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NUTRITIONAL ASSESSMENT OF CADETS AT THE U.S. MILITARY ACADEMY: PART 1. ANTHROPOMETRIC & BIOCHEMICAL MEASURES

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

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Technical Report No. T4-91

NUTRITIONAL ASSESSMENT OF CADETS AT THE U.S. MILITARY ACADEMY: PART 1. ANTHROPOMETRIC & BIOCHEMICAL MEASURES

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We conducted a study of 128 male and 90 female cadet volunteers at the U.S. Military Academy in April 1990 to assess nutritional health endpoints of body composition, serum lipids, and iron status, as part of a larger nutrition study. The body composition of cadets has not changed from that measured in cadets 10 years ago. Mean values of circumferentially-determined body fat were 12% (men) and 26.5% (women); no men and only 14% of the women were overfat by AR 600-9 standards for 21-27 year olds, although by the standards of the Cadet Weight Management Program, half of the women would be classified as overfat. In this fit sample of cadets, 80% of women and 37% of men stated that they were attempting to lose weight. Serum lipid profiles indicated low cardiovascular disease risk for this population; 6% of men and 3% of women in this study exceeded the cholesterol and LDL-cholesterol screening limits recommended by the National Cholesterol Education Program. When all cadets in this population were considered, skinfold-determined fatness, fasting serum insulin levels, and family history of high blood pressure were the factors most related to higher

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Block 19 (abstract), continued.

levels of chlesterol and/or decreased HDL-cholesterol for the males, but
fatness was unrelated for the women. All measures of iron status indicated
a greater risk of iron deficiency anemia in comparison to the 1979 study of
cadets, a direct result of a blood drive which occured in the week prior to
our study; one third of the women who had given blood were classified with
iron deficiency anemia, suggesting that prior to blood donation a more
intensive screening procedure should be applied to female cadets. Comparisons
of mean values indicated that the use of iron supplements by the women was
beneficial to various hematological parameters, including those women who
gave blood. We recommend that women should not be held to a body fat standard
which is more stringent than the current Army standard described in AR 600-9.
This may, in part, be encouraging the high rate of desired weight loss in
these cadets and dieting is known to be associated with deficient intake of
essential nutrients such as iron. At the other extreme, excess fat intakes
should be discouraged through appropriate dietary education and, most
importantly, through the example established by the Cadet Mess with the
observance of Army-wide goals of fat content at less than 30% of total calories.

For the two out of three adult Americans who do not smoke and do not drink excessively, one personal choice seems to influence long-term health prospects more than any other: what we eat.

The Surgeon General's Report on Nutrition and Health, 1988

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SUMMARY

The authors conducted a study of 128 male and 90 female cadet volunteers at the U.S. Military Academy in April 1990 to assess nutrient intake and nutritional health endpoints (body composition, serum lipid profiles, and iron status). This report summarizes the anthropometric and biochemical measurements, as related to the nutritional health of the cadets. The primary findings and conclusions are as follows.

The body composition of cadets in this study is the same as that measured in cadets 10 years ago. Mean weights, circumferences, and skinfold thickness were no different than in the previous study. Body fat compared by the same method of skinfold measures was also unchanged, with mean values of 14 and 24% for male and female cadets. The mean values obtained from the prescribed (AR 600-9) Army circumference equations were 12 and 26.5% body fat, for men and women. Although 18% of male and 29% of female cadets exceeded the AR 600-9 screening weight tables for 21-27 year olds, no men and only 14% of the women exceeded the circumferentially-determined fat standards. However, by standards of the Cadet Weight Management Program, half of the women studied could be categorized as above the body fat limit of 26%. A majority of female cadets (79.5%) and 37% of male cadets in the study population stated that they were attempting to lose weight.

