuarial association between obesity, chronic disease, and premature death, possible relationships between obesity, absenteeism and increased illness should be examined in military personnel.

Bardsley (1978) has commented on a substantial cost to the armed services from "diseases of choice," where risk is influenced by lifestyle—conditions such as myocardial infarction, bronchitis, emphysema and alcoholism (Table 12-5). As shown in this table, in 1973, the Canadian forces expended $5.9M for replacement of the dead, $5.8M for replacement of the released, $12.4M for those who were hospitalized, and $1.5M for those who were on sick leave due to "diseases of choice." However, much of this expense is related to the adverse health effects of smoking and alcohol abuse rather than to the adverse consequences of obesity; a substantial excess body mass (20 to 30 kg) is needed for an appreciable increase of morbidity from back problems and of deaths from such diseases as coronary atherosclerosis and diabetes (Society of Actuaries, 1959). Moreover, the economic impact of obesity-related morbidity and mortality would be greatest in older members of the labor force, after the normal time of retirement

TABLE 12-5 Estimated Monetary Costs Incurred by the Canadian Forces in 1973 (1973 Canadian dollars) Due to Diseases Associated with Choice of an Adverse Personal Lifestyle

	Cost ($ million)
Replacement of the dead	$ 5.9
Replacement of the released	5.8
Hospitalization + lost wages	12.4
Wages of those on sick leave	1.5
Total	25.6*

*This cost is spent on a labor force of about 80,000 military personnel.

SOURCE: Bardsley (1978).

from the armed services. Finally, many of the absences from work among younger individuals are attributable to causes other than organic disease, and such personnel would be unlikely to respond to the correction of obesity or indeed to any other form of medical treatment (Williamson and Van Nieuwenhuijzen, 1974). While there remains scope for more detailed analyses of the economic impact of "diseases of choice," at first inspection it thus seems much more important to correct smoking and an excessive consumption of alcohol than to attempt a reduction of body fat in military personnel.

OTHER IMPLICATIONS OF OBESITY

Image is an important aspect of effectiveness in many organizations, including the armed services (Shephard, 1986). Obese personnel do not fit the public image of a soldier, and it seems logical that for this reason they will weaken the military effectiveness of a unit, although there has been no experimental examination of this point.

Baun et al. (1986) have further commented on an association between achievement orientation and personal fitness. By selecting personnel who meet specified standards of body composition and physical fitness, a unit may be enriched by the recruitment of premium personnel.

HOT AND COLD ENVIRONMENTS

Because heat exchange is proportional to body surface area, tolerance of hot and cold environments may be influenced somewhat by the differences of body surface area between a tall, thin ectomorph and a short, fat endomorph. Indeed, at one time anthropologists sought to explain the colonization of hot and cold regions in terms of body linearity, the so-called "rules" of Bergmann (1847) and Allen (1877). However, the effects of body form are at most of secondary importance in a normal working population.

The main impact of obesity on thermal balance comes from the added insulation of subcutaneous fat (Shephard, 1985), although an increased constriction of subcutaneous blood vessels may further augment the insulation of a fat person (Jequier et al., 1974), and there are also effects of body fat stores upon cold-induced thermogenesis. It has been shown that a 5 kg accumulation of fat may add 1.5 mm to the subcutaneous fat layer of a man and 2.5 mm to that of a woman. The functional value of this thin layer of fat can be gauged from the importance that distance swimmers attach to covering their skins with a few mm of grease. At rest, the thermal gradient across a layer of superficial fat is only about 0.15°C/mm, but the insulating effect is proportional to heat flux. Thus, when a person is working at 10 times the basal metabolic rate, there will be a 10-fold increase of thermal gradient, to about 1.5°C/mm of superficial fat (Pugh et al., 1960). Assuming an energy expenditure of 10 METS (the ratio of observed to basal metabolism) and a uniform pattern of heat loss, a woman who had accumulated 5 kg of body fat, with a resultant 2.5 mm increase of the subcutaneous fat layer, would have a subcutaneous temperature some 3.8°C higher than a person of ideal body composition.

It might be thought that a thick layer of subcutaneous fat would be an advantage when adapting to a very cold climate. Certainly skin temperatures drop to a lower level in the obese before their metabolism is stimulated (Wyndham et al., 1968), perhaps because of an altered setpoint in the hypothalamic thermal regulators (Zahorska-Markiewicz and Straszkiewicz, 1987), although this change has adverse consequences for manual dexterity. The very low skinfold readings of traditional Inuit (Rennie, 1963; Shephard, 1978) is one strong argument against the view that fat accumulation has any great adaptive value in the cold. It is only with acculturation to "western" civilization that body fat has accumulated (Rode and Shephard, 1984). The main problem of the fat person who is living in the arctic is that the extent of insulation cannot be reduced once physical work is begun; in fact, because of the increased heat flux, the effectiveness of any insulation is actually increased during work. Body temperature thus rises to the point where sweating is initiated; this wets the clothing from within, largely destroying its insulation, and the individual rapidly becomes hypothermic when a rest-break must be taken. In contrast, a traditional Inuit hunter with a very thin layer of subcutaneous fat is able to conserve body heat by using skillfully fashioned clothing that provides up to 11 CLO[1] units of insulation (Burton and Edholm, 1969).

One fascinating feature shown by military personnel who have recently arrived in the arctic is an increased metabolism of fat. Both field observations and laboratory crossover trials have shown that a given amount of activity produces a fat loss in the cold that is not mirrored in a warm or temperate environment (O'Hara et al., 1978, 1979). Reasons for this fat loss are still not entirely clear. Contributing factors include energy lost in a substantial ketosis, small increases in the energy cost of movement due to the weight and hobbling effect of arctic clothing, and a possible cold-induced stimulation of resting metabolism; it remains unclear whether this last response occurs through residual brown fat (Huttunen et al., 1981) or

[1] The CLO unit was originally defined as the insulation provided by British indoor clothing. It is now defined in terms of the thermal gradient from the skin to ambient air ($Ts - Ta$, °C), the body surface area (m^2) and the heat loss (kJ/hour); therefore, CLO units = 0.75 ($T_s - T_a$) m^2 kJ per hour.

TABLE 12-6 Effects of a 2-mm Increase in Subcutaneous Fat (a 4-mm Increase in Skinfold Readings) on the Performance of Physical Work in the Heat

Intensity of Work (kJ/min)	Core Temperatures (°C)*	Work Rate (percent)†
Light (<14)	+0.8	-11
Moderate (<23)	1.2	-17
Heavy (<38)	2.0	-28

*If work-rate is unchanged.
†If core temperature is unchanged.
NOTE: It is assumed there is an initial thermal gradient of 7°C from the body core to the environment.
SOURCE: Based on a concept of Pugh et al. (1960).

the initiation of futile metabolic cycles in other tissues. Interestingly, it seems easier to produce the fat loss in obese men than in those who are initially slim (O'Hara et al., 1978), and it is also more readily developed in men than in women (Murray et al., 1986). Perhaps fat stores in women are more stable, in order to meet the demands of pregnancy and lactation.

Obese subjects have difficulty undertaking vigorous work in a hot environment, partly because they must expend more energy to complete a given task and partly because insulation is increased by the thicker layer of superficial fat. One potential method of restoring thermal balance in the obese person is a greater relative increase in skin blood flow during exercise. However, if blood is directed to the skin, it cannot be directed elsewhere—to the working muscle and the brain. The peak oxygen transport and peak power output are thus reduced in the heat. The obese person works more slowly than a slimmer peer, or if pace is maintained, collapse occurs earlier than in a thin subject. One recent calculation suggested that with an initial thermal gradient of 7°C from the body core to the environment, the core temperature would rise by an additional 0.8 to 2.0°C if a person with an additional 2 mm of subcutaneous fat undertook industrial work (Shephard, 1987; Table 12-6); conversely, if the rise of core temperature were to be avoided by a slower rate of working, it would be necessary to reduce the work-rate by 11 to 28 percent.

CONCLUSIONS AND RECOMMENDATIONS

In young adults who make up the bulk of military personnel, the main argument for controlling the burden of body fat is a deterioration of physical performance rather than the risk of morbid conditions. Deterioration of function in a temperate environment is almost directly proportional to excess fat mass, without evidence of a threshold. It is thus recommended that the target body fat percentage set for military personnel correspond to their actuarial ideal of body mass. The adverse effect of body fat upon performance is exacerbated when personnel must operate in a hot climate, but a modest excess of fat may contribute to buoyancy and insulation when working in cold water.

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13

Sex Differences and Ethnic/Racial Differences in Body Size and Body Composition

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SEX DIFFERENCES IN BODY SIZE AND BODY COMPOSITION

At all ages, from the first trimester through the tenth decade, the man is the larger of the two chromosomal sexes, being longer and heavier and with a larger lean body weight (LBW). Even during childhood, when boys and girls are most alike dimensionally, the chromosomal XY is considerably larger than the chromosomal XX of the same physiologic (or skeletal) age. Because there is some increase in stature even after age 20 and some gain in the LBW through the midtwenties, the full expression of sex differences in dimensions and LBW is not evident until late. There are also sex differences in fat weight (FW), although the woman is not necessarily fatter, either in absolute terms (FW) or even as a percentage of body weight (percent fat [% F]), as so commonly believed.

In adulthood, the man is generally taller, by about 6 or 7 percent across the socioeconomic (SES) range and in different genetic populations. This stature excess is disproportionately expressed in the appendicular skeleton, a factor of considerable importance to vehicular design and to the design and operation of equipment and firearms and the location of controls. In adulthood, the man generally has a larger LBW by a ratio of approximately 3:2 (for example, 61 kg or so versus 43 kg or so). This sex difference in LBW is reflected in the sex difference in basal energy requirements, in the caloric

TABLE 13-1 Distributions of Stature, Weight, Fat Weight, and Lean Body Weight in 30- to-39-year-old Tecumseh, Michigan Men and Women

Stature			Weight			Fat Weight*			Lean Body Weight†		
	Percent			Percent			Percent			Percent	
cm	Men	Women	kg	Men	Women	kg	Men	Women	kg	Men	Women
140	.0	.0	43	.0	4.1	4	.4	.4	20	.0	.0
142	.0	0	48	.4	13.5	6	3.1	4.1	25	.0	2.0
144	.0	0	53	.8	14.3	8	4.2	5.3	30	.4	10.2
146	.0	.0	58	5.8	23.3	10	6.2	7.7	35	.4	25.3
148	0	.8	63	10.0	17.1	12	7.3	10.6	40	3.1	30.2
150	.0	1.2	68	15.4	10.2	14	7.3	8.5	45	14.2	20.0
152	.0	4.1	73	16.5	6.5	16	7.3	7.3	50	21.9	9.8
154	0	7.3	78	18.5	4.5	18	9.6	9.3	55	28.1	8
156	.0	8.2	83	16.2	3.3	20	8.5	7.3	60	23.1	1.2
158	.4	7.3	88	6.2	.4	22	9.2	6.9	65	6.5	.0
160	.8	13.5	93	6.2	.8	24	8.1	4.9	70	1.5	.0
162	1.9	16.3	98	1.5	.0	26	3.8	2.8	75	.8	.0
164	1.9	9.8	103	1.5	.4	28	5.0	6.5	80	.0	.4
166	3.5	12.2	108	1.2	1.6	30	6.9	4.5	85	.0	.0
168	6.5	6.5	113	0	0	32	4.6	3.3			
170	10.4	6.1				34	5.0	2.8			
172	11.9	3.3				36	1.5	.8			
174	13.5	1.2				38	1.5	2.0			
176	15.0	1.6				40	.0	1.2			
178	11.5	.4				42	.4	0			
180	5.0	.0				44	.0	1.6			
182	8.5	.0				46	.0	.4			
184	2.7	0				48	.0	.4			
186	2.7	0				50	.0	.8			
188	1.9	0				52	.0	.4			
190	1.9	0				54	0	.0			
192	0	0				56	0	.0			
194	0	.0				58	.0	.0			

*Individually calculated from the regression of weight on four skinfolds.
†Total body weight (TBW) minus fat weight (FW).

allowances set by the Food and Nutrition Board's (FNB) Committee on Dietary Allowances (the Recommended Dietary Allowances—the RDAs) and in caloric intakes actually reported in major nutritional surveys (Ten-State, NHANES I and II, the Tecumseh Community Health Survey, and so on).

There is, of course, an overlap between the two sexes[1] in body size, LBW, FW, and also in skeletal weight (which will be discussed later). For

[1] For the discussions that follow, also see Figures 13-1 through 13-9 in the chapter appendix, which graphically present the sexual overlap for body and skeletal weight and size variables in men and women aged 40-49 years from the Tecumseh Community Health Survey.

TABLE 13-2 Distributions of Bone Area, Cortical Area, and Skeletal Weight in 30-to-39-year-old Tecumseh, Michigan Men and Women

Bone Area (TA)			Cortical Area (CA)			Medullary Area (MA)			Skeletal Weight (SW)*		
	Percent			Percent			Percent			Percent	
mm	Men	Women	mm	Men	Women	mm	Men	Women	g	Men	Women
35	.0	4.1	20	.0	.4	0	.0	5.3	1400	.0	8
40	.0	12.8	25	.0	.0	1	2.8	7.8	1900	0	9.1
45	1.2	24.8	30	0	1.2	2	3.6	11.9	2400	.8	42.3
50	4.4	22.3	35	.0	11.5	3	4.4	12.3	2900	7.6	32.8
55	4.8	21.1	40	.4	28.0	4	5.2	11.1	3400	16.7	11.2
60	7.6	6.2	45	4.8	30.5	5	6.0	13.2	3900	29.1	3 3
65	16.4	6.6	50	8.8	16.9	6	5.6	10.3	4400	22.3	4
70	20.0	2.1	55	17.9	7.8	7	11.6	10.7	4900	15.5	.0
75	15.2	.0	60	23.9	2.5	8	6.8	3.3	5400	7.2	.0
80	13.2	0	65	20.7	1.2	9	5.6	2.9	5900	8	.0
85	6.8	0	70	13.1	.0	10	5.2	2.1	6400	0	0
90	4.8	.0	75	6.4	.0	11	6.4	2.1			
95	3.6	.0	80	2.4	0	12	7.2	1.6			
100	2.0	.0	85	1.6	.0	13	6.4	2.9			
						14	4.8	.8			
						15	4.0	1.2			
						16	1.2	.4			
						17	2.0	0			
						18	4.8	.0			
						19	4	.0			
						20	1.6	0			
						21	8	0			
						22	2.0	.0			
						23	4	.0			
						24	.4	.0			
						25	.4	.0			

*SW = 0.969 CA × L or 0.7611 $(T^2 - M^2)L$, where: SW = skeletal weight; CA = cortical area; L = bone length; T = total width; and M = medullary width.

weight and FW, the overlap is considerable (see Tables 13-1 and 13-2); the overlap area is of importance to military planning and materiel tariffs from several points of view. Moreover the actual or operational overlap may be greater or less depending on recruitment standards, self-selection of volunteers, and selective dropout rates. If women who volunteer for service are self-selected for greater stature or for a larger LBW, as is likely, or if training programs and the service academies further select, then the women in service will exceed their total-population (civilian) counterparts in body size and robust build. At the same time, entry standards, self-selection, and attrition during basic training may also exclude the smaller and less-muscled men, thereby decreasing the dimensional and ponderal overlap between the sexes.

Furthermore, there is the question (which cannot be properly answered here) as to how much basic training and in-service physical training may modify, decrease, or even increase sex differences in muscle mass of male and female volunteers. Both sexes do gain in muscle mass during such training. There is a common belief that men, with their testosterone, gain disproportionately more muscle with training, but with joint-sex exercise programs and suitable motivation, women may gain as much LBW proportionately—although they may be liable to exercise-induced amenorrhea due to decreased estrogenic levels.

Skeletal weight, bone sizes, and amounts of tissue bone all differ between the sexes even more than LBW differs. So, the calcium content of the male skeleton approximates 1,000 g as compared with perhaps 750 g for the female skeleton, and the skeletal weight ratio is then on the order of 4:3. Moreover the "overlap" in skeletal size or skeletal weight may be well under 30 percent (see Table 13-2). With smaller skeletons, less tissue bone, smaller bone widths, and smaller cortical bone area (CA) one might expect bone fracture rates to be higher in women than in men, an expectation of potential importance to the military both with respect to training injuries and to vehicular accidents. However in actual experience, civilian fracture rates are higher for men than for women in the age range of 20 to 40 years. Only after the fifth decade does the fracture rate in women begin to exceed the fracture rate in men.

Why men under 45 years of age fracture more and women aged 20 to 45 fracture less is not known, although men are more often engaged in high-risk construction occupations, and they are more accident-prone when they drive (and they do drive more miles). However, the smaller bones of young adult women do not necessarily result in a higher fracture rate in civilian life. Again, the overlap in bone size and bone area between men and women must be considered as shown in Table 13-2. What the actual osseous overlap is in enlisted men and women and those at noncommissioned officer and officer ranks remains to be ascertained. Also to be ascertained is the incidence of forearm (Colles' and Barry) fractures in military-age individuals of both sexes.

The question of sex differences in fat weight (FW) and percent fat (%F) is complicated, and some of the answers are surprising. That women generally do have a thicker panniculus of outer fat is well known, but this is not always the case; some women have less outer fat than men do. When FW is measured, the two sexes are often quite similar, a fact that is not well appreciated (Table 13-3). Yet percent fat (%F) is generally higher in women because FW may be the same, but total body weight (TBW) is considerably less. Even so, the overlap in percent BF is considerable.

TABLE 13-3 Correspondences Between Male and Female Percentiles for Size and Body Composition in 30-to-39-year-old Tecumseh, Michigan Men and Women

	Male Centiles Corresponding to	
Measure	Women's Fiftieth Percentile	Women's Eighty-fifth Percentile
Stature	2.0	13.1
Weight	7.0	40.6
Fat weight	45.0	88.5
Lean body weight	2.3	18.1
Bone area (TA)	3.4	10.4
Cortical area (CA)	2.0	14.0
Medullary area (MA)	34.4	48.0
Skeletal weight (SW)	0.8	8.4

NOTE: *This table is to be read in the following manner.* The fiftieth percentile for stature in women corresponds to the second percentile in men. The eighty-fifth percentile for stature in women corresponds to the thirteenth percentile for men. Note that the sexes are most alike in fat weight and skeletal weight.

As a complication, fatness—either fat thickness or FW—is inversely related to education in women at a rate of nearly 0.5 kg per year of education, which suggests that how fat a woman is depends largely on her socioeconomic status. If the military recruits only women of high school education (12 years) or beyond, their fatness may be lower than the average, and even lower than that for men of similar educational level. Moreover, leaner women may self-select for military service, and fatter women may be excluded from advancement or continuation in the service. The point here is that the appropriate level of fatness for service-oriented women cannot be prejudged from total population or national-probability FW distributions.

A further point about fatness is derived from family line studies. There are large familial differences in fatness levels. Daughters of lean families are far leaner than sons of obese families. This finding again opens the question as to whether women are necessarily or inherently fatter than men even though—on the average—they are.

In the civilian population, fat weight (FW) increases regularly and linearly with age at a rate of approximately 0.5 kg/year in women. However, this age-related increase is *not necessarily* a biological "given," occurring far less in the affluent and somewhat more in the poor. So an age-related increase in fatness is not necessarily the universal rule. Indeed in some third world countries fatness actually *decreases* with age. With one exception, one might even consider a no-increase rule for FW in the military as being both desirable and practical. The exception has to do with pregnancy, where higher levels of fatness are advantageous for fetal growth and development (see below, "Relevant Epidemiologic Aspects of Fatness and Fitness").

ETHNIC AND RACIAL DIFFERENCES IN BODY MASS AND BODY COMPOSITION

Although many ethnic and racial differences in size and body composition have been claimed and some documented, it is quite difficult to separate most such differences from years of residence in the United States and from socioeconomic status (SES). Male and female immigrants of recent arrival tend to be smaller, poorer, and shorter, but the immigrant women soon become fatter and more often obese. However, both size and body composition change as ratios of income to needs improve. Such differences between immigrants and their F_1 progeny pose problems in setting military standards—exactly the same problems that were encountered by the first Committee on Military Anthropometry in 1917. That wartime committee recommended a lowering of stature and weight standards so that recent immigrants from Russia and the Austro-Hungarian Empire would not be subjected to the height and weight standards established for so-called "native Americans".

In recent years there has been much litigation concerning weight and weight-height standards for airline stewardesses, oil industry workers, postal workers, and even Sears Roebuck shipping clerks. Courts have ruled that military, National Center for Health Statistics (NCHS), and the Metropolitan Life Table standards for size or weight-for-height are not necessarily appropriate for Mexican-Americans, Puerto Ricans, Colombians, and others. Even people with extremes of weight-for-height have been ruled as employable as long as those individuals can do their jobs, such as lifting 80-pound mail sacks.

Most immigrants from Meso-America, South America, the West Indies, and the Philippines and Asia are shorter than the NCHS norms and consequently have a smaller lean body weight (LBW). Such individuals and their foreign-born children are small by American military standards and may be accorded restricted military duties or excluded from certain classes of troops. With increased length of stay in the United States, and now in the F_2 generation, these immigrants more nearly parallel other Americans.

American Blacks (Americans of largely African ancestry) pose an intriguing problem, for they are taller as children and adolescents (ages 2 through 14) than are Whites of comparable age. As adults they average close to the U.S. means, may be taller than other Americans of comparable socioeconomic status, and with an excess above the ninety-fifth percentile limits. American Blacks (or African-Americans) also appear to have a slightly higher LBW, which indicates a larger muscle mass.

Best documented and of considerable interest is the larger bone mass in African-Americans. This difference is apparent in the fetal condition, during infancy and childhood, and continuing through the tenth decade of life. This larger skeletal mass (larger bone diameters and larger volumes of cortical bone) may be one factor behind the lower fracture rates for adult Blacks of both sexes. However the larger skeletal masses (bone weights and tissue bone volumes) may not be translatable into duty assignments.

Much attention has been given in the literature to the greater fatness of Black women, Hispanic women, Native American women, and so on. Indeed, fatness and obesity in Native American women have been attributed to population-specific "thrifty" genes. However this greater fatness appears to be more of a poverty-related phenomenon than a true genetic difference. Poor White women are fatter than affluent White women, and fatness decreases linearly with both years of education and family income. Fat weight (FW) also decreases with increasing socioeconomic status in Black women. There may be good political reasons to accept higher-weight and fatter Black, Meso-American, and Native American women into military service, but there can be no assumption that such differences are necessarily genetic.

Studies have also claimed racial and ethnic differences in fat placement, fat distribution, or fat "patterning". Expressed as ratios (for example, triceps:subscapular), such differences do exist, but these ratios are inherently fatness dependent. The triceps:abdominal circumferential ratio is much higher in lean individuals and much lower in the obese, so that some racial differences in fat placement may be no more than simple differences in the amount of fat. Of course, clothing and other covering equipment may be affected by such differences, but differences in relative leg length or hand size or foot size relative to stature may be more important. For constant stature, hand lengths and foot lengths (or metacarpal lengths and tarsal lengths) are approximately 1 standard deviation (SD) longer in American Blacks, whatever their nutritional status.

There are real and considerable ethnic and racial differences in body size and body composition, and in an emergency or crisis situation they may be taken into account. However, many of these differences (except the greater LBW and bone weight in African-Americans) disappear with time, affluence, and generational changes. The greater fatness of low-income women of all ancestries is very real and bears on recruitment and enlistment standards, but it is not necessarily genetic. How such differences are addressed involves political decisions, which may be discriminatory, however decided. It is probably beyond the scope of this advisory group to attempt ethnic-specific recommendations.

RELEVANT EPIDEMIOLOGIC ASPECTS OF FATNESS AND FITNESS

The weight of fat (FW) and therefore the percent of fat (%F) is controllable both by caloric restriction and by increasing energy expenditure. This fact is important both with respect to field performance and to long-term mortality and morbidity. Controlling FW or percent F affects field performance over the short term and affects the development of atherosclerosis, coronary artery disease, diabetes, and hypertension later on.

However, existing recommendations regarding the ideal, suggested, or optimal weight of fat are complicated by the nonlinear relationship between FW and age-specific mortality. At the upper end of the J-shaped curve, both morbidity and mortality rise with increasing levels of fatness. In contrast, morbidity and mortality also increase at the bottom end of the curve, where diseases of the respiratory system, including lung cancer, predominate. Very lean individuals of either sex are clinically anorectic and at greater long-term risk. Very fat individuals are also at greater long-term risk.

Low fat weights in women are of concern if they are associated with amenorrhea, and premature bone loss is likely for this group. Women athletes may find such low fat levels advantageous in the short term because it frees them from the inconveniences of menstruation. However, the premature onset of bone loss and involutional osteoporosis in these women might then be claimed as a service-related disability.

Furthermore, the ideal level of fatness associated with ideal fitness in women is far less than the level of fatness associated with optimal fetal growth and survival. Too lean a mother may be at greater risk for fetal loss, premature delivery, low birth weight, and increased neonatal mortality. Because a low prepregnancy weight (PPW) can be compensated for by a greater pregnancy weight gain, this aspect of body composition also merits attention in military service.

The long-term consequences of differences in FW also merit consideration. Because the Veterans Administration bears the cost of diseases associated with excessive fatness, body composition long after separation from service may well be an extended task of this conference. Pregnancy and pregnancy-associated risks are not necessarily part of the assigned mission, but body composition is important during pregnancy; too little fat is a risk factor with respect to pregnancy outcomes, and insufficient weight or fat may be a life-long risk factor.

Concerns of the military in the past were relatively short-term, relating to the ability of draftees and recruits to perform assigned tasks after entry into the services. Body size and bodily proportions also had some bearing on the design of equipment and on the number of sizes to be stocked.

Concerns now include changes in body composition during extended periods of service—up to 2 decades and more—and fatness control to meet service standards. Moreover, there are the long-term implications both to service-induced disabilities and to the cost of medical care long after separation from the services. If the services are to be equal-opportunity employers, they must accommodate racial and ethnic differences in size and body composition, including Vietnamese and Hispanics from southern Texas, California, and Florida. Looking to the future, there are the costs of hospitalization and medical care for those with excessive fatness and claims for service-induced disabilities. Even the children of those now in the service may seek compensation for excessive physical demands on their parents or for their own premature birth if their mothers were allowed to be too lean when they were in utero.

ACKNOWLEDGMENTS

All tabulations for age 30-39 year old men and women were specially calculated for this paper by Timothy V. E. Sullivan using raw data from the Tecumseh, Michigan Community Health Survey, including radiogrammetic measurements made under contract 53-3K06-5-10 with the Human Nutrition Research Center on Aging. Graphic representations for the 40-49 year old age group in Figures 13-1 through 13-9 in the chapter appendix use superimposed transparencies made from computer-generated histograms for men and women separately.

APPENDIX

The following figures were generated from superimposed transparencies made separately for men and women from computer-generated histograms. Data from the Tecumseh, Michigan Community Health Survey for individuals aged 40-49 were used throughout and thus provide comparative information for sexual overlap with the data from the same population on individuals aged 30-39 presented in Tables 13-1 through 13-3.

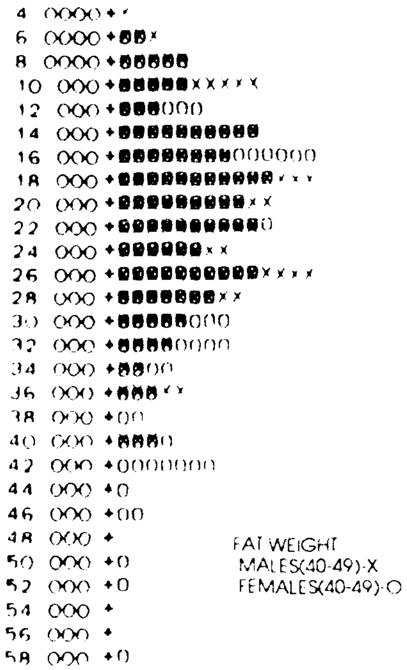

FIGURE 13-1 Distribution of fat weight *(FW) in kilograms (kg)* in fifth decade (40-49 y) men (O) and women (X), where each X or O = 1 person. Note the completely overlapping distributions of FW in fifth decade men and women. Although percent body fat does differ markedly between the sexes, because of the larger body weight in men, the distribution of fat weight is similar.

FIGURE 13-2 Distribution of body weight in kilograms (kg) for fifth decade (40-49 y) men (O) and women (X), where each X or O = 1 person. Note the overlapping distributions of weight in men and women. Because the fat-free weight of men is considerably larger than that of women, there is some bimodality in the body weight distribution, and this is especially apparent at the higher income levels.

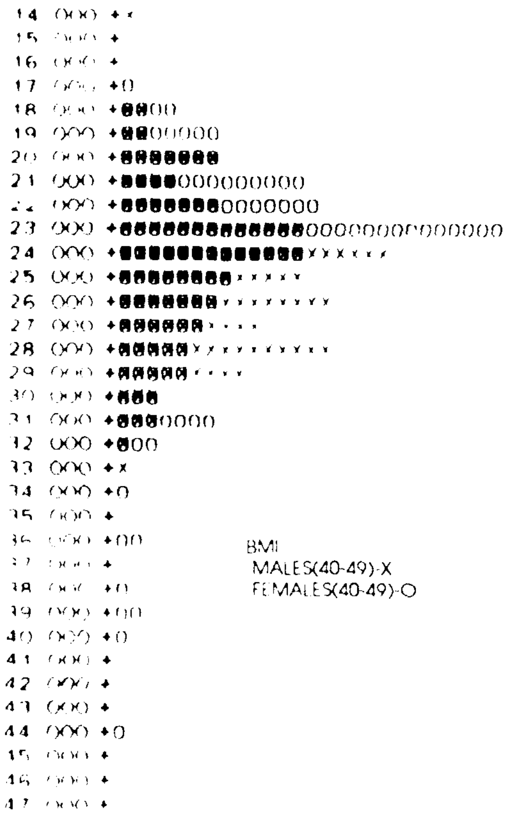

FIGURE 13-3 Distribution of body mass index (BMI) in weight (kg) divided by height (m) squared (wt/ht^2) for fifth decade (40-49 y) men (X) and women (O), where each X or O = 1 person. Note the overlapping distributions of the body mass index (BMI). Because the BMI, as currently calculated, is so highly weighted by weight, it assumes the distribution and characteristics of weight.

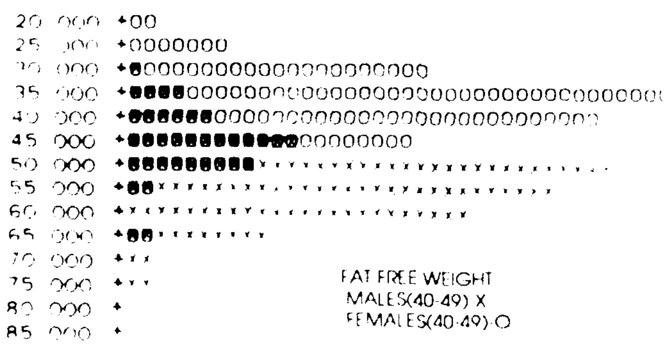

FIGURE 13-4 Distribution of fat-free weight (FFW) in kilograms (kg) for fifth decade (40-49 y) men (X) and women (O), where each X or O = 1 person. Note that FFW shows considerable bimodality (or sexual dimorphism) in distribution because the ratio of FFW in men to women is 3:2. This dimorphism in FFW is reflected in sex differences in caloric intake and total energy expenditure.

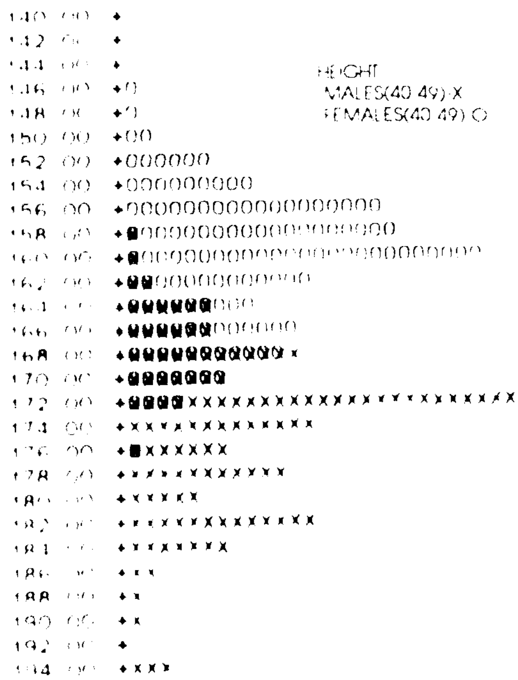

FIGURE 13-5 Distribution of height in centimeters (cm) for fifth decade (40-49 y) men (X) and women (O), where each X or O = 1 person. Although the percentage difference in stature is small—only 7 percent or so male and female statures show very little distributional overlap, a fact that has considerable bearing on equipment design, materiel tariffs, and purchasing schedules.

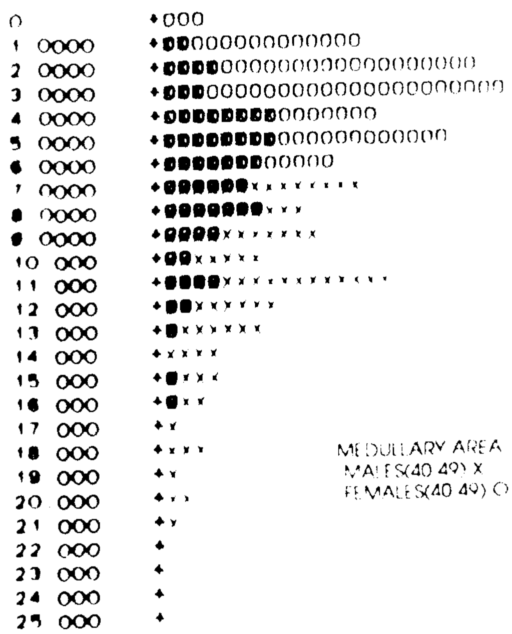

FIGURE 13-6 Distribution of medullary cavity area in millimeters (mm) for fifth decade (40-49 y) men (X) and women (O), where each X or O = 1 person. Note that there is considerable overlap between the sexes in medullary cavity area, although the men, with greater hematopoietic capacity, do have larger amounts of red marrow.

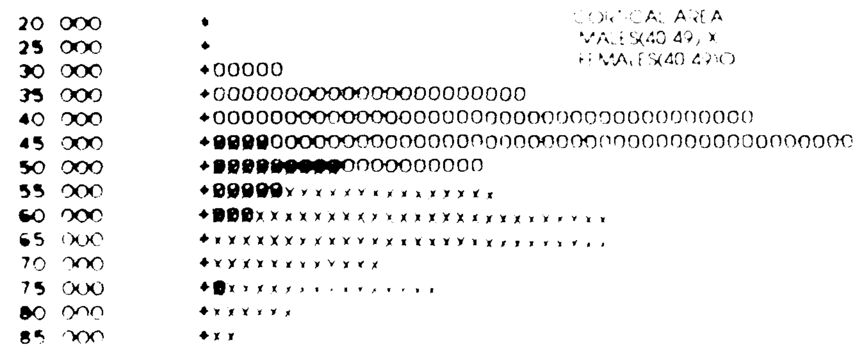

FIGURE 13-7. Distribution of cortical area in millimeters (mm) for fifth decade (40-49 y) men (X) and women (O), where each X or O = 1 person. Note that there is considerable sexual dimorphism in the cortical area. The overlap is small — less than 15 percent — because men have far more tissue bone.

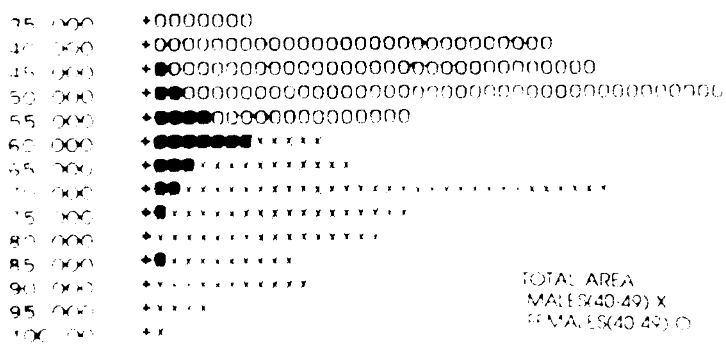

FIGURE 13-8. Distribution of total bone area in millimeters (mm) in fifth decade (40-49 y) men (X) and women (O), where each X or O = 1 person. Note that when total bone area is taken into account there is even further sexual dimorphism than for cortical area alone. The male skeleton possesses greater impact resistance than the female skeleton. This is especially true in the forearm where relatively light trauma — such as falling — can result in a Colles or Parry fracture.

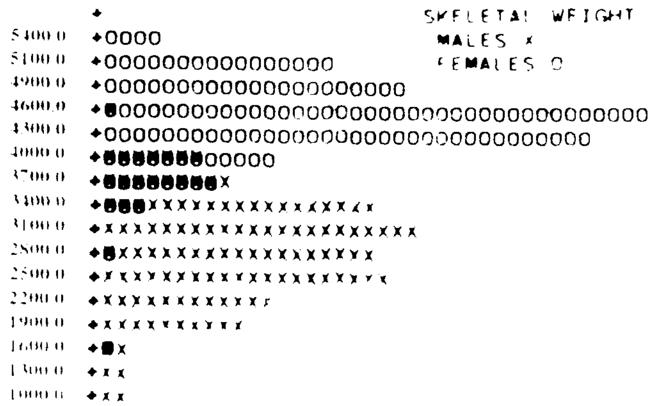

FIGURE 13.9 Distribution of skeletal weight in grams (g) for fifth decade (40-49 yr) men (X) and women (O), where each X or O = 1 person. Note that the skeletal weight distributions in men and women are most different with very little overlap. Skeletal weight thus sums, in effect, the distributional properties of stature and the fat-free weight. The sex difference in skeletal weight plays an important role in human identification in mass disasters and skeletal weight alone affords close to 90 percent sex discrimination.

PART III

Committee Discussion Paper

PART III CONSISTS OF the preliminary discussion paper that was written by one committee member, by request of the committee, after the workshop was held. The purpose of this paper was: to summarize some of the critical issues for discussion; to indicate, for the committee, scientific areas where additional information may be needed; and to pose, to the committee, specific questions for pointed discussion during further deliberations. This paper is included to provide further information on the committee deliberation process concerning accession and retention of military personnel as it relates to body composition and performance.

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14

Body Composition Measurement: Accuracy, Validity, and Comparability

Joël A. Grinker

BACKGROUND

Because estimates of body composition may vary as a function of gender, age, or ethnicity, their universal applicability needs to be considered with care. Current military standards include both gender- and age-specific norms. Are they sufficient? Are norms for older women more restrictive than for comparable men? Should norms be adjusted for race as well? Should norms be based not on total body composition, but on fat distribution patterns? Finally, should performance rather than body composition be the major determinant? The substitution of tests of health and physical capacity is possible, such as submaximal treadmill test performance, blood pressure test to rule out hypertension, spirometry to check lung health, Cybex to check quadriceps strength, hand grip dynamometer for hand strength, and evaluation of endurance via field performance or mini marathon. Would these tests provide more information than arbitrary standards based on changing norms? How relevant is physical appearance to effective military service, and how well correlated are arbitrary standards of body composition with preferred physical appearance?

To assess these questions, it is necessary to document a number of factors. The applicability of different methods of assessing body composition can be compared in relationship to assumptions of universal applicability. Secular, gender, and age-related differences in body composition and fatness can be documented. Ethnic or racial differences both in body composition and in age-related effects can also be documented.

METHODS AND ASSUMPTIONS

Is the two-compartment model (lean body mass [LBM] and body fat [BF]) still useful? Should the four-compartment model (LBM, BF, body water, and bone mineral) be used? How well do multiple anthropometric measures mirror body composition, body density, and ethnic, racial, and age-related differences in fat distribution or changes in bone density?