Serum lipid profiles indicated low cardiovascular disease risk status for this population. Six percent of men and three percent of women in this study exceeded the cholesterol and LDL-cholesterol screening limits recommended by the National Cholesterol Education Program (NCEP) but it was uncertain that any of these individuals would qualify for intervention on the basis of two or more associated risk factors. When all cadets in this fit population were considered, fatness, fasting serum insulin levels, and family history of high blood pressure were the factors most related to higher levels of cholesterol and/or decreased HDL-cholesterol for the males, but fatness was unrelated for the women. The NCEP recommendation for the first line of intervention for individuals with elevated cholesterol is to reduce fat intake to less than 30% of total calories, but this is recommended for all individuals as well. Excess fat intake is undesirable for any cadets although, for many individuals, this may not be manifested as excess body fatness and in alterations of serum lipid profiles without a longer term exposure to high fat intake.

All measures of iron status indicated a greater risk of iron deficiency anemia in comparison to the 1979 study of cadets. This difference in iron status parameters was a direct result of a blood drive which occured in the week prior to our study. While this prevented us from adequately assessing the relationship between current dieting and iron deficiency, other observations were instructive. One third of the women who had given blood were classified with iron deficiency anemia, suggesting that a more intensive screening procedure should be applied to female blood donor volunteers. The single male cadet who fell into the iron deficiency anemia classification (on the basis of low ferritin, low iron saturation, and low hemoglobin) had not given blood and was referred for medical treatment. Comparisons of mean values indicated that the use of iron supplements by the women (including those who gave blood) was beneficial to various hematological parameters.

INTRODUCTION

This report is the first of several papers reporting the results of the 1990 Nutritional Assessment of U.S. Military Academy Cadets performed by the US Army Research Institute of Environmental Medicine (USARIEM). A similar study was performed 10 years ago (1-3). The intent of this new study was to assess the current nutritional status of cadets at USMA in terms of their actual nutrient intake and in terms of their nutritional health. This report addresses a piece of the study, the nutritional health of cadets.

Nutritional health of the cadets was examined in terms of three principal endpoints: body composition, serum lipids, and iron balance. These three factors are interrelated (4) and each is closely related to nutrient intake. Persistently high dietary fat intake promotes fatness and increases the risk of ischemic heart disease through effects on serum lipids and other metabolic derangements. Some of these interrelationships and their hypothesized associations through hormonal regulators are illustrated in Figure 1 (for reviews, see refs 5-8). On the other hand, excessive caloric restriction may result in inadequate nutrient intakes such as inadequate dietary intake of iron, producing an iron deficiency.