Body composition can be measured directly by chemical analysis of animal or human carcasses or cadavers. Indirect measures include densitometry via hydrostatic weighing; anthropometric measures of skinfolds/circumferences; and the more recent procedures of isotope dilution, neutron activation analysis, and potassium-40 counting (Boling et al., 1962; Brozek and Henschel, 1961; Forbes and Hursh, 1963; Lukaski, 1987). However, it is important to realize that the use of any indirect method of assessing human body composition results in errors of prediction. The usual errors range from 2.5 percent for predicting BF from densitometry to 3 to 9 percent by anthropometry (Lohman, 1981). An early comparison of ultrasonic and skinfold measurements to evaluate subcutaneous fat thickness and to predict total BF weight suggested that skinfolds were the more effective and less costly procedure (Borkan et al., 1982b).

The prevalent use of anthropometric measures (that is, height, weight, skinfolds and circumferences, and associated nomograms) is based on ease of application, simplicity, and reasonable correspondence with other techniques. Skinfolds of major interest include biceps, triceps, subscapular, suprailiac, abdomen, thigh, and medial calf. However, systematic errors can be introduced if the differential compressibility of skinfolds with age and skinfold thickness are not controlled (Himes et al., 1979) This technique depends on two assumptions: that selected skinfold thicknesses are representative of the total subcutaneous adipose tissue mass and that subcutaneous adipose tissue has a known relationship with total BF. However, the relationships between skinfold thickness and total BF reportedly differ with ethnicity, gender, and age (Chumlea et al., 1984; Durnin and Womersley, 1974; Jones et al., 1976; Wilmore and Behnke, 1970; Yuhasz, 1962). In addition, these measurements are highly susceptible to experimenter bias or error leading to wide variability among experimenters.

Densitometry has generally been considered the gold standard or criterion against which other techniques have been validated (Lohman, 1984; Roche, 1987). This technique assumes the two-compartment model: fat and fat-free mass (FFM; lipid-free) (Behnke et al, 1942). Fat is assumed to have a constant density of 0.9, although interstitial muscle fat is slightly higher (Mendez et al., 1960; Morales et al., 1945). However, the density of FFM is not constant (Lohman, 1986; Roche, 1987). Until middle age, bone mineral mass and muscle mass increase, and extracellular fluid decreases within the FFM. In old age, these differences are reversed for bone mineral and muscle. The density of FFM is also increased with marked physical activity due to the greater percentage of bone mineral (Mendez and Keys, 1960; Morales et al., 1945). Negative estimates of percent BF for some athletes are probably due to a greater density of FFM than allowed in the usual calculations (Roche, 1987).

Although the two-compartment model has been considered adequate for young White men, it is not as useful for different ages, women, other ethnic groups, or even the extremely active (Lohman, 1986; Parizkova, 1977; Roche, 1987; Womersley et al., 1976). Because of variations in the density of the FFM the correct model requires assessment of total body water and skeletal mass, in addition to measurement of body density. Physical training may also alter the fat-free body mass, suggesting that the new gold standard include separate measures of water, muscle, and bone mineral content. Greater delineation of lean body components—that is, total body nitrogen, total body water, potassium, and so on—have emerged. Newer technologies such as photon absorptiometry and neutron activation analysis are among the more quantitative means of measuring mineral content. The technique of dual-energy x-ray absorptiometry (DEXA), although as yet unverified, holds promise for its ability to measure accurately total body as well as regional bone and soft tissue composition (Mazess et al., 1990; Peppler and Mazess, 1981).

Measurement and Definitions in Body Composition

The application of limits in allowable body composition in the military depends on several assumptions. The first and primary assumption is that a single arbitrary point on the continuum of body fatness represents a "reversible abnormality". Overfatness or obesity is assumed to be a distinct abnormality that can be treated. Treatments consist of various procedures to induce "temporary" weight loss. Another assumption is that patterns of fat distribution at specific ages are less important or critical to overall health than is absolute fatness. Also implicit in the application of restrictive age-specific standards is the assumption that overweight/obesity at all ages is equivalently associated with increased health risks and/or poorer performance. Definitions of overweight and obesity, however, are population specific and subject to pronounced secular influences. Application to individuals may often be arbitrary or inappropriate. Second, reversal of overweight or obesity may be not only difficult to maintain but may itself be correlated with increased health risks (Williamson and Levy, 1988).

Estimates of the population prevalence of overweight or overfatness are dependent both on the criteria and the measures used (Bray, 1987; Garrow, 1983; Simopoulos and Van Itallie, 1984). Among the most commonly used criteria are relative weights (adjusted for height and gender) corresponding to specific percentiles for a specific population, ideal body weight, or body mass index (BMI: typically, weight in kg per height in m^2). One common external standard for overfatness is based on a BMI above 26 while a frequently employed standard of ideal body weight is based on the Metropolitan Life Insurance mortality results (1959, 1983). National Center for Health Statistics (NCHS) surveys reported that 29 percent of the 1960–1962 and 26 percent of the 1977 U.S. adult population were overweight based on the 1959 Metropolitan Life Insurance norms of ideal weight-for-height (NCHS, 1966, 1980).

More direct measures of fatness such as those derived from the sum of various skinfolds have also been used in large population-based studies with criteria based on population distributions. Norms are based on data from national health surveys such as the National Health and Nutrition Evaluation Survey (NHANES) I or II or data from insurance companies. The use of even multiple skinfolds or nomograms based on skinfolds and circumferences poses several problems. In overweight and obese subjects, these measurements show poor reliability (Forbes, 1964). Skin thickness and skinfold compressibility vary as a function of age, site, and gender (Brozek and Kinzey, 1960; Clegg and Kent, 1967; Garn and Gorman, 1956; Himes et al., 1979; Lee and Ng, 1965; Martin et al., 1985; Ruiz et al., 1971; Millar and Stephens, 1987).

Discrepancies in reports of the prevalence of obesity have also been the result of applying different criteria for defining obesity (for example, NHANES I versus NHANES II or Metropolitan Life Insurance norms for 1959 versus 1983). In addition, differences in sampling (for example, randomized census tract selection versus random digit telephone dialing), or measurements (for example, telephone self report versus direct measures) have produced differences in reported obesity prevalence.

Average fatness and prevalence rates for overweight/obesity can also vary markedly as a consequence of socioeconomic status (SES), age, race, and gender (Cronk and Roche, 1982; NCHS, 1986, 1987; Forman et al., 1986). Overweight and level of education or SES are inversely associated (Baecke et al., 1983; Forman et al., 1986; Garn and Clark, 1976; Garn, 1985; Moore et al., 1962; NCHS, 1980; Silverstone et al., 1969). Within each of the four National Health and Education Surveys (NHES) surveys, even younger adults (18 to 35 years old; especially those above the median of the distribution) had higher BMIs at progressively older ages (Harlan et al., 1988). The prevalence of overweight and obesity increases until individuals are approximately 50 years of age, then levels and declines (Jeffrey et al., 1984, NCHS, 1966; Ross and Mirowsky, 1983; Stewart and Brook, 1983).

Secular trends in the American population have been recognized in increased values in the criteria for defining obesity in the recent Metropolitan Life Insurance tables (1983) based on changes in measured fatness of sampled populations (eighty-fifth percentile) and risk. However, this latest version failed to include age as a variable, and consequently, the recommended weights are reported to be too liberal for young adults to accurately reflect total mortality for 40 year olds, and may be too restrictive even for 50 or 60 year olds (Andres et al., 1985).

Obesity Prevalence, Age Effects and Weight Fluctuations

Population Based Data

Cross-sectional studies have documented differences in fatness as a function of gender, age, race, and secular influences (Abraham et al. 1983; Garn, 1985; NCHS, 1965, 1986, 1980; Malina et al., 1983; Wong and Trowbridge, 1984; Zillikens and Conway, 1990). The U.S. population has reportedly gained weight over the last 2 decades, and the prevalence of obesity has increased (Simopoulos, 1987) even in childhood and adolescence (Dietz et al., 1985; Gortmaker et al., 1987). Overweight among adults of varying ages has increased within the last 10 years despite widespread health concerns and dieting (Fisher and Bennet, 1985). Recent statistics suggest that in 1986, 28.4 percent of U.S. adults 25 to 74 years of age were 20 percent or more overweight as judged by BMI greater than 27.8 for men and greater than 27.3 for women (NCHS, 1986).

Cross-sectional studies in England, Canada, the United States, and Holland report that in both men and women, relative weight increases during adulthood, is maintained in middle age, and decreases in old age (Baecke et al., 1983; Bray, 1987; Jeffrey et al., 1984; Khosla and Lowe, 1968; Millar and Stephens, 1987; Montoye et al., 1965; NCHS, 1980; Rosenbaum et al., 1985; Stewart and Brook, 1983). Although such associations between age and overweight could be due in part to a confusion between cohort and age effects possible in cross-sectional studies, data from prospective studies support these general findings. These longitudinal studies suggest age-related trends in relative weight (Friedlaender et al., 1977; Hsu et al., 1977; Kannel et al., 1979).

Individual-Based Data

At present, little is known about patterns of individual weight change within the population during adult years. When and to what extent does weight loss or gain occur? Is stability in BF related to pattern of fat distribution? It has recently been suggested that stability in body habitus may be related to a lower risk for chronic disease such as coronary heart disease (CHD) (Hamm et al., 1989). Whether the risk of other chronic diseases, such as cancer or noninsulin dependent diabetes (NIDD) are also related to weight fluctuations is unknown. The few existing prospective studies suggest relative consistency in body weight patterns over time. (See, for example, Kramer et al., 1989.)

Changes in weight, BMI, and skinfold thickness (triceps and subscapular) were studied after intervals of 4 to 7 years in over 17,000 Finnish adults as part of a recent health survey (Rissanen et al., 1988). Average weight and BMI increased with age in men and women below age 50 at entry, changed little in men aged 50 to 70 (women aged 50 to 60), and declined at later ages. Both moderate overweight (BMI = 27.0 to 29.9 kg/m^2) and severe overweight (BMI $\geq$ 30 kg/m^2) increased in successive age cohorts of men and women until age 70. A relatively high proportion of Finnish adults, approximately 24.7 percent of all men and 33.7 percent of all women were considered overweight, and 8.3 percent of men and 17.4 percent of women were estimated to be severely overweight.

Small changes in individual weights were reported, with two-thirds of these Finnish participants maintaining their weight within 5 kg of their original weight classification (lean, normal, moderately overweight, or severely overweight). A weight gain of 10 kg or more occurred in 9 percent of the men and 4 percent of the women, and a 10-kg weight loss occurred in only 2 percent of the men and 4 percent of the women. Both weight loss and weight gain occurred among overweight subjects. Weight loss was associated with old age and higher initial BMI, whereas weight gain was most common in young adults, even among those with high initial BMI. Men aged 20 to 29 at entry gained an average 3.3 kg/5 years. Weight gain was less common among older subjects. Among 40 to 69-year-old men, there were negligible changes, with 15 percent losing or gaining 5 kg. BMI increased until age 50 and decreased thereafter.

Results from the normative aging study (NAS) (Borkan et al., 1983, 1986; P. Vokonos, Boston Veterans Administration, pers. com.) illustrate strong age, cohort, and secular effects in fatness among healthy male adult volunteers. During the 20 years of this study, the average weight reportedly increased until age 55, with subsequent stability and then reduction. Patterns of central fat distribution have been examined in a small group of selected subjects from the NAS using CAT scans. Great variability among individuals in the redistribution of fat with increased age leading to an uneven thinning of subcutaneous fat and increased intra-abdominal fat has been documented (Borkan et al., 1982a; Borkan and Norris, 1977; Mueller, 1982). Estimates of internal abdominal fat appear to be poorly correlated with overall estimates of fatness and not well correlated with estimates such as the waist-hip ratio (Shimokata et al., 1989). Abdominal fat and internal depots have been closely associated with cardiovascular disease (CVD). Data from the NAS have also been used to assess the effects of weight change and age on coronary disease risk factors (Borkan et al., 1986). Even after controlling for age, smoking status, initial weight, and initial levels of the risk factor, increases in weight were significantly related to increases in most risk factors (for example, cholesterol levels, fasting glucose, triglycerides). However, data from at least one other longitudinal study suggest a curvilinear relationship between fatness and mortality (Andres et al., 1985).

Recently, several studies have focused on the potential deleterious consequences of weight changes and have reported greater morbidity and mortality solely as a consequence of weight fluctuations (Hamm et al., 1989; Hoffman and Kromhout, 1989). Recent reports from the MRFIT, Goteborg, and Framingham populations suggest an association between weight cycling (individual variations in body weight) and coronary heart disease and mortality, which are reportedly independent of BMI or age (Lissner et al., 1988, 1990, 1991). Whether undiagnosed illness is also a factor is under discussion. The factors related to success or failure in dieting and thus in promoting weight stability such as gender, ethnicity, intentionality, use of exercise, degree and duration of overweight/fatness, and fat distribution patterns need to be clarified.

The appropriateness of age-specific criteria, however, remains somewhat controversial. With affluence, fatness increases regularly with age, but it is unclear whether this is biologically desirable or inevitable. Perhaps, as with losses in muscle mass and strength, adequate exercise and attention to diet can prevent age-associated increases in total fatness but not, perhaps changes in fat distribution. Although certain preindustrial societies may not demonstrate age-related increase in weight (Dietz et al., 1989), the documentation of shifts in the pattern of fat distribution suggests that ideal body weight and body composition are in fact age dependent. Andres (1990) has argued persuasively that modest increases in weight with increasing age (10 pounds/decade) are associated with minimum mortality among healthy, insured individuals. However, many analyses of these epidemiological data sets have included "healthy" smokers.

A recent study (Must et al., 1991) reports data from NHANES I on persons ranging in age from childhood to 74 years during 1971 to 1974. Population- and race-specific percentiles of BMI for obesity and superobesity were obtained. Significant variability as a function of age, gender, and race were reported. In women, racial differences in the eighty-fifth and ninety-fifth percentiles of BMI emerged in the teens and persisted into adulthood with a continued divergence with age. The BMI at the fiftieth percentile was also higher in Black women starting in the teen years. In men, Whites had greater BMI at the eighty-fifth percentile until age 35; afterwards BMIs for Black men were greater. Black men had greater BMIs at the ninety-fifth percentile throughout adulthood with a continued divergence with age.

RESEARCH APPLICATIONS

Data from routine physicals in the military should provide both prospective data as well as cross-sectional data. The incidence and prevalence of weight shifts or changes in body composition in the military population can be documented. The existence of long-term trends in weight/fatness stability or cycling in individuals differing in body habitus can be explored. Initial anthropometric measures and pattern of fat deposition as well as estimates of percent BF or BMI can be compared with routine periodic measures of body composition and the incidence or degree of weight fluctuations individually determined. Secular and generational trends as well as relative stability in weight and fatness can be explored among different ethnic and racial groups. Retrospective case-cohort analysis can also be performed to determine the overall pattern of weight fluctuation; the initial fatness patterns of subjects subsequently exceeding specific fatness criteria can be contrasted against the entry status of a random selection of all participants at entry (Sorensen and Sonne-Holm, 1988).

Weight and fatness stability can be defined as weight plus 5 pounds of starting weight per year. Weight stability can also be estimated by the intraindividual variability in body weights or fat distribution patterns, that is, the coefficient of variation (CV) of at least three consecutive body weights taken at regular intervals (3 to 5 years). Weight change can be defined as at least a 5-kg loss or gain; and weight cycling can be defined as two or more weight changes within the last 15 years. Comparisons can be made among current weight, initial weight, and "cycled" weights. Current and prior anthropometric measures can be used to provide estimates and adjustments of body composition and fat deposition and to estimate gender, ethnic, race, and age effects. It would also be of interest to measure adipose tissue in selected subjects for lipolysis and conduct $\dot{V}_{O_2 max}$ testing or measure total metabolic rate by doubly labeled water technique in selected subjects with high or low weight fluctuations. These data would allow estimates of individual differences in rates of lipolysis or energy utilization. These latter relationships might begin to provide partial answers to the major question of the relationships among body composition, body fatness, and performance.

SUMMARY

The body composition criteria for entrance and for retention in the military services especially the Army, are not identical. Screening criteria are primarily based on weight/height for age with retention criteria based on body composition standards that are only moderately related to performance. This paper discussed several key issues of measurement which influence both the accuracy and the reliability of measures of body composition. Further research is necessary to examine the relationships among the various methods of measuring body composition and various performance criteria.

Major issues that were addressed in this discussion of criteria included those related to validity or accuracy and precision as well as issues of reliability. These factors are related not only to technical measurement error but also to issues concerning stability in body composition in adult men and women and differences in body composition among various subgroups for example, racial or ethnic. Body composition and the adequacy (validity and reliability) of measurements were discussed in relation to age, pattern of fat distribution, gender, and ethnic or racial differences. The prevalence and significance of weight shifts with aging or dieting were also discussed. Finally, the relationship between standards of body composition and performance in relation to differences among age, ethnic, and gender groups was addressed. Additional research should address these remaining issues:

- What should be used as the true "gold standard" in determining body composition? Is the two- or four-compartment model more useful?
- How accurate are the large scale screening techniques versus experimental procedures? How reliable? What are the correlations among measurements?
- What corrections in weight or fatness should be allowed for gender, race and ethnic origin? How should ethnic differences in fatness distribution patterns be translated into body composition standards?
- How stable are the weights and body compositions of adults? Are age associated corrections desirable or necessary?
- If certain patterns of fat distribution (centripetal or abdominal depots) are more likely to occur with older age and be more closely linked with morbidity/mortality, should body composition recommendations and standards be differentially aimed at specific subgroups, i.e. especially men (and women) with centripetal fat distribution patterns? Should standards of acceptable weight/fatness be relaxed for women (or those meeting lower waist/hip ratios)? Since smoking (in women) is related to higher waist/hip ratios should fatness/appearance recommendations include restrictions on cigarettes?

Standards of measurement (validity and reliability) must be considered along with issues of applicability to military needs.

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APPENDIXES

A. Accession Standards for the Military Services
B. Retention Standards for the Military Services
C. Weight-for-Height Tables
D. Proposed Revisions to Accession (AR 40-501) and Retention (AR 600-9) Body Weight and Body Fat Standards
E. Recent Changes to the U.S. Army Standards for Accession and Retention
F. Biographical Sketches

A

Accession Standards for the Military Services

The physical screening standards by height-weight and body fat for accession into the military services are included within broader military regulations governing general health specifications for recruits entering each branch of the military. For the Air Force and recently for the Marines (effective 1 June 1992) the retention standards for height, weight and body fat are also used for accession. These regulations are excerpted in Appendix B. The Army and Navy maintain separate standards for accession and retention. This Appendix only includes excerpts from U.S. Army and U.S. Navy regulations that govern physical characteristics for accession, however, the regulation specifications are provided for additional information.

U.S. ARMY

The standards for accession into the U.S. Army are included in Army Regulation 40-501: **Standards of Medical Fitness** (update 15 May 1989). This regulation is extensive and only excerpts from Chapter 2, Physical Standards for Enlistment, Appointment, and Induction, that apply to height, weight, and body composition with supporting tables are included here.[1] The recent Interim Change to this regulation is included in Appendix E.

[1]Further information concerning this regulation can be obtained from Headquarters, Department of the Army (SGPS-CO-B), 5109 Leesburg Pike, Falls Church, VA 22041-2358

Chapter 2
Physical Standards for Enlistment, Appointment, and Induction

2-1. General
This chapter implements Department of Defense (DOD) Directive 6130.3 "Physical Standards for Enlistment, Appointment, and Induction," March 31, 1986, which established physical standards for enlistment, appointment, and induction into the Armed Forces of the United States in accordance with section 133, title 10, United States Code (10 USC 133).

2-2. Application and responsibilities
a. Application

(1) This chapter prescribes the medical conditions and physical defects which are causes for rejection for military service. Those individuals found medically qualified based on the medical standards of chapter 2 that were in effect prior to March 9, 1987, will not be reevaluated or medically disqualified solely on the basis of the new standards. Other standards may be prescribed in the event of mobilization or a national emergency.

(2) The standards of chapter 2 apply to

(a) Applicants for appointment as commissioned or warrant officers in the Regular Army, the Army of the United States (AUS), or in the Reserve Components of the Army, including the ARNG of the United States and the USAR.

(b) Applicants for enlistment in the Regular Army. For medical conditions or physical defects predating original enlistment, these standards are applicable for enlistees' first 6 months of active duty. (However, for members of the ARNG or USAR who apply for enlistment in the Regular Army or who reenter active duty for training under the "split-training" option, the standards of chapter 3 are applicable.)

(c) Applicants for enlistment in the USAR and Federally recognized units or organizations of the ARNG. For medical conditions or physical defects predating original enlistment, these standards are applicable during the enlistees' initial period of active duty for training until their return to Reserve Component units.

(d) Applicants for reenlistment in the Regular Army, Army Reserve components, and Federally recognized units or organizations of the ARNG after a period of more than 6 months has elapsed since discharge.

(e) Applicants for the United States Military Academy (USMA), Scholarship or Advanced Course Army Reserve Officers' Training Corps (ROTC), Uniformed Services University of the Health Sciences (USUHS), and all other Army special officer procurement programs; for example, Officer Candidate School (OCS).

SOURCE: AR40-501 UPDATE, p. 5.

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2-21. Height
The causes for rejection for appointment, enlistment, and induction in relation to height standards are established by each of the military Services. Standards for the Army are-

a. Men: Height below 60 inches or over 80 inches.

b. Women: Height below 58 inches or over 80 inches.

2-22. Weight
The causes for rejection for appointment, enlistment, and induction in relation to weight standards are established by each of the military Services. Standards for the Army are contained in tables 2-1 and 2-2 (located after the last appendix of this regulation). All Army applicants for initial appointment as a commissioned officer (to include appointment as a commissioned

warrant officer) meet the standards of AR 600-9. Body composition measurements may be used as the final determinant in evaluating an applicant's acceptability.

2-23. Body build

The causes for rejection for appointment, enlistment, and induction are

a. Congenital malformation of bones and joints. (See paras 2-9, 2-10, and 2-11.)

b. Deficient muscular development which would interfere with the completion of required training.

c. Evidence of congenital asthenia or body build which would interfere with the completion of required training.

SOURCE: AR40-501 UPDATE, p. 11

TABLE 2-1 Militarily acceptable weight (in pounds) as related to age and height for males—initial Army procurement

Height (inches)	Minimum weight (any age)	Maximum weight by years of age 16–20	21–30	31–35	36–40	41 and over
60	100	158	163	162	157	150
61	102	163	168	167	162	155
62	103	168	174	173	168	160
63	104	174	180	178	173	165
64	105	179	185	184	179	171
65	106	185	191	190	184	176
66	107	191	197	196	190	182
67	111	197	203	202	196	187
68	115	203	209	208	202	193
69	119	209	215	214	208	198
70	123	215	222	220	214	204
71	127	221	228	227	220	210
72	131	227	234	233	226	216
73	135	233	241	240	233	222
74	139	240	248	246	239	228
75	143	246	254	253	246	234
76	147	253	261	260	252	241
77	151	260	268	266	259	247
78	153	267	275	273	266	254
79	159	273	282	281	273	260
80	166	280	289	288	279	267

SOURCE: AR 40-501, UPDATE, p. 74

TABLE 2-2 Militarily acceptable weight (in pounds) as related to age and height for females—initial Army procurement

Height (inches)	Minimum weight (any age)	Maximum weight by years of age 18–20	21–24	25–30	31–35	36–40	41 and over
58	90	120	124	126	129	132	135
59	92	122	126	128	131	134	137
60	94	124	128	130	133	136	139
61	96	127	130	132	135	139	141
62	98	128	132	134	137	140	144
63	100	132	134	136	139	143	145
64	102	135	136	139	143	145	149
65	104	138	140	144	148	150	153
66	106	141	145	148	151	153	157
67	109	145	149	152	156	158	162
68	112	150	153	156	160	162	166
69	115	154	157	161	164	167	170
70	118	158	162	165	168	171	174
71	122	162	166	169	173	175	179
72	125	167	171	174	178	183	184
73	128	171	[illegible]	179	183	186	190
74	130	175	182	185	188	191	195
75	133	179	[illegible]	190	194	196	200
76	136	184	192	196	199	202	205
77	139	188	197	201	204	207	211
78	141	192	203	206	209	213	216
79	144	196	208	211	215	218	220
80	147	201	213	216	219	223	225

SOURCE: AR 40-501, UPDATE, p. 74

U.S. NAVY

The standards for accession into the U.S. Navy are included in the *Navy Recruiting Manual, Enlisted* (COMNAVCRUITCOM INSTRUCTION 1130.8C (CRUITMAN-ENL). This manual is extensive and only excerpts from Chapter 1, (4) NAVY HEALTH AND PHYSICAL READINESS PROGRAM that apply to height, weight, and body composition with supporting tables are included here.[2]

(4) NAVY HEALTH AND PHYSICAL READINESS PROGRAM

(a) It is the expressed policy of the Chief of Naval Operations that all members of the Navy except those excused for medical reasons, shall attain and maintain a condition of health and physical readiness consistent with their duties. Excess body fat is a serious detriment to health, longevity, stamina and military appearance. The need to maintain a high state of health and physical readiness throughout the service is essential to ensure combat readiness and personal effectiveness. All Navy applicants must become familiar with and understand physical readiness standards contained in OPNAV Instruction 6110.1 Series.

(b) The physical readiness standards for all enlisted programs include a Height/Weight Screening Table (pg 1-I-64) and a backup procedure for measuring body fat percentage as the determinant for qualification. Applicants who exceed the limits of the screening tables will be measured for body fat by MEPS personnel. Male applicants measuring 29% body fat or greater and female applicants measuring 34% or greater, will not be enlistment eligible. Procedures for body fat measurement are outlined in OPNAVINST 6110.1 Series.

(c) All applicants for enlistment who exceed the height/weight screening tables (pg 1-I-64) shall be counseled on the need to conform to Navy physical readiness standards in order to be enlisted, promoted or reenlisted in the U.S. Navy, a page 13 entry (NAVPERS 1070/613), shall be made documenting the counseling and acknowledging the Navy's Physical Readiness Standards. The proper page 13 documentation is contained in this paragraph.
SOURCE: CRUITMAN-ENL 1130.8C, p. 1-I-63.

[2] Further information concerning the Navy recruitment regulations can be obtained from Commander, Navy Recruiting Command, 4015 Wilson Boulevard, Arlington, VA 22203-1991.

Table of minimum waiverable weight and height

	Male		Female	
Height (inches)	Accession Minimum	Waiverable To	Accession Minimum	Waiverable To
58*	98	88	90	81
59	99	89	92	83
60	100	90	94	85
61	102	92	96	86
62	103	93	98	88
63	104	94	100	90
64	105	95	102	92
65	106	95	104	94
66	107	96	106	98
67	111	100	109	98
68	115	104	112	101
69	119	111	118	106
70	123	111	118	106
71	127	114	122	110
72	131	118	125	113
73	135	122	128	115
74	139	125	132	119
75	143	129	136	122
76	147	132	139	125
77	151	136	143	129
78	153	138	147	132

*Height waiver required.

SOURCE: U.S. Navy: COMNAVCRUITCOM INSTRUCTION 1130.8C, p. 11-15.

Navy Screening Tables for Weight by Height

Height (inches)	Maximum Weight (pounds)	Height (inches)	Maximum Weight (pounds)
58*	130	58*	124
59*	134	59*	127
60	139	60	131
61	143	61	135
62	148	62	138
63	152	63	142
64	157	64	145
65	162	65	149
66	167	66	153
67	172	67	156
68	176	68	160
69	182	69	163
70	187	70	167
71	192	71	171
72	197	72	175
73	202	73	178
74	208	74	181
75	213	75	185
76	219	76	189
77	224	77	192
78	230	78	196

*Height waiver required.

NOTE: In this table standards for men are listed on the left and standards for women are listed on the right.

SOURCE: U.S. NAVY: COMNAVCRUITCOM INSTRUCTION 1130.8C, p. 1-1-64.

B

Retention Standards for the Military Services

The military services maintain separate physical standards for height, weight, and body fat for retention. These are included in the regulations that implement the Department of Defense (DOD) directive 1308.1 dated 29 June 1981 that established a weight control program in all the Services. For each service the physical standards are included within broader military regulations governing the entire weight control program. This Appendix therefore includes excerpts from the regulations currently in effect that govern height, weight, and body fat estimation for retention for the U.S. Army, U.S. Navy, U.S. Air Force, and U.S. Marine Corps. However, the full military regulation titles and numeric specifications are provided for additional information.

U.S. ARMY

The standards for retention in the U.S. Army are included in Army Regulation 600-9: **The Army Weight Control Program** (update 1 September 1986) and include the changes listed in the 1 October 1991 Interim Change to this regulation detailed in Appendix E. This regulation is extensive and excerpts here include: the stated purpose of the regulation, details of procedures, and relevant reference tables.[1]

Section I Introduction

1. Purpose
This regulation establishes policies and procedures for the implementation of the Army Weight Control Program.

2. References
Required publications are listed in appendix A.

3. Explanation of abbreviations and terms
Abbreviations and special terms used in this regulation are explained in the glossary.

4. Objectives

a. The primary objective of the Army Weight Control Program is to insure that all personnel—

(1) Are able to meet the physical demands of their duties under combat conditions.

(2) Present a trim military appearance at all times.

b. Excessive body fat—

(1) Connotes a lack of personal discipline.

(2) Detracts from military appearance.

(3) May indicate a poor state of health, physical fitness, or stamina.

c. Objectives of the Army Weight Control Program are to—

(1) Assist in establishing and maintaining—

(*a*) Discipline.

(*b*) Operational readiness.

(*c*) Optimal physical fitness.

(*d*) Health.

(*e*) Effectiveness of Army personnel through proper weight control.

(2) Establish appropriate body fat standards.

(3) Provide procedures for which personnel are counseled to assist in meeting the standards prescribed in this regulation.

(4) Foster high standards of professional military appearance expected of all personnel.

[1]Further information concerning this regulation can be obtained from Headquarters, Department of the Army (SGPS-CO B), 5109 Leesburg Pike, Falls Church, VA 22041-2358.

Section II Responsibilities

5. General

The Army traditionally has fostered a military appearance which is neat and trim. Further, an essential function of day-to-day effectiveness and combat readiness of the Army is that all personnel are healthy and physically fit. Self-discipline to maintain proper weight distribution and high standards of appearance are essential to every individual in the Army.

SOURCE: AR 600-9 UPDATE, p. 3.

*****

Section III Weight Control

20. Policy

a. Commanders and supervisors will monitor all members of their command (officers, warrant officers, and enlisted personnel) to insure that they maintain proper weight, body composition (as explained in the glossary), and personal appearance. At minimum, personnel will be weighed when they take the Army Physical Fitness Test (APFT) or at least every 6 months. Personnel exceeding the screening table weight shown in table 1) or identified by the commander or supervisor for a special evaluation will have a determination made of percent body fat. Identification and counseling of overweight personnel are required.

b. Commanders and supervisors will provide educational and other motivational programs to encourage personnel to attain and maintain proper weight standards. Such programs will include:

(1) Nutrition education sessions conducted by qualified health care personnel.

(2) Exercise programs, even though minimum APFT standards are achieved.

c. Maximum allowable percent body fat standards are as follows:

Age Group: 17-20

Male (% body fat): 20
Female (% body fat): 28

Age Group: 21-27

Male (% body fat): 22
Female (% body fat): 30

Age Group: 28-39

Male (% body fat): 24
Female (% body fat): 32

Age Group: 40 & Older

Male (% body fat): 26
Female (% body fat): 34

However, all personnel are encouraged to achieve the more stringent Department of Defense (DOD) wide goal, which is 20 percent body fat for males and 26 percent body fat for females.

d. Personnel who are overweight (as explained in the glossary):

(1) Will be considered nonpromotable (to the extent such nonpromotion is permitted by law).

(2) Will not be authorized to attend professional military or civilian schooling.

(3) Will not be assigned to command positions.

21. Procedures

a. Body fat composition will be determined for personnel:

(1) Whose body weight exceeds the screening table weight in table 1.

(2) When the unit commander or supervisor determines that the individual's appearance suggests that body fat is excessive.

b. Routine weigh-ins will be accomplished at the unit level. Percent body fat measurements will be accomplished by company or similar level commanders (or their designee) in accordance with standard methods prescribed in Appendix B to this regulation. Soldiers will be measured by individuals of the same gender. If this cannot be accomplished, a female soldier will be present when males measure females. IRR members on AT, ADT, and SADT will have a weigh in, and body fat evaluation (if required) by the unit to which attached. Active and Reserve component personnel and units with soldiers exceeding the body fat standards in paragraph 20c, above, will be provided weight reduction counseling.

c. The sample correspondence shown in figure 1 will be completed and retained by the unit commander or supervisor to document properly recommendations and actions taken in each case.

d. A medical evaluation will be accomplished by health care personnel when the soldier has a medical limitation, or is pregnant, or when requested by the unit commander. One is also required for soldiers being considered for separation due to failure to make satisfactory progress in a weight control program, or within 6 months of ETS. Aircraft crew members, who exceed the body fat standards, will be referred to a flight surgeon for possible impact on flight status. If an individual's condition is diagnosed by medical authorities to result from an underlying or associated disease process, health care personnel will take one of the following actions.

(1) Prescribe treatment to alleviate the condition and return personnel to their unit.

(2) Hospitalize individuals for necessary treatment; this action applies to Active Army personnel only. Reserve Component personnel will be referred to their personal physician for further evaluation or treatment at the individual's expense.

(3) Determine whether the individual's condition is medically disqualifying for continued service. In these cases, disposition will be made under provisions of appropriate regulations.

e. If health care personnel discover no underlying or associated disease process as the cause of the condition and the individual is classified as overweight, these facts will be documented and the individual entered in a weight control program. Suspension of favorable personnel actions will be initiated under AR 600-31 for personnel in a weight control program.

(1) The required weight loss goal of 3 to 8 pounds per month is considered a safely attainable goal to enable soldiers to lose excess body fat and meet the body fat standards described in para 20c. Weigh ins will be made by unit personnel monthly (or during unit assemblies for ARNG and USAR personnel) to measure progress. A body fat evaluation may also be done by unit personnel to assist in measuring progress.

(2) As an exception to *g* below, an individual who has no weight loss after any two consecutive monthly weigh ins may be referred by the commander or supervisor to health care personnel for reevaluation. If health care personnel are unable to determine a medical reason for lack of weight loss, and if the individual is not in compliance with the body fat standards at paragraph 20, and still exceeds the screening table weight (table 1), the commander or supervisor will inform the individual that

(*a*) Progress is unsatisfactory.

(*b*) He or she is subject to separation as specified in *j* below.

f. Commanders and supervisors will remove individuals administratively from a weight control program as soon as the body fat standard is achieved. The removal action will be documented as shown in figure 1; removal of suspension of favorable personnel actions will be accomplished at that time.

g. After a period of dieting and/or exercise for 6 months, soldiers who have not made satisfactory progress (as explained in the glossary) and who still exceed the screening table and body fat standards will be processed as follows.

(1) If health care personnel determine that the condition is due to an underlying or associated disease process, action described in *d* above will be taken.

(2) If no underlying or associated disease process is found to cause the overweight condition, the individual will be subject to separation from the Service under appropriate regulations indicated in *j* below.

h. Personnel will be continued in a weight control program (as provided in *c* through *g* above) after the initial 6-month period if they:

(1) Still exceed the body fat standard.

(2) Have made satisfactory progress toward their weight loss (as indicated in the glossary), or are at or below the screening table weight (table 1).

(3) For RC personnel only. If the individual has not obtained an evaluation from his/her personal physician UP of para 20*d*(2) above, and cannot demonstrate that the overweight condition results from an underlying or associated disease process, the individual may be separated under appropriate regulations without further medical evaluation by health care personnel.

i. To assist commanders and supervisors, a flow chart outlining procedural guidance is shown at figure 2.

j. The commander or supervisor will inform the individual in writing that initiation of separation proceedings is being considered under the following regulations: AR 635-200, chapter 5-15; AR 635-100, chapter 5; NGR 600-200, chapter 7; NGR 600-101; NGR 600-5; NGR 635-100; AR 135-175; or AR 135-178. This procedure will be followed unless a medical reason is found to preclude the loss of weight or there is other good cause to justify additional time in the weight control program.

(1) The individual will immediately respond to the separation consideration letter in writing. The commander or supervisor will consider the response and initiate separation action if no adequate explanation is provided, unless the individual submits an application for retirement, if eligible. USAR personnel in an AGR status who fall under the purview of this paragraph will be released from AD and returned to the appropriate Reserve control group.

(2) If separation action is not initiated or does not result in separation, the individual will be entered or continued in a weight control program, as specified in *e* above.

k. Following removal from a weight control program, if it is determined (under *a* above) that an individual exceeds the screening table weight (table 1) and the body fat standard prescribed in paragraph 20*c* within 36 months, the following will apply: (1) If the unit commander determines that the individual exceeds the screening table weight and the body fat standard:

(*a*) Within 12 months from the date of the previous removal from the program and no underlying or associated disease process is found as the cause of the condition, the individual will be subject to separation from the Service under *j* above. (Satisfactory progress in a previous weight control program will not be considered a good reason to justify time in a new program.)

(*b*) After the 12th month, but within 36 months from the date of the previous removal from the program, and no underlying or associated disease process is found as the cause of the condition, the individual will be allowed 90 days to meet the standards. Personnel who meet the body fat standard after that period will be removed from the program. All others will be subject to separation from the Service under *j* above.

(*c*) Personnel who meet the AR 600-9 standards and become pregnant will be exempt from the standards for the duration of the pregnancy plus the period of convalescent leave after birth of the child. They will be entered or reentered in a weight control program, if required, after completion of convalescent leave and approval of a medical doctor that they are fit for participation in a weight control program. This procedure also applies to individuals in a medical holding unit who have been hospitalized for long periods. Soldiers entered/reentered in a weight control program after pregnancy, prolonged treatment, or hospitalization will be considered to be in a new weight control program. Para 20*k* of this regulation will not apply at that time.

(2) If the individual is determined to exceed the body fat standard and the condition is due to an underlying or associated disease process, action described in *d* above will be taken.

l. Inherent in the responsibility of selection boards is the obligation to select only those individuals who are considered to be physically fit to perform the duties required of them at all times. Compliance with the Army Weight Control Program as prescribed in this regulation will be considered in the selection process for promotion, professional military or civilian schooling, or assignment to command positions. Procedures for commanders and supervisors to provide current information for use by selection boards indicating whether individuals meet the prescribed standards will be included in DA regulations or issued by separate correspondence.

m. Records will be maintained in unit files for personnel in weight control programs. On transfer from one unit to another, the losing commander or supervisor will forward the records and a statement to the gaining unit with information indicating the status of the individual's participation in a weight control program. When the transfer is a permanent change of station, the unit commander's statement and records will be—

(1) Filed as transfer documents in the Military Personnel Records Jacket, US Army, under AR 640-10.

(2) Removed on inprocessing.

n. Upon removal from the weight control program, unit records on participation in a weight control program will be maintained at unit level for a period of 36 months from date of removal. If the soldier is transferred to another unit prior to completion of 36 months, action will be taken in accordance with paragraph 21*m* above.

22. Reenlistment criteria

a. Personnel who exceed the screening table weight at table 1 and the body fat standard for their current age group in paragraph 20*c* will not be allowed to reenlist or extend their enlistment.

b. Exceptions to policy for Active Army personnel (including RC personnel on AD) are prescribed in this subparagraph. For soldiers who are otherwise physically fit and have performed their duties in a satisfactory manner, the commander exercising General Court Martial Convening Authority or the first general officer in the soldier's normal chain of command (whichever is in the most direct line to the soldier) may approve the following exceptions to policy.

(1) Extension of enlistment may be authorized for personnel who meet one of the following criteria:

(*a*) Individuals who have a temporary medical condition which precludes loss of weight. In such cases, the nature of on-going treatment will be documented; the extension will be for the minimum time necessary to correct the condition and achieve the required weight loss.

(*b*) Pregnant soldiers who are otherwise fully qualified for reenlistment, including those with approved waivers, but who exceed acceptable standards prescribed in this regulation, will be extended for the minimum period which will allow birth of the child, plus 6 months. Authority, which will be cited on DA Form 1695 (Oath of Extension of Enlistment), is AR 601-280, paragraph 3-3. On completion of the period of extension, the soldier will be reevaluated under paragraph 20.

(2) Exceptions to policy allowing reenlistment/extension of enlistment are authorized only in cases where:

(*a*) Medically documented conditions (para 21*b*) preclude attainment of required standards.

(*b*) Disability separation is not appropriate.

c. All requests for extension of enlistment for ARNG and USAR (TPU and IRR) personnel not on AD will be processed under NGR 600-200 or AR 140-111, chapter 3, as appropriate.

d. Requests for exceptions to policy will be forwarded through the chain of command, with the commander's personal recommendation and appropriate comment at each level. As a minimum, requests will include:

(1) The physician's evaluation.

(2) A record of progress in the weight control program.

(3) Current height and weight.

(4) Body fat content.

(5) Years of active Federal service.

(6) Other pertinent information.

e. Soldiers, who have completed a minimum of 18 years of Active Federal Service (AFS), may, if otherwise eligible, be extended for the minimum time required to complete 20 years AFS. Retirement must be accomplished not later than the last day of the month in which the soldier attains retirement eligibility. Application for retirement will be submitted at the time extension is authorized. Approval/disapproval authority is outlined in AR 601-280.

f. USAR soldiers, who have completed a minimum of 18 years of qualifying service for retired pay at age 60, may be extended for the minimum time required to complete 20 years qualifying service. Transfer to the IRR, Retired Reserve, or discharge will be accomplished at the end of the retirement year (RYE) in which the soldier attains the 20 qualifying years.

SOURCE: AR 600-9 UPDATE, pp. 4-6.

TABLE 1 Weight for Height Table (Screening Table Weight)

Height (in inches)	Male Age 17–20	Male Age 21–27	Male Age 28–39	Male Age 40+	Female Age 17–20	Female Age 21–27	Female Age 28–39	Female Age 40+
58					109	112	115	119
59					113	116	119	123
60	132	136	139	141	116	120	123	127
61	136	140	144	146	120	124	127	131
62	141	144	148	150	125	129	132	137
63	145	149	153	155	129	133	137	141
64	150	154	158	160	133	137	141	145
65	155	159	163	165	137	141	145	149
66	160	163	168	170	141	146	150	154
67	165	169	174	176	145	149	154	159
68	170	174	179	181	150	154	159	164
69	175	179	184	186	154	158	163	168
70	180	185	189	192	159	163	168	173
71	185	189	194	197	163	167	172	177
72	190	195	200	203	167	172	177	183
73	195	200	205	208	172	177	182	188
74	201	206	211	214	178	183	189	194
75	206	212	217	220	183	188	194	200
76	212	217	223	226	189	194	200	206
77	218	223	229	232	193	199	205	211
78	223	229	235	238	198	204	210	216
79	229	235	241	244	203	209	215	222
80	234	240	247	250	208	214	220	227

Notes:

1. The height will be measured in stocking feet (without shoes), standing on a flat surface with the chin parallel to the floor. The body should be straight but not rigid, similar to the position of attention. The *measurement* will be rounded to the nearest inch with the following guidelines:
   a. If the height fraction is less than 1/2 inch, round down to the nearest whole number in inches.
   b. If the height fraction is 1/2 inch or greater, round up to the next highest whole number in inches.
2. The weight should be measured and recorded to the nearest pound within the following guidelines:
   a. If the weight fraction is less than 1/2 pound, round down to the nearest pound.
   b. If the weight fraction is 1/2 pound or greater, round up to the next highest pound.
3. All measurements will be in a standard PT uniform (gym shorts and T-shirt, without shoes).
4. If the circumstances preclude weighing soldiers during the APFT, they should be weighed within 30 days of the APFT.

SOURCE: AR 600-9, UPDATE, p. 7

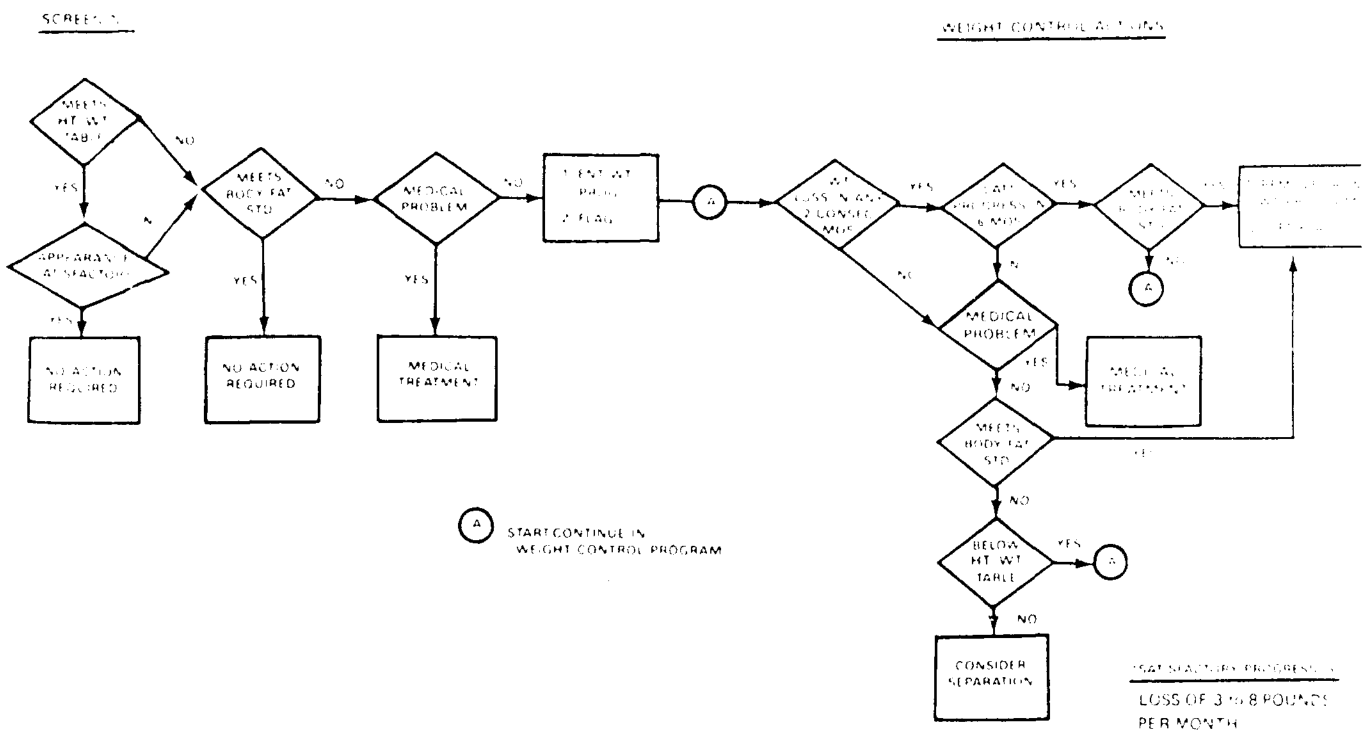

Figure 2. Flow process guide for screening and weight control actions (applies to all personnel; officers, warrant officers, enlisted)
SOURCE: AR 600-9, UPDATE, p. 11.

AR 600-9 UPDATE: Appendix B
Standard Methods for Determining Body Fat Using Body Circumferences, Height and Weight

B-1. Introduction

a. The procedures for the measurements of height, weight, and specific body circumferences for the estimation of body fat are described in this appendix.

b. Although circumferences may be looked upon by untrained personnel as easy measures, they can give erroneous results if proper precautions are not followed. The individual taking the measurements must have a thorough understanding of the appropriate anatomical landmarks and measurement techniques. Unit commanders should require that designated personnel have hands-on training and read the instructions regarding technique and location, and practice before official determinations are made. Two members of the unit should be utilized in the taking of measurements, one to place the tape measure and determine measurements, the other to assure proper placement and tension of the tape, as well as to record the measurement on the worksheet. The individual taking the measurements should be of the same sex as the soldier being measured; the individual who assists the measurer and does the recording may be of either sex. The two should work with the soldier between them so the tape is clearly visible from all sides. Measurements will be made three times, in accordance with standard anthropometric measurement procedures. This is necessary for reliability purposes, since the greater number of measurements, the lesser the standard of deviation. Also, if only two measurements were taken, there would be no way to tell which measurement was the most accurate. If there is greater than ¼-inch difference between the measurements, then continue measuring until you have three measurements within ¼-inch of each other. An average of the scores that are within ¼-inch of each other will be used.

c. When measuring circumferences, compression of the soft tissue is a problem that requires constant attention. The tape will be applied so that it makes contact with the skin and conforms to the body surface being measured. It should not compress the underlying soft tissues. Note, however, that in the hip circumference, more firm pressure is needed to compress gym shorts. All measurements are made in the horizontal plane, (i.e., parallel to the floor), unless indicated otherwise.

d. The tape measure should be made of a non-stretchable material, preferably fiberglass; cloth or steel tapes are unacceptable. Cloth measuring tapes will stretch with usage and most steel tapes do not conform to body surfaces. The tape measure should be calibrated, i.e., compared with a yardstick or a metal ruler to ensure validity. This is done by aligning the fiberglass tape measure with the quarter inch markings on the ruler. The markings should match those on the ruler; if not, do not use that tape measure. The tape should be ¼- to ½-inch wide (not exceeding ½-inch) and a minimum of 5-6 feet in length. A retractable fiberglass tape is the best type for measuring all areas. Tapes currently available through the Army Supply System (Federal Stock Number 8315-00-782-3520) may exceed the ½-inch width limits and could impact on circumferential measurements. Efforts are being made to replace the supply system tape with a narrower retractable tape. In the interim, the current Army supply system tape may be used if retractable tapes cannot be purchased by unit budget funds available and approved by installation commanders.

B-2. Height and weight measurements

a. The height will be measured with the soldier, in stocking feet (without shoes) and standard PT uniform, i.e., gym shorts and T-shirt, standing on a flat surface with the head held horizontal, looking directly forward with the line of vision horizontal, and the chin parallel to the floor. The body should be straight but not rigid, similar to the position of attention. Unlike the screening table weight this measurement will be recorded to the nearest ¼-inch in order to gather a more accurate description of the soldier's physical characteristics.

b. The weight will be measured with the soldier in a standard PT uniform, i.e., gym shorts and a T-shirt. Shoes will not be worn. The measurement should be made on scales available in units and recorded to the nearest pound with the following guidelines:

(1) If the weight fraction of the soldier is less than ½-pound, round down to the nearest pound.

(2) If the weight fraction of the soldier is ½-pound or greater, round up to the next whole pound.

B-3. Description of circumference sites, and their anatomical landmarks and technique

a. All circumference measurements will be taken three times and recorded to the nearest ¼-inch (or 0.25). If the measurements are within ¼-inch of each other, derive a mathematical average to the nearest quarter (¼) of an inch. If the measurements differ by ¼-inch or more continue measurements until you obtain three measures within ¼-inch of each other. Then average the three closest measures.

b. Each set of measurements will be completed sequentially to discourage assumption of repeated measurement readings. For males, complete 1 set of abdomen and neck measurements, NOT three abdomen circumferences followed by three neck circumferences. Continue the process by measuring the abdomen and neck in series until you have three sets of measurements. For females, complete one set of hip, forearm, neck, and wrist measurements, NOT 3 hip followed by three forearm etc. continue the process by measuring hip, forearm, neck, and wrist series until you have 3 sets of measurements.

c. Worksheets for computing body fat are at figure B-1 (males) and figure B-3 (females). Local reproduction is authorized. A blank copy of DA Forms 5500-R and 5501-R is located at the back of this volume. These forms will be reproduced locally on 8½ × 11-inch paper. Supporting factor tables are located at tables B-1 and B-2 (males) and tables B-3 through B-8 (females) and include specific steps for preparing body fat content worksheets.

d. Illustrations of each tape measurement are at figure B-2 (males) and figure B-4 (females). A training videotape (TVT 8-103) is also available at Visual Information Libraries, and/or Training Audiovisual Support Centers (TASC).

B-4. Circumference sites and landmarks for males

a. Abdomen. The soldier being measured will be standing with arms relaxed. The abdominal measurement is taken at a level coinciding with the midpoint of the navel (belly button) with the tape placed so that it is level all the way around the soldier being measured. Record the measurement at the end of a normal expiration. It is important that the soldier does not attempt to hold his abdomen in, thus resulting in a smaller measurement. Also the tape must be kept level across the abdomen and back.

b. Neck. The soldier being measured will be standing, looking straight ahead, chin parallel to the floor. The measurement is taken by placing the tape around the neck at a level just below the larynx (Adam's apple). Do not place the tape measure over the Adam's apple. The tape will be as close to horizontal (the tape line in the front of the neck should be at the same height as the tape line in the back of the neck) as anatomically feasible. In many cases the tape will slant down toward the front of the neck. Therefore, care should be taken so as not to involve the shoulder/neck muscles (trapezius) in the measurement. This is a possibility when a soldier has a short neck.

B-5. Circumference sites and landmarks for females

a. Neck. This procedure is the same as for males.

b. Forearm. The soldier being measured will be standing with the arm extended away from the body so that the forearm is in plain view of the measurer, with the hand palm up. The soldier should be allowed to choose which arm he/she prefers to be measured. Place the tape around the largest forearm circumference. This will be just below the elbow. To ensure that this is truly the largest circumference, since it is being visually identified, slide the tape along the forearm to find the largest circumference.

c. Wrist. The soldier being measured will stand with the arm extended away from the body so that the wrist is in plain view of the measurer. The tape will be placed around the wrist at a point above the hand but below the lower end of the bones of the forearm.

d. Hip. The soldier taking the measurement will view the person being measured from the side. Place the tape around the hips so that it passes over the greatest protrusion of the gluteal muscles (buttocks) keeping the tape in a horizontal plane (i.e., parallel to the floor). Check front to back and side to side to be sure the tape is level to the floor on all sides before the measurements are recorded. Since the soldier will be wearing gym shorts, the tape can be drawn snugly to minimize the influence of the shorts on the size of the measurement.

B-6. Preparation of the body fat content worksheets

NOTE: IT IS EXTREMELY IMPORTANT THAT YOU READ ALL OF THESE INSTRUCTIONS BEFORE ATTEMPTING TO COMPLETE THE BODY FAT CONTENT WORKSHEETS. MAKE SURE THAT YOU HAVE A COPY OF THE WORKSHEET IN FRONT OF YOU WHEN YOU ARE READING THESE INSTRUCTIONS.

a. The following paragraphs will provide information needed to prepare the Body Fat Content Worksheets for males and females, DA Form 5500-R and 5501-R, Dec 85. The worksheets are written in a stepwise fashion. The measurements and computation processes are different for males and females.

b. You will be responsible for completing a worksheet for soldiers who exceed the screening table weight (Table 1) located in this regulation, or when a unit commander or supervisor determines that the individual's appearance suggests that body fat is excessive (para 20*a* AR 600-9). The purpose of this form is to help you determine the soldier's percent body fat using the circumference technique described in this regulation.

Before you start, you should have a thorough understanding of the measurements to be made as outlined in this appendix. You will also need a scale for measuring body weight, a height measuring device, and a measuring tape, with quarter inch increments, for the circumference measurements. The specific description of these are found earlier in this appendix.
SOURCE: AR 600-9 UPDATE, pp. 12-13.

*****

B-7. Steps for preparing the Male Body Fat Content Worksheet, DA Form 5500-R, Dec 85

Name Print the soldier's last name, first name, and middle initial in the NAME block. Also include his Rank, and Social Security Number.
Age Print his age in years in the AGE block.

Weight Measure the soldier's weight as described in this appendix, to the nearest quarter of an inch, and record the measurement in the WEIGHT block.

Height Measure the soldier's height as described in this appendix, to the nearest pound, and record in the HEIGHT block.

Note: Follow the rules for rounding of height and weight measurements as described earlier in this appendix.

Step 1. Abdominal Measurement
Measure the soldier's abdominal circumference to the nearest quarter of an inch, and record in the block labeled "FIRST".

Step 2. Neck Measurement
Measure the soldier's neck circumference to the nearest quarter of an inch, and record in the block labeled "FIRST".

Note: REPEAT STEPS 1 and 2, in series until you have completed three sets of abdomen and neck circumferences.

Step 3. Average Abdominal Measurement
Find the mathematical average of the FIRST, SECOND, and THIRD abdominal circumferences by adding them together and dividing by three. Place this number to the nearest quarter of an inch, in the block marked AVERAGE, for STEPS 1 and 3.

Step 4. Average Neck Measurement
Find the mathematical average of your FIRST, SECOND, and THIRD neck circumferences by adding them together and dividing by three. Place this number to the nearest quarter of an inch in the block marked AVERAGE, for STEPS 2 and 4.

Step 5. Abdomen-Neck Difference
Subtract the number found in the AVERAGE block of STEP 4 from the number found in the AVERAGE block in STEP 3. Enter the result in STEP 5. This is the difference between the abdomen and neck circumferences.

Step 6. Abdomen-Neck Factor
Go to Table B-1 the Abdomen-Neck Factor Table, and locate the abdomen-neck difference in the left-most column. If the difference is a whole number, i.e., 15 inches, the Abdomen-Neck Factor is 89.93. If the difference is 15.25 inches, the factor would be 90.48, if the difference is 15.50, the factor is 91.02, and if the difference is 15.75, the factor is 91.55. Enter the appropriate factor in STEP 6.

Step 7. Height Factor
Go to Table B-2, the Height Factor Table, and locate the soldier's height in the left most column. If the height is a whole number, i.e., 64 inches, the factor is 77.15. If the height is not a whole number, i.e., 64.25 inches, the factor is 77.27, if the height is 64.50 inches the factor is 77.39, and if the height is 64.75 inches, the factor is 77.50. Enter the appropriate factor in STEP 7.

Note: Therefore, the general rule for the factor tables is if the measure or difference is a whole number, your factor will be located under the 0.00 column, directly across from the inches column. Columns .25, .50, .75 correspond to measurements that are not whole numbers, but rather are fractions of an inch.

Step 8. Percent Body Fat
Subtract the number found in the AVERAGE block of STEP 7 from the number found in the AVERAGE block of STEP 6 and enter the difference in STEP 8. This is the soldier's PERCENT BODY FAT.
SOURCE: AR 600-9 UPDATE, pp. 12-14

TABLE B-1 Male Abdomen and Neck Factor

Difference in inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	53.44	55.06	56.61	58.09
6	59.50	60.85	62.16	63.41
7	64.62	65.78	66.91	68.00
8	69.05	70.07	71.07	72.03
9	72.96	73.87	74.76	75.62
10	76.46	77.28	78.08	78.86
11	79.63	80.37	81.10	81.82
12	82.52	83.20	83.87	84.53
13	85.17	85.81	86.43	87.04
14	87.64	88.22	88.80	89.37
15	89.93	90.48	91.02	91.55
16	92.07	92.58	93.09	93.59
17	94.08	94.57	95.05	95.52
18	95.98	96.44	96.69	97.34
19	97.78	98.21	98.64	99.06
20	99.48	99.89	100.30	100.70
21	101.10	101.49	101.88	102.26
22	102.64	103.02	103.39	103.76
23	104.12	104.48	104.83	105.19
24	105.53	105.88	106.22	106.56
25	106.69	107.22	107.55	107.87
26	108.19	108.51	108.82	[illegible]
27	109.44	109.75	110.05	110.35
28	110.65	110.95	111.24	111.53
29	111.82	112.10	112.39	112.67
30	112.94	113.22	113.49	113.76
31	114.03	114.30	114.56	114.83
32	115.09	115.35	115.60	115.86
33	116.11	116.36	116.61	116.85
34	117.10	117.34	117.56	117.82
35	118.06	118.30	118.53	118.77
36	119.00	119.23	119.46	119.68
37	119.91	120.13	120.35	120.57
38	120.79	121.01	121.23	121.44
39	121.66	121.87	122.08	122.29
40	122.50	122.70	122.91	123.11

SOURCE: AR 600-9, UPDATE, p. 15.

TABLE B-2 Male Height Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
60	75.23	75.35	75.48	75.60
61	75.72	75.84	75.96	76.09
62	76.21	76.33	76.45	76.56
63	76.68	76.80	76.92	77.04
64	77.15	77.27	77.39	77.50
65	77.62	77.73	77.84	77.96
66	78.07	78.18	78.30	78.41
67	78.52	78.63	78.74	78.85
68	78.96	79.07	79.18	79.29
69	79.40	79.50	79.61	79.72
70	79.83	79.93	80.04	80.14
71	80.25	80.35	80.46	80.56
72	80.67	80.77	80.87	80.98
73	81.08	81.18	81.28	81.36
74	81.48	81.58	81.68	81.78
75	81.88	81.98	82.08	82.18
76	82.28	82.38	82.47	82.57
77	82.67	82.77	82.86	82.96
78	83.05	83.15	83.24	83.34
79	83.43	83.53	83.62	83.72
80	83.81	83.90	83.99	84.09

SOURCE: AR 600-9, UPDATE, p. 15.

B-8. Steps for preparing the Female Body Fat Content Worksheet, DA Form 5501-R, Dec 85

Name Print the soldier's last name, and middle initial in the NAME block. Also include her Rank, and Social Security Number.

Age Print her age in years in the AGE block.

Height Measure the soldier's height as described in this appendix, to the nearest quarter of an inch, and record the measurement in the HEIGHT block.

Weight Measure the soldier's weight as described in this appendix, to the nearest pound, and record in the WEIGHT block.

Note: Follow the rounding rules for rounding height and weight measurements as described earlier in this appendix.

Step 1. Weight Factor
Go to Table B-3, the Weight Factor Table, and locate the soldier's weight in the left-most column, which is in 10 pound increments. If the weight is exactly 120 pounds, the factor is found under the "0" column and is 147.24. If the weight is 121 pounds, the factor is found under the "1" column and is 147.62. If the weight is 126 the factor is found under the "6" column and is 149.47. Enter the appropriate weight factor in the CALCULATIONS section, STEP 11 A.

Step 2. Height Factor
Go to *Table B-4, the Height Factor Table, and locate* the soldier's height in the left most column. If the height is a whole number, i.e., 64 inches, the factor is found under the 0.00 column and is 83.75. If the height is not a whole number, i.e., 64.25 inches, the factor is 84.07. If the height is 64.50 inches, the factor is 84.40, and if the height is 64.75 inches, the factor is 84.73. Enter the *appropriate height factor in the* CALCULATIONS section, STEP 11 D.

Step 3. Hip Measurement
Measure the soldier's hip circumference to the nearest quarter of an inch, and record in the block labeled "FIRST."

Step 4. Forearm Measurement
Measure the soldier's forearm to the nearest quarter of an inch, and record in the block labeled "FIRST."

Step 5. Neck Measurement
Measure the soldier's neck circumference to the nearest quarter of an inch, and record in the block labeled "FIRST."

Step 6. Wrist Measurement
Measure the soldier's wrist to the nearest quarter of an inch, and record in the block labeled "FIRST."

Note: REPEAT STEPS 3, 4, 5, and 6 IN SERIES, until you have completed 3 sets of Hip, Forearm, Neck, and Wrist circumferences. When you have completed this series, find the mathematical average *for each of the 4 circumference measures and place* each average in its respective AVERAGE block.

Step 7. Hip Factor
Go to Table B-5, the Hip Factor Table, and locate the soldier's AVERAGE hip circumference in the left most column. If the circumference is a whole number, i.e., 36 inches, the Hip Factor is found in the 0.00 column and is 15.83. If the circumference is not a whole number but is 36.25 inches, the factor is 15.94. If the circumference is 36.50 the factor is 16.05. Enter the appropriate factor in the CALCULATIONS section, 11 B.

Step 8. Forearm Factor
Go to Table B-6, the Forearm Factor Table, and locate the soldier's AVERAGE forearm circumference in the left-most column. If the circumference is a whole number, i.e., 10 inches, the factor is found under 0.00 column and is 39.97. If the circumference is not a whole number but is 10.25 inches, the factor is 40.97. *If the circumference* is 10.75 inches, the factor is 40.97. Enter the appropriate factor in the CALCULATIONS, 11 E.

Step 9. Neck Factor
Go to Table B-7, the Neck Factor Table, and locate the soldier's AVERAGE neck circumference in the left-most column. If the circumference is a whole number, i.e., 12 inches, the factor is found under the 0.00 column and is 16.25. If the circumference is not a whole number but is 12.25 inches, the factor is 16.59. If the circumference is 12.50 inches, the factor is 16.93. If the circumference is 12.75 inches, the factor is 17.26. Enter the appropriate factor in the CALCULATIONS section, 11 F.

Step 10. Wrist Factor
Go to Table B-8, the Wrist Factor Table, and locate the soldier's AVERAGE wrist circumference in the left-most column. If the circumference is a whole number, i.e., 7 inches, the factor is found under the 0.00 column and is 3.56. If the circumference is not a whole number but is 7.25 inches, the factor is 3.69. If the circumference is 7.50 inches, the factor is 3.82. If the circumference is 7.75 inches, the factor is 3.94. Enter the appropriate factor in the CALCULATIONS section, 11 G.

Calculations

Line C. Addition of Weight and Hip Factors
Add 11 A, Weight Factor, to 11 B, Hip Factor. Enter the result on line 11 C (Total).

Line H. Addition of Height, Forearm, Neck, and Wrist Factors
Add 11 D, Height Factor, 11 E, Forearm Factor, 11 F, Neck Factor, and 11 G, Wrist Factor together. Enter the result on line 11 H. (Total).

Line I. Percent Body Fat
Subtract Line 11-H from Line-C and enter on Line I. This is the soldier's PERCENT BODY FAT.
SOURCE: AR 600-9 UPDATE, p. 16.

TABLE B-3 Female Weight Factor

Pounds	0	1	2	3	4	5	6	7	8	9
90	134.08	134.58	135.08	135.58	136.07	136.55	137.03	137.50	137.97	138.44
100	138.90	139.35	139.60	140.25	140.69	141.13	141.56	141.99	142.42	142.84
110	143.26	143.67	144.08	144.49	144.89	145.29	145.69	146.08	146.47	146.85
120	147.24	147.62	147.99	148.37	148.74	149.10	149.47	149.83	150.19	150.54
130	150.90	151.25	151.60	151.94	152.28	152.62	152.96	153.30	153.63	153.96
140	154.29	154.61	154.94	155.26	155.58	155.89	156.21	156.52	156.83	157.14
150	157.44	157.75	158.05	158.35	158.65	158.94	159.24	159.53	159.82	160.11
160	160.40	160.68	160.96	161.25	161.53	161.80	162.08	162.35	162.63	162.90
170	163.17	163.44	163.70	163.97	164.23	164.49	164.76	165.01	165.27	165.53
180	165.78	166.04	166.29	166.54	166.79	167.04	167.28	167.53	167.77	168.02
190	168.26	168.50	168.74	168.97	169.21	169.44	169.68	169.91	170.14	170.37
200	170.60	170.83	171.06	171.28	171.51	171.73	171.96	172.18	172.40	172.62
210	172.83	173.05	173.27	173.48	173.70	173.91	174.12	174.33	174.54	174.75

SOURCE: AR 600-9, UPDATE, p. 17.

TABLE B-4 Female Height Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
55	71.97	72.30	72.62	72.95
56	73.28	73.61	73.93	74.26
57	74.59	74.91	75.24	75.57
58	75.90	76.22	76.55	76.88
59	77.20	77.53	77.66	78.19
60	78.51	78.84	79.17	79.49
61	79.82	80.15	80.48	80.80
62	81.13	81.46	81.78	82.11
63	82.44	82.77	83.09	83.42
64	83.75	84.07	84.40	84.73
65	85.06	85.38	85.71	86.04
66	86.36	86.69	87.02	87.35
67	87.67	88.00	88.33	88.65
68	88.98	89.31	89.64	89.96
69	90.29	90.62	90.94	91.27
70	91.60	91.93	92.25	92.58
71	92.91	93.23	93.56	93.89
72	94.22	94.54	94.87	95.20
73	95.52	95.85	96.18	96.51
74	96.83	97.16	97.49	97.81
75	98.14	98.47	98.80	99.12
76	99.45	99.78	100.10	100.43
77	100.76	101.09	101.41	101.74
78	102.07	102.39	102.72	103.05
79	103.38	103.70	104.03	104.36
80	104.68	105.01	105.34	105.67

SOURCE: AR 600-9, UPDATE, p. 17

TABLE B-5 Female Hip Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
30	13.19	13.30	13.41	13.52
31	13.63	13.74	13.85	13.96
32	14.07	14.18	14.29	14.40
33	14.51	14.62	14.73	14.84
34	14.95	15.06	15.17	15.28
35	15.39	15.50	15.61	15.72
36	15.83	15.94	16.05	16.15
37	16.26	16.37	16.48	16.59
38	16.70	16.81	16.92	17.03
39	17.14	17.25	17.36	17.47
40	17.58	17.69	17.60	17.91
41	18.02	18.13	18.24	18.35
42	18.46	18.57	18.68	18.79
43	18.90	19.01	19.12	19.23
44	19.34	19.45	19.56	19.67
45	19.78	19.89	20.00	20.11
46	20.22	20.33	20.44	20.55
47	20.66	20.77	20.88	20.99
48	21.10	21.21	21.32	21.43
49	21.54	21.65	21.76	21.87
50	21.98	22.09	22.20	22.31

SOURCE: AR 600-9 UPDATE, p. 17.

TABLE B-6 Female Forearm Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	19.98	20.98	21.98	22.98
6	23.98	24.98	25.98	26.98
7	27.98	28.98	29.98	30.97
8	31.97	32.97	33.97	34.97
9	35.97	36.97	37.97	38.97
10	39.97	40.97	41.97	42.97
11	43.96	44.96	45.96	46.96
12	47.96	48.96	49.96	50.96
13	51.96	52.96	53.96	54.96
14	55.95	56.95	57.95	58.95
15	59.95	60.95	61.95	62.95

SOURCE: AR 600-9, UPDATE, p. 17.

TABLE B-7 Female Neck Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	6.77	7.11	7.45	7.79
6	8.12	8.46	8.80	9.14
7	9.48	9.82	10.16	10.49
8	10.83	11.17	11.51	11.85
9	12.19	12.53	12.86	13.20
10	13.54	13.88	14.22	14.56
11	14.90	15.23	15.57	15.91
12	16.25	16.59	16.93	17.26
13	17.60	17.94	18.28	18.62
14	18.96	19.30	19.63	19.97
15	20.31	20.65	20.99	21.33

SOURCE: AR 600-9, UPDATE, p. 17.

TABLE B-8 Female Wrist Factor

Inches	0.00	.25 (¼)	.50 (½)	.75 (¾)
5	2.54	2.67	2.80	2.93
6	3.05	3.18	3.31	3.43
7	3.56	3.69	3.82	3.94
8	4.07	4.20	4.33	4.45
9	4.58	4.71	4.83	4.96
10	5.09	5.22	5.34	5.47
11	5.60	5.72	5.85	5.98
12	6.11	6.23	6.36	6.49
13	6.62	6.74	6.87	7.00
14	7.12	7.25	7.38	7.51
15	7.63	7.76	7.89	8.01

SOURCE: AR 600-9, UPDATE, p. 17.

BODY FAT CONTENT WORKSHEET *(Male)*

For use of this form, see AR 600-9; the proponent agency is DCSPER

NAME (Last, First, Middle Initial)	SSN	RANK	NOTE
DOE JOHN	198-00-0000	SGT	¼ = .25
HEIGHT (to nearest 0.25 inch)	WEIGHT (to nearest pound)	AGE	½ = .50
72	175	21	¾ = .75

STEP	FIRST	SECOND	THIRD	AVERAGE (to nearest 0.25 in.)
1 Measure abdomen at the level of the navel *(belly button)* to the nearest 0.25 inch *(Repeat 3 times.)*	36.25	36.50	36.25	36.25
2 Measure neck just below level of larynx *(Adam's apple)* to the nearest 0.25 inch *(Repeat 3 times.)*	16.25	16.25	16.50	16.25
3 Enter the average abdominal measurement to the nearest 0.25 inch				36.25
4 Enter the average neck measurement to the nearest 0.25 inch				16.25
5 Subtract Step 4 from Step 3 *(Enter result)* to the nearest 0.25 inch				20.00
6 Find result from Line 5 *(the difference between Neck and Abdomen)* in Table B-1 *(Abdomen-Neck Factor)*. Enter factor				99.48
7 Find the height in Table B-2 *(Height Factor)*. Enter factor				80.67
8 Subtract Step 7 from Step 6 *(Enter result)*. This is Soldier's Percent Body Fat				18.81

REMARKS

CHECK ONE

✓ Individual is in compliance with Army Standards   _ is not in compliance with the standards

Recommended monthly weight loss is 3-8 lbs

PREPARED BY *(Signature)*	RANK	DATE	APPROVED BY SUPERVISOR *(Printed Name and Signature)*	RANK	DATE

DA FORM 5500-R, DEC 85

Figure B-1. Sample of a completed DA Form 5500

SOURCE: AR 600-9, UPDATE, p. 18.

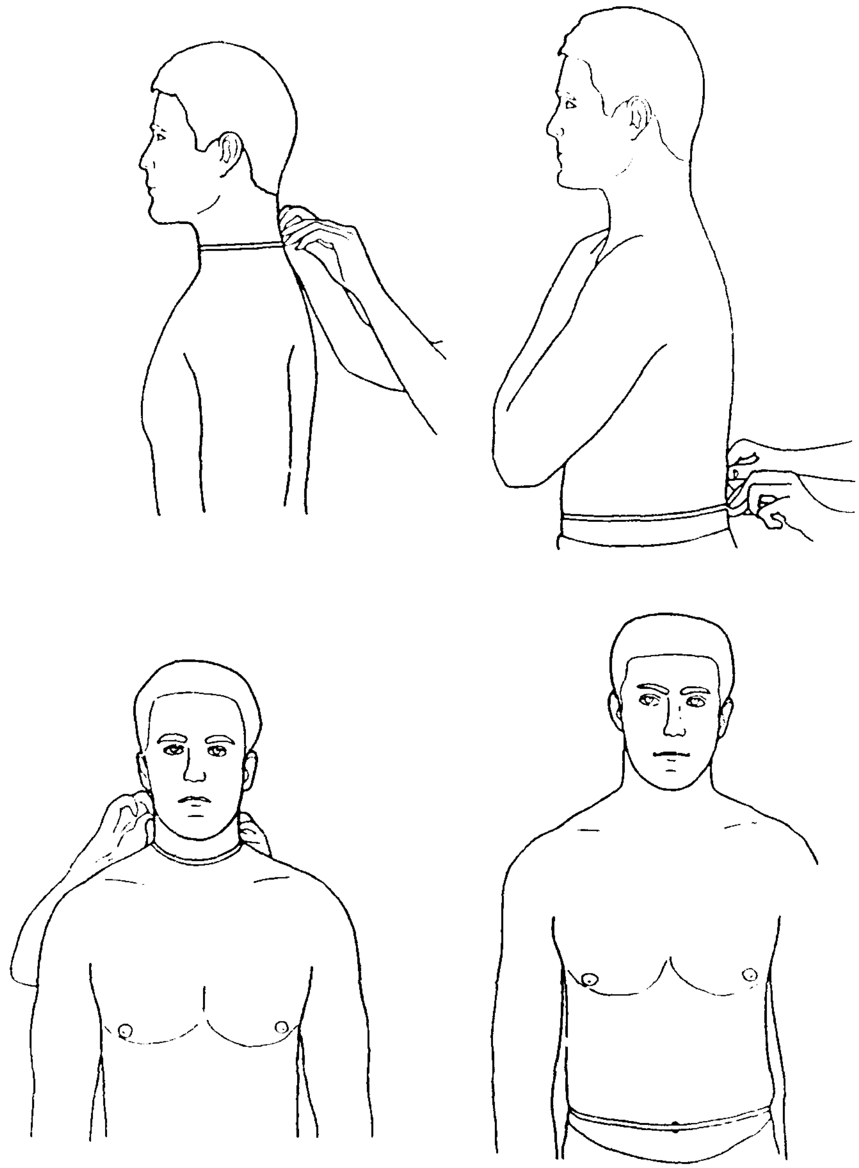

Figure B-2. Male measurement. Upper left, neck measurement; upper right, abdomen measurement; lower left, neck measurement; lower right, abdomen measurement.
SOURCE: AR 600-9, UPDATE, p. 19.

BODY FAT CONTENT WORKSHEET *(Female)*

For use of this form see AR 600-9; the proponent agency is DCSPER

NAME *(Last, First, Middle initial)* DOE, JANE	SSN 432-00-0000	RANK SGT	NOTE ¼ = 25, ½ = 50, ¾ = 75
HEIGHT *(to nearest 0.25 inch)* 63.00	WEIGHT *(to nearest pound)* 132	AGE 21	

STEP	FIRST	SECOND	THIRD	AVERAGE *(to nearest 0.25 in.)*
1 Find the soldier's weight in Table B-3 *(Weight Factor)*. Enter factor in 11A below				
2 Find soldier's height in Table B-4 *(Height Factor)*. Enter factor in 11D below				
3 Measure hips at point where the gluteus muscles *(buttocks)* protrude backward the most. Round off to nearest 0.25 inch. Repeat three times, then average	29.75	30.00	30.25	30.00
4 Measure forearm at its largest point *(with arm horizontal, palm up)* to nearest 0.25 inch. Repeat three times, then average	8.25	8.50	8.75	8.50
5 Measure neck just below level of larynx *(Adam's apple)* to nearest 0.25 inch. Repeat three times and average	13.25	13.50	13.75	13.50
6 Measure wrist between the bones of the hand and forearm to nearest 0.25 inch. Repeat three times, then average	5.75	6.00	6.25	6.00
7 Find average hip measurement in Table B-5 *(Hip Factor)*. Enter factor in 11B below				
8 Find average forearm measurement in Table B-6 *(Forearm Factor)*. Enter factor in 11E below				
9 Find average neck measurement in Table B-7 *(Neck Factor)*. Enter factor in 11F below				
10 Find average wrist measurement in Table B-8 *(Wrist Factor)*. Enter factor in 11G below				

11 CALCULATIONS			REMARKS
A Weight factor	151.60		
B Hip factor	13.19		
C TOTAL *(11A + 11B)*		164.79	
D Height factor	82.44		
E Forearm factor	33.97		
F Neck factor	18.28		
G Wrist factor	3.05		
H TOTAL *(11D + E + F + G)*		137.74	
I SOLDIER'S PERCENT BODY FAT *(Line 11C - 11H)*		27.05	

CHECK ONE
✓ Individual is in compliance with Army Standards ___ is not in compliance with the standards
___ Recommended monthly weight loss 3 to 8 lbs

PREPARED BY *(Signature)* RANK DATE APPROVED BY SUPERVISOR *(Printed Name and Signature)* RANK DATE

DA FORM 5501-R, DEC 85

Figure B-3. Sample of a completed DA form 5501
SOURCE: AR 600-9, UPDATE, p. 20.