Excess body fat in males is primarily deposited in the abdominal region and fat cells in this region tend to be highly responsive to adrenaline which stimulates the removal of this fat under influences such as aerobic exercise. There is also a health risk association which is presumed to be a consequence of the high concentration of fats which circulate directly to the liver from these large abdominal fat stores before reaching general circulation in the body (Figure 1). This in turn affects insulin action and disposal in the liver and the elevated levels of insulin further stimulate abdominal fat storage and disturb serum lipid metabolism. The elevated insulin and increased amount of fat in circulation also inhibits the transport of sex steroids (testosterone and estrogens), altering their actions in the body. The net effect of these latter changes is to also stimulate the fat cell fat-storage enzymes (lipoprotein lipase) to further store fat in a male type (abdominal) pattern. The abdominal fat store may also serve as a marker of stress signifying the presence of other factors which directly affect lipid balance. Thus, prediction of total body fat in males through the use of abdominal circumferences also conveniently predicts long-term health risks (cardiovascular disease, stroke, and diabetes) as well as
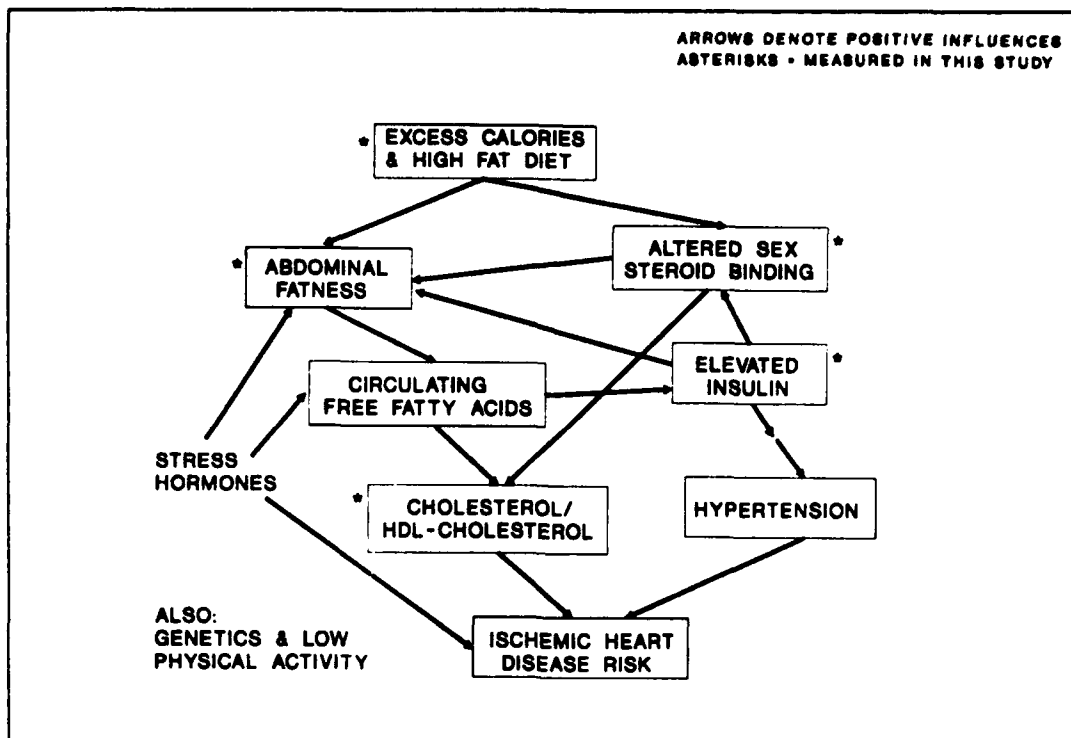
Figure 1. Some hypothesized relationships in the link between excess fat intake and cardiovascular disease. Abdominal fat and cholesterol are closely related through hormonal regulators such as insulin and sex steroid hormones.

predicting underexercise and/or overeating, and poor military appearance (specifically, pot-belly)(9).

Total body fat is a less useful predictor of longterm health, physical fitness, and military appearance in women. This is because total fatness encompasses multiple body sites which have different functions and different regulatory controls (e.g. breast fat and thigh fat are stored in preparation for post-pregnancy milk production and fat in these sites is less likely to be mobilized during exercise). Even the site of excess fat storage may vary and has different health consequences. For some women, excess fat accumulates primarily in the abdomen (an apple-shaped body fat configuration) and this confers some male health risks. Other women deposit excess fat in the more typical female pear-shaped configuration. Moderate levels of this type of fat deposition do not appear to be associated with increased health risks. Thus, for women, the location as well as the relative amount of fat is important.

Increased risk of cardiovascular disease begins in part with high fat and excessive calorie intake, but it may be years before these appear as a measureably altered serum lipid profile. The effects of high fat intake may also be offset by regular physical activity. Thus, in young cadets, selected to attend the Academy partly on the basis of high fitness and current health, genetics (assessed by family history) is expected to be the main association with an unfavorable serum lipid profile. For cadets with high cholesterol, the first step of medical intervention would be to decrease the fat content in their diet, but all cadets can benefit in the long-term from such a reduction. The 1979 study of cadet nutrient intake found a high level of dietary fat consumption (an average of 38% of total calories) and the report recommended that this be reduced (3). The current Army goal is to reduce soldier fat intake to less than 30% of caloric intake, the recommended first step in treatment of hypercholesterolemia (10).

Iron balance is important because iron deficiency can result in anemia and reduce exercise performance (11). Iron status is linked to caloric intake since it represents a relatively constant proportion of total intake. Thus, the derangements observed in iron status can be related to inappropriate attempts to regulate body fat. Iron status can be assessed by measuring serum levels of iron, its carrier protein (transferrin), and ferritin, a protein which provides a good indication of total body iron stores. In addition to measuring hematological endpoints such as hematocrit and hemoglobin, it is also valuable to assess some of the factors involved in red blood cell production such as Vitamin B12 and folic acid to differentiate the reasons for a low hemoglobin. The 1979 study found that a large proportion of cadets, especially female cadets, had low serum levels of both iron and folic acid. The report recommended that the menus be modified accordingly and that "if necessary, iron supplements or the fortification of selected foods to increase the intake of iron, especially for the female cadets, should be considered" (2).