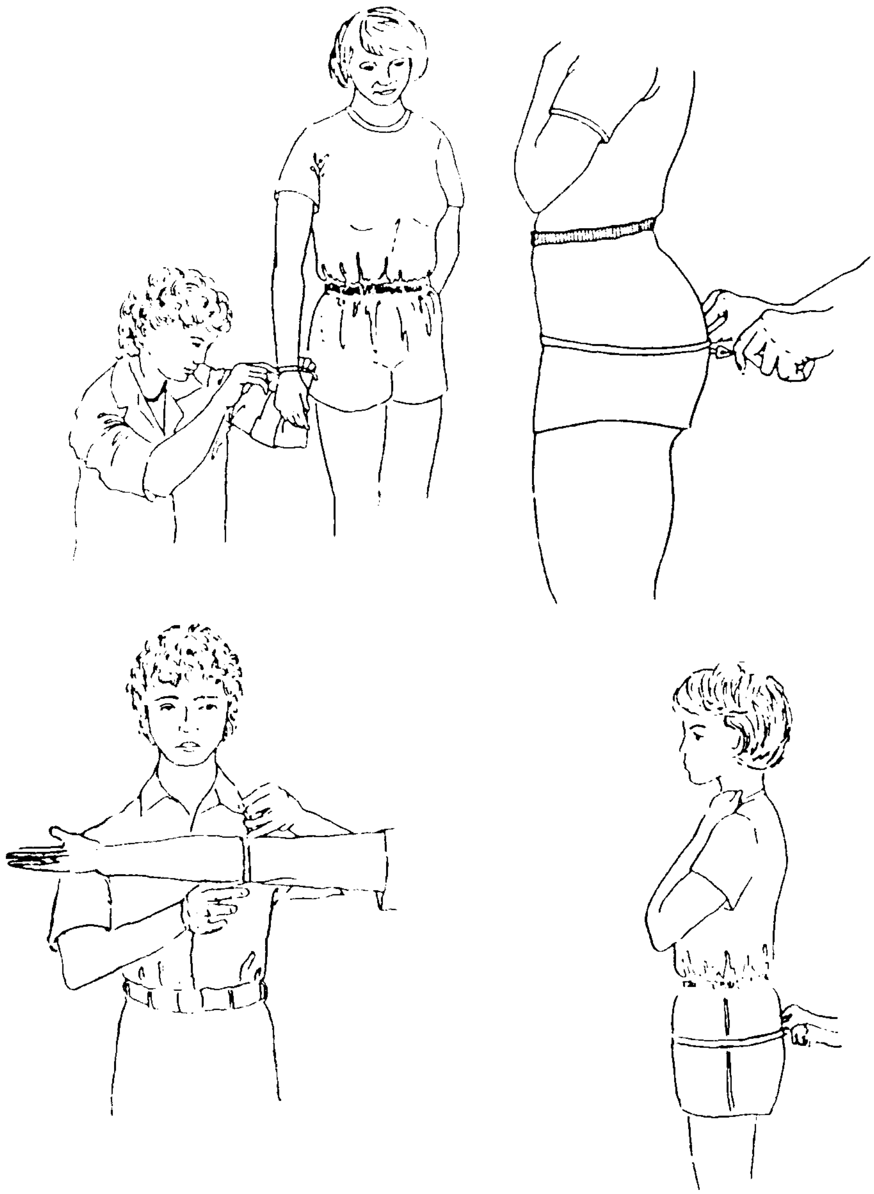

Figure B-4. Female measurement. Upper left, wrist measurement; upper right, hip measurement; lower left, forearm measurement; lower right, hip measurement.
SOURCE: AR 600-9, UPDATE, p. 21.

U.S. Navy

The standards for retention in the U.S. Navy are included OPNAV INSTRUCTION 6110.1D (NMPC-68): **PHYSICAL READINESS PROGRAM.** This instruction is extensive and excerpts here include: the state purpose of the regulation, details of procedures, and relevant reference tables[1].

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1. Purpose. To provide revised policy and guidance for the implementation of the Physical Readiness Program in the Navy as directed by references (a) and (b). This instruction is a major revision and should be reviewed in its entirety.

2. Cancellation. OPNAVINST 6110.1C.

3. Policy. To ensure the operational effectiveness of the Navy, every member shall achieve and maintain standards of physical readiness and participate in a lifestyle that promotes optimal health. This program is designed to support and enhance the physical readiness of all personnel. Physical readiness training is a complete conditioning program which reduces excess body fat and develops and maintains the flexibility, cardiorespiratory, muscular strength and endurance needed to perform routine and emergency tasks. The program is a part of the Navy's Health Promotion Program, reference (c), which includes the following elements: weight/fat control, nutrition education, smoking education and prevention, high blood pressure identification, stress management, alcohol/drug abuse prevention, low back injury prevention and physical fitness and sports. Each command will ensure personnel meet standards.

SOURCE: OPNAV INSTRUCTION 6110.1D, p. 2.

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10. Commanding officers and officers in charge shall:

a. Aggressively support the Health and Physical Readiness Program.

b. Ensure an effective command directed physical conditioning program is available for members not meeting physical readiness test and body fat standards.

c. Ensure that physical fitness and nutrition education be provided through General Military Training (GMT). Education shall stress a combination of healthy food choices, exercise and lifestyle change.

d. Appoint a minimum of one CFC in the command using departmental and divisional CFC assistants to carry out this instruction.

e. Ensure that all CFCS:

(1) are E-5 or above
(2) are CPR certified
(3) are encouraged to obtain ACSM certification
(4) meet satisfactory PRT standards
(5) are not overfat or obese
(6) are not tobacco users

[1]Further information concerning this regulation can be obtained from Headquarters, Department of the Navy, Office of the Chief of Naval Operations, Washington, D.C. 20350-2000.

f. Ensure Cardiorespiratory Resuscitation (CPR) certification training (i.e. American Red Cross) is conducted at least annually to maintain a minimum of two qualified personnel. Information concerning CPR certification may be obtained by contacting the Medical Department.

g. Maintain member's OPNAV 6110/2, Risk Factor Screening/Physical Readiness Test Results, and ensure this form is forwarded to the appropriate Personnel Support Activity Detachment/Personnel Office upon member's transfer.

h. Enter the most recent performance on the official PRT in the Fitness Report/Evaluation using guidance contained in references (f) and (g). Additionally, members who achieve an overall score of outstanding should have this fact noted in the narrative section of the FITREP/EVAL.

i. Ensure a copy of the most recent command PRT Summary Report is forwarded to COMNAVMILPERSCOM (NMPC-68), copy to chain of command, by 30 September of each year.

j. Ensure that all members are provided the opportunity to attain and maintain a level of physical readiness consistent with the standards defined in this instruction.

k. Ensure the physical readiness of members is tested twice each fiscal year, no less than 4 months apart. Commands shall designate two tests each fiscal year for official administrative and reporting actions outlined in Table I. Commands shall ensure that all members are properly notified of the official test dates and the OPNAV 6110/2 shall be completed no less than 10-12 weeks before the official PRT is administered. Commands may conduct testing more frequently than the required two official tests.

l. Ensure members fulfill the physical examination requirements stipulated in reference (h), before participating in their Physical Readiness Program. Those members who are identified by medical as sickle cell trait (SCT) shall be given appropriate precautions regarding proper hydration before participation in the Physical Readiness Program.

m. Ensure those members requiring medical clearance, as indicated on the OPNAV 6110/2 are referred to an Authorized Medical Department Representative (AMDR) for medical clearance prior to participation in the PRT. An AMDR is a health care provider whose current, authorized scope of care, either independent or supervised, includes the taking of a medical history and performing a physical examination. An AMDR shall be a medical officer, physician's assistant or nurse practitioner, but not an independent duty corpsman. When an AMDR is not assigned or not otherwise available, members requiring medical clearance shall not participate in the PRT until examined by an AMDR at the first available ship or shore facility.

n. Ensure members not meeting percent body fat or physical readiness standards participate in a command directed physical readiness program. Participation in this program shall continue until the next official PRT.

o. Ensure any member, officer or enlisted, failing to maintain standards is subject to administrative action following references (i) through (w) as outlined in Table I (e.g., a member who is diagnosed as obese on two consecutive tests and the medical diagnosis of obesity is removed for the third consecutive test is considered overfat for the third consecutive test). Formal notification of such action shall be made by page 13 entry (enlisted) or commanding officer written notification (officer). Administrative separation shall be initiated for members who:

(1) Fail to pass, fail to participate when required or remain medically diagnosed as obese for three consecutive official PRTs (except those medically waived or diagnosed pregnant).

(2) Are diagnosed obese at the time of graduation or commissioning from: Recruit Training, "A" School, U. S. Naval Academy, Officer Candidate School, Officer Indoctrination School, or Naval Reserve Officer Training Corps.

(3) Are determined rehabilitation failures during the 12 month aftercare period by the commanding officer (see paragraph 11e).

p. Ensure members granted medical waivers for any portion of the PRT for three consecutive official PRTs (over a minimum of 13 months), are referred to a medical board, if appropriate, based on the recommendation of the medical specialist.

11. Members identified as overfat or diagnosed as obese and who meet the referral criteria listed below, should participate in a non-residential Counseling and Assistance Center/ Alcohol Rehabilitation Center (CAAC/ARC) or residential (ARC) obesity rehabilitation program as appropriate.

a. Criteria for Non-Residential Rehabilitation at CAAC: Members who have been identified as overfat or medically diagnosed as obese may be referred to the local Counseling and Assistance Center (CAAC) non-residential rehabilitation program (where available). If meeting criteria, the CAAC may screen members for the appropriate level of treatment and make recommendations to the members command.

b. Criteria for Non-Residential Rehabilitation at ARC: Members who meet the following criteria shall be referred to a Non-Residential Obesity Rehabilitation Program/Alcohol Rehabilitation Center (ARC) (where available).

(1) No previous participation in non-residential (CAAC/ARC) or residential (ARC) obesity rehabilitation programs during Navy career.

(2) Medically diagnosed obese.

(3) Do not have an eating disorder (anorexia or bulimia).

(4) Desire to participate in the program. (If not amenable to program participation, an entry shall be made in the service record indicating that rehabilitation was offered and refused. The member shall be processed for administrative separation per reference (k) for enlisted, reference (m) for officers).

(5) E-5 or above, with strong potential for continued service.

(6) An average of 3.6 or above evaluation marks (except for military bearing) for 2 years.

(7) Documentation of 6 months of participation in a command directed physical conditioning program.

(8) One year of active duty remaining following completion of the non-residential obesity program, and

(9) Recommendation by the commanding officer.

c. Criteria for Residential Obesity Program: Members who meet the following criteria shall be referred to a Residential Obesity Rehabilitation Program at either an ARC or Alcohol Rehabilitation Department (ARD) (where available):

(1) Meet all the above criteria in paragraph 11b(1)-(9), and

(2) A non-residential (CAAC or ARC) obesity rehabilitation program is not available within the geographical area, operational commitments do not allow for participation in a non-residential obesity rehabilitation program or recommended by CAAC screening.

d. Aftercare. Upon completion of an obesity rehabilitation program, the member shall remain in a command directed physical conditioning program until the 22 percent (male) or 30 percent (female) standard is achieved. Aftercare recommendations from the rehabilitation facility shall be sent to the member's command fitness coordinator and shall be included in the conditioning program. This aftercare program shall be tracked by the command fitness coordinator for a minimum of 1 year to provide feedback to the rehabilitation facility on the member's progress.

e. Rehabilitative Failure. Members who fail to show consistent and significant progress towards meeting Navy body fat standards, fail to move from the obese to the overfat category during the 12 month aftercare period, or enters the obese category after the 12 month aftercare period, shall be considered for administrative separation. Individuals should lose 1-2 pounds of weight per week or approximately 1 percent of body fat every 2 weeks.

12. Commanding officers and officers in charge are strongly encouraged to provide opportunity to attain and maintain fitness during the normal work day.

SOURCE: OPNAVINST 6110.1D, Enclosure (1), pp. 3-7.

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16. The individual service member shall:

a. Participate in a lifestyle that promotes optimal health and physical readiness. Failure to take PRT due to lack of members preparedness shall constitute a PRT failure.

b. Develop a personal fitness program using resource information, the assistance of the CFC, and recreation services departments.

c. Take the PRT as required unless medically waived or diagnosed obese.

SOURCE: OPNAVINST 6110.1D, Enclosure (1), p. 9.

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TABLE 1 Administrative Action for Members Who Consecutively Fail the Physical Readiness Test or Exceed Body Fat Standards.

	FAILS PRT OR FAILS TO PARTICIPATE[1] WHEN REQUIRED		OVERFAT*		OBESE**	
	1st/2nd test	3rd+ test	1st/2nd test	3rd+ test	1st/2nd test	3rd+ test
Recommend promotion/ eligible for advancement	yes	no	yes	no	no	no
Delay promotion/withhold advancement	no	yes	no	yes	yes	yes
Eligible for Frocking	no	no	no	no	no	no
Fitrep/Eval entry[2,3]	yes	yes	yes	yes	yes	yes
Eligible for Redesignation/ Re-enlistment/ Commissioning/ Continuation	yes	no[4]	yes	yes	no[4]	no[4]
Notify NMPC via MSG/NAVGRAM[5]	no	yes	no	no	yes	yes
Transfer (PCS, TEMDUINS)	yes	no	yes	yes	no	no
Possible Separation	no	yes	no	no	no	yes

[1]Except those medically waived, TEMDU/TAD or ACDU TRA.

[2]Entries indicating PRT failure, fails to participate in PRT, or overfat/obese require comment in narrative section.

[3]The entry will reflect the most recent official PRT result.

[4]May be extended until they have had 13 months in a Command Directed Physical Conditioning Program.

[5]For enlisted NMPC-24, for officers NMPC 82, NMPC-4 for all.

*Overfat - Male 23-25 percent, Female 31-35 percent.

**Obese - Male ≥26 percent, Female ≥36 percent and medically diagnosed obese by an AMDR.

SOURCE: OPNAVINST 6110.1D, Enclosure (1), p. 10.

c. Section C. Body Composition. Values for height, weight, circumference measurements and percent body fat values shall be recorded for all members following the procedures described in enclosure (4). For administrative purposes, this assessment becomes the official percent body fat value and shall be taken 10-12 weeks prior to the PRT. The CFC shall advise members who exceed body fat standards that their assignment to a command directed physical conditioning program is mandatory and initiate appropriate documentation action per paragraph 10o. Automated systems may be used to perform calculations but do not substitute for completion of this section.

(Exception: The body fat assessment is waived from the time of the official medical diagnosis of pregnancy and for 6 months following delivery.)

d. Section D. Medical Referral. The CFC shall enter the date of referral and place an "X" in the appropriate box(s). Those members with one or more "X"s shall require referral to an AMDR for evaluation and determination as to their eligibility to participate in the PRT and command directed physical conditioning program.

e. Section E. Medical Evaluation. Males with percent body fat equal to or greater than 26 percent or females with percent body fat equal to or greater than 36 percent must be examined by an AMDR to confirm obesity.

(1) The clinical diagnosis of obesity shall be based on a consideration of the individual's:

(a) percent body fat value

(b) tendency to be obese

1. family history

2. age of onset

3. eating habits

4. location of body fat

5. psychological burden

6. level of physical activity

(c) presence of health risks associated with obesity

1. hypercholesterolemia

2. hypertension

3. diabetes

4. cardiovascular dysfunction

(d) metabolic or endocrine abnormalities resulting in obesity; and

(e) the clinical judgment of the AMDR

(2) Refer the member as appropriate to a conditioning/ rehabilitation program as per guidelines of enclosure (4).

(3) Members diagnosed as obese shall not be allowed to take the PRT.

(4) Only an AMDR can diagnose a member obese.

(5) Only an AMDR can release the member from the diagnosis of obesity and clear the individual to take the PRT.

f. Section F. Physical Readiness Test Results. The CFC shall conduct an official PRT following the guidelines of enclosure (5), verify that raw scores for each event performed are correct and calculate points for overall classification. Automated systems may be used to perform calculations but do not substitute for completion of this section. (Note: Members waived from any portion of the PRT shall be marked pass/fail for each item performed and overall classification. No point calculations are required.) Member and CFC shall sign this section to certify accuracy of entries.

SOURCE: OPNAVINST 6110.1D, Enclosure (3), p. 2-4.

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4. Pregnancy. After confirmation of pregnancy, a pregnant member shall be exempt from the regular physical readiness program and physical fitness testing. The body fat assessment is waived from the time of the diagnosis of pregnancy and for 6 months following delivery. Members exempted for pregnancy may take up to 6 months following delivery to take an official PRT. Pregnant members shall be counselled and encouraged to participate in an approved American College of Obstetricians and Gynecologists (ACOG) exercise program, unless exempted by her health care provider for medical reasons.
SOURCE: OPNAVINST 6110.1D, Enclosure (3), p. 6-7.

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Body Composition Determination Procedure

1. BACKGROUND. The body is composed of fat and lean (muscle) tissue. Percent body fat is expre d as a percentage of the total body weight. Attempts to interchange the use of body fat and dy weight measures as an indicator of fitness/military appearance have frequently resulted in misconceptions and inequities. Obesity is an excess of body fat frequently resulting in a significant impairment of health. Obesity (excess body fat) is clearly associated with hypertension (high blood pressure), hypercholesterolemia (high blood cholesterol level), diabetes and is considered a risk factor for cardiovascular disease. Overweight is the condition in which a member's weight exceeds the average weight-for-height standards based on insurance industry standards. Although height/weight tables are still used to assess body composition of members based on age and body size, these tables do not provide information on the degree of obesity or the quality of a member's body weight. It is possible to be overweight and not be overfat.

2. DEFINITION. Reference (a) defines the accepted percent body fat values for men and women as less than or equal to 20 percent and 26 percent respectively. The Department of Defense goal has been adjusted upward to account for the standard error associated with anthropometric measurement. Therefore, the percent body fat values indicating the potential for obesity are equal to or greater than 26 percent for males, and equal to or greater than 36 percent for females. Males 23-25 percent and females 31-35 percent are considered to be overfat.

3. GUIDANCE. TAB A to enclosure (4) illustrates the body composition screening decision process to be followed. The initial body composition screen shall be conducted by the CFC using the circumference measurement method described in TAB B. The CFC's percent body fat assessment will remain valid for administrative purposes. Those members with percent body fat 23-25 (males) or 31-35 percent (females) are required to participate in a command directed physical conditioning program and should receive dietary/nutritional information. Enclosure (2) is recommended for the exercise component and an AMDR can provide dietary assistance. Members with percent body fat equal to or greater than 26 percent (males) or equal to or greater than 36 percent (females) must be evaluated by an AMDR. Members diagnosed as obese shall NOT be allowed to take the PRT. Only an AMDR shall diagnose a member obese. Removal of the diagnosis of obesity and approval for participation in the PRT shall be given only by an AMDR. The body fat assessment is waived from the time of the diagnosis of pregnancy and for 6 months following delivery.
SOURCE: OPNAVINST 6110.1D, Enclosure (4), pp. 1-2.

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TAB A BODY COMPOSITION DETERMINATION PROCEDURE

"Determined by CFC"	Males	Females	Action
Within Standards	less than or equal to 22%	less than or equal to 30%	none
Over Standard	23%-25%	31%-35%	Command Directed Physical Conditioning Program (Mandatory)
	greater than or equal to 26%	greater than or equal to 36%	Refer to Medical
"Determined by Medical"			
MEDICAL DETERMINATION	OVERFAT	OVERFAT	Command Directed Physical Conditioning Program (Mandatory)
	OBESE*	OBESE*	Command Directed Physical Conditioning Program (Mandatory) Recommend Non-Residential or Residential Rehabilitation Program (if eligible)

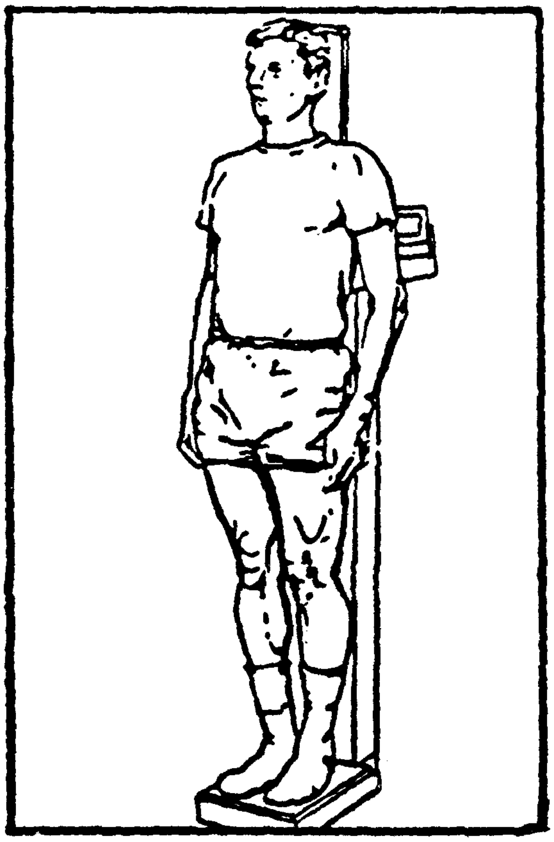
*(Member not eligible to take PRT)
SOURCE: OPNAVINST 6110.1D, TAB A, p. 3.

TAB B PERCENT BODY FAT MEASUREMENT PROCEDURES

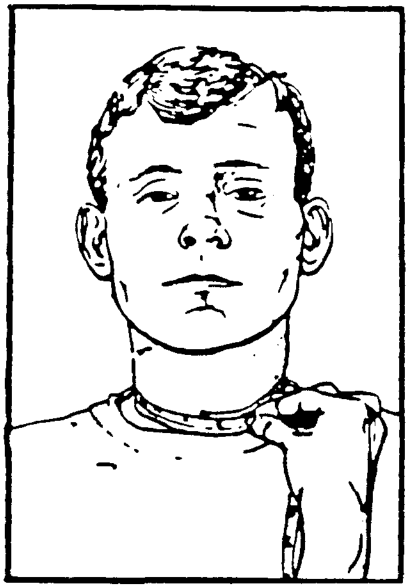
1. General Instructions. Procedures for determining body fat require the use of a standard NON-ELASTIC (metal, cloth or fiberglass) tape measure. The tape should be applied to body landmarks with sufficient tension to keep it in place without indenting the skin surface. Record measurements to the nearest half inch. With the exception of the hip measurement for women, all measurements will be taken on bare skin.

2. Percent Body Fat-Determination (Males)

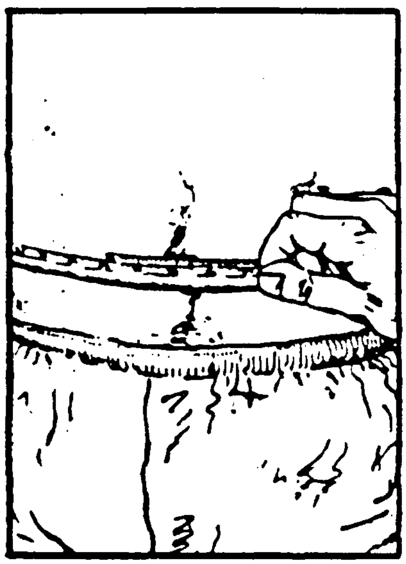
a. Measure height without shoes to nearest half inch. Instruct members to stand with feet together, flat on the deck, take a deep breath and stretch tall.



b. Measure the neck circumference at a point just below the larynx (Adam's Apple) and perpendicular to the long axis of the neck. Member should look straight ahead with shoulders down (not hunched). Round neck measurement up and record to half inch. (i.e. Round 16 1/4 inches to 16.5 inches).



c. Measure the abdominal circumference at the navel, level to the deck. Arms are at the sides. Take measurement at the end of member's normal, relaxed exhalation. Round abdominal measurement down and record to half inch. (i.e. Round 34 3/4 to 34.5 inches)



d. Determine percent body fat by subtracting the neck from the abdominal measurement and comparing this value against the height measurement from Chart A.

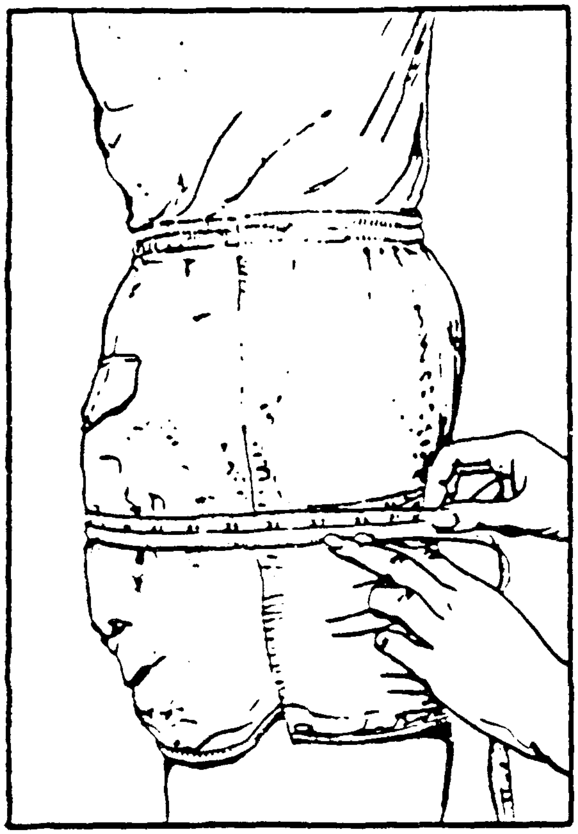
3. Percent Body Fat Determination (FEMALES)

a. Measure height without shoes to the nearest half inch. Instruct member to stand with feet together and flat on the deck, take a deep breath and stretch tall.

b. Measure the neck circumference at a point just below the larynx (Adam's Apple) and perpendicular to the long axis of the neck. Member should look straight ahead during measurement, with shoulders down (not hunched). Round neck measurement up and record to half inch. (i.e. Round 13 3/8 inches to 13.5 inches).

c. Measure the natural waist circumference at the point of minimal abdominal circumference, usually located about half-way between the navel and the lower end of the sternum (breast bone). When this site is not easily observed, take several measurements at probable sites and use the smallest value. Be sure that the tape is level. Arms are at the sides. Record measurements at the end of member's normal relaxed exhalation. Round waist measurement down and record to half inch. (i.e. Round 28 5/8 inches to 28.5 inches).

d. Measure the hip circumference while facing the subject's right side by placing the tape around the hips so that it passes over the greatest protrusion of the gluteal muscles (buttocks) and is level to the deck. Apply sufficient tape tension so that the effect of clothing is minimized. Round the hip measurement <u>down</u> and record to half inch. (i.e. Round 44 3/8 inches <u>down</u> to 44.0 inches).



e. Determine percent body fat by adding the waist and the hip measurements, subtracting the neck measurement, and comparing this value against the height measurement from Chart B.

SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), pp. 4-8.

CHART A PERCENT FAT ESTIMATION FOR MALES

Circumference Value*	Height (inches) 60.0	60.5	61.0	61.5	62.0	62.5	63.0	63.5	64.0	64.5
11.0	3	2	2	2	2	1	1	1	1	1
11.5	4	4	4	3	3	3	3	2	2	2
12.0	6	5	5	[illegible]	5	4	4	4	4	3
12.5	7	7	6	6	6	6	6	5	5	5
13.0	8	8	8	8	7	7	[illegible]	7	6	6
13.5	10	9	9	9	9	8	8	8	8	8
14.0	11	11	10	10	10	10	10	9	9	9
14.5	12	12	12	11	11	11	11	11	10	10
15.0	13	13	13	13	12	12	12	12	12	11
15.5	15	14	14	14	14	13	13	13	13	12
16.0	16	15	15	15	15	15	14	14	14	14
16.5	[illegible]	17	16	16	16	16	15	15	15	15
17.0	18	18	17	17	17	17	16	16	16	16
17.5	19	19	19	18	18	18	18	17	17	17
18.0	20	20	20	19	19	19	19	18	18	18
18.5	[illegible]	21	21	20	20	20	20	19	19	19
19.0	22	22	22	21	21	21	21	20	20	20
19.5	23	23	23	22	22	22	22	21	21	21
20.0	24	24	23	23	23	23	22	22	22	22
20.5	25	25	24	24	24	24	23	23	23	23
21.0	26	26	25	25	25	25	24	24	24	24
21.5	27	26	26	26	26	25	25	25	25	24
22.0	28	27	27	27	27	26	26	26	26	25
22.5	28	28	28	28	27	27	27	27	26	26
23.0	29	29	29	29	28	28	28	28	27	27
23.5	30	30	30	29	29	29	29	28	28	28
24.0	31	31	30	30	30	30	29	29	29	29
24.5	32	31	31	31	31	30	30	30	30	29
25.0	33	32	32	32	31	[illegible]	31	31	30	30
25.5	33	33	33	[illegible]	32	[illegible]	32	31	31	31
26.0	34	34	34	33	33	33	32	32	32	32
26.5	35	35	34	34	34	33	33	33	33	32
27.0	36	35	35	35	34	34	34	34	33	33
27.5	36	36	36	35	35	35	35	34	34	34
28.0	37	37	[illegible]	36	36	36	35	35	35	35
28.5	38	37	37	37	37	36	36	36	36	[illegible]
29.0	38	38	38	38	37	37	37	37	36	[illegible]
29.5	39	39	39	38	38	38	37	37	37	37
30.0	40	39	39	39	39	38	38	38	38	37
30.5	-	-	40	40	39	39	39	38	38	38
31.0	-	-	-	-	40	40	39	39	39	39
31.5	-	-	-	-	-	-	-	40	40	39
32.0	-	-	-	-	-	-	-	-	-	40
32.5	-	-	-	-	-	-	-	-	-	-
33.0	-	-	-	-	-	-	-	-	-	-
33.5	-	-	-	-	-	-	-	-	-	-
34.0	-	-	-	-	-	-	-	-	-	-
34.5	-	-	-	-	-	-	-	-	-	-
35.0	-	-	-	-	-	-	-	-	-	-

*Circumference Value = abdomen circumference neck circumference (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p. 9.

CHART A PERCENT FAT ESTIMATION FOR MALES

Circumference Value*	Height (inches) 65.0	65.5	66.0	66.5	67.0	67.5	68.0	68.5	69.0	69.5
11.0:	0	0	-	-	-	-	-	-	-	-
11.5:	2	2	1	1	1	1	1	0	0	-
12.0:	3	3	3	3	2	2	2	2	2	1
12.5:	5	4	4	4	4	4	3	3	3	3
13.0:	6	6	6	5	5	5	5	5	4	4
13.5:	7	7	7	7	6	6	6	6	6	5
14.0:	9	8	8	8	8	8	7	7	7	
14.5:	10	10	9	9	9	9	9	8	8	8
15.0:	11	11	11	10	10	10	10	10	9	9
15.5:	12	12	12	12	11	11	11	11	11	10
16.0:	13	13	13	13	12	12	12	12	12	11
16.5:	14	14	14	14	14	13	13	13	13	13
17.0:	16	15	15	15	15	14	14	14	14	14
17.5:	17	16	16	16	16	16	15	15	15	15
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21.5:	24	24	24	24	23	23	23	23	22	22
22.0:	25	25	25	24	24	24	24	24	23	23
22.5:	26	26	25	25	25	25	25	24	24	24
23.0:	27	27	26	26	26	26	25	25	25	25
23.5:	28	27	27	27	27	26	26	26	26	26
24.0:	28	28	28	28	27	27	27	27	27	26
24.5:	29	29	29	29	28	28	28	28	27	27
25.0:	30	30	30	29	29	29	29	28	28	28
25.5:	31	31	30	30	30	30	29	29	29	29
26.0:	32	31	31	31	31	30	30	30	30	29
26.5:	32	32	32	32	31	31	31	31	30	30
27.0:	33	33	32	32	32	32	32	31	31	31
27.5:	34	33	33	33	33	33	32	32	32	32
28.0:	34	34	34	34	33	33	33	33	33	32
28.5:	35	35	35	34	34	34	34	33	33	33
29.0:	36	36	35	36	35	35	34	34	34	34
29.5:	36	36	36	36	36	35	35	35	35	34
30.0:	37	37	37	36	36	36	36	35	35	35
30.5:	38	38	37	37	37	37	36	36	36	36
31.0:	38	38	38	38	37	37	37	37	37	36
31.5:	39	39	39	38	38	38	38	37	37	37
32.0:	40	39	39	39	39	38	38	38	38	38
32.5:	-	-	40	40	39	39	39	39	38	38
33.0:	-	-	-	-	40	40	39	39	39	39
33.5:		-	-	-	-	-	-	40	40	39
34.0:	-		-	-	-	-	-	-	-	40
34.5:	-		-		-	-	-	-	-	-
35.0:	-			-	-	-	-	-	-	-

*Circumference Value = abdomen circumference   neck circumference (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p. 10.

CHART A PERCENT FAT ESTIMATION FOR MALES

Circumference Value*	Height (inches) 70.0	70.5	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.5
11.0:	-		-	-	-	-	-	-	-	-
11.5:	-	-	-	-	-	-	-	-	-	-
12.0:	1	1	1	1	0	0	0	-	-	-
12.5:	3	2	2	2	2	2	1	1	1	1
13.0:	4	4	4	3	3	3	3	3	2	2
13.5:	5	5	5	5	4	4	4	4	4	4
14.0:	7	6	6	6	6	6	5	5	5	5
14.5:	8	8	7	7	7	7	7	6	6	6
15.0:	9	9	9	8	8	8	8	8	7	7
15.5:	10	10	10	9	9	9	9	9	9	8
16.0:	11	11	11	11	10	10	10	10	10	9
16.5:	12	12	12	12	12	11	11	11	11	11
17.0:	13	13	13	13	13	12	12	12	12	12
17.5:	14	14	14	14	14	13	13	13	13	13
18.0:	15	15	15	15	15	14	14	14	14	14
18.5:	16	16	16	16	16	15	15	15	15	15
19.0:	17	17	17	17	17	16	16	16	16	16
19.5:	18	18	18	18	18	17	17	17	17	17
20.0:	19	19	19	19	18	18	18	18	18	17
20.5:	20	20	20	20	19	19	19	19	19	18
21.0:	21	21	21	20	20	20	20	20	19	19
21.5:	22	22	22	21	21	21	21	21	20	20
22.0:	23	23	22	22	22	22	22	21	21	21
22.5:	24	23	23	23	23	23	22	22	22	22
23.0:	25	24	24	24	24	23	23	23	23	23
23.5:	25	25	25	25	24	24	24	24	24	23
24.0:	26	26	26	25	25	25	25	25	24	24
24.5:	27	27	26	26	26	26	26	25	25	25
25.0:	28	27	27	27	27	27	26	26	26	26
25.5:	28	28	28	28	28	27	27	27	27	27
26.0:	29	29	29	29	28	28	28	28	27	27
26.5:	30	30	29	29	29	29	29	28	28	28
27.0:	31	30	30	30	30	30	29	29	29	29
27.5:	31	31	31	31	30	30	30	30	30	29
28.0:	32	32	32	31	31	31	31	31	30	30
28.5:	33	33	32	32	32	32	31	31	31	31
29.0:	33	33	33	33	33	32	32	32	32	31
29.5:	34	34	34	33	33	33	33	33	32	32
30.0:	35	35	34	34	34	34	33	33	33	33
30.5:	35	35	35	35	35	34	34	34	34	33
31.0:	36	36	36	35	35	35	35	34	34	34
31.5:	37	36	36	36	36	36	35	35	35	35
32.0:	37	37	37	37	36	36	36	36	36	35
32.5:	38	38	37	37	37	37	37	36	36	36
33.0:	39	38	38	38	38	37	37	37	37	37
33.5:	39	39	39	38	38	38	38	38	37	37
34.0:	40	39	39	39	39	39	38	38	38	38
34.5:	-	-	40	40	39	39	39	39	39	38
35.0:	-	-	-	-	40	40	40	39	39	39

*Circumference Value = abdomen circumference - neck circumference (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p 11.

CHART A PERCENT FAT ESTIMATION FOR MALES

Circumference Value*	Height (inches) 75.0	75.5	76.0	76.5	77.0	77.5	78.0	78.5	79.0	79.5
11.0:	-	-	-	-	-	-	-	-	-	-
11.5:	-				-	-	-	-	-	-
12.0:	-	-	-	-	-	-	-	-	-	-
12.5:	1	1	0	0	-	-	-	-	-	-
13.0:	2	2	2	1	1	1	1	1	1	0
13.5:	3	3	3	3	3	2	2	2	2	2
14.0:	5	4	4	4	4	4	3	3	3	3
14.5:	6	6	5	5	5	5	5	5	4	4
15.0:	7	7	7	6	6	6	6	6	6	5
15.5:	8	8	8	8	7	7	7	7	7	6
16.0:	9	9	9	9	8	8	8	8	8	8
16.5:	10	10	10	10	10	9	9	9	9	9
17.0:	11	11	11	11	11	10	10	10	10	10
17.5:	12	12	12	12	12	11	11	11	11	11
18.0:	13	13	13	13	13	12	12	12	12	12
18.5:	14	14	14	14	14	13	13	13	13	13
19.0:	15	15	15	15	15	14	14	14	14	14
19.5:	16	16	16	16	16	15	15	15	15	15
20.0:	17	17	17	17	16	16	16	16	16	16
20.5:	18	18	18	18	17	17	17	17	17	16
21.0:	19	19	19	18	18	18	18	18	18	17
21.5:	20	20	20	19	19	19	19	19	18	18
22.0:	21	21	20	20	20	20	20	19	19	19
22.5:	22	21	21	21	21	21	20	20	20	20
23.0:	22	22	22	22	22	21	21	21	21	21
23.5:	23	23	23	23	22	22	22	22	22	21
24.0:	24	24	24	23	23	23	23	23	22	22
24.5:	25	25	24	24	24	24	24	23	23	23
25.0:	26	25	25	25	25	25	24	24	24	24
25.5:	26	26	26	26	26	25	25	25	25	25
26.0:	27	27	27	26	26	26	26	26	25	25
26.5:	28	28	27	27	27	27	27	26	26	26
27.0:	28	28	28	28	28	27	27	27	27	27
27.5:	29	29	29	29	28	28	28	28	28	27
28.0:	30	30	29	29	29	29	29	28	28	28
28.5:	31	30	30	30	30	30	29	29	29	29
29.0:	31	31	31	31	30	30	30	30	30	29
29.5:	32	32	31	31	31	31	31	30	30	30
30.0:	33	32	32	32	32	32	31	31	31	31
30.5:	33	33	33	33	32	32	32	32	32	31
31.0:	34	34	33	33	33	33	33	32	32	32
31.5:	34	34	34	34	34	33	33	33	33	33
32.0:	35	35	35	34	34	34	34	34	33	33
32.5:	36	35	35	35	35	35	34	34	34	34
33.0:	36	36	36	36	35	35	35	35	35	34
33.5:	37	37	36	36	36	36	36	35	35	35
34.0:	37	37	37	37	37	36	36	36	36	36
34.5:	38	38	38	37	37	37	37	37	36	36
35.0:	39	38	38	38	38	38	37	37	37	37

*Circumference Value = abdomen circumference – neck circumference (*in inches*)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p 12.

CHART A PERCENT FAT ESTIMATION FOR MALES

Circumference Value*	Height (inches) 75.0	75.5	76.0	76.5	77.0	77.5	78.0	78.5	79.0	79.5
35.5:	39	39	39	39	38	38	38	38	38	37
36.0:	40	40	39	39	39	39	39	38	38	38
36.5:	-	-	40	40	39	39	39	39	39	38
37.0:	-	-	-			40	40	39	39	39
37.5:			-	-	-			40	40	40
38.0:			-	-	-			-	-	-
38.5:	-							-	-	-

*Circumference Value = abdomen circumference – neck circumference (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p. 13

CHART B PERCENT FAT ESTIMATION FOR FEMALES

Circumference Value*	Height (inches) 58.0	58.5	59.0	59.5	60.0	60.5	61.0	61.5	62.0	62.5
34.5:	1	0								
35.0:	2	1	1	1	0					
35.5:	3	2	2	2	1	1	0	0		
36.0:	4	3	3	3	2	2	1	1	0	0
36.5:	5	4	4	4	3	3	2	2	2	1
37.0:	6	5	5	4	4	4	3	3	3	2
37.5:	7	6	6	5	5	5	4	4	4	3
38.0:	7	7	7	6	6	6	5	5	5	4
38.5:	8	8	8	7	7	7	6	6	5	5
39.0:	9	9	9	8	8	7	7	7	6	6
39.5	10	10	9	9	9	8	8	8	7	7
40.0:	11	11	10	10	10	9	9	8	8	8
40.5:	12	12	11	11	10	10	10	9	9	9
41.0:	13	12	12	12	11	11	11	10	10	10
41.5:	14	13	13	13	12	12	11	11	11	10
42.0:	14	14	14	13	13	13	12	12	12	11
42.5:	15	15	15	14	14	13	13	13	12	12
43.0:	16	16	15	15	15	14	14	14	13	13
43.5:	17	17	16	16	15	15	15	14	14	14
44.0:	18	17	17	17	16	16	16	15	15	14
44.5:	19	18	18	17	17	17	16	16	16	15
45.0:	19	19	19	18	18	17	17	17	16	16
45.5:	20	20	19	19	19	18	18	18	17	17
46.0:	21	20	20	20	19	19	19	18	18	18
46.5:	22	21	21	20	20	20	19	19	19	18
47.0:	22	22	22	21	21	20	20	20	19	19
47.6:	23	23	22	22	22	21	21	21	20	20
48.0:	24	23	23	23	22	22	22	21	21	21
48.5:	25	24	24	23	23	23	22	22	22	21
49.0:	25	25	25	24	24	23	23	23	22	22
49.5:	26	26	25	25	24	24	24	23	23	23
50.0:	27	26	26	26	25	25	24	24	24	23
50.5:	27	27	27	26	26	26	25	25	24	24
51.0:	28	28	27	27	27	26	26	25	25	25
51.5:	29	28	28	28	27	27	27	26	26	25
52.0:	29	29	29	28	28	28	27	27	27	26
52.5	30	30	29	29	29	28	28	28	27	27
53.0:	31	30	30	30	29	29	29	28	28	27
53.5	31	31	31	30	30	30	29	29	28	28
54.0:	32	32	31	31	31	30	30	30	29	29
54.5	33	32	32	32	31	31	31	30	30	29
55.0:	33	33	33	32	32	32	31	31	30	30
55.5	34	34	33	33	33	32	32	31	31	31
56.0:	35	34	34	33	33	33	32	32	32	31
56.5	35	35	34	34	34	33	33	33	32	32
57.0:	36	35	35	35	34	34	34	33	33	33
57.5:	36	36	36	36	35	35	34	34	34	33
58.0	37	37	36	36	36	35	35	35	34	34
58.5	38	37	37	37	36	36	35	35	35	34

*Circumference Value = abdomen (waist) 1 + hip − neck circumference (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B Enclosure (4), p. 34.

CHART B PERCENT FAT ESTIMATION FOR FEMALES

Circumference Value*	Height (inches) 63.0	63.5	64.0	64.5	65.0	65.5	66.0	66.5	67.0	67.5
34.5:	-	-	-	-	-	-	-	-	-	-
35.0:	-	-	-	-	-	-	-	-	-	-
35.5:	-	-	-	-	-	-	-	-	-	-
36.0:	0	-	-	-	-	-	-	-	-	-
36.5:	1	1	0			-	-	-	-	-
37.0:	2	2	1	1	1	0	-		-	-
37.5:	3	3	2	2	2	1	1	1	0	-
38.0:	4	3	3	3	2	2	2	1	1	1
38.5:	5	4	4	4	3	3	3	2	2	2
39.0:	6	5	5	5	4	4	4	3	3	3
39.5:	7	6	6	6	5	5	5	4	4	4
40.0:	7	7	7	6	6	6	5	5	5	4
40.5:	8	8	8	7	7	7	6	6	6	5
41.0:	9	9	8	8	8	7	7	7	6	6
41.5:	10	10	9	9	9	8	8	8	7	7
42.0:	11	10	10	10	9	9	9	8	8	8
42.5:	12	11	11	11	10	10	10	9	9	9
43.0:	12	12	12	11	11	11	10	10	10	9
43.5:	13	13	13	12	12	12	11	11	11	10
44.0:	14	14	13	13	13	12	12	12	11	11
44.5:	15	15	14	14	14	13	13	13	12	12
45.0	16	15	15	15	14	14	14	13	13	13
45.5:	16	16	16	15	15	15	14	14	14	13
46.0:	17	17	17	16	16	16	15	15	15	14
46.5:	18	18	17	17	17	16	16	16	15	15
47.0:	19	18	18	18	17	17	17	16	16	16
47.5:	19	19	19	18	18	18	17	17	17	16
48.0:	20	20	20	19	19	18	18	18	18	17
48.5:	21	21	20	20	20	19	19	19	18	18
49.0:	22	21	21	21	20	20	20	19	19	19
49.5	22	22	22	21	21	21	20	20	20	19
50.0:	23	23	22	22	22	21	21	21	20	20
50.5:	24	23	23	23	22	22	22	21	21	21
51.0:	24	24	24	23	23	23	22	22	22	21
51.5:	25	25	24	24	24	23	23	23	22	22
52.0:	26	25	25	25	24	24	24	23	23	23
52.5	26	26	26	25	25	25	24	24	24	23
53.0:	27	27	26	26	26	25	25	25	24	24
53.5:	28	27	27	27	26	26	26	25	25	25
54.0:	28	28	28	27	27	27	26	26	26	25
54.5:	29	29	28	28	28	27	27	27	26	26
55.0:	30	29	29	29	28	28	28	27	27	27
55.5:	30	30	30	29	29	29	28	28	28	27
56.0:	31	31	30	30	30	29	29	29	28	28
56.5	32	31	31	31	30	30	30	29	29	29
57.0	32	32	32	31	31	31	30	30	30	29
57.5	33	32	32	32	31	31	31	30	30	30
58.0	33	33	33	32	32	32	31	31	31	30
58.5	34	34	33	33	33	32	32	32	31	31

*Circumference Value = abdomen (waist) + hip − neck circumference (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p 15

CHART B PERCENT FAT ESTIMATION FOR FEMALES

Circumference Value*	Height (inches) 68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5	72.0	72.5
34.5		-	-	-	-	-	-		-	-
35.0		-	-	-	-	-	-	-	-	-
35.5					-	-	-	-	-	-
36.0	-		-	-	-	-	-	-	-	-
36.5	-	-	-	-	-	-	-	-	-	-
37.0		-		-	-	-	-		-	-
37.5		-	-		-	-	-	-	-	-
38.0	0	0	-	-	-	-	-	-	-	-
38.5	1	1	1	0	0	-	-		-	-
39.0	2	2	2	1	1	1	0	0	-	-
39.5	3	3	3	2	2	2	1	1	1	0
40.0	4	4	3	3	3	3	2	2	2	1
40.5	5	5	4	4	4	3	3	3	2	2
41.0	6	5	5	5	5	4	4	4	3	3
41.5	7	6	6	6	5	5	5	4	4	4
42.0	8	7	7	7	6	6	6	5	5	5
42.5	8	8	8	7	7	7	6	6	6	6
43.0	9	9	9	8	8	8	7	7	7	6
43.5	10	10	9	9	9	8	8	8	7	7
44.0	11	10	10	10	9	9	9	9	8	8
44.5	12	11	11	11	10	10	10	9	9	9
45.0	12	12	12	11	11	11	10	10	10	10
45.5	13	13	12	12	12	12	11	11	11	10
46.0	14	14	13	13	13	12	12	12	11	11
46.5	15	14	14	14	13	13	13	12	12	12
47.0	15	15	15	14	14	14	13	13	13	13
47.5	16	16	15	15	15	15	14	14	14	13
48.0	17	17	16	16	16	15	15	15	14	14
48.5	18	17	17	17	16	16	16	15	15	15
49.0	18	18	18	17	17	17	16	16	16	15
49.5	19	19	18	18	18	17	17	17	17	16
50.0	20	19	19	19	18	18	18	18	17	17
50.5	20	20	20	19	19	19	19	18	18	18
51.0	21	21	20	20	20	20	19	19	19	18
51.5	22	21	21	21	21	20	20	20	19	19
52.0	22	22	22	22	21	21	21	20	20	20
52.5	23	23	22	22	22	22	21	21	21	20
53.0	24	23	23	23	23	22	22	22	21	21
53.5	24	24	24	23	23	23	23	22	22	22
54.0	25	25	24	24	24	24	23	23	23	22
54.5	26	25	25	25	24	24	24	24	23	23
55.0	26	26	26	25	25	25	24	24	24	24
55.5	27	27	26	26	26	25	25	25	25	24
56.0	28	27	27	27	26	26	26	25	25	25
56.5	28	28	28	27	27	27	26	26	26	25
57.0	29	29	28	28	28	27	27	27	26	26
57.5	30	29	29	29	28	28	28	27	27	27
58.0	30	30	29	29	29	29	28	28	28	27
58.5	31	30	30	30	29	29	29	29	28	28

*Circumference Value = abdomen (waist) + hip − neck circumferences (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p. 16

CHART B PERCENT FAT ESTIMATION FOR FEMALES

Circumference Value*	Height (inches) 73.0	73.5	74.0	74.5	75.0	75.5	76.0	76.5	77.0	77.5
34.5:	-	-	-	-			-		-	
35.0:	-	-	-	-	-	-	-	-	-	-
35.5:	-	-	-	-	-	-	-	-	-	-
36.0:	-	-	-	-	-	-	-	-	-	-
36.5:	-	-			-	-	-	-	-	-
37.0:		-	-	-	-	-	-	-	-	-
37.5:	-	-	-		-	-	-	-	-	-
38.0:	-	-		-	-			-	-	-
38.5:	-	-	-	-		-	-	-	-	-
39.0:	-		-	-	-	-	-	-	-	-
39.5:	0		-			-	-	-	-	-
40.0:	1	1	0	0	-	-	-	-	-	-
40.5:	2	2	1	1	1	0	0	-	-	-
41.0:	3	2	2	2	2	1	1	1	0	0
41.5:	4	3	3	3	2	2	2	2	1	1
42.0:	4	4	4	4	3	3	3	2	2	2
42.5:	5	5	5	4	4	4	3	3	3	3
43.0:	6	6	5	5	5	5	4	4	4	3
43.5:	7	7	6	6	6	5	5	5	5	4
44.0:	8	7	7	7	6	6	6	6	5	5
44.5:	8	8	8	8	7	7	7	6	6	6
45.0:	9	9	9	8	8	8	7	7	7	7
45.5:	10	10	9	9	9	9	8	8	8	7
46.0:	11	10	10	10	10	9	9	9	8	8
46.5:	12	11	11	11	10	10	10	9	9	9
47.0:	12	12	12	11	11	11	11	10	10	10
47.5:	13	13	12	12	12	12	11	11	11	10
48.0:	14	13	13	13	13	12	12	12	11	11
48.5:	14	14	14	14	13	13	13	12	12	12
49.0:	15	15	15	14	14	14	13	13	13	13
49.5:	16	16	15	15	15	14	14	14	14	13
50.0:	17	16	16	16	15	15	15	15	14	14
50.5:	17	17	17	16	16	16	16	15	15	15
51.0:	18	18	17	17	17	17	16	16	16	15
51.5:	19	18	18	18	17	17	17	17	16	16
52.0:	19	19	19	18	18	18	18	17	17	17
52.5:	20	20	19	19	19	19	18	18	18	17
53.0:	21	20	20	20	20	19	19	19	18	18
53.5:	21	21	21	20	20	20	20	19	19	19
54.0:	22	22	21	21	21	21	20	20	20	19
54.5:	23	22	22	22	21	21	21	21	20	20
55.0:	23	23	23	22	22	22	22	21	21	21
55.5:	24	24	23	23	23	22	22	22	22	21
56.0:	25	24	24	24	23	23	23	22	22	22
56.5:	25	25	25	24	24	24	23	23	23	23
57.0:	26	25	25	25	25	24	24	24	23	23
57.5:	26	26	26	26	25	25	25	24	24	24
58.0:	27	27	26	26	26	26	25	25	25	24
58.5:	28	27	27	27	26	26	26	26	25	25

*Circumference Value = abdomen (waist) + hip neck circumferences (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p. 17.

CHART B PERCENT FAT ESTIMATION FOR FEMALES

Circumference Value*	Height (inches) 58.0	58.5	59.0	59.5	60.0	60.5	61.0	61.5	62.0	62.5
59.0:	38	38	38	37	37	36	36	36	35	35
59.5:	39	38	38	38	37	37	37	36	35	35
60.0:	39	39	39	38	38	38	37	37	37	36
60.5:	40	40	39	39	39	38	38	37	37	37
61.0:	41	40	40	39	39	39	38	38	38	37
61.5:	41	41	40	40	40	39	39	39	38	38
62.0:	42	41	41	41	40	40	40	39	39	38
62.5:	42	42	42	41	41	40	40	40	39	39
63.0:	43	42	42	42	41	41	41	40	40	40
63.5:	43	43	43	42	42	42	41	41	40	40
64.0:	44	44	43	43	42	42	42	41	41	41
64.5:	45	44	44	43	43	43	42	42	42	41
65.0:	-	45	44	44	44	43	43	42	42	42
65.5:	-	-	45	44	44	44	43	43	43	42
66.0:	-	-	-	-	45	44	44	44	43	43
66.5:	-	-	-	-	-	45	44	44	44	43
67.0:	-	-	-	-	-	-	45	45	44	44
67.5:	-	-	-	-	-	-	-	-	45	44
68.0:	-	-	-	-	-	-	-	-	-	45
68.5:	-	-	-	-	-	-	-	-	-	-
69.0:	-	-	-	-	-	-	-	-	-	-
69.5:	-	-	-	-	-	-	-	-	-	-
70.0:	-	-	-	-	-	-	-	-	-	-
70.5:	-	-	-	-	-	-	-	-	-	-
71.0:	-	-	-	-	-	-	-	-	-	-
71.5:	-	-	-	-	-	-	-	-	-	-
72.0:	-	-	-	-	-	-	-	-	-	-
72.5:	-	-	-	-	-	-	-	-	-	-
73.0:	-	-	-	-	-	-	-	-	-	-
73.6:	-	-	-	-	-	-	-	-	-	-
74.0:	-	-	-	-	-	-	-	-	-	-
74.5:	-	-	-	-	-	-	-	-	-	-
75.0:	-	-	-	-	-	-	-	-	-	-
75.5:	-	-	-	-	-	-	-	-	-	-

*Circumference Value = abdomen (waist) + neck circumference (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p. 18.

CHART B PERCENT FAT ESTIMATION FOR FEMALES

Circumference Value*	Height (inches) 63.0	63.5	64.0	64.5	65.0	65.5	66.0	66.5	67.0	67.5
59.0:	35	34	34	34	33	33	33	32	32	32
59.5:	35	35	35	34	34	34	33	33	33	32
60.0:	36	35	35	35	34	34	34	33	33	33
60.5:	36	36	36	35	35	35	34	34	34	33
61.0:	37	37	36	36	36	35	35	35	34	34
61.5:	38	37	37	37	36	36	36	35	35	35
62.0:	38	38	37	37	37	36	36	36	35	35
62.5:	39	38	38	38	37	37	37	36	36	36
63.0:	39	39	39	38	38	38	37	37	37	36
63.5:	40	39	39	39	38	38	38	37	37	37
64.0:	40	40	40	39	39	39	38	38	38	37
64.5:	41	41	40	40	40	39	39	39	38	38
65.0:	41	41	41	40	40	40	39	39	39	38
65.5:	42	42	41	41	41	40	40	40	39	39
66.0:	43	42	42	41	41	41	40	40	40	39
66.5:	43	43	42	42	42	41	41	41	40	40
67.0:	44	43	43	43	42	42	42	41	41	41
67.5:	44	44	43	43	43	42	42	42	41	41
68.0:	45	44	44	44	43	43	43	42	42	42
68.5:		45	44	44	44	43	43	43	42	42
69.0:			45	45	44	44	44	43	43	43
69.5:				-	45	44	44	44	43	43
70.0:					-	45	45	44	44	44
70.5:			-	-	-	-	-	45	45	44
71.0:				-	-	-	-	-	-	-
71.5:				-	-	-	-	-	-	-
72.0:		-		-	-	-	-	-	-	-
72.5:					-	-	-	-	-	-
73.0:		-	-	-	-	-	-	-	-	-
73.5:	-			-	-	-	-	-	-	-
74.0:		-	-	-	-	-	-	-	-	-
74.5:	-			-	-	-	-	-	-	-
75.0:			-		-	-	-	-	-	-
75.5:			-	-	-	-	-	-	-	-

*Circumference Value = abdomen (waist) I + hip − neck circumferences (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to Enclosure (4), p. 19.

CHART B PERCENT FAT ESTIMATION FOR FEMALES

Circumference Value*	Height (inches) 68.0	68.5	69.0	69.5	70.0	70.5	71.0	71.5	72.0	72.5
59.0	31	31	31	30	30	30	29	29	29	28
59.5	32	32	31	31	31	30	30	30	29	29
60.0	32	32	32	32	31	31	31	30	30	30
60.5	33	33	32	32	32	31	31	31	31	30
61.0	34	33	33	33	32	32	32	31	31	31
61.5	34	34	34	33	33	33	32	32	32	31
62.0	35	34	34	34	34	33	33	33	32	32
62.5	35	35	35	34	34	34	33	33	33	33
63.0	36	36	35	35	35	34	34	34	33	33
63.5	36	36	36	35	35	35	35	34	34	34
64.0	37	37	36	36	36	35	35	35	35	34
64.5	38	37	37	37	36	36	36	35	35	35
65.0	38	38	37	37	37	37	36	36	36	35
65.5	39	38	38	38	37	37	37	36	36	36
66.0	39	39	39	38	38	38	37	37	37	36
66.5	40	39	39	39	38	38	38	37	37	37
67.0	40	40	40	39	39	39	38	38	38	37
67.5	41	40	40	40	39	39	39	39	38	38
68.0	41	41	41	40	40	40	39	39	39	38
68.5	42	41	41	41	40	40	40	40	39	39
69.0	42	42	42	41	41	41	40	40	40	39
69.5	43	42	42	42	42	41	41	41	40	40
70.0	43	43	43	42	42	42	41	41	41	40
70.5	44	43	43	43	43	42	42	42	41	41
71.0	44	44	44	43	43	43	42	42	42	41
71.5	45	44	44	44	43	43	43	43	42	42
72.0	-	45	45	44	44	44	43	43	43	42
72.5			-	45	44	44	44	44	43	43
73.0	-		-	-	45	45	44	44	44	43
73.5	-		-		-	-	45	44	44	44
74.0		-	-		-	-	-	45	45	44
74.5				-	-	-	-	-	-	45
75.0			-	-	-	-	-		-	-
75.5	-	-		-	-	-	-	-	-	-

*Circumference Value = abdomen (waist) + hip - neck circumferences (in inches)
SOURCE: OPNAVINST 6110.1D, Tab B to *Enclosure (4), p. 20.*

U.S. Air Force

The height, weight, and body fat standards for accession and retention in the U.S. Air Force are included in **Military Personnel: THE AIR FORCE WEIGHT AND FITNESS PROGRAMS** (AF REGULATION 35-11, 10 April 1985). This regulation is extensive and excerpts here include: the stated purpose of the regulation, details of procedures, and relevant reference tables[1].

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CHAPTER 1

GENERAL INFORMATION

1-1. General Information. Department of Defense (DOD) Directive 1308.1, 29 June 1981, requires each military service to provide a weight management and physical fitness program. The weight and fitness programs are tailored to meet DOD objectives and the specific needs of the Air Force. Weight management and physical fitness are linked to self image and self esteem and promote an overall healthy lifestyle for all Air Force members while improving military appearance and performance. Air Force members are responsible for achieving and maintaining the standards of weight and physical fitness defined in this regulation.

1-2. Terms Explained:

a. Aerobic Activity. An endurance exercise which lasts continuously over a period of time (minimum 20 minutes) and enhances the ability of the body to move air into and out of the lungs. Includes activities such as running, walking, cycling, rope skipping, swimming.

b. Body Fat. The percent of body fat tissue versus total body weight (body muscle and bone, water and fat).

c. Body Fat Measure (BFM) Adjustment. An upward or *downward adjustment* to a member's maximum allowable weight standard based on determination of an individual's percentage of body fat. Compliance with body fat standards will be determined by circumference measurement procedures as outlined in attachment 4 and AFR 160-17. Personnel Data System (PDS) code 4.

d. Clinical Obesity. A subjective decision by the medical practitioner that the member appears obese and there [illegible] underlying medical condition that causes obesity (AFR 160-17) or prevents weight loss [illegible]eting.

e. *Fitness Evaluation.* At least an annual event consisting of the 1.5 mile run or 3 mile walk.

[1]Further information concerning this regulation can be obtained from the DEPARTMENT OF THE AIR FORCE, Headquarters U.S. Air Force, Washington, D.C. 20330-5000.

f. Fitness Improvement Training (FIT) Program. A rehabilitative program that includes an exercise regimen for members who are not prepared for or who do not successfully complete their fitness evaluation. Placement in this program for a minimum of 90 days is mandatory. Extension beyond 90 days is at the unit commander's discretion.

g. Desired Body Weight. The weight at which a person is the healthiest and should have the best life expectancy. Desired weight is approximately 10 percent or more below the maximum allowable weight.

h. Maximum Allowable Weight (MAW). An individual's maximum allowable weight as required by Air Force weight tables (attachments 2 or 3) or as adjusted based on an approved body fat measurement or weight waiver.

i. MAW Standard Adjustment. An adjustment to the MAW standard. May be either an approved BFM or weight waiver.

j. Medical Practitioner. A physician, or a physician assistant (PA), nurse or nurse practitioner (NP) working under a physician's supervision, who is authorized to certify the individual's weight condition is controllable, the body fat measurement was properly administered, and provide a determination of clinical obesity. May recommend entry into a safe exercise program.

k. Monthly. Calendar month, or period of time from any day of the month to the corresponding day of the next month. Periods of approximately 30 days.

l. Observation Period (Weight Management Program (WMP) Phase II). Phase II indicates the member has met his or her MAW. During this 6-month period, the member continues monthly weight checks and diet counselings to reinforce a healthy lifestyle. PDS code 3.

m. Overfat. A condition characterized most accurately by the excess body fat or more roughly by body weight exceeding the MAW according to Air Force standards of weight. As used in this directive, overfat refers to the condition which exists when the body fat exceeds 20 percent for men, age 29 years and under; 24 percent for men, 30 years and over; 26 percent for women, age 29 years and under; 30 percent for women, 30 years and over.

n. Overweight Individual. An individual whose weight exceeds the MAW tables or an approved BFM or weight waiver adjustment.

o. Physical Fitness. The ability to rapidly transform stored energy into work. The ability to do daily tasks efficiently, without undue fatigue, and have ample energy remaining for military contingencies, emergencies, and leisure time pursuits.

p. AF Form 422, Physical Profile Serial Report. According to AFR 160-43, Medical Examination and Medical Standards, an AF Form 422 is used for communicating information from a medical facility to personnel, command, and training authorities. Describes the examinee's condition in nontechnical terms, and is used for noting duty restrictions and assignment limitations.

q. Personnel Data System (PDS). A computer system to vertically flow and update personnel information from the base personnel file to Headquarters Air Force personnel file.

r. Probation Period. A 1-year period of time following removal from the WMP. Commanders and supervisors maintain documentation on individuals who successfully complete the WMP. Documentation indicates previous WMP participation and is maintained for 1 year from the date the member is removed from WMP. PDS code 7.

s. Satisfactory Progress. Weight loss of at least 3 pounds each month for women and 5 pounds each month for men. PDS code 1.

t. Temporary Medical Deferral. A temporary deferral from a fitness evaluation, FIT, WMP, or 90-day exercise program for documented medical reasons. Recommended by a medical practitioner and approved or disapproved by the unit commander. Approved or revalidated by the unit commander in increments not to exceed 6 months. PDS code 5 for WMP deferral, only.

u. Unit Fitness Program Manager. An individual selected by the unit commander to assist and advise the unit commander regarding the unit fitness program responsibilities.

v. Unit Weight Program Manager. An individual selected by the unit commander to assist and advise the unit commander regarding weight program responsibilities.

w. Unsatisfactory Progress. Failure to lose 3 pounds each month for women and 5 pounds each month for men while in Phase I, or a weight gain over an individual's MAW at any time during Phase II or while in the probation period. PDS code 2.

x. Weight Management Program (WMP). A rehabilitation program designed to assist overweight individuals in obtaining satisfactory weight loss in order to meet Air Force standards. While in the WMP, members will weigh monthly, receive recurring diet counselings, and a 90-day exercise program to complement their weight loss program.

y. Weight Program. A program for all Air Force members that establishes Air Force standards of weight and provides a rehabilitation program for those who are not within standards.

z. Weight Waiver Adjustment. An upward adjustment to a member's MAW approved by the base commander. Medical practitioner determines member is not clinically obese, unit commander determines member presents a professional military appearance, and base commander approves or disapproves. PDS code 4.

SOURCE: AF Regulation 35-11, pp. 5-6.

* * * * *

CHAPTER 2

AIR FORCE WEIGHT PROGRAM

Section A—The Weight Program

2-1. Introduction. The American public and its elected representatives draw certain conclusions on military effectiveness based on the appearance presented by Air Force members. There must be no doubt Air Force members live by a common standard and are responsive to military order and discipline. Obesity detracts from military appearance and weight management is linked to self-image and self-esteem. The goals of the Air Force Weight Program include encouraging an overall healthy lifestyle and improving military appearance and personal readiness.

2-2. The Weight Program:

a. Weight management is an individual responsibility and applies to all Air Force members. Reaching and maintaining a desired body weight is medically advised. Weight reduction normally reduces high blood pressure, improves blood sugar utilization and often decreases excessive blood fats associated with coronary artery disease. Military members must have the physical and mental stamina to deal with the stress of military life while functioning at peak efficiency. Poor weight management can negatively affect flexibility, mobility, and endurance, and thereby impact Air Force readiness; therefore, weight management is a vital part of our peacetime preparation for combat readiness. All Air Force members must be prepared for worldwide military operations and contingencies. The Air Force Weight Program objectives are to:

(1) Establish a uniform system for weight management for Air Force people.

(2) Provide standards which enhance the attainment and retention of good health and physical fitness.

(3) Enhance the overall appearance and effectiveness of the military organization.

b. The WMP is a rehabilitative program for members who are not within the weight standards defined by this regulation. The objectives of the rehabilitation program are to:

(1) Provide rehabilitative counseling using available base resources and facilities;

(2) Encourage safe weight loss and development of a healthy lifestyle;

(3) Provide commanders a tool to evaluate a member's progress on a monthly basis; and

(4) Provide commanders options concerning administrative action for WMP participants.

c. Weight management is a continuing process that requires a healthy lifestyle to promote productivity and efficiency. Each Air Force member is responsible for developing and maintaining a lifestyle that includes a properly balanced diet and an effective physical conditioning program. Such a lifestyle will support our profession and the objectives of this regulation. The success of this program requires the personal effort from each Air Force member and the support from commanders and supervisors at all echelons.
SOURCE: AF Regulation 35-11, p 8

2-13. Individual Responsibilities. The individual is responsible for keeping his or her weight within the established Air Force standards of weight, maintaining a safe and proper diet regimen and participating in a year-round conditioning program that complements the weight program goals and objectives. Members in the WMP must meet the monthly weight loss standard and make every effort to be within the appropriate Air Force standard of weight by the date established by the unit commander. Establishment of a retirement date does not relieve the member of the responsibility to meet mission requirements, nor does a retirement date justify relaxing Air Force standards. Just as importantly, a member's retirement date does not relieve commanders or supervisors of the responsibility of enforcing standards or of offering quality rehabilitative support. The member's health, well-being, and personal readiness are important throughout military service and into retirement since members remain subject to recall for national emergencies.
SOURCE: AF Regulation 35-11 p. 11.

Section C—Weight Standards and Maximum Allowable Weight (MAW) Standard Adjustments

2-15. Weight Standards. Individuals are responsible for keeping their weight within the prescribed weight standards. Weight tables define standards (attachments 2 and 3). Weight checks for all personnel are necessary to ensure compliance with Air Force standards and to identify and assist people who exceed standards. Air Force body fat standards are 20 percent for men 29 years and under, 24 percent for men 30 years and over; 26 percent for women 29 and under; 30 percent for women 30 years and over. Members who are identified as overweight or overfat are entered into the WMP to help them safely lose weight, achieve a professional military appearance, and ultimately, comply with Air Force standards.

2-16. Maximum Allowable Weight (MAW) Standard Adjustments. An adjustment to the MAW standard may be either an approved BFM or weight waiver. Members who exceed the weight table standard may be overfat. Members who are within the weight table standard may be overfat. To allow for these situations, two methods are available to commanders to adjust a member's weight standard.

a. Body Fat Measurement Adjustment. The unit commander is the approving officer for BFM adjustments. A body fat measurement adjustment may be approved for a person who exceeds the MAW, but presents a professional military appearance. In this instance, the individual may require an upward adjustment of the MAW. Conversely, an individual who is within the weight standard, but does not present a professional military appearance, may require a downward adjustment of the MAW. The unit commander may do a BFM within the unit, or request a BFM be performed as part of a medical evaluation. Procedures: Involvement of a medical practitioner is at the unit commander's discretion. Upon receipt of a medical recommendation or after completing the BFM in the unit, the unit commander establishes the member's MAW by using either the tables at attachment 2 or 3, or the BFM results at attachment 4. The commander should consider personal appearance and if provided, the medical practitioner's recommendation, when establishing the MAW.

b. Weight Waiver Adjustment. The base commander is the approving authority for weight waiver adjustments. A weight waiver adjustment may be approved for people who exceed their MAW, are not clinically obese, present a professional military appearance, and the BFM does not adequately adjust their MAW. Procedures: The unit commander refers the member to the medical practitioner for a clinical obesity evaluation. The medical practitioner responds to the unit commander stating the member is or is not clinically obese and, if considered appropriate, recommends a MAW standard adjustment. The unit commander endorses the medical evaluation to the base commander recommending approval or disapproval. The base commander establishes the member's MAW based on the medical practitioner's and unit commander's recommendation, or disapproves the request. The decision is returned to the member's unit commander.

c. MAW Adjustment Procedures. The unit commander advises the member and the member's immediate supervisor of an approved or disapproved MAW adjustment. If the member is not in the WMP, the unit weight program manager reports an approved MAW adjustment (code 4) to CBPO/DPMQA. If the member is in the WMP, the adjustment does not excuse the member from completing the WMP. Members in the WMP must progress through the 6-month observation period (code 3) and 1-year probation period (code 7) before the adjustment is reported to the PDS as code 4. Individuals with approved MAW adjustment, are weighed at least semiannually and the adjustment is revalidated semiannually by the unit commander. Approval and semiannual reviews of the MAW adjustments are recorded on the AF Form 379 and reported to the CBPO/DPMQA for PDS update. Should the member exceed the approved MAW adjustments, the member is entered into Phase I of the WMP and is reported accordingly. The unit commander may reevaluate either MAW adjustment at any time. Based upon the recommendation of the medical practitioner and (or) an unacceptable military appearance, unit commanders may revoke a BFM adjustment any time. Unit commanders may also recommend a weight waiver be revoked by the base commander at any time. Members and their immediate supervisors are advised in writing of any change to the member's MAW adjustment.

2-17. Appeal Procedures for MAW Adjustments. A member may appeal a decision to approve, disapprove, or revoke a MAW adjustment.

a. The wing or equivalent commander is the final approval or disapproval authority for MAW adjustment appeals. The wing commander may act individually or by case file review, by individual presentation, or may convene an appeal council of officers for determination of proper disposition of the appeal. An appeal council of officers may be created on an ad hoc basis. If the appeal council option is elected, the wing commander (or representative) is responsible for selection of members and establishing council procedures. The wing commander's final decision is sent by letter to the individual's unit commander, who informs the individual and supervisor. During the appeal the WNP participant is weighed monthly, but is not subject to administrative action. Appeal procedures are outlined below:

b. The individual initiates an appeal in writing (attachment 14) to the wing commander through the appropriate chain of command within 10 duty days after notification of the MAW adjustment decision (attachment 13). All appeals must include indorsements of the immediate supervisor, unit commander, and the base commander. If unusual circumstances warrant, such as temporary duty (TDY), hospitalization, emergency leave, the 10 workday suspense may be adjusted by the unit commander accordingly

c. The unit commander provides the following documents as a part of the appeal application:

(1) WMP case file.

(2) Current records review Report on Individual Personnel (RIP).

(3) Copies of last three APRs or OERS.

(4) Copy of AF Form 1137, Unfavorable Information File Summary, if applicable.

(5) Unit personnel folder (if applicable). The RIP and copies of last three APR or OERs will be provided to the unit commander by CBPO/Military Personnel (DPM) upon request.

Section D—Weight Program Requirements

2-18. Weight Program Requirements. The MAW tables (attachments 2 and 3) by no means reflect individuals' desired weight but rather their "maximum allowable weight." Desired weight is the weight at which a person should have the best life expectancy. Desired body weight is usually determined individually, depending upon the person's bone structure and muscle mass. As a rule of thumb, 10 percent below individual's MAW for height more closely approximates his or her desired weight as calculated by the accepted height and weight charts. Maintaining a desired weight is medically prudent. The weight program requirements apply to all Air Force members. There are no exceptions for flying personnel under the provisions of this regulation. Flying personnel who are determined overweight by the unit commander are referred to the servicing flight surgeon for medical evaluation. The flight surgeon decides if the overweight condition is a threat to flying safety, member's flying status, and forwards appropriate documentation and recommendations to the servicing flight management officer and unit commander. The flight surgeon then refers members to the DBMS appointed medical OPR for the base weight program for evaluation for possible entry into the WMP.

2-19. Weight Checks, Height Measurements, and Scale Calibration:

a. Weight Checks. Air Force members are weighed semiannually during the months of January and July. However, members who are 10 percent or more under their MAW, only require an annual weight check. Unit commanders and supervisors may weigh members as often as deemed necessary; for example, if they believe a member exceeds the weight standard and (or) does not present a professional military appearance, a weight check may be required. Event-related weight checks (for example, weight checks prior to PME, TDY or PCS) occurring in January or July may satisfy the semiannual or annual requirement. For specific weight check procedures, see attachment 1, paragraph a.

b. Height Measurements. A member's official height is determined at the commander's first directed weigh-in after the member arrives PCS or the unit commander may elect to use the height from the individual's last official physical exam. The official height is documented on AF Form 379 and may be used for the duration of the member's assignment to the installation. Unit commanders may remeasure a member's height if deemed necessary. For specific height measurement procedures, see attachment 1, paragraph b.

c. Scale Calibration. Scales should be calibrated every 12 to 15 months. (Reference AFTO 33K-1-100.) Movement of scales should be avoided. Placement of scales on noncarpeted surface or plexiglass is recommended.

2-20. Permanent Change of Station (PCS) or Permanent Change of Assignment (PCA) Procedures. In addition to the semiannual or annual weight checks, members will be weighed upon receipt of PCS notification and prior to PCS departure.

a. Upon notification of PCS assignment, losing commanders ensure each member, whether or not in the WMP, is weighed. Another weight check is conducted NET 45 and NLT 30 days before projected departure date. Members in Phase I of the WMP, regardless if progression is satisfactory or unsatisfactory, are removed from assignment unless making a mandatory move according to AFR 39-11 or AFR 36-20. The unit commander will immediately notify CBPO Outbound Assignments, Personnel Utilization Section (DPMUO) and CBPO/DPMQA if a member is entered into Phase I of the WPM. Members may become eligible for PCS assignment when entered into Phase II of the WMP.

b. PCA reassignment for members in the WMP is permissible when losing and gaining unit commanders are in agreement and rehabilitative efforts are not interrupted.

c. No earlier than 45 days and NLT 30 days before PCS or PCA reassignment projected departure date, the losing unit will provide the gaining unit commander the WMP case file by transmittal letter. The relocation processing letter (see AFR 35-17, attachment 2) will be completed and returned to CBPO/DPMUO by the established suspense date.

d. Commanders of the losing and gaining units will correspond with each other to resolve questions concerning individuals in the WMP. Information copies of such correspondence are addressed to the parent base or MAJCOM/DP(MP).

e. Gaining commanders ensure members in the WMP are weighed upon arrival and the AF Form 393 is annotated. Weight checks of all other personnel upon arrival are at the discretion of the gaining unit commander.

2-21. Temporary Duty (TDY) Procedures:

a. General Policy:

(1) A member's TDY eligibility may be affected by his or her WMP status. Except where specified below, unit commanders determine TDY eligibility. TDY and parent unit commanders will communicate directly regarding member's status in the WMP. Personnel are not automatically excluded from mobilization deployment, military or operational exercises because they are in the WMP or making unsatisfactory progress.

(2) TDY unit commanders have the authority to enter personnel in the WMP, monitor progress and take administrative action concerning TDY members who are in the WMP or who are found overweight and must be entered in the WMP.

(3) Personnel who have an approved BFM or weight waiver adjustment will hand-carry a copy of the approved adjustment documentation to the TDY unit commander.

(4) If in the WMP, a copy of AF Form 393 will be hand-carried by the WMP participant to the TDY unit commander

b. Command Support TDY. Command support TDY is considered a TDY to attend a conference, meeting, workshop, manning or staff assistance visit or an orientation. Command support and normal mission requirements will be at the unit commander's discretion. Personnel in the WMP making satisfactory progress must be closely scrutinized by the unit commander before final selection is made and orders processed. Personnel in the WMP making unsatisfactory progress should not be allowed to attend a command support TDY. The unit commander may send the member TDY with MAJCOM/DP(MP) concurrence.

c. Professional Military Education (PME). (See AFRs 50-39 and 53-8.) Unit commanders weigh members selected for PME NLT 3 weeks before projected departure date. Members who are not within weight standards are ineligible to attend PME. PME selectees who do not meet weight standards will be reported as ineligible to the CBPO, Classification and Training Unit, Career Progression Section, (DPMPC) with information copy to CBPO/DPMQA. Students who arrive at PME schools overweight are returned to the parent or projected unit at the parent unit's expense. Members returned are entered into the WMP initial entry (code 6) or the observation period (code 3), whichever is appropriate. Administrative action is appropriate See paragraph 2-20 for procedures for PME which require PCS assignments.

d. Retraining. Airmen in Phase I of the WMP are ineligible for voluntary retraining (such as CAREERS and Palace Balance, reference AFR 39-4).

(1) Airmen will be weighed by the unit manager upon receipt of approved retraining and again within 10 days before projected departure date. Retrainees not meeting AFR 35-11

standards are ineligible for voluntary retraining, will not be permitted to depart for training, and will be entered into Phase I of the WMP. Such retrainees must be reported according to AFR 394, table 2-2.

(2) Retrainees arriving at the TDY location in a TDY-and-return status who are overweight as defined by this regulation will be reported to HQ AFMPC Directorate of Procurement, Pipeline Management and Retraining Division, Retraining Operations Branch (MPCMSR) for disposition instructions. (For retrainees attending Headquarters Air Training Command (ATC) conducted courses, forward an information copy of the message to HQ ATC Student Resources Division, Technical Training (TTPR) and Personnel Actions Division (DPAA)). Include all pertinent information available to help in the decision process. HQ AFMPC/MPCMSR will forward disposition instructions. TDY en route and PCS student retrainees will be handled as outlined in paragraph e(5) below.

e. Formal Training Career Enhancement. All members selected to attend a training course (formal training, specialization and qualification training) will be weighed by the unit manager upon receipt of the approved training notice from the CBPO and again within 10 workdays before projected departure date. If found overweight at the 10 workday weight check, the member will be placed in the WMP before departure. Members making satisfactory progress are eligible for training except as indicated in paragraph c and d above. Members making unsatisfactory progress are ineligible for training. If a member is making unsatisfactory progress in the WMP and is the only member eligible to satisfy the allocated training, the unit commander may send the member TDY with MAJCOM/DP (MP) concurrence. MAJCOM/DP (MP) is strongly encouraged to relevy the training quota. If the MAJCOM approves the member to attend school in an unsatisfactory progress condition, the member will hand-carry a copy of the approved MAJCOM correspondence to the TDY unit commander.

(1) TDY personnel will be weighed upon arrival at the discretion of the TDY unit commander.

(2) Upon arrival at the TDY location if a member is making unsatisfactory progress in the WMP, or is found overweight and not in the WMP, the member is not entered into the training course and is returned at the parent unit's expense. Additionally, the TDY unit commander will notify the parent unit or base commander and COM/DP (MP) of the member's grade, name, SSN, and other relevant information. Upon the member's return, the unit commander will enter the member into the WMP, initial entry (code 6) or observation period (code 3), whichever is appropriate and take appropriate administrative action.

(3) Members weighed during the training course and found to exceed the weight standard are placed into the WMP by the TDN unit commander. Progress is monitored and appropriate administrative action is taken. The servicing CBPO, parent base and unit commanders will be advised of member's placement in the WPM, and the member will hand-carry the TDY WMP case file to the parent unit commander upon return.

(4) If a member is weighed during the training course and is found to be making unsatisfactory progress in the WMP, the TDY unit commander will take appropriate administrative action. In addition, the TDY unit commander will notify the parent unit or base commander, and parent MAJCOM/DP (MP) that the individual is making unsatisfactory progress and that administrative action has been taken.

(5) Personnel TDY en route PCS who are determined overweight and not in the WMP, or on a mandatory move and found unsatisfactory in the WMP, are reported by the TDY commander to the gaining MAJCOM/DP (MP), and the base and unit commanders. In addition, an information copy will be forwarded to HQ AFMPC Directorate of Assignments, Assignment Policy Section (MPCRPP1). These personnel will be allowed to complete the scheduled training, however, the TDY commander and gaining unit commander will communicate directly with each other to determine the appropriate rehabilitative and administrative action.

Section E—Weight Management Program (WMP) and Related Information

2-22. Weight Management Program (WMP). The WMP is a rehabilitative program that consists of Phase I (initial entry and weight loss period) and Phase II (observation period). The probation period is a follow-on to the WMP and is not a part of the WMP. Individuals who exceed the MAW are sent to DBMS by the unit commander for medical evaluation. Medical evaluation procedures are outlined in AFR 160-17, and will be completed within 10 working days from the date the member acknowledges receipt of the unit commander's notification letter of WMP appointments (attachment 10). The designated DBMS representative will evaluate each member to determine clinical obesity, if safe weight loss can occur, and if entry into a 90-day exercise program is feasible. The DBMS representative will perform a BFM, if deemed appropriate, or the unit commander requests one. (BFM generally is not required if the individual is more than 10 to 15 percent above MAW.) Results of the medical evaluation will be provided to the unit commander (attachment 1). Diet counseling will be provided by the appropriate medical representative to define a weight loss program that will not adversely affect the member's health and will assist his or her meeting the MAW.

2-23. Phase I (Initial Entry and Weight Loss Period). On receipt of the DBMS evaluation, the unit commander will enter the member into the WMP if the individual is overweight or overfat. The unit manager weighs the member after the medical evaluation and records the weight on the AF Form 393 to ensure an accurate entry weight is documented. The unit commander will inform the member in writing of formal entry into the WMP and will establish the member's MAW (attachment 6). NOTE: The MAW is not the desired body weight but the maximum body weight (paragraph 1-2g and 1-2h). Commanders may apply the weight tables, the BFM or the weight of an adjusted weight waiver. Health and appearance concerns should be used in setting standards.

a. The commander will advise enlisted members they are ineligible for reenlistment, PCS reassignment, voluntary retraining, PME attendance, and similar career actions. Commanders must advise enlisted members they may be eligible to test and be selected for promotion but will not assume a higher grade, if selected, until their MAW is met and then are recommended for promotion. Each of these career actions apply until such time that he or she is within the weight standard (entered into Phase II). Officers are advised they are ineligible for PCS reassignment or to attend PME. Officers must also be advised that it is Air Force policy that action will be initiated to delay an officer's promotion, Regular Appointment or Indefinite Reserve status if the officer does not meet Air Force standards of weight. Career actions for officers and enlisted members concerning promotion, reenlistment and PCS reassignment will be processed by unit commanders according to the governing directive for that action (attachment 24).

b. Reserve members may extend to cover the period of time required to comply with the weight standards, for example, a male member who exceeds the weight standard by 20 pounds would be allowed to extend 4 months. According to U.S.C. Title 32, Section 302, minimum extension period for ANG members is 6 months.

c. Quarterly diet counselings are mandatory during Phase I and enrollment in a 90-day exercise is mandatory for all members in Phase I (reference attachment 16). Extension beyond 90 days is at the unit commander's discretion. (See attachment 6)

d. The individual will acknowledge receipt and understanding and date the letter of notification. The date the member acknowledges receipt will serve as the official entry date in the WMP (code 6). Copies of the Initial Entry Letter will be distributed at a minimum to the individual, his or her supervisor, CBPO/DPMQA and unit weight program manager for inclusion in the WMPCF.

e. During Phase I, individuals will be weighed on a monthly basis. Commanders may weigh members more frequently to reinforce rehabilitative efforts; however, only the weight check at the end of the monthly period will be considered as an official weigh-in. (Water retention during the week before a menstrual cycle is not uncommon. Commanders may adjust women's weigh-in dates accordingly.) Satisfactory weight loss is 5 pounds each month for men and 3 pounds each month for women. The difference in weight loss required between men and women is based on body composition and physiological differences. Men normally have more lean tissue mass (muscle) than women. Calories are burned in lean tissue mass. Therefore, men have a greater opportunity to burn calories (lose weight) than women. Successful completion of Phase I allows a member to be entered into Phase II.

2-24. Phase II (Observation Period). Members are notified in writing when they meet their MAW and are officially entered into Phase II (code 3) for 6 months.

a. A weight gain over the MAW at any time during this phase constitutes unsatisfactory progress (code 2) and members are returned to Phase I of the WMP with appropriate administrative action by the unit commander according to paragraph 2-28. The member must be advised in writing that career actions such as reenlistment, promotion, and PCS reassignment, once again apply.

b. When members are identified as exceeding their MAW but subsequently meet their standard by the time the medical evaluation results are provided to the unit commander, the members are entered directly into Phase II. Commanders will enter them into a minimum 90-day exercise program. Extension beyond 90 days is at the unit commander's discretion. During this 6 month phase, at least monthly weigh-ins are required to make sure individuals maintain their weight at or under the MAW. Commanders and supervisors also will ensure the individuals continue to receive quarterly diet counseling during this phase of the WMP to enhance the lifestyle change.

c. An individual is considered officially removed from the WMP on successful completion of Phase II and receipt of the unit commander's letter entering the individual into the probation period (attachment 9). The date of removal is the date the individual acknowledges receipt of the removal letter.

2-25. Probation Period. After removal from the WMP and entering the probation period, monthly weight checks and quarterly diet counselings may be discontinued. However, individuals remain identified in the PDS for 12 months (code 7) from the effective date of WMP removal. While in the probation period, commanders and supervisors should reinforce positive lifestyle habits and, when necessary, identify repeat offenders of Air Force standards of weight.

a. Commanders and supervisors should be aware these individuals are in a probationary period and a weight gain over the MAW at any time constitutes unsatisfactory progress (code 2). In such instances members are reentered into Phase I of the WMP. If the member has not had a medical evaluation within the past 12 months, an evaluation must be completed prior to reentry into Phase I. If a medical evaluation was completed during the past 12 months, another evaluation is not required. Upon reentry, commanders will take appropriate administrative action according to paragraph 2-28.

b. Following completion of the 1-1/2 year probationary period, if the member again exceeds MAW, he or she is entered into Phase I of WMP (PDS code 6), without prejudice of previous WMP participation.

2-26. Participation in a 90-day Exercise Program. Unit commanders will direct individuals to participate in a 90-day exercise program when entered into Phase I of the WMP. Members entered directly into Phase II of the WMP will also be required to complete the 90-day exercise program. Participation in a 90-day exercise program is documented on AF Form 1975, Personal Fitness Progress Chart. Extensions beyond 90 days are at the unit commander's discretion.

a. Unit commanders may direct individuals to participate in a 90-day exercise program if they do not present a professional military appearance, although they may not be overweight. A downward BFM may be appropriate (paragraph 2-16a). Members in this category should be sent to DBMS for a medical evaluation before entry into the 90-day exercise program. Commanders should notify the member and supervisor of the 90-day exercise program requirement and reason for entry. When military appearance is the reason for entry, the commander should also specify in writing the expected criteria and the date for successful completion and removal.

b. While individual physical conditioning is an individual responsibility, and should be performed primarily during normal off-duty time, unit commanders have the prerogative to allow on-duty conditioning when possible as mission requirements permit.

2-27. Temporary Medical Deferral. A WMP participant may receive a temporary medical deferral from a weight loss program or 90-day exercise program. PDS code 5 is used only when the temporary medical deferral applies to the weight loss program. A medical practitioner must recommend a temporary medical deferral to the unit commander by documenting the individual's limitations and (or) condition on an AF Form 422. The unit commander has final approval or disapproval authority for temporary medical deferral. Approved temporary medical deferrals only may be granted for the length of time as specified on the AF Form 422 or a maximum of 6 months, whichever is shorter. After an initial 6-month increment, the unit commander will review the temporary medical deferral for possible continuation. In those unique situations that clearly justify an additional deferment, the unit may approve a maximum 6-month continuation. The results are recorded on AF Forms 379 and 393. Unit commanders may not approve temporary medical deferrals to exceed 12 months. A temporary medical deferral beyond 12 months must be approved by the base commander (except for pregnancy, see paragraph b below). The request should include the following information through the unit commander in the justification for extension: background on the medical condition, approval dates of previous medical deferral, medical diagnosis, when the medical problem may be resolved, and any other pertinent information. After the temporary medical deferral expires, the unit commander weighs the member and takes appropriate action according to this regulation.

a. Any member in the WMP who receives an approved temporary medical deferral which precludes their ability to lose weight will be placed in an inactive status (code 5). On removal from the temporary medical deferral the member is weighed and the unit commander determines appropriate action. If the member is not within his or her MAW, placement into Phase I is required. The member is placed in satisfactory status (code 1) until the next monthly weigh in period following removal from the inactive status. If an unsatisfactory progress period occurs, the level of administrative action is determined by the member's progress in the WMP since initial entry; that is, disregard the inactive period. If the member has met his or her MAW, entry into Phase II is appropriate.

b. Pregnant women who are in the WMP are placed in an inactive status and reported to CBPO/DMPQA as temporarily medically deferred (code 5). The pregnancy deferral expires 90 days after termination of pregnancy, unless extenuating circumstances occur and medical documentation is provided on a subsequent AF Form 422. The unit commander has the authority to approve up to 18 months of the temporary medical deferral for pregnancy without seeking the approval of the base commander. The medical practitioner is encouraged to use AFM 160-8, chapter 3, as an appropriate guide for prescribing a diet during pregnancy to prevent excessive weight gain. At a minimum, AFP 166-21 is available to support prenatal diet counselings.

2-28. Administrative Actions. Individuals who fail to comply with the prescribed weight standards as outlined in this regulation are entered into the WMP. They are ineligible for reassignment and will have rendered themselves ineligible for reenlistment, retraining, and other career opportunities. Administrative action on individual Reserve participants will be according to paragraph 2-4b(2). An AFRES supplement to AFR 35-11 will address the administrative actions for unit assigned reservists. An ANG supplement to AFR 35-11 will address the administrative actions for members of the ANG.

a. It is the member's responsibility to be at or below the established weight standard. Members who exceed the MAW are not within Air Force standards. The WMP is designed to assist and encourage a safe, healthy weight loss and to encourage a lifestyle change.

b. The WMP is a rehabilitative program that provides a medical evaluation, recurring diet counseling, a 90-day exercise program, and a stabilized environment. The member should be encouraged to maintain a positive attitude toward the program and follow instructions provided by both diet and conditioning counselors. Positive individual participation should result in satisfactory progress in the WMP. If an individual is not making satisfactory progress (less than 5 pounds each month for men or less than 3 pounds each month for women), commander's action is required. Commanders exercise their prerogative by selecting an administrative action(s) from the appropriate Unsatisfactory Period List (paragraph e below).

c. Return to Phase I from Phase II or the probation period requires administrative action. Action must come from a level equal to or more severe in action than the last one used when the member was in Phase II. This approach is designed to minimize inconsistencies and inequities among units (paragraph e below).

d. Nonjudicial punishment may not be imposed solely for the condition of being overweight. There must have been some violation with respect to a specific duty, such as failure to report for an appointment. Punitive actions must be based upon violations of the Uniform Code of Military Justice (UCMJ), and commanders should consult with their servicing Staff Judge Advocate (SJA) when determining whether article 15 action is appropriate.

e. Unsatisfactory Period Lists. Upon entry into the WMP, the individual jeopardizes his or her career. Unsatisfactory period(s) require administrative action by the commander. Commanders exercise their prerogative when dealing with their people by selecting at least one administrative action for each unsatisfactory monthly period. Unsatisfactory periods need not be consecutive. The administrative action(s) are selected from the coinciding Unsatisfactory Period List. (Example: For an individual's first unsatisfactory period, the commandant selects an action from the list of administrative actions within the First Unsatisfactory Period List.) Commanders may select more than one action from the list. Actions on each list are not prioritized and do not have to be used in the order provided. Fully document administrative actions on the AF Form 393 and complete in a timely manner.

(1) First Unsatisfactory Period. When deciding upon action(s), commanders should consider that the member does not meet Air Force standards of weight and he or she is not progressing satisfactorily in a rehabilitation program. After the commander selects the administrative action(s), full documentation is required. The commander also is encouraged to consider other possible rehabilitative actions such as additional diet counselings, supervised exercise periods, and more frequent weight checks. While the primary objective is to encourage the member to meet Air Force standards, commanders should keep in mind if the member continues to make unsatisfactory progress in the WMP, adequate documentation must be available to support administrative separation (see (4) below).

(a) Options for Officers:

1. Verbal Counseling

2. Letter of Admonition

3. Letter of Reprimand

4. Establish UIF

5. Limit supervisory and (or) Command Responsibilities

6. Comment in OER on Unsatisfactory progress; consider lack of progress when evaluating "Professional Qualities"

(b) Options for Enlisted:

1. Verbal Counseling

2. Letter of Admonition

3. Letter of Reprimand

4. Establish UIF

5. Limit Supervisory Responsibilities

6. Comment in APR on unsatisfactory progress; consider lack of progress when evaluating "Bearing"

(2) Second Unsatisfactory Period. Commanders should remind members of their responsibility to develop and maintain a lifestyle which allows them to meet the Air Force standards of weight. A lack of commitment to the rehabilitation program, poor attitude, and a lack of self-discipline may be indicated by a second unsatisfactory period. Commanders should consider the grade, experience, and position of the member since higher ranking Air Force members are more familiar with Air Force standards, supervisory responsibilities, and the need of role models for subordinates. Individuals who fail to maintain standards are less effective at enforcing Air Force standards on subordinates. Unit commanders exercise their prerogative when selecting action(s) from the Second Unsatisfactory Period List to document the continued lack of progress in the WMP. Additional rehabilitative actions not previously taken are encouraged at this time. Once again, commander should remind members that continued unsatisfactory progress can result in administrative separation (see (4) below).

(a) Options for Officers:

1. Verbal Reprimand

2. Letter of Reprimand

3. Establish UIF

4. Limit or Remove Supervisory and (or) Command Responsibilities

5. Control Roster

6. Comment in OER on Unsatisfactory progress; consider lack of progress when evaluating "Professional Qualities" and (or) prepare a "Directed by Commander" OER

7. Initiate appropriate proprietary action (NQ, removal) concerning promotion, Regular Appointment and *Indefinite* Reserve status or selective continuation

(b) Options for Enlisted:

1. Verbal Reprimand

2. Letter of Reprimand

3. Establish UIF

4. Limit or Remove Supervisory Responsibilities

5. Control Roster

6. Comment in APR on Unsatisfactory progress; consider lack of progress when evaluating "Bearing" and (or) prepare a "Directed by Commander" APR

7. Deny or Vacate NCO Status (Sergeant, Senior Airman)

8. Remove from Promotion List

(3) Third Unsatisfactory Period. Previous rehabilitative actions should be considered when determining the action which is appropriate for the third failure to make satisfactory progress in the WMP. The lack of commitment in meeting Air Force standards may not only reflect poorly on the individual, but also on the individual's commander and *unit*. An overweight condition limits flexibility, endurance, and contributes to heart disease, thereby creating a negative impact on the readiness of the force. Unit commanders should caution members that another unsatisfactory period may result in administrative separation (see (4) below).

(a) Options for Officers:

1. Letter of Reprimand

2. Establish UIF

3. Limit or Remove Supervisory and (or) Command Responsibilities

4. Control Roster

5. Comment in OER on Unsatisfactory progress; consider lack of progress when evaluating "Professional Qualities" and (or) prepare a "Directed by Commander" OER

6. Initiate appropriate propriety action (NQ, Removal) concerning promotion, Regular Appointment and Indefinite Reserve status or selective continuation

(b) Options for Enlisted

1. Letter of Reprimand

2. Establish UIF

3. Limit or Remove Supervisory Responsibilities

4. Control Roster

5. Comment in APR on Unsatisfactory progress; consider lack of progress when evaluating "Bearing" and (or) prepare a "Directed by Commander" APR

6. Deny or Vacate NCO Status (Sergeant, Senior Airman)

7. Remove from Promotion List

8. Administrative Demotion

(4) Fourth Unsatisfactory Period. The WMP is a rehabilitation program designed to assist, encourage, and support a member's personal effort to meet Air Force standards of weight. The member now clearly has indicated his or her unwillingness to meet Air Force standards. The member's repeated failures to make satisfactory progress in the WMP indicate a poor attitude and demonstrate a lack of self-discipline, not only for his or her own well-being but toward the mission of the Air Force as well. Since previous attempts at rehabilitation have failed, commanders are strongly encouraged to initiate administrative separation action. If the unit commander determines separation action is appropriate, the unit commander will follow the procedures contained in AFR 36-2 for officers, or AFR 39-10 for airmen. After the unit commander makes the decision whether to retain or separate an airman, the commander advises the Special Court Martial authority of the decision. For an officer, the unit commander provides the recommendation for discharge or retention to the initiating commander according to AFR 36-2.

(a) Options for Officers:

1. Administrative Separation or

2. Retention with continuation in WMP and appropriate administrative action from the Third Unsatisfactory Period list.

(b) Options for Enlisted.

1. Administrative Separation or

2. Retention with continuation in WMP and appropriate administrative action from the Third Unsatisfactory Period list.

SOURCE: AF REGULATION 35-11, pp. 12-20.

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PROCEDURES FOR WEIGHT CHECKS AND HEIGHT MEASUREMENT

a. Weight Checks:

(1) The member's weight will be measured with shoes off, and in basic duty uniform.

(2) The member may remove contents of pockets and any extraneous equipment (tools, guns, keys) or outer clothing.

(3) The member should stand still while on the scale.

(4) Measurement should be read with the measurer directly in front or behind the scale if possible. Reading the scale from either side rather than straight-on reduces accuracy.

(5) Subtract 3 pounds for clothing for men and women.

(6) Weight will be recorded to the nearest quarter pound.

(7) Recommend the weight standard tables be prominently displayed near unit weighing scales.

b. Height Measurement. The preferred method for height measurement is the back to hard surface method. However, a scale height-measurement bar is acceptable.

(1) Height will be measured and not transferred from the military identification (ID) card.

(2) Height will be measured without shoes.

(3) Member should stand facing the person measuring him or her with heels together and back straight.

(4) The member's line of sight should be horizontal.

(5) Measuring bar should rest lightly on the crown of the head.

(6) Measurement should be read directly in front of the rod, not at an angle from either side.

(7) Measurement should be taken to the nearest quarter inch.

SOURCE: AF REGULATION 35-11, Attachment 1, p. 31

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WEIGHT STANDARDS—MEN (see note)

HEIGHT (IN INCHES)	MAXIMUM ALLOWABLE WEIGHT (MAW)	INTERPOLATED WEIGHT			10% CRITERIA WEIGH ANNUALLY
		¼"	½"	¾"	
60	153	151	154	154	138
61	155	155	156	157	139
62	158	158	159	159	142
63	160	161	162	163	144
64	164	165	166	167	148
65	169	170	171	172	152
66	174	174	175	176	157
67	179	180	181	182	161
68	184	185	186	187	166
69	189	190	191	192	170
70	194	195	196	197	175
71	199	200	202	203	179
72	205	206	208	209	184
73	211	212	214	216	190
74	218	219	221	222	196
75	224	225	227	228	202
76	230	231	233	234	207
77	236	237	239	240	212
78	242	243	245	246	218
79	248	249	251	251	223
80	254	255	257	258	229

NOTE: For every inch under 60 inches, subtract 2 pounds from the **MAW**. For every inch over 80 inches, add 6 pounds to the **MAW**.

SOURCE: AF REGULATION 35-11, Attachment 2, p. 32

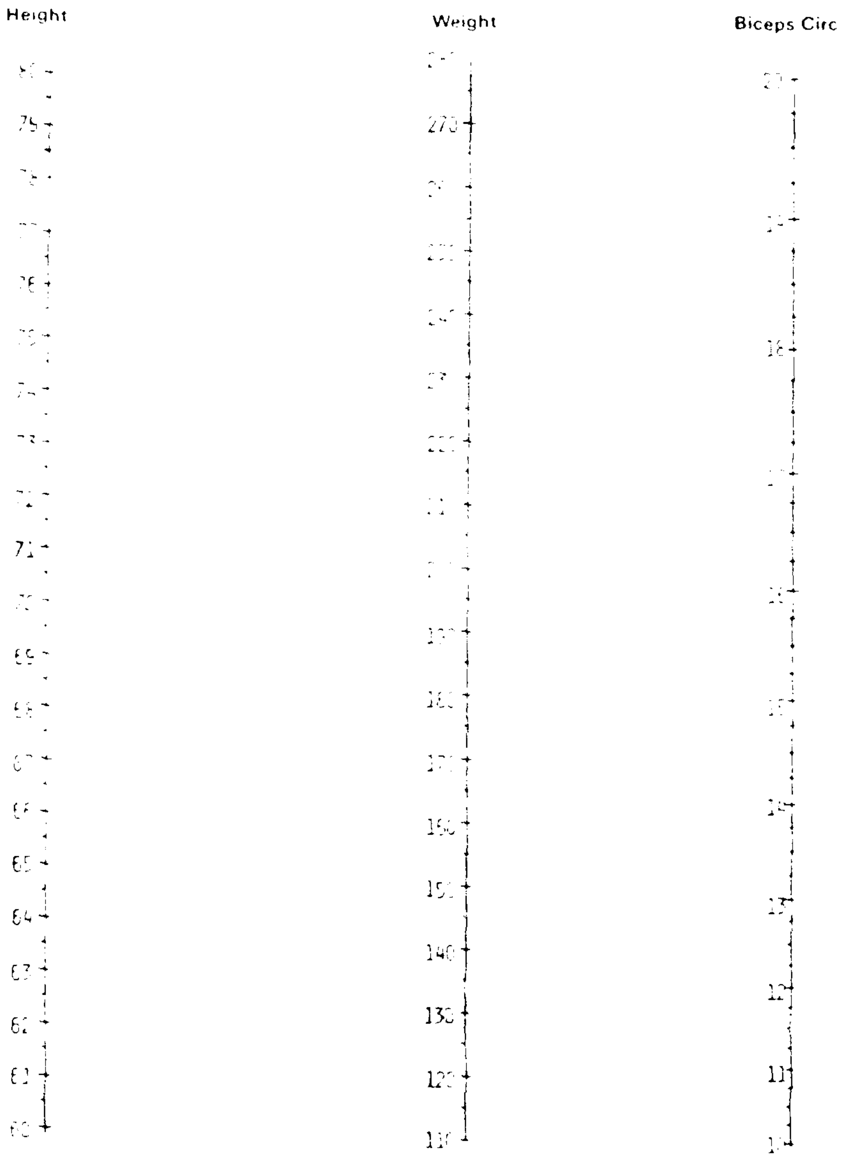
WEIGHT STANDARDS—WOMEN (see note)

HEIGHT (IN INCHES)	MAXIMUM ALLOWABLE WEIGHT (MAW)	INTERPOLATED WEIGHT			10% CRITERIA WEIGHT ANNUALLY
		¼"	½"	¾"	
58	126	126 [illegible]	127	127 [illegible]	113
59	128	128 [illegible]	129	129 [illegible]	115
60	130	130	131	131 [illegible]	117
61	132	132 [illegible]	133	133 [illegible]	119
62	134	134 [illegible]	135	135 [illegible]	121
63	136	136 [illegible]	137 [illegible]	138 [illegible]	122
64	139	140 [illegible]	141 [illegible]	142 [illegible]	125
65	144	145	146	147	130
66	148	149	150	151	133
67	152	153	154	155	137
68	156	157 [illegible]	158 [illegible]	159 [illegible]	140
69	161	162	163	164	145
70	165	166	167	168	148
71	169	170 [illegible]	171 [illegible]	172 [illegible]	152
72	174	175 [illegible]	176 [illegible]	177 [illegible]	157
73	179	180 [illegible]	182	183 [illegible]	161
74	185	186 [illegible]	187 [illegible]	188 [illegible]	166
75	190	191 [illegible]	193	194 [illegible]	171
76	196	197 [illegible]	198 [illegible]	199 [illegible]	176
77	201	202 [illegible]	203 [illegible]	204 [illegible]	181
78	206	207 [illegible]	208 [illegible]	209 [illegible]	185

NOTE: For every inch under 58 inches, subtract 2 pounds from the MAW. For every inch over 78 inches, add 6 pounds to the MAW.
SOURCE: AF REGULATION 35-11, Attachment 3, p. 33.

BODY FAT MEASUREMENT

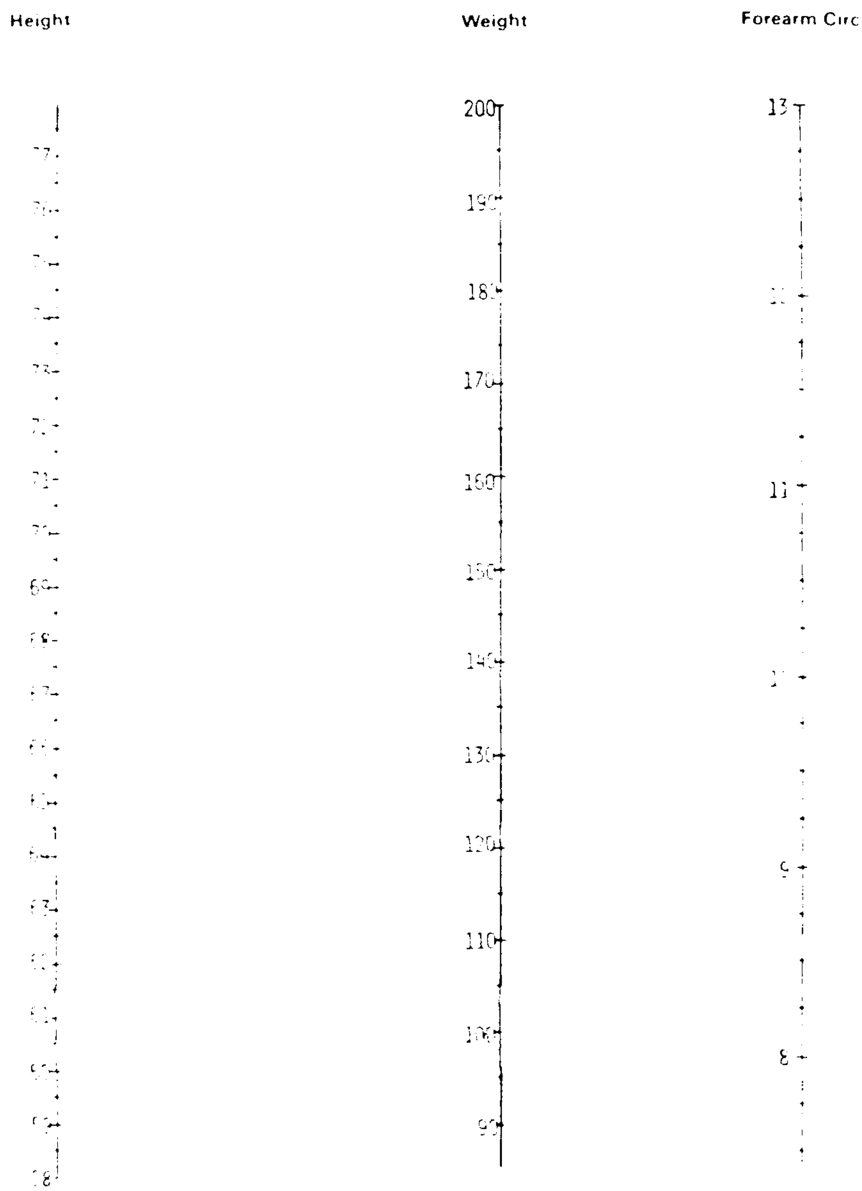
MALES UNDER 30 YEARS--HEIGHT AND BICEPS IN INCHES



SOURCE: AF REGULATION, Attachment 4, p. 34.

BODY FAT MEASUREMENT

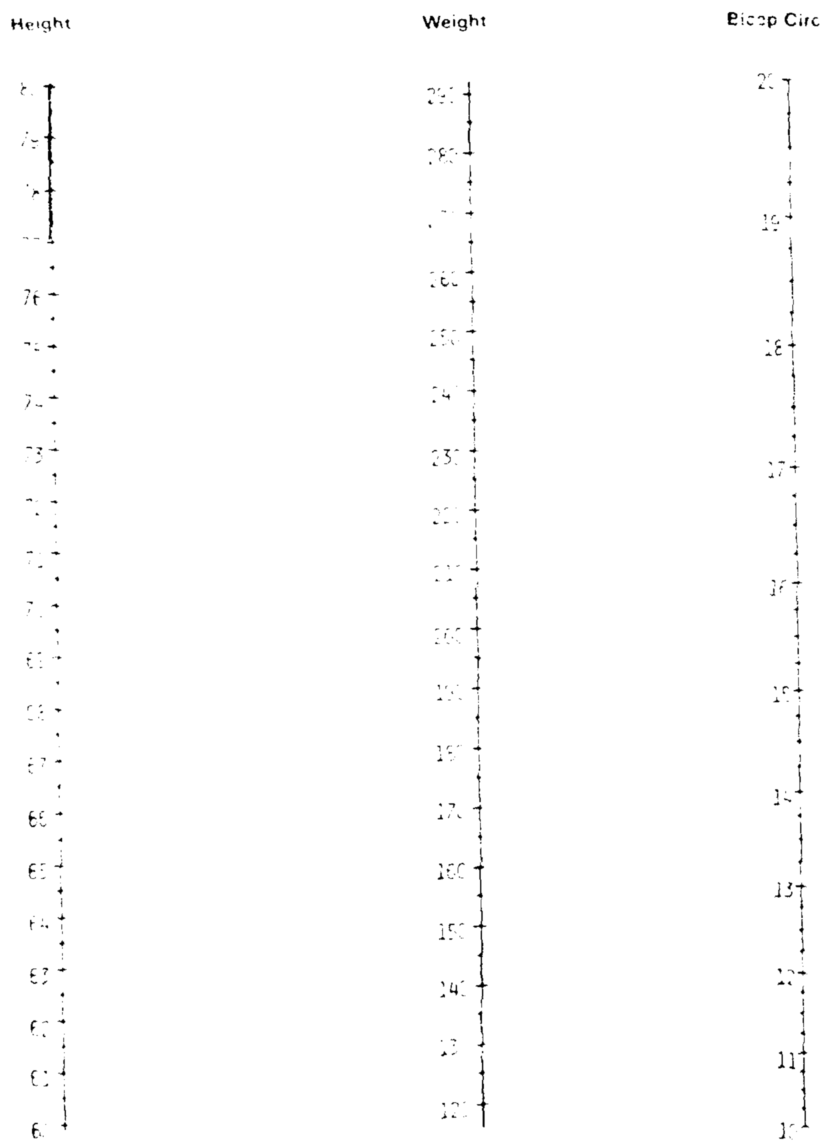
FEMALES UNDER 30 YEARS--HEIGHT AND FOREARM IN INCHES



SOURCE: AF REGULATION, Attachment 4, p. 35.

BODY FAT MEASUREMENT

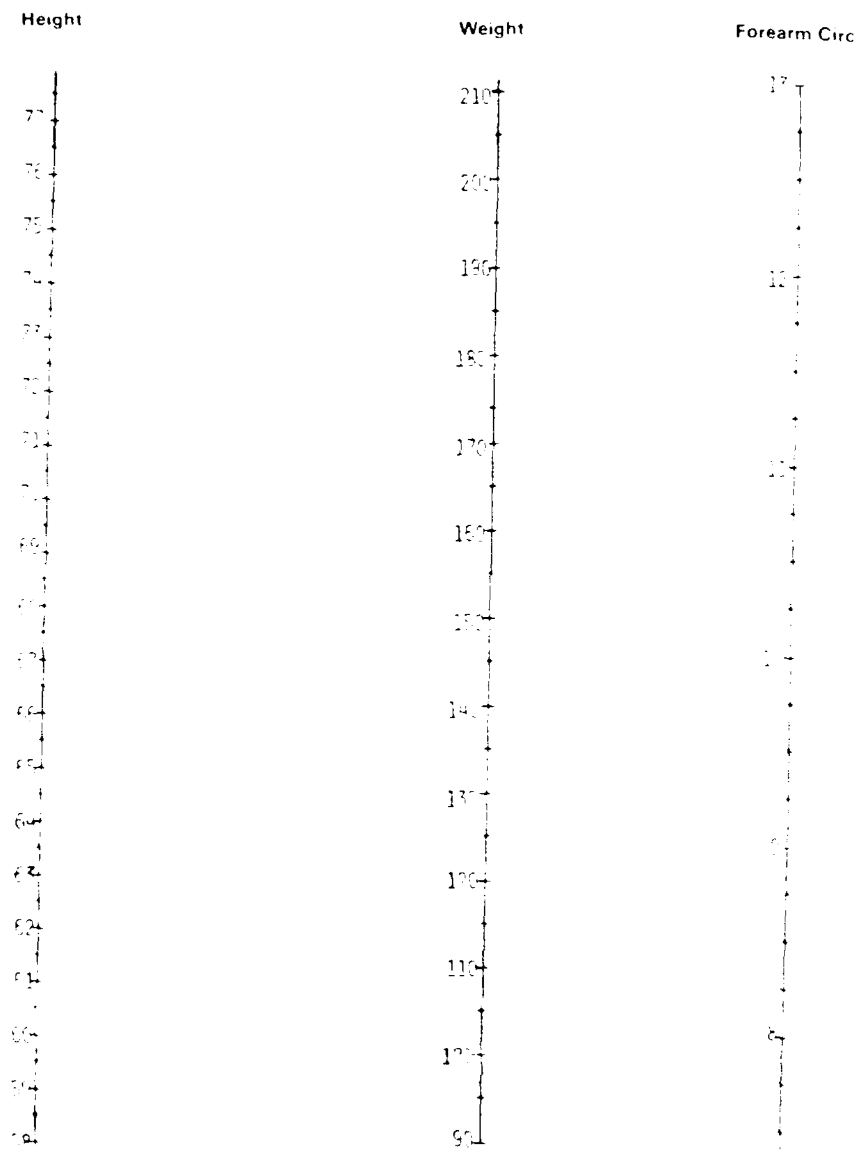
MALES OVER 30 YEARS--HEIGHT AND BICEPS IN INCHES



SOURCE: AF REGULATION, Attachment 4, p. 36.

BODY FAT MEASUREMENT

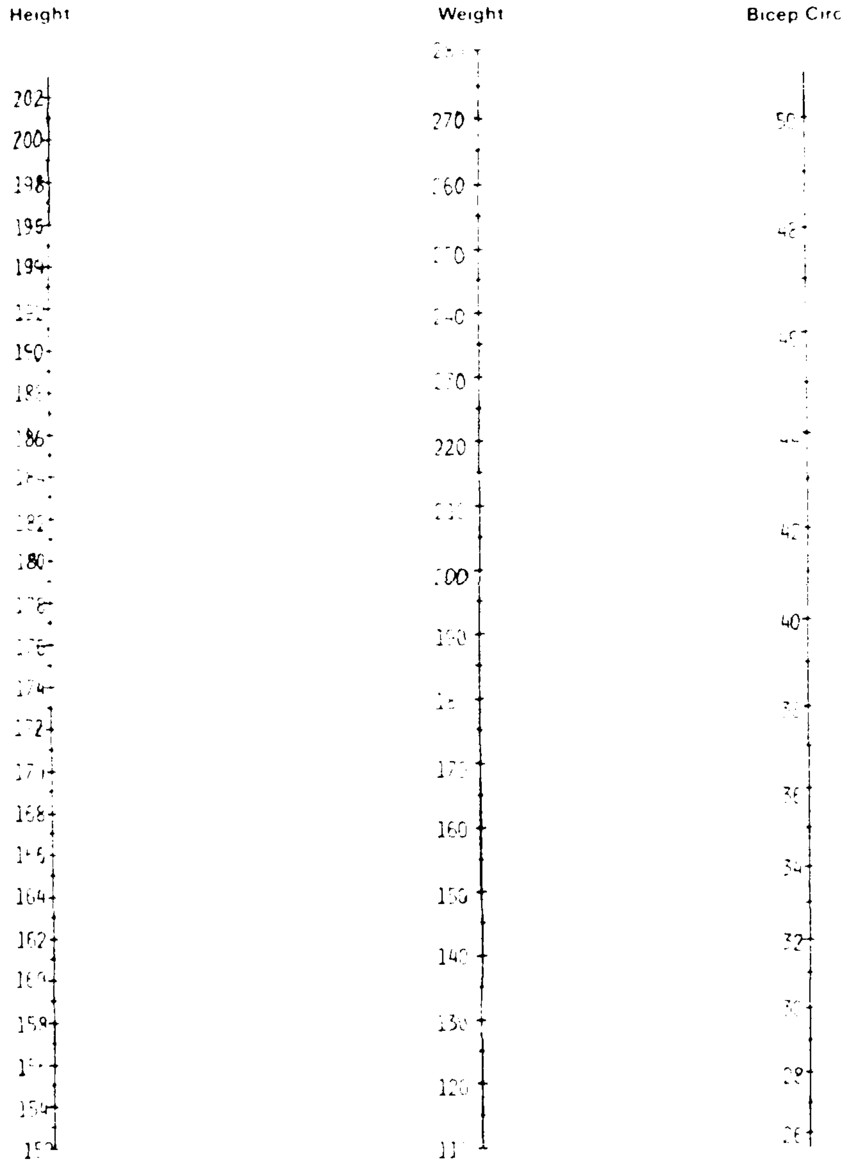
FEMALES OVER 30 YEARS--HEIGHT AND FOREARM IN INCHES



SOURCE: AF REGULATION, Attachment 4, p. 37.

BODY FAT MEASUREMENT

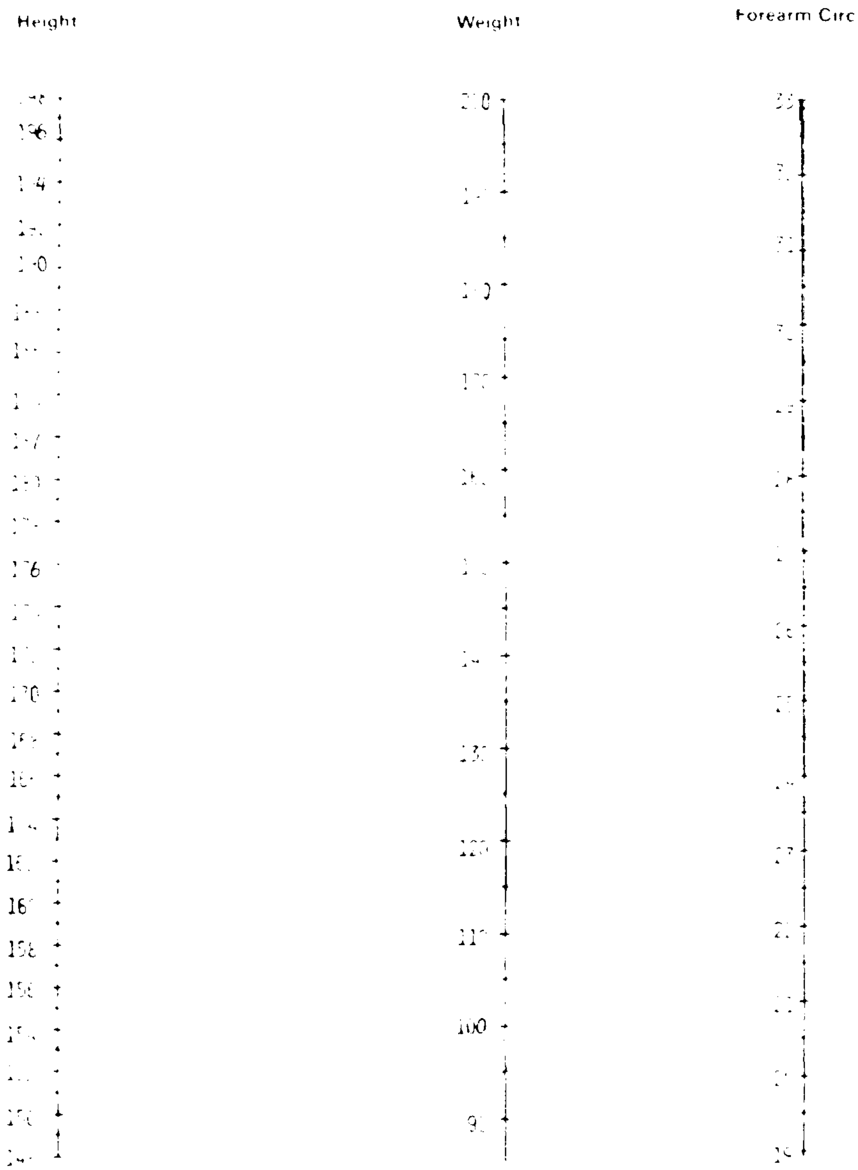
MALES UNDER 30 YEARS--HEIGHT AND BICEPS IN CM



SOURCE: AF REGULATION, Attachment 4, p. 38.

BODY FAT MEASUREMENT

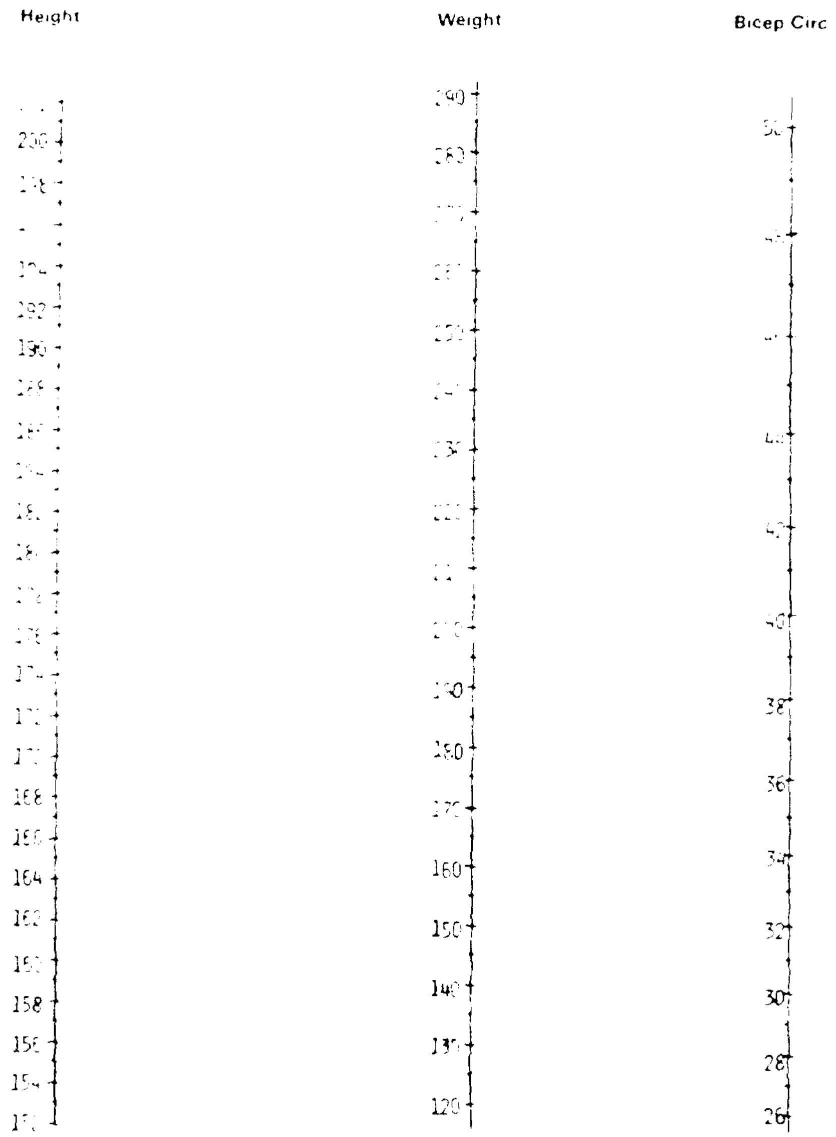
FEMALES UNDER 30 YEARS--HEIGHT AND FORARM IN CM



SOURCE: AF REGULATION, Attachment 4, p. 39.

BODY FAT MEASUREMENT

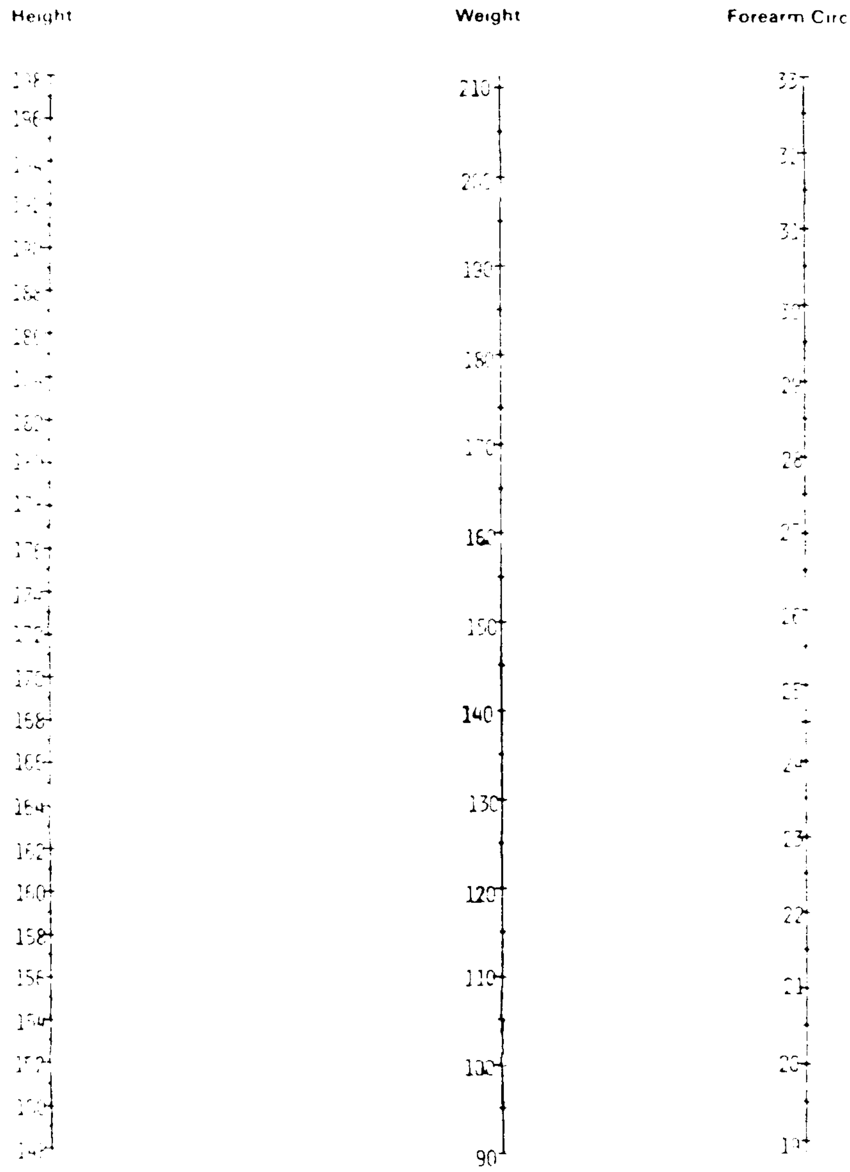
MALES OVER 30 YEARS--HEIGHT AND BICEPS IN CM



SOURCE: AF REGULATION, Attachment 4, p. 40.

BODY FAT MEASUREMENT

FEMALES OVER 30 YEARS--HEIGHT AND FOREARM IN CM



SOURCE: AF REGULATION, Attachment 4, p. 41

INSTRUCTIONS FOR USING THE NOMOGRAM (MALE)

STEP 1: Determine the individual's height in either centimeters or inches.

STEP 2: Measure the circumference of the individual's flexed biceps in either centimeters or inches.

NOTE: Taking the Flexed Biceps Measurement. With a clinched fist and 90-degree bend in the elbow, measure the circumference. Take the measurement at the point of the maximum flexion.

STEP 3. Locate the height and circumference in centimeters or inches on the left and right scales of the nomogram. With a straight edge, determine where a line drawn between these two points intersects the center scale (weight in kilograms or pounds). This point provides the maximum weight allowance.

EXAMPLE: A man who is 70.78 inches tall (180 centimeters) has a biceps circumference of 17.32 inches (44 centimeters). His maximum weight would be 224 pounds (102 kilograms).

SOURCE: AF REGULATION 35-11, Attachment 4, p. 42.

INSTRUCTIONS FOR USING THE NOMOGRAM (WOMEN)

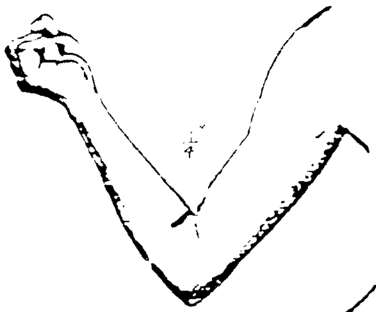
STEP 1: Determine the individual's height in either centimeters or inches.

STEP 2: Measure the circumference of the individual's forearm in either centimeters or inches. Forearm must be relaxed when the measurement is taken.

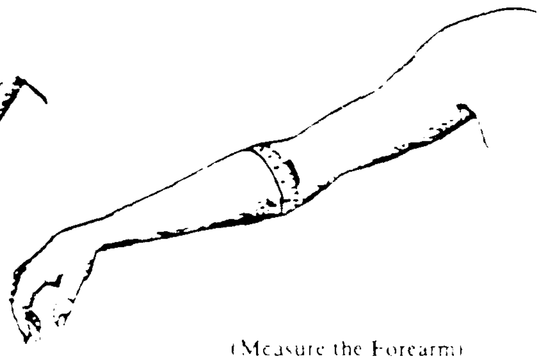
NOTE: **Taking the forearm measurement:** With a clenched fist and 90 degree bend in the elbow, mark a point 1/4 inch down from the bend in the elbow. Then allow the arm to hang relaxed and measure the forearm circumference at the mark. Take the measurement with one edge of the tape on the mark and the other edge toward the hand.

STEP 3: Locate the height and circumference in centimeters or inches on the left and right scales of the nomogram. With a straight edge, determine where a line drawn between these two points intersects the center scale (weight in kilograms or pounds). This point provides the maximum weight allowable.

SOURCE: AR REGULATION 35-11, Attachment 4, p. 43.



(Mark the Forearm)



(Measure the Forearm)

U.S. Marine Corps

The height, weight, and body fat standards for retention in the U.S. Marine Corps are included in **MARINE CORPS ORDER 6100.10A with Change 1: Weight Control and Military Appearance** (MCO 6100.10A TDE-32, 24 JULY 1986). The same standards were implemented for use at accession on 1 June 1992. This regulation is extensive and excerpts here include: the stated purpose of the regulation, details of procedures, and relevant reference tables[1].

*****

HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C. 20360

MCO 6100.10A
TDE-32
24 Jul 1986

MARINE <u>CORPS ORDER</u> <u>6100.10A</u> (with typed changes added to appropriate sections as designated in MARINE CORPS ORDER 6100.10a Ch 1, see following pages)

From: Commandant of the Marine Corps
To: Distribution List

Subj: Weight Control and Military Appearance

Ref: (a) MCO P1900.16C
(b) MCO 6100.3H
(c) MCO P1610.7C
(d) MCO P1070.12D
(e) MCO P1080.35E

Encl: (1) Weight Standards for Marines
(2) Alternate Maximum Weight Limits for Male Marines
(3) Alternate Maximum Weight Limits for Female Marines
(4) Format for Requesting Preliminary Medical Evaluation

1. Purpose. To promulgate policy and implementing instructions concerning weight control and military appearance in the Marine Corps.

[1]Further information concerning this regulation can be obtained from Headquarters United States Marine Corps, Washington, D.C. 20380.

2. Cancellation. MCO 6100.10
3. General. The Marine Corps has traditionally been associated with a military image that is neat and trim in appearance. It is essential to the day-to-day effectiveness and combat readiness of the Marine Corps that every Marine maintain the established standards of health, fitness, and appearance. The habits of self-discipline required to gain and maintain a healthy body, inherent in the Marine Corps' way of life, must be part of the character of every Marine.
4. Responsibility. The evaluation of a Marine's military appearance is the responsibility of the commanding officer. The medical officer's responsibility is to certify a Marine's health and ability to participate in physical training and/or prescribe a diet, if required, to return the Marine to an acceptable military appearance.
5. Objectives. The objectives of the Marine Corps weight control and military appearance program are:

a. To contribute to the health and well-being of every Marine by continuously monitoring weight and personal appearance.

b. To preserve high standards of professional military appearance traditionally expected of all Marines.

c. To establish acceptable weight standards for all Marines and to ensure those Marines who do not meet the standards are counseled and given the opportunity to achieve the standards.

d. To encourage all Marines to set the example by maintaining proper appearance and weight standards.

6. Policy

a. Commanders will continually monitor all members of their commands, both officer and enlisted, to ensure they maintain the proper weight distribution and personal appearance. Identification of personnel who do not present a suitable military appearance because of overweight or improper weight distribution is required.

b. Commanders should consider educational programs and other motivational means to encourage Marines to achieve and maintain weight and personal appearance standards. Such programs could include, but are not limited to, periodic mandatory weight control seminars and individual consultations conducted by qualified dieticians/medical personnel for all individuals identified as requiring a weight reduction.

c. Marines are considered overweight when their weight exceeds the maximum allowable weight standards as set forth in enclosure (1). Women Marines returning from maternity leave have 6 months from the date of delivery to reestablish their weight and military appearance standards as set forth in this Order. When a Marine is determined to be overweight, the commander will either assign the Marine to the weight control program or request an alternate weight standard.

d. It is recognized that exceptions to the standards in enclosure (1) may be justified for Marines who, although lean, exceed the prescribed weight standards because of a high volume of lean muscle mass and a low percent of body fat. Commanders may request approval in writing of an alternate maximum weight limit from Marine officers in the chain of command exercising special court-martial convening authority. For Marines who do not have a Marine officer in the chain of command exercising special court-martial convening authority, an alternate maximum weight limit may be requested from the Commandant of the Marine Corps (1). The request must be supported by the following:

(1) A body composition analysis indicating body fat percent based on hydrostatic weighing or anthropometric measurement. Enclosure (2) details the anthropometric measurement process that will be used to estimate the percent of body fat for male Marines and enclosure (3) will be used for female Marines.

(2) Marines who request a waiver from the Commandant of the Marine Corps (1) must provide full length frontal and profile photographs taken at the desired alternate weight

limit in service "A" uniform. The anthropometric measurement of the individual Marine as explained in either enclosure (2) or (3) will be certified by the commanding officer.

e. Commanders will inspect the Marine in the service "A" uniform prior to requesting an alternate weight standard to ensure proper fit of the uniform. An alternate maximum weight standard is not permanent, and commanders will ensure the purpose of the waiver remains valid. As long as the waiver remains valid, the written authorization for an alternate weight will be kept on the document side of the Marine's OQR/SRB. Commanders will reconfirm the alternate weight standard for those Marines who are being transferred from or joined to a unit.

f. The alternate maximum weight limit granted by the Commandant of the Marine Corps (ASA) for naval aviators concerning physical qualifications for duty involving actual control of aircraft is not to be used as the standard for the Marine Corps weight control and military appearance program as set forth in this Order.

* g. Those individuals who are identified as overweight will be referred to an ACHCP for evaluation. Enclosure (4) will be completed and retained by the commanding officer to properly document the recommendation and action taken in such an individual's case.

* h. If the ACHCP diagnoses the individual's condition to be a result of an underlying or associated disease process, one of the following actions will be taken:

(1) Treatment to alleviate the condition and return of the Marine to the unit.

(2) Hospitalization for necessary treatment.

* i. If the ACHCP discovers no underlying or associated disease process as the cause of the individual's condition, this fact will be certified and a reducing diet and/or exercise program will be recommended.

(1) In cases where the need for a weight or body fat loss is indicated, realistic goals per enclosures (1) through (3) of this order will be established to include the number of pounds or inches to be lost. Weigh ins or measurements will be taken at least every 2 weeks (monthly for SMCR) at the unit to determine the individual's progress. Any individual who, after 2 weeks (1 month for SMCR), has had no loss will be counseled at the unit level.

* (2) In cases where a weight loss is not required, the commander will initiate an exercise program per reference (b) to correct the individual's military appearance. Although Marines may not be discharged for failure to maintain appropriate military appearance, this failure to make satisfactory progress while on a personal appearance program must be reflected in section C of fitness reports per paragraph 4007.4b(5) of reference (c) for sergeants and above or incorporated in the conduct marks of corporals and below per paragraph 4008.6 of reference (d).

* j. Entries will be made in the JUMPS/MMS for Marines assigned to the weight control or military appearance program per paragraph 8119 of reference (e). Further, upon assignment to the weight control program, all Marines will receive a formal page 11 counselling entry per the provisions of paragraph 6105.3 of reference (a).

* k. After a period of dieting and/or exercise, not to exceed 6 months, Marines who still do not present a suitable military appearance because they are overweight will be referred to an ACHCP for reevaluation.

* (1) If the ACHCP determines the individual's condition is caused by an underlying or associated disease process, action described in paragraph 6h will be taken.

* (2) If the ACHCP finds there is no underlying or associated disease process causing the individual's overweight condition, two courses of action are open.

(a) If satisfactory progress has been made, even though the weight goals have not been met, one extension of up to 6 months may be granted, at the end of which time the individual will again be reevaluated. If weight goals are not met by the end of the extension, the individual will be recommended for discharge from the naval service by reason of unsatisfactory performance per the provisions of paragraph 6206.1 of reference (a).

(b) If satisfactory progress has not been made, it can be concluded that the condition is because of apathy or a lack of self-discipline. The individual, therefore, will be recommended for discharge per the provisions of paragraph 6206.1 of reference (a).

l. The commander will administratively remove the individual from the weight control or military appearance program once the prescribed goals are met. Appropriate entries will made in the JUMPS/MMS per reference (e).

m. If after having been removed from the weight control program, the Marine's adverse weight condition reappears, that individual will be accorded one 90-day period to conform to Marine Corps weight standards. At the end of the 90-day period, if goals are not met, discharge processing per paragraph 6206.1 of reference (a) is required.

n. If the Marine successfully meets prescribed goals within the 90-day period yet later fails to meet weight standards, administrative discharge processing will immediately be initiated.

o. A copy of enclosure (4) will be placed on the document side of the OOR/SRB for those Marines who are transferred while assigned to the subject program.

p. It is imperative that all JUMPS/MMS entries concerning weight control and military appearance be coordinated between the unit diary clerk and the training NCO.

7. Action

a. Commanding officers will establish and maintain an effective weight control and military appearance program per this Order.

b. The commanding officer's subjective judgment, in consonance with the provisions of this Order, will form the standards for this program.

8. Reserve Applicability. This Order is applicable to the Marine Corps Reserve.

JOHN P. BURKE
Deputy Chief of Staff
for Training

DISTRIBUTION: A plus 7000038 (100)
7352009 (41)
6306093, 122 (2)
6306 (less 6306093, 122) (1)

Copy to: 9540004 (25)
8145001 (1)

SOURCE: MCO 6100.10A, pages 1-5.

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HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C. 20380-0001

MCO 6100.IOA Ch
TDE32
29 Dec 1986

MARINE CORPS ORDER 6100.10A Ch 1

From: Commandant of the Marine Corps
To: Distribution List

Subj: Weight Control and Military Appearance

Encl: (1) New page inserts to MCO 6100.10A.

1. Purpose. To transmit new page inserts and direct pen changes to the basic order.
2. Background. By definition, the term "medical officer" does not include nurse practitioners and physician assistants. These personnel were previously prohibited, again by definition, from evaluating Marines for assignment to the weight control and military appearance programs. Nurse practitioners and physician assistants, however, are fully qualified to evaluate Marines for these programs; their participation in this process provides for the most efficient use of a commander's medical assets and complies with the spirit and intent of the basic order.
3. Action

a. Remove present pages 3 and 4, and replace with corresponding pages contained in the enclosure.

b. On the letterhead page, paragraph 4, third line, delete the words "medical officer's" and after the word "responsibility" insert "of the appropriately credentialed health care provider (ACHCP)".

c. In enclosure (4), make the following pen changes:

(1) On pages 1, 2, 4, and 5, in "From" or "To" line as appropriate, change the words "Medical Officer" to read "Appropriately Credentialed Health Care Provider".

(2) On page 3, paragraph 2, fourth line, change "reference (b)" to read "reference (a)".

(3) On page 3, paragraph 2, sixth line, change "reference (c)" to read "reference (b)".

4. Summary of Change. This Change establishes provisions for nurse practitioners and physician assistants to join medical officers as individuals authorized to evaluate Marines for assignment to the weight control and military appearance programs. This change also corrects erroneous references in the forms used to assign Marines to these programs.
5. Change Notation. Paragraphs denoted by an asterisk (*) symbol contain changes not previously published.
6. Filing Instructions. This Change transmittal will be filed immediately following the signature page of the basic order.

F. E. SISLEY
Deputy Chief of Staff
for Training

DISTRIBUTION: A plus 7000045 (100)
7352009 (41)
6306093, 122 (2)
6306 (less 6306093, 122) (1)

Copy to: 9540004 (25)
8145001 (1)

SOURCE: MCO 6100.10A CH1 pages 7-8.

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WEIGHT STANDARDS FOR MARINES

Male Marines (regardless of age)

Height (inches)	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Weight (pounds)															
minimum	105	106	107	111	115	119	123	127	131	135	139	143	147	151	153
maximum	160	165	170	175	181	186	192	197	203	209	214	219	225	230	235

Women Marines (regardless of age)

Height (inches)	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
Weight (Pounds)																
minimum	90	92	94	96	98	100	102	104	106	109	112	115	118	122	125	128
maximum	121	123	125	127	130	134	138	142	147	151	156	160	165	170	175	180

SOURCE: MCO 6100.10A, Enclosure (1), p. 1.

ALTERNATE MAXIMUM WEIGHT LIMITS FOR MALE MARINES

1. The body may be divided between two basic components, fat tissue and lean weight (muscle and other parts of the body such as bones). A Marine's fat content may be expressed as a percent of the total individual's body weight. There are several methods for assessment of total body fat which vary from the simple and inexpensive (anthropometric measurement) to the very sophisticated and extremely expensive (potassium-40 scintillation counting). Hydrostatic weighing (weighing a person underwater to determine specific gravity which is convertible to a relative percentage of fat) is generally accepted as the most accurate measurement of body composition. Anthropometry is a term that applies to measurement of the external aspects of the body, such as body diameters, circumference, and skin fold thickness. These anthropometric measurements have shown a high correlation with hydrostatic weighing as an accepted method to determine body composition.

2. Scientific research has demonstrated that physical performance is adversely affected by excess body fat. From a health standpoint, the carrying of excess body fat has been recognized as a significant risk factor. Although there are no readily definable percent fat values for acceptable performance, there are ranges when it can be said that performance will be helped or hampered by body composition. Successful marathon runners average 10 percent body fat. Research with professional football players has shown that backs and wide receivers will usually be 8-10 percent fat, while linemen are between 10-16 percent on the average. Individuals, generally, are considered grossly obese at 30 percent and above, while 20 percent body fat and above for average males is generally considered inappropriate for activity involving strenuous exertion. The average percent of body fat for male Marines is 16.5 percent. The Marine Corps, more than any other military service, relies on maximum physical fitness of all its personnel. Accordingly, the maximum allowable percent of body fat for the establishment of an alternate weight standard for male Marines is established at 18 percent and below.

3. The following chart is provided as a field measurement for the estimation of percent of body fat for male Marines. The waist circumference should be taken at the navel with the Marine standing evenly on both legs. The waist should not be "sucked in" but in a normal relaxed position. The tape should not cut into the skin but be able to move freely. The neck circumference should be measured at a point just below the larynx (adam's apple). Measurements should be read to the nearest one-fourth inch for the neck and one half inch for the waist. Find the appropriate waist measurement of the left side of the chart and the appropriate neck measurement along the top of the chart.

EXAMPLE

NECK - 16 INCHES
WAIST - 35 INCHES
BODY FAT % - 15.6%

SOURCE: MCO 6100.10A, Enclosure (2), p. 2.

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PERCENT FAT PREDICTION IN MALES FROM ABDOMEN AND NECK CIRCUMFERENCE

NECK (IN.)

ABDOMEN (IN.)	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25
25.0	6.3	5.5	4.7	3.9	3.1	2.3	1.5	.7						
25.5	7.2	6.4	5.6	4.8	4.0	3.3	2.5	1.7	.9	.1				
26.0	8.2	7.4	6.6	5.8	5.0	4.2	3.4	2.6	1.8	1.0	.2			
26.5	9.1	8.3	7.5	6.7	5.9	5.1	4.3	3.5	2.8	2.0	1.2	.4		
27.0	10.0	9.2	8.4	7.7	6.9	6.1	5.3	4.5	3.7	2.9	2.1	1.3	.5	
27.5	11.0	10.2	9.4	8.6	7.8	7.0	6.2	5.4	4.6	3.8	3.0	2.3	1.5	.7
28.0	11.9	11.1	10.3	9.5	8.7	7.9	7.2	6.4	5.6	4.8	4.0	3.2	2.4	1.6
28.5	12.9	12.1	11.3	10.5	9.7	8.9	8.1	7.3	6.5	5.7	4.9	4.1	3.3	2.5
29.0	13.8	13.0	12.2	11.4	10.6	9.8	9.0	8.2	7.4	6.7	5.9	5.1	4.3	3.5
29.5	14.7	13.9	13.1	12.4	11.6	10.8	10.0	9.2	8.4	7.6	6.8	6.0	5.2	4.4
30.0	15.7	14.9	14.1	13.3	12.5	11.7	10.9	10.1	9.3	8.5	7.7	6.9	6.2	5.4
30.5	16.6	15.8	15.0	14.2	13.4	12.6	11.9	11.1	10.3	9.5	8.7	7.9	7.1	6.3
31.0	17.6	16.8	16.0	15.2	14.4	13.6	12.8	12.0	11.2	10.4	9.6	8.8	8.0	7.2
31.5	18.5	17.7	16.9	16.1	15.3	14.5	13.7	12.9	12.1	11.4	10.6	9.8	9.0	8.2
32.0	19.4	18.6	17.8	17.1	16.3	15.5	14.7	13.9	13.1	12.3	11.5	10.7	9.9	9.1
32.5	20.4	19.6	18.8	18.0	17.2	16.4	15.6	14.8	14.0	13.2	12.4	11.6	10.9	10.1
33.0	21.3	20.5	19.7	18.9	18.1	17.3	16.6	15.8	15.0	14.2	13.4	12.6	11.8	11.0
33.5	22.3	21.5	20.7	19.9	19.1	18.3	17.5	16.7	15.9	15.1	14.3	13.5	12.7	11.9
34.0	23.2	22.4	21.6	20.8	20.0	19.2	18.4	17.6	16.8	16.1	15.3	14.5	13.7	12.9
34.5	24.1	23.3	22.5	21.8	21.0	20.2	19.4	18.6	17.8	17.0	16.2	15.4	14.6	13.8
35.0	25.1	24.3	23.5	22.7	21.9	21.1	20.3	19.5	18.7	17.9	17.1	16.3	15.6	14.8
35.5	26.0	25.2	24.4	23.6	22.8	22.0	21.3	20.5	19.7	18.9	18.1	17.3	16.5	15.7
36.0	27.0	26.2	25.4	24.6	23.8	23.0	22.2	21.4	20.6	19.8	19.0	18.2	17.4	16.6
36.5	27.9	27.1	26.3	25.5	24.7	23.9	23.1	22.3	21.5	20.8	20.0	19.2	18.4	17.6
37.0	28.8	28.0	27.2	26.5	25.7	24.9	24.1	23.3	22.5	21.7	20.9	20.1	19.3	18.5
37.5	29.8	29.0	28.2	27.4	26.6	25.8	25.0	24.2	23.4	22.6	21.8	21.0	20.3	19.5
38.0	30.7	29.9	29.1	28.3	27.5	26.7	26.0	25.2	24.4	23.6	22.8	22.0	21.2	20.4

38.5	31.7	30.9	30.1	29.3	28.5	27.7	26.9	26.1	25.3	24.5	23.7	22.9	22.1	21.3
39.0	32.6	31.8	31.0	30.2	29.4	28.6	27.8	27.0	26.2	25.5	24.7	23.9	23.1	22.3
39.5	33.5	32.7	31.9	31.2	30.4	29.6	28.8	28.0	27.2	26.4	25.6	24.8	24.0	23.2
40.0	34.5	33.7	32.9	32.1	31.3	30.5	29.7	28.9	28.1	27.3	26.5	25.7	25.0	24.2
40.5	35.4	34.6	33.8	33.0	32.2	31.4	30.7	29.9	29.1	28.3	27.5	26.7	25.9	25.1
41.0	36.3	35.6	34.8	34.0	33.2	32.4	31.6	30.8	30.0	29.2	28.4	27.6	26.8	26.0
41.5	37.3	36.5	35.7	34.9	34.1	33.3	32.5	31.7	30.9	30.2	29.4	28.6	27.8	27.0
42.0	38.2	37.4	36.6	35.8	35.1	34.3	33.5	32.7	31.9	31.1	30.3	29.5	28.7	27.9
42.5	39.2	38.4	37.6	36.8	36.0	35.2	34.4	33.6	32.8	32.0	31.2	30.4	29.7	28.9
43.0	40.1	39.3	38.5	37.7	36.9	36.1	35.4	34.6	33.8	33.0	32.2	31.4	30.6	29.8
43.5	41.0	40.3	39.5	38.7	37.9	37.1	36.3	35.5	34.7	33.9	33.1	32.3	31.5	30.7
44.0	42.0	41.2	40.4	39.6	38.8	38.0	37.2	36.4	35.6	34.9	34.1	33.3	32.5	31.7
44.5	42.9	42.1	41.3	40.5	39.8	39.0	38.2	37.4	36.6	35.8	35.0	34.2	33.4	32.6
45.0	43.9	43.1	42.3	41.5	40.7	39.9	39.1	38.3	37.5	36.7	35.9	35.1	34.4	33.6
45.5	44.8	44.0	43.2	42.4	41.6	40.8	40.0	39.3	38.5	37.7	36.9	36.1	35.3	34.5
46.0	45.7	45.0	44.2	43.4	42.6	41.8	41.0	40.2	39.4	38.6	37.8	37.0	36.2	35.4
46.5	46.7	45.9	45.1	44.3	43.5	42.7	41.9	41.1	40.3	39.5	38.8	38.0	37.2	36.4
47.0	47.6	46.8	46.0	45.2	44.5	43.7	42.9	42.1	41.3	40.5	39.7	38.9	38.1	37.3
47.5	48.6	47.8	47.0	46.2	45.4	44.6	43.8	43.0	42.2	41.4	40.6	39.8	39.0	38.3
48.0	49.5	48.7	47.9	47.1	46.3	45.5	44.7	44.0	43.2	42.4	41.6	40.8	40.0	39.2
48.5	50.4	49.7	48.9	48.1	47.3	46.5	45.7	44.9	44.1	43.3	42.5	41.7	40.9	40.1
49.0	51.4	50.6	49.8	49.0	48.2	47.4	46.6	45.8	45.0	44.2	43.5	42.7	41.9	41.1
49.5	52.3	51.5	50.7	49.9	49.2	48.4	47.6	46.8	46.0	45.2	44.4	43.6	42.8	42.0
50.0	53.3	52.5	51.7	50.9	50.1	49.3	48.5	47.7	46.9	46.1	45.3	44.5	43.7	43.0

SOURCE: MCO 6100.10A, Enclosure (2), p. 3.

PERCENT FAT PREDICTION IN MALES FROM ABDOMEN AND NECK CIRCUMFERENCE

NECK (IN.)

ABDOMEN (IN.)	16.50	16.75	17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75
25.0														
25.5														
26.0														
26.5														
27.0														
27.5														
28.0	.8	.0												
28.5	1.8	1.0	.2											
29.0	2.7	1.9	1.1	.3										
29.5	3.6	2.8	2.0	1.3	.5									
30.0	4.4	3.8	3.0	2.2	1.4	.6								
30.5	5.5	4.7	3.9	3.1	2.3	1.5	.8							
31.0	6.5	5.7	4.9	4.1	3.3	2.5	1.7	.9	.1					
31.5	7.4	6.6	5.8	5.0	4.2	3.4	2.6	1.8	1.0	.3				
32.0	8.3	7.5	6.7	6.0	5.2	4.4	3.6	2.8	2.0	1.2	.4			
32.5	9.3	8.5	7.7	6.9	6.1	5.3	4.5	3.7	2.9	2.1	1.3	.5		
33.0	10.2	9.4	8.6	7.8	7.0	6.2	5.5	4.7	3.9	3.1	2.3	1.5	.7	
33.5	11.1	10.4	9.6	8.8	8.0	7.2	6.4	5.6	4.8	4.0	3.2	2.4	1.6	.8
34.0	12.1	11.3	10.5	9.7	8.9	8.1	7.3	6.5	5.7	5.0	4.2	3.4	2.6	1.8
34.5	13.0	12.2	11.4	10.6	9.9	9.1	8.3	7.5	6.7	5.9	5.1	4.3	3.5	2.7
35.0	14.0	13.2	12.4	11.6	10.8	10.0	9.2	8.4	7.6	6.8	6.0	5.2	4.5	3.7
35.5	14.9	14.1	13.3	12.5	11.7	10.9	10.1	9.4	8.6	7.8	7.0	6.2	5.4	4.6
36.0	15.8	15.1	14.3	13.5	12.7	11.9	11.1	10.3	9.5	8.7	7.9	7.1	6.3	5.5
36.5	16.8	16.0	15.2	14.4	13.6	12.8	12.0	11.2	10.4	9.6	8.9	8.1	7.3	6.5
37.0	17.7	16.9	16.1	15.3	14.6	13.8	13.0	12.2	11.4	10.6	9.8	9.0	8.2	7.4
37.5	18.7	17.9	17.1	16.3	15.5	14.7	13.9	13.1	12.3	11.5	10.7	9.9	9.2	8.4
38.0	19.6	18.8	18.0	17.2	16.4	15.6	14.8	14.1	13.3	12.5	11.7	10.9	10.1	9.3

38.5	20.5	19.8	19.0	18.2	17.4	16.6	15.8	15.0	14.2	13.4	12.6	11.8	11.0	10.2
39.0	21.5	20.7	19.9	19.1	18.3	17.5	16.7	15.9	15.1	14.3	13.6	12.8	12.0	11.2
39.5	22.4	21.6	20.8	20.0	19.3	18.5	17.7	16.9	16.1	15.3	14.5	13.7	12.9	12.1
40.0	23.4	22.6	21.8	21.0	20.2	19.4	18.6	17.8	17.0	16.2	15.4	14.6	13.8	13.1
40.5	24.3	23.5	22.7	21.9	21.1	20.3	19.5	18.8	18.0	17.2	16.4	15.6	14.8	14.0
41.0	25.2	24.5	23.7	22.9	22.1	21.3	20.5	19.7	18.9	18.1	17.3	16.5	15.7	14.9
41.5	26.2	25.4	24.6	23.8	23.0	22.2	21.4	20.6	19.8	19.0	18.3	17.5	16.7	15.9
42.0	27.1	26.3	25.5	24.7	24.0	23.2	22.4	21.6	20.8	20.0	19.2	18.4	17.6	16.8
42.5	28.1	27.3	26.5	25.7	24.9	24.1	23.3	22.5	21.7	20.9	20.1	19.3	18.5	17.8
43.0	29.0	28.2	27.4	26.6	25.8	25.0	24.2	23.5	22.7	21.9	21.1	20.3	19.5	18.7
43.5	29.9	29.2	28.4	27.6	26.8	26.0	25.2	24.4	23.6	22.8	22.0	21.2	20.4	19.6
44.0	30.9	30.1	29.3	28.5	27.7	26.9	26.1	25.3	24.5	23.7	23.0	22.2	21.4	20.6
44.5	31.8	31.0	30.2	29.4	28.7	27.9	27.1	26.3	25.5	24.7	23.9	23.1	22.3	21.5
45.0	32.8	32.0	31.2	30.4	29.6	28.8	28.0	27.2	26.4	25.6	24.8	24.0	23.2	22.5
43.5	33.7	32.9	32.1	31.3	30.5	29.7	28.9	28.2	27.4	26.6	25.8	25.0	24.2	23.4
46.0	34.6	33.9	33.1	32.3	31.5	30.7	29.9	29.1	28.3	27.5	26.7	25.9	25.1	24.3
46.5	35.6	34.8	34.0	33.2	32.4	31.6	30.8	30.0	29.2	28.4	27.7	26.9	26.1	25.3
47.0	36.5	35.7	34.9	34.1	33.4	32.6	31.8	31.0	30.2	29.4	26.6	27.8	27.0	26.2
47.5	37.5	36.7	35.9	35.1	34.3	33.5	32.7	31.9	31.1	30.3	29.5	28.7	27.9	27.2
48.5	38.4	37.6	36.8	36.0	35.2	34.4	33.6	32.9	32.1	31.3	30.5	29.7	28.9	28.1
48.5	39.3	38.5	37.8	37.0	36.2	35.4	34.6	33.8	33.0	32.2	31.4	30.6	29.8	29.0
49.0	40.3	39.5	38.7	37.9	37.1	36.3	35.5	34.7	33.9	33.1	32.4	31.6	30.8	30.0
49.5	41.2	40.4	39.6	38.8	38.1	37.3	36.5	35.7	34.9	34.1	33.3	32.5	31.7	30.9
50.0	42.2	41.4	40.6	39.8	39.0	38.2	37.4	36.6	35.8	35.0	34.2	33.4	32.6	31.9

SOURCE: MCO 6100.10A, Enclosure (2), p. 4.

ALTERNATE MAXIMUM WEIGHT LIMITS FOR FEMALE MARINES

1. In 1978, a study was conducted of 226 women Marines from ages 18 to 47 years and grades of private to general. Each Marine was subjected to 35 anthropometric measurements including skinfold, girths, and diameters. As with the male study, each woman Marine was hydrostatically weighed to determine total body fat and lean body weight. With the hydrostatic weighing as the criteria method, a computer analysis was conducted to indicate which single or combination of measurements would be the best field method for determining percent body fat and lean body weight.

2. This study established the average percent of body fat for women Marines at 23.1 percent. It should be noted that women, due to their sex characteristics, will normally have a higher percent body fat than males. Research with women athletes has shown that the average *gymnasts are 11-15 percent fat, runners* are 16-19 percent, and swimmers are 13-19 percent fat. Women, generally, are considered grossly obese at 30 percent and above.

3. The maximum allowable percent of body fat for the establishment of an alternate weight standard for women Marines is established at 26 percent and below.

4. The following charts are provided as a field measurement for the estimation of percent of body fat for female Marines. A Marine need only find her specific measurement in each of the five girth columns. The point columns to the left of each girth measurement represent fat percentage points. Add the points representing each girth measurement, subtract from that the constant correction factor (54.598), and the resulting figure represents the total percent body fat.

EXAMPLE

NECK -	10 0/8 inches	=	12.7 pts.
ABDOMEN -	28 0/8 inches	=	8.6 pts.
BICEP	12 4/8 inches	=	17.8 pts.
FOREARM -	11 0/8 inches	=	25.7 pts.
THIGH -	19 0/8 inches	=	11.0 pts.
TOTAL GIRTH MEASUREMENT POINTS		=	75.800 pts
MINUS CORRECTION FACTOR			54.598
BODY FAT PERCENTAGE		=	21.202

SOURCE: MCO 6100.10A, Enclosure (3), p. 1.

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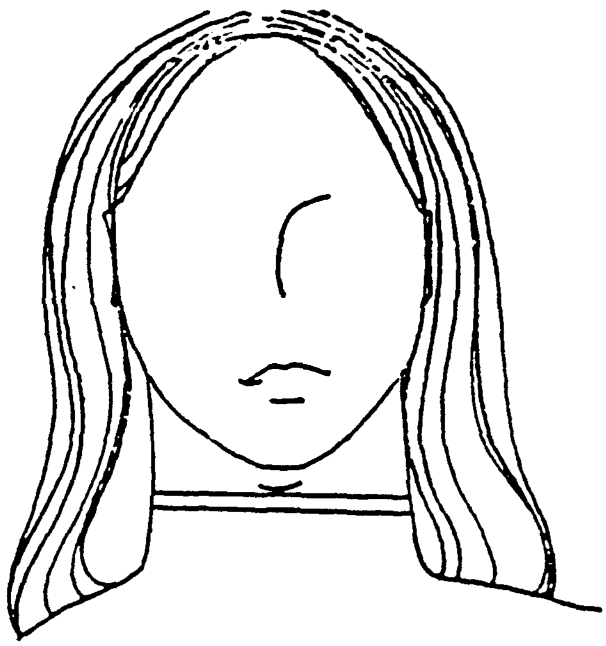
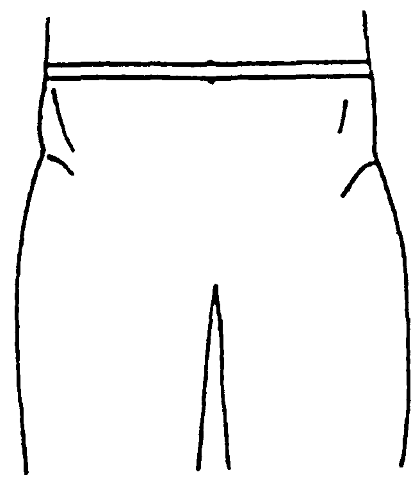


Neck. The neck is measured at a point just below the larynx (adam's apple).

PTS	NECK	PTS	NECK	PTS	NECK	PTS	NECK	PTS	NECK
.1	15 ⅞	4.1	13 ⅞	8.0	12 ⅜	11.9	10 ¾	15.8	8 ⅝
.4	15 ¾	4.3	13 ¾	8.2	12 ⅛	12.1	10 ⅝	16.1	8 ½
.7	15 ⅝	4.6	13 ⅝	8.5	11 ⅞	12.4	10 ½	16.3	8 ⅜
1.0	15 ½	4.9	13 ½	8.8	11 ⅞	12.7	10 ⅛	16.7	8 ¼
1.3	15 ⅜	5.2	13 ⅜	9.1	11 ⅝	13.0	9 ⅞	16.9	8 ⅛
1.5	15 ⅛	5.4	13 ¼	9.4	11 ¾	13.3	9 ⅝	17.2	8 ⅛
1.8	14 ⅞	5.7	13 ⅛	9.6	11 ⅜	13.5	9 ⅝	17.4	7 ⅞
2.1	14 ⅞	6.0	13 ⅛	9.9	11 ⅜	13.8	9 ½	17.7	7 ⅝
2.4	14 ⅝	6.3	12 ⅞	10.2	11 ⅛	14.1	9 ⅞	18.0	7 ⅝
2.7	14 ⅜	6.6	12 ⅝	10.6	11 ⅛	14.4	9 ⅜	18.3	7 ⅜
2.9	14 ⅜	6.8	12 ⅝	10.8	10 ⅞	14.7	9 ⅛	18.6	7 ⅛
3.2	14 ⅞	7.1	12 ⅜	11.0	10 ⅝	14.9	9 ⅛		
3.5	14 ⅛	7.4	12 ⅜	11.3	10 ⅝	15.2	8 ⅞		
3.8	14 ⅛	7.7	12 ⅜	11.6	10 ¾	15.5	8 ⅝		

SOURCE: MCO 6100.10A, Enclosure (3), p. 2.

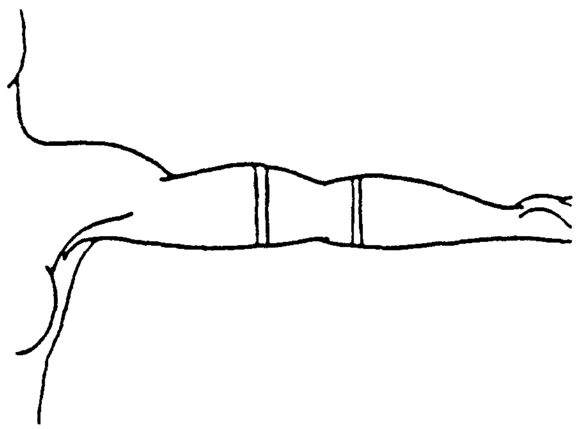
Abdomen. Laterally at the level of the iliac crests, and anteriorly at the umbilicus (Belly Button)



PTS	ABDOMEN	PTS	ABDOMEN	PTS	ABDOMEN	PTS	ABDOMEN	PTS	ABDOMEN	PTS	ABDOMEN
.0	17 5/8	4.4	23 0/8	8.9	28 2/8	13.3	33 6/8	17.8	39 1/8	22.2	44 4/8
.1	17 7/8	4.5	23 1/8	9.0	28 3/8	13.4	33 7/8	17.9	39 2/8	22.3	44 5/8
.2	17 7/8	4.6	23 2/8	9.1	28 5/8	13.5	34 0/8	18.0	39 3/8	22.4	44 6/8
.3	18 0/8	4.7	23 3/8	9.2	28 6/8	13.6	34 1/8	18.1	39 4/8	22.5	44 7/8
.4	18 1/8	4.8	23 4/8	9.3	28 7/8	13.7	34 2/8	18.2	39 5/8	22.6	45 0/8
.5	18 2/8	4.9	23 5/8	9.4	29 0/8	13.8	34 3/8	18.3	39 6/8	22.7	45 1/8
.6	18 3/8	5.0	23 6/8	9.5	29 1/8	14.0	34 4/8	18.4	39 7/8	22.9	45 2/8
.7	18 4/8	5.2	23 7/8	9.6	29 2/8	14.1	34 5/8	18.5	40 0/8	23.0	45 3/8

8	18 [illegible]	5.3	24 [illegible]	9.7	29 [illegible]	14.2	34 [illegible]	18.6	40 [illegible]	23.1	45 [illegible]
9	18 [illegible]	5.4	24 [illegible]	9.8	29 [illegible]	14.3	34 [illegible]	18.7	40 [illegible]	23.2	45 [illegible]
1.0	18 [illegible]	5.5	24 [illegible]	9.9	29 [illegible]	14.4	35 [illegible]	18.8	40 [illegible]	23.3	45 [illegible]
1.1	19 [illegible]	5.6	24 [illegible]	10.0	29 [illegible]	14.5	35 [illegible]	18.9	40 [illegible]	23.4	45 [illegible]
1.2	19 [illegible]	5.7	24 [illegible]	10.1	29 [illegible]	14.6	35 [illegible]	19.0	40 [illegible]	23.5	46 [illegible]
1.3	19 [illegible]	5.8	24 [illegible]	10.2	30 [illegible]	14.7	35 [illegible]	19.1	40 [illegible]	23.6	46 [illegible]
1.4	19 [illegible]	5.9	24 [illegible]	10.3	30 [illegible]	14.8	35 [illegible]	19.2	40 [illegible]	23.7	46 [illegible]
1.5	19 [illegible]	6.0	24 [illegible]	10.4	30 [illegible]	14.9	35 [illegible]	19.3	41 [illegible]	23.8	46 [illegible]
1.6	19 [illegible]	6.1	25 [illegible]	10.5	30 [illegible]	15.0	35 [illegible]	19.4	41 [illegible]	23.9	46 [illegible]
1.7	19 [illegible]	6.2	25 [illegible]	10.6	30 [illegible]	15.1	35 [illegible]	19.5	41 [illegible]	24.0	46 [illegible]
1.8	19 [illegible]	6.3	25 [illegible]	10.7	30 [illegible]	15.2	36 [illegible]	19.6	41 [illegible]	24.1	46 [illegible]
1.9	20 [illegible]	6.4	25 [illegible]	10.8	30 [illegible]	15.3	36 [illegible]	19.7	41 [illegible]	24.2	46 [illegible]
2.0	20 [illegible]	6.5	25 [illegible]	10.9	30 [illegible]	15.4	36 [illegible]	19.9	41 [illegible]	24.3	47 [illegible]
2.2	20 [illegible]	6.6	25 [illegible]	11.1	31 [illegible]	15.5	36 [illegible]	20.0	41 [illegible]	24.4	47 [illegible]
2.3	20 [illegible]	6.7	25 [illegible]	11.2	31 [illegible]	15.6	36 [illegible]	20.1	41 [illegible]	24.5	47 [illegible]
2.4	20 [illegible]	6.8	25 [illegible]	11.3	31 [illegible]	15.7	36 [illegible]	20.2	42 [illegible]	24.6	47 [illegible]
2.5	20 [illegible]	6.9	26 [illegible]	11.4	31 [illegible]	15.8	36 [illegible]	20.3	42 [illegible]	24.7	47 [illegible]
2.6	20 [illegible]	7.0	26 [illegible]	11.5	31 [illegible]	15.9	36 [illegible]	20.4	42 [illegible]	24.8	47 [illegible]
2.7	20 [illegible]	7.1	26 [illegible]	11.6	31 [illegible]	16.0	37 [illegible]	20.5	42 [illegible]	24.9	47 [illegible]
2.8	21 [illegible]	7.2	26 [illegible]	11.7	31 [illegible]	16.1	37 [illegible]	20.6	42 [illegible]	25.0	47 [illegible]
2.9	21 [illegible]	7.3	26 [illegible]	11.8	31 [illegible]	16.2	37 [illegible]	20.7	42 [illegible]	25.1	48 [illegible]
3.0	21 [illegible]	7.4	26 [illegible]	11.9	32 [illegible]	16.3	37 [illegible]	20.8	42 [illegible]	25.2	48 [illegible]
3.1	21 [illegible]	7.5	26 [illegible]	12.0	32 [illegible]	16.4	37 [illegible]	20.9	42 [illegible]	25.3	48 [illegible]
3.2	21 [illegible]	7.6	26 [illegible]	12.1	32 [illegible]	16.5	37 [illegible]	21.0	43 [illegible]	25.4	48 [illegible]
3.3	21 [illegible]	7.7	27 [illegible]	12.2	32 [illegible]	16.6	37 [illegible]	21.1	43 [illegible]	25.5	48 [illegible]
3.4	21 [illegible]	7.8	27 [illegible]	12.3	32 [illegible]	16.7	37 [illegible]	21.2	43 [illegible]	25.6	48 [illegible]
3.5	21 [illegible]	7.9	27 [illegible]	12.4	32 [illegible]	16.8	38 [illegible]	21.3	43 [illegible]	25.8	48 [illegible]
3.6	22 [illegible]	8.1	27 [illegible]	12.5	32 [illegible]	17.0	38 [illegible]	21.4	43 [illegible]	25.9	48 [illegible]
3.7	22 [illegible]	8.2	27 [illegible]	12.6	32 [illegible]	17.1	38 [illegible]	21.5	43 [illegible]	26.0	49 [illegible]
3.8	22 [illegible]	8.3	27 [illegible]	12.7	33 [illegible]	17.2	38 [illegible]	21.6	43 [illegible]	26.1	49 [illegible]
3.9	22 [illegible]	8.4	27 [illegible]	12.8	33 [illegible]	17.3	38 [illegible]	21.7	43 [illegible]		
4.0	22 [illegible]	8.5	27 [illegible]	12.9	33 [illegible]	17.4	38 [illegible]	21.8	44 [illegible]		
4.1	22 [illegible]	8.6	28 [illegible]	13.0	33 [illegible]	17.5	38 [illegible]	21.9	44 [illegible]		
4.2	22 [illegible]	8.7	28 [illegible]	13.1	33 [illegible]	17.6	38 [illegible]	22.0	44 [illegible]		
4.3	22 [illegible]	8.8	28 [illegible]	13.2	33 [illegible]	17.7	39 [illegible]	22.1	44 [illegible]		

SOURCE: MCO 6100.10A, Enclosure 3, p. 3



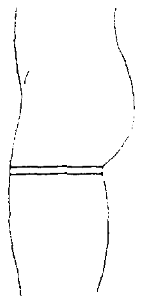
Biceps Extended. The biceps are measured in the extended position with the arm abducted to 90° and the palm supinated. The tape is placed over the largest part of the bicep/tricep group.
Forearm. The forearm is measured over the largest part of the forearm while the subject has the shoulder abducted to 90°, elbow extended and the palm supinated.

PTS	BICEPS	PTS	BICEPS	PTS	BICEPS	PTS	BICEPS	PTS	BICEPS
1	[illegible]	4.8	7 [illegible]	9.4	9 [illegible]	14.1	11 [illegible]	18.8	12 [illegible]
4	6 [illegible]	5.1	7 [illegible]	9.8	9 [illegible]	14.5	11 [illegible]	19.1	13 [illegible]
8	6 [illegible]	5.4	7 [illegible]	10.1	9 [illegible]	14.8	11 [illegible]	19.5	13 [illegible]
1.1	6 [illegible]	5.8	8 [illegible]	10.4	9 [illegible]	15.1	11 [illegible]	19.8	13 [illegible]
1.4	6 [illegible]	6.1	8 [illegible]	10.8	9 [illegible]	15.5	11 [illegible]	20.1	13 [illegible]
1.8	6 [illegible]	6.4	8 [illegible]	11.1	10 [illegible]	15.8	11 [illegible]	20.5	13 [illegible]
2.1	6 [illegible]	6.8	8 [illegible]	11.4	10 [illegible]	16.1	11 [illegible]	20.8	13 [illegible]
2.4	6 [illegible]	7.1	8 [illegible]	11.8	10 [illegible]	16.5	12 [illegible]	21.1	13 [illegible]
2.8	6 [illegible]	7.4	8 [illegible]	12.1	10 [illegible]	16.8	12 [illegible]		
3.1	7 [illegible]	7.8	8 [illegible]	12.4	10 [illegible]	17.1	12 [illegible]		
3.4	7 [illegible]	8.1	8 [illegible]	12.8	10 [illegible]	17.5	12 [illegible]		
3.8	[illegible]	8.4	9 [illegible]	13.1	10 [illegible]	17.8	12 [illegible]		
4.1	7 [illegible]	8.8	9 [illegible]	13.5	10 [illegible]	18.1	12 [illegible]		
4.4	7 [illegible]	9.1	9 [illegible]	13.8	11 [illegible]	18.5	12 [illegible]		

PTS	FORE-ARM	PTS	FORE-ARM	PTS	FORE-ARM	PTS	FORE-ARM	PTS	FORE-ARM
2	17 [illegible]	9.3	15 [illegible]	18.5	12 [illegible]	27.7	10 [illegible]	36.8	8 [illegible]
6	17 [illegible]	9.8	15 [illegible]	19.0	12 [illegible]	28.1	10 [illegible]	37.3	8 [illegible]
1.1	17 [illegible]	10.3	15 [illegible]	19.5	12 [illegible]	28.5	10 [illegible]	37.8	7 [illegible]
1.6	17 [illegible]	10.8	14 [illegible]	19.9	12 [illegible]	29.1	10 [illegible]	38.3	7 [illegible]
2.1	17 [illegible]	11.2	14 [illegible]	20.4	12 [illegible]	29.6	10 [illegible]	38.8	7 [illegible]
2.5	17 [illegible]	11.7	14 [illegible]	20.9	12 [illegible]	30.1	9 [illegible]	39.3	7 [illegible]
3.0	16 [illegible]	12.2	14 [illegible]	21.4	12 [illegible]	30.6	9 [illegible]	39.7	7 [illegible]
3.5	16 [illegible]	12.7	14 [illegible]	21.9	12 [illegible]	31.0	9 [illegible]	40.2	7 [illegible]
4.0	16 [illegible]	13.2	14 [illegible]	22.3	11 [illegible]	31.5	9 [illegible]	40.7	7 [illegible]
4.5	16 [illegible]	13.7	14 [illegible]	22.8	11 [illegible]	32.0	9 [illegible]	41.2	7 [illegible]
5.0	16 [illegible]	14.1	14 [illegible]	23.3	11 [illegible]	32.5	9 [illegible]	41.7	6 [illegible]
5.4	16 [illegible]	14.6	13 [illegible]	23.8	11 [illegible]	33.0	9 [illegible]	42.2	6 [illegible]
5.9	16 [illegible]	15.1	13 [illegible]	24.3	11 [illegible]	33.5	9 [illegible]	42.5	6 [illegible]
6.4	16 [illegible]	15.6	13 [illegible]	24.9	11 [illegible]	33.9	8 [illegible]	0	0 [illegible]
6.9	15 [illegible]	16.1	13 [illegible]	25.2	11 [illegible]	34.4	8 [illegible]		
7.4	15 [illegible]	16.6	13 [illegible]	25.7	11 [illegible]	34.9	8 [illegible]		
7.9	15 [illegible]	17.0	13 [illegible]	26.2	10 [illegible]	35.4	8 [illegible]		
8.3	15 [illegible]	17.5	13 [illegible]	26.7	10 [illegible]	36.0	8 [illegible]		
8.8	15 [illegible]	18.0	13 [illegible]	27.2	10 [illegible]	36.4	8 [illegible]		

SOURCE: MCO 6110.10A, Enclosure (3), p. 4

Thigh. The thigh measurement is taken with the subject's feet slightly apart. The tape is placed just below the gluteal fold with the subject standing evenly on both legs.



PTS	THIGH	PTS	THIGH	PTS	THIGH	PTS	THIGH	PTS	THIGH
0	11 [illegible]	7.0	16 [illegible]	13.7	20 [illegible]	20.5	25 [illegible]	27.3	29 [illegible]
.2	11 [illegible]	7.1	16 [illegible]	13.9	20 [illegible]	20.7	25 [illegible]	27.5	29 [illegible]
.4	12 [illegible]	7.3	16 [illegible]	14.1	21 [illegible]	20.9	25 [illegible]	27.7	30 [illegible]
.6	12 [illegible]	7.4	16 [illegible]	14.3	21 [illegible]	21.1	25 [illegible]	27.9	30 [illegible]
.8	12 [illegible]	7.6	16 [illegible]	14.5	21 [illegible]	21.3	25 [illegible]	28.1	30 [illegible]
1.0	12 [illegible]	7.8	16 [illegible]	14.6	21 [illegible]	21.5	25 [illegible]	28.3	30 [illegible]
1.2	12 [illegible]	8.0	17 [illegible]	14.8	21 [illegible]	21.7	26 [illegible]	28.5	30 [illegible]
1.4	12 [illegible]	8.2	17 [illegible]	15.0	21 [illegible]	21.8	26 [illegible]	28.9	30 [illegible]
1.6	12 [illegible]	8.4	17 [illegible]	15.2	21 [illegible]	22.0	26 [illegible]	29.0	30 [illegible]
1.8	12 [illegible]	8.6	17 [illegible]	15.4	21 [illegible]	22.2	26 [illegible]	29.2	31 [illegible]
1.9	13 [illegible]	8.8	17 [illegible]	15.6	22 [illegible]	22.4	26 [illegible]	29.4	31 [illegible]
2.1	13 [illegible]	9.0	17 [illegible]	15.8	22 [illegible]	22.6	26 [illegible]	29.6	31 [illegible]
2.3	13 [illegible]	9.1	17 [illegible]	16.0	22 [illegible]	22.8	26 [illegible]	29.8	31 [illegible]
2.5	13 [illegible]	9.3	17 [illegible]	16.2	22 [illegible]	23.0	26 [illegible]	30.0	31 [illegible]
2.7	13 [illegible]	9.5	18 [illegible]	16.3	22 [illegible]	23.2	27 [illegible]	30.2	31 [illegible]
2.9	13 [illegible]	9.7	18 [illegible]	16.5	22 [illegible]	23.4	27 [illegible]	30.4	31 [illegible]
3.1	13 [illegible]	9.9	18 [illegible]	16.7	22 [illegible]	23.6	27 [illegible]	30.6	31 [illegible]
3.3	13 [illegible]	10.1	18 [illegible]	16.9	22 [illegible]	23.7	27 [illegible]	30.8	32 [illegible]
3.5	14 [illegible]	10.3	18 [illegible]	17.1	23 [illegible]	23.9	27 [illegible]	30.9	32 [illegible]
3.6	14 [illegible]	10.5	18 [illegible]	17.3	23 [illegible]	24.1	27 [illegible]	31.1	32 [illegible]
3.8	14 [illegible]	10.7	18 [illegible]	17.5	23 [illegible]	24.3	27 [illegible]	31.3	32 [illegible]
4.0	14 [illegible]	10.9	18 [illegible]	17.7	23 [illegible]	24.5	27 [illegible]	31.5	32 [illegible]
4.2	14 [illegible]	11.0	19 [illegible]	17.9	23 [illegible]	24.7	28 [illegible]	31.7	32 [illegible]
4.4	14 [illegible]	11.2	19 [illegible]	18.1	23 [illegible]	24.9	28 [illegible]	31.9	32 [illegible]
4.6	14 [illegible]	11.4	19 [illegible]	18.2	23 [illegible]	25.1	28 [illegible]	32.1	32 [illegible]
4.8	14 [illegible]	11.6	19 [illegible]	18.4	23 [illegible]	25.3	28 [illegible]	32.3	33 [illegible]
5.0	15 [illegible]	11.8	19 [illegible]	18.6	24 [illegible]	25.4	28 [illegible]	32.5	33 [illegible]
5.2	15 [illegible]	12.0	19 [illegible]	18.8	24 [illegible]	25.6	28 [illegible]	32.7	33 [illegible]
5.4	15 [illegible]	12.2	19 [illegible]	19.0	24 [illegible]	25.8	28 [illegible]	32.8	33 [illegible]
5.5	15 [illegible]	12.4	19 [illegible]	19.2	24 [illegible]	26.0	28 [illegible]	32.9	33 [illegible]
5.7	15 [illegible]	12.6	20 [illegible]	19.4	24 [illegible]	26.2	29 [illegible]		
5.9	15 [illegible]	12.7	20 [illegible]	19.6	24 [illegible]	26.4	29 [illegible]		
6.1	15 [illegible]	12.9	20 [illegible]	19.8	24 [illegible]	26.6	29 [illegible]		
6.3	15 [illegible]	13.1	20 [illegible]	20.0	24 [illegible]	26.8	29 [illegible]		
6.5	16 [illegible]	13.3	20 [illegible]	20.1	25 [illegible]	27.0	29 [illegible]		
6.7	16 [illegible]	13.5	20 [illegible]	20.3	25 [illegible]	27.2	29 [illegible]		

SOURCE: MCO 6100.10A, Enclosure (3), p. 5

C

Weight-for-Height Tables

from

The Surgeon General's Report on Nutrition and Health[1]
1988
U.S. Department of Health and Human Services
Public Health Service
DHHS (PHS) Publication No. 88-50210

[1] For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. GPO Stock Number 017-001-00465-1.

TABLE 6-1 Comparison of Metropolitan Desirable Weights with Average Weights from U.S. Cohort Studies

Height (Without Shoes), cm (ft in)	Metropolitan Tables[a] (Medium Frame), Weight in Kilograms (Pounds) (Without Clothing)		Average Weight for Age 40–49 y, kg (lb)			
			Insured Lives			
	1959[a]	1983	Build and Blood Pressure Study 1959[b] (1935–1953)[e]	Build Study 1979[b] (1950–1971)[e]	American Cancer Society Study 1979[c] (1959)[e]	Health and Nutrition Examination Survey (HANES I, 1979)[d] (1971–1974)[e]
			Men			
156 (5 1)	50–55 (111–122)	57–62 (126–136)	60 (133)	61 (135)	—	—
159 (5 2)	52–57 (114–126)	58–63 (128–138)	62 (137)	63 (139)	67 (148)	66 (145)[f]
162 (5 3)	53–59 (117–129)	59–64 (130–140)	64 (141)	65 (144)	68 (149)	68 (150)[f]
164 (5 4)	54–60 (120–132)	60–65 (132–143)	66 (145)	68 (149)	69 (153)	73 (162)
167 (5 5)	56–62 (123–136)	61–66 (134–146)	68 (149)	69 (153)	71 (156)	72 (159)
169 (5 6)	58–64 (127–140)	62–68 (137–149)	70 (154)	72 (158)	73 (160)	75 (166)
172 (5 7)	59–66 (131–145)	64–69 (140–152)	72 (158)	73 (162)	74 (163)	78 (173)
174 (5 8)	61–68 (135–149)	65–70 (143–155)	73 (162)	76 (167)	77 (169)	79 (174)
177 (5 9)	63–69 (139–153)	66–72 (146–158)	76 (167)	78 (171)	78 (173)	79 (175)
179 (5 10)	65–72 (143–158)	68–73 (149–161)	78 (171)	80 (176)	80 (177)	83 (184)
182 (5 11)	67–74 (147–163)	69–75 (152–165)	80 (176)	82 (181)	83 (182)	85 (188)
185 (6 0)	68–76 (151–168)	70–77 (155–169)	82 (180)	85 (187)	85 (187)	88 (194)
187 (6 1)	70–78 (155–173)	72–78 (159–173)	84 (185)	87 (192)	87 (192)	92 (203)
190 (6 2)	73–81 (160–178)	73–80 (162–177)	86 (190)	90 (198)	90 (198)	92 (203)[f]
192 (6 3)	75–83 (165–183)	75–83 (166–182)	89 (196)	92 (203)	92 (203)	—

Women

146 (4 9)	43–48 (94–106)	48–54 (106–118)	54 (120)	52 (115)	—	58 (127)[f]
149 (4 10)	44–49 (97–109)	48–54 (106–120)	56 (123)	54 (118)	52 (115)	59 (131)[f]
151 (4 11)	45–51 (100–112)	50–56 (110–123)	57 (126)	54 (120)	55 (121)	62 (136)
154 (5 0)	47–52 (103–115)	51–57 (112–126)	59 (129)	56 (124)	57 (126)	64 (141)
156 (5 1)	48–54 (106–118)	52–59 (115–129)	60 (132)	57 (126)	58 (128)	63 (138)
159 (5 2)	49–55 (109–122)	54–60 (118–132)	62 (136)	59 (130)	60 (132)	64 (141)
162 (5 3)	51–57 (112–126)	55–61 (121–135)	63 (139)	60 (133)	62 (136)	67 (148)
164 (5 4)	53–59 (116–131)	56–63 (124–138)	65 (143)	62 (136)	63 (139)	68 (151)
167 (5 5)	54–61 (120–135)	58–64 (127–141)	67 (147)	64 (140)	64 (142)	71 (156)
169 (5 6)	56–63 (124–139)	59–65 (130–144)	68 (151)	65 (144)	66 (146)	71 (156)
172 (5 7)	58–65 (128–143)	60–67 (133–147)	70 (155)	67 (147)	68 (150)	72 (158)
174 (5 8)	60–67 (132–147)	62–68 (136–150)	73 (160)	70 (152)	71 (156)	78 (172)
177 (5 9)	62–68 (136–151)	63–69 (139–153)	75 (165)	70 (155)	73 (161)	—
179 (5 10)	64–70 (140–155)	64–71 (142–156)	77 (170)	72 (159)	75 (165)	—

[a]Not age specific: 1959 tables recommended for ages 25 and older; 1983 tables for ages 25 to 59 years.
[b]Without shoes or clothing.
[c]Values are means for age groups 40 to 44 and 45 to 49. Self-reported heights without shoes and weights with indoor clothing.
[d]Values are means for age groups 35 to 44 and 45 to 54. Measured without shoes; clothing ranged from 0.20 to 0.62 lb (not deducted from weights shown).
[e]Years when measurements taken.
[f]Estimated values obtained from linear regression equations.

Source: Manson, J.E.; Stampfer, M.J., Hennekens, C.H., and Willett, W.C. 1987. Body weight and longevity. A reassessment. *Journal of the American Medical Association* 257:353–58. Copyright 1987, American Medical Association, reprinted with permission.

D

Proposed Revisions to Accession (AR 40-501) and Retention (AR 600-9) Body Weight and Body Fat Standards

Briefers: Dr. J. A. Vogel and Major K.E. Friedl
Occupational Health and Performance Directorate
U.S. Army Research Institute of Environmental Medicine

2 April 1991

RECOMMENDATIONS

AR 40-501

- Change to a body fat standard, retaining weight tables only as a preliminary screen
- Male standards should not exceed 4 percent body fat units over retention fat standards
- Female standards should be the same as retention fat standards

AR 600-9

- Female standards should be increased by 2 percent body fat units for each age category

TABLE D-1 Proposed Changes to Body Fat Standards

Men				Women			
Retention		Accession		Retention		Accession	
Current Standard	Proposed Standard	Current Standard	Proposed Standard	Current Standard	Proposed Standard	Current Standard	Proposed Standard
20	20	(32)*	24	28	30	(28)	30
22	22	(34)	26	30	32	(30)	32
24	24	(33)	28	32	34	(32)	34
26	26	(32)	30	34	36	(34)	36
(no change)		(more stringent)		(less stringent)		(same as retention)	

*estimated from BMI

E

Recent Changes to the U.S. Army Standards for Accession and Retention

Contents of an Unclassified ALARACT dated 5/7/91:

1. To support readiness and fairness in the system, the following change to AR 600-9 is effective immediately. AR 600-9, Para 20C, maximum allowable percent body fat standards for females are:

Age Group	17-20	30%
	21-27	32%
	28-39	34%
	40+	36%

2. All women currently enrolled in the Army Weight Control Program will be disenrolled when they attain the new body fat standard.
3. File this message with AR 600-9 until receipt of a change to regulation. This message expires upon receipt of a change to regulation.

*****

Extracts from the Immediate Action Interim Change referred to on the previous page that apply to weight standards:

Headquarters
Department of the Army
Washington, DC
1 October 1991

AR 40-501
Interim Change
No. 101
Expires 1 October 1993

Medical Services
Standards of Medical Fitness

Justification. This interim change is necessary to implement the new weight standards of tables 2-1 and 2-2, as contained in DAPE-MPA message 212000Z Aug 91 Subject: New Accession Weight and Body Fat Standards. It also repeats the policies outlined in Interim Change 101 which expired on 2 October 1991; repeats clarification of pregnancy profile as outlined in HQDA (SGPS-CP-B) message 251800Z May 90, Subject: Physical Profile for Pregnant Soldiers; reinserts a paragraph on mammograms erroneously omitted in the last update as outlined in HQDA (SGPS-CP-B) message 281300Z Aug 89, Subject: Mammograms, and revises the requirements for Special Forces at the request of the John F. Kennedy Special Warfare Center.

Expiration. This interim change expires 2 years from the date of publication. It will be destroyed at that time unless sooner rescinded or superseded by a permanent change or revision.

1. AR 40-501, 15 May 1989, is changed as follows:

Page 11. Paragraph 2-22 is superseded as follows:

2-22. Weight

a. Army applicants for initial appointment as a commissioned officer (to include appointment as a commissioned warrant officer) must meet the standards of AR 600-9. All other initial Army applicants must meet the new standards contained in table 2-1 and table 2-2 (located at the end of this change). Body fat will be used as the final determinant for those applicants who exceed the weight tables. Those individuals found medically qualified on the basis of the old weight standards that were in effect prior to 1 October 1991, will not be reevaluated or medically disqualified solely on the basis of the new standards.

101, AR 40-501 1 October 1991

b. The screening weight standard in effect before 1 October 1991 will also apply to those individuals who enlisted in the Delayed Entrance Program prior to 1 October 1991. If these individuals exceed the old screening weight standard when weighed during the physical inspection, the new body fat standard will apply. All applicants for enlistment processing under prior service rules (chap 3, AR 40-501) will have to meet the weight and body fat standards of AR 600-9.

*****

TABLE 2-1 Military acceptable weight (in pounds) as related to age and height for males - initial Army procurement

Height (inches)	Minimum weight any age	Maximum weight by years of age 17-20	21-27	28-39	40 and over
60	100	139	141	143	146
61	102	144	146	148	151
62	103	148	150	153	156
63	104	153	155	158	161
64	105	158	160	163	166
65	106	163	165	168	171
66	107	168	170	173	177
67	111	174	176	179	182
68	115	179	181	184	187
69	119	184	186	189	193
70	123	189	192	195	199
71	127	194	197	201	204
72	131	200	203	206	210
73	135	205	208	212	216
74	139	211	214	218	222
75	143	217	220	224	228
76	147	223	226	230	234
77	151	229	232	236	240
78	153	235	238	242	247
79	159	241	244	248	253
80	166	247	250	255	259

1. If a male exceeds these weights, percent body fat will be measured per the method described in AR 600-9.
2. If a male also exceeds this body fat, he will be rejected for service:

Maximum body fat by years of age

17-20	21-27	28-39	40 and over
24 percent	26 percent	28 percent	30 percent

TABLE 2-2 Military acceptable weight (in pounds) as related to age and height for females—initial Army procurement

Height (inches)	Minimum weight any age	Maximum weight by years of age 17-20	21-27	28-39	40 and over
58	90	112	115	119	122
59	92	116	119	123	126
60	94	120	123	127	130
61	96	124	127	131	135
62	98	129	132	137	139
63	100	133	137	141	144
64	102	137	141	145	148
65	104	141	145	149	153
66	106	146	150	154	158
67	109	149	154	159	162
68	112	154	159	164	167
69	115	158	163	168	172
70	118	163	168	173	177
71	122	167	172	177	182
72	125	172	177	183	188
73	128	177	182	188	193
74	130	183	189	194	198
75	133	188	194	200	204
76	136	194	200	206	209
77	139	199	205	211	215
78	141	204	210	216	220
79	144	209	215	222	226
80	147	214	220	227	232

1. If a female exceeds these weights, percent body fat will be measured per the method described in AR 600-9.
2. If a female also exceeds this body fat, she will be rejected for service:

Maximum body fat by years of age 17-20	21-27	28-39	40 and over
30 percent	32 percent	34 percent	36 percent

F

Biographical Sketches

COMMITTEE MEMBERS

RICHARD L. ATKINSON Since 1986, he has been Professor of Internal Medicine at Eastern Virginia Medical School and Associate Chief of Staff for Research and Development at the Department of Veterans Affairs Medical Center in Hampton, Virginia. He received an M.D. degree from the Medical College of Virginia. His research interests are in nutrition, particularly in obesity and the regulation of body weight and energy balance.

ANDRE BENSADOUN He is a Professor of biochemistry in the Division of Nutritional Sciences at Cornell University, Ithaca, New York. His areas of research include lipid transport in vertebrates and specifically the study of lipolytic enzymes.

WILLIAM J. EVANS He is the Chief of the Human Physiology Laboratory at the U.S.D.A. Human Nutrition Research Center on Aging at Tufts University and an Associate Professor of Nutrition and Physiology in the School of Nutrition and the Medical School of Tufts University. He is a Fellow of the American College of Sports Medicine and of the American College of Nutrition. He received his Master's and Ph.D. degrees at the Ball State University Human Performance Laboratory. His laboratory examines the relationship between exercise, nutrition and aging.

JOEL A. GRINKER She is currently Professor in the Human Nutrition Program, School of Public Health, Professor in Pediatrics at the Medical School and a member of the Center for Human Growth and Development at the University of Michigan. She received a Ph.D. in experimental social psychology from New York University and was the recipient of a Russell Sage Foundation Fellowship at the Rockefeller University in biochemistry, biology and behavior. After 15 years at Rockefeller University in the laboratory of Human Behavior and Metabolism, she moved to the University of Michigan to become Chair of the Program in Human Nutrition. Major areas of interest are in obesity, specifically the development and maintenance of obesity through the life span.

EDWARD S. HORTON He is Professor and Chairman of the Department of Medicine at the University of Vermont College of Medicine, Burlington, Vermont. He is a graduate of Harvard Medical School and received his training in internal medicine and endocrinology and metabolism at Duke University. Since 1967, he has been at the University of Vermont where his major research has involved studies of the regulation of energy expenditure in humans, the interrelationships between obesity and diabetes mellitus and the mechanisms of insulin resistance in skeletal muscle and adipose tissue. He is, particularly, interested in the effects of exercise and physical conditioning on insulin sensitivity and the regulation of glucose transport and metabolism in skeletal muscle. He is immediate Past President of the American Diabetes Association and a Past President of the American Society for Clinical Nutrition.

G. RICHARD JANSEN He is Emeritus Professor of nutritional science and formerly Head of the Department of Food Science and Human Nutrition at Colorado State University. His Ph.D. in biochemistry was from Cornell University. His research interests deal primarily with protein nutrition, and he has co-authored a book on diet and health issues. Prior to his appointment at Colorado State, he was a research fellow at the Merck Institute. He served in the United States Air Force from 1950 to 1953.

GILBERT A. LEVEILLE He is Vice President of Research and Technical Services for Nabisco Brands, Inc. Prior to joining Nabisco in 1986 he was Director of Nutrition and Health for General Foods, and from 1971 to 1980 was Professor and Chairman of the Department of Food Science and Human Nutrition at Michigan State University. He holds a Ph.D. in nutrition and biochemistry from Rutgers University. His areas of research interest include carbohydrate and lipid metabolism, obesity and metabolic adaptations to diet.

JOHN A. MILNER Since 1989 he has been Professor and Head of the Nutrition Department at The Pennsylvania State University. He has a Ph.D. degree in nutrition from Cornell University. He has a broad background in both fundamental and applied nutrition. His own research deals with the role of the diet as a modifier of cancer risk.

ROBERT O. NESHEIM (Committee Chairman) He retired as Vice President, Science and Technology, for the Quaker Oats Company, Chicago, Illinois, in 1983, and in 1991, as President of Advanced HealthCare, Monterey, California. He earned a Ph.D. degree in nutrition from the University of Illinois and has had extensive experience in research management. He has been involved in food and nutrition issues for many years, serving on many national committees, including the Food and Nutrition Board and the Food Advisory Committee, Office of Technology Assessment, U.S. Congress. He is a Fellow of the American Institute of Nutrition.

JOHN E. VANDERVEEN Since 1975, he has been the Director, Division of Nutrition at the Food and Drug Administration. He is responsible for planning, developing, and implementing programs that provide scientific knowledge required to carry out the Food, Drug, and Cosmetic Act with respect to the field of nutrition. His duties also include providing scientific counsel in the formation of regulations and regulatory programs in the broad field of nutrition and food labeling as well as providing nutritional review of petitions submitted for regulatory actions, exemptions and/or food additive approvals. He earned a Ph.D. degree in chemistry from the University of New Hampshire.

ALLISON A. YATES She is Dean of the College of Health and Human Sciences at the University of Southern Mississippi and Associate Professor of foods and nutrition. She has a Ph.D. degree in nutrition from the University of California at Berkeley, and an M.S. in public health from U.C.L.A., and is a registered dietitian. She currently serves as Project Director for the Division of Applied Research of the National Food Service Management Institute. Her areas of expertise are in food habits, diet composition, and protein and energy interrelationships.

AUTHORS

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