This report summarizes our observations on these interrelated nutritional status endpoints. The observations are compared to the results of the study conducted 10 years ago and to current Army Weight Control Program standards and national health guidelines.

METHODS

The study subjects consisted of 128 men and 90 women who were selected from the U.S. Military Academy Cadet Corps by onsite coordinators. These cadets were identified from a responding sample of the 4374 cadets who were asked to answer an electronic mail survey and who answered that they would be interested in participating in this study. All women who volunteered were selected, and an equal number of nonsmoking men was also chosen on the basis of a distribution of the number of meals eaten in or out of the cadet mess. This latter criterion was used to group the data for the main study. An additional group of interested male volunteers was added before the study was completed. The ages of the test subjects and their distribution by class are summarized in Table 1. The ethnic distribution of the cadets closely paralleled the ethnic representation in the entire cadet corps, 86% white, 6% black, 2% hispanic, and 6% asian, native american or other.

Table 1. Age and class distribution of male and female cadets in the study sample compared to overall distributions in the USMA population (* one female cadet did not complete a questionnaire).

Parameter	Males (n=128)	Females (n=89)*	Combined (n=217)	Population (n=4374)
Age	20.5 ±1.3	20.1 ±1.5	20.4 ±1.4	
Class (percent)				
- Fourth	16	26	20	28
- Third	30	30	30	25
- Second	34	21	29	24
- First	20	23	21	23

The cadets were studied in single early morning sessions which spanned a one week period, 2-6 April 1990. This period was chosen because it followed a one week Spring break by at least two weeks and did not run into an exam period. A blood drive which occurred in the preceding week (26-29 March) was unplanned but provided additional interesting observations. The test period

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began after at least three days of nutrient intake collection. Thus, the nutrient intake for 3-8 days preceding morning testing was obtained for all cadets. The analysis of this nutrient intake and the relationship to measures reported here will form the basis of another report scheduled to follow this one.

Following 8-10 hours of fasting, cadets reported to a clinic in their gym clothes (shorts & T-shirt). They were weighed and measured for height without shoes. For all cadets, circumference measurements were performed in duplicate for neck, "r. tural" waist (thinnest abdominal measurement), abdomen (at the navel), and hips (horizontal to the ground and at the largest protrusion of the buttocks). For female cadets only, right thigh, right forearm, and right wrist also were measured, as required for various body fat equations. The hip circumference was measured over gym shorts while all other measurements were made over bare skin. The intra- and interobserver coefficient of variation for circumference measurements was less than 1%. Skinfold thicknesses were made in triplicate for biceps, triceps, subscapular and suprailiac sites on the right side of the body, by the method of Durnin and Womersley (12). These measurements were made with Harpenden skinfold calipers by three skilled anthropometrists with inter- and intraobserver coefficients of variation of less than 5%.

Venous blood samples were collected from each cadet in a prone position. Samples of whole blood preserved in EDTA were well mixed and chilled in ice until hematocrit and hemoglobin concentrations were measured using a Coulter clinical analyzer within 1-2 hours. Other aliquots of EDTA treated whole blood were preserved in 0.4% ascorbic acid (1:11) and frozen for later analysis of erythrocyte fo .te (only a random subset of these samples were preserved and analyzed). The remaining blood was allowed to clot, centrifuged, and the serum was divided into 10 aliquots and promptly frozen at -20 C for subsequent serum biochemical analyses.

In the dietary assessment portion of the study, cadets were given a brief questionnaire. Twelve of these questions, designed to assess family health history, demographic characteristics, and other covariables of the measures reported here, were analyzed for this report. Subject codes were removed from the other questions and the information will be summarized independently in the subsequent report. Family history questions were asked in reference to natural parents and siblings.

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Anthropometric calculations. Body fat was calculated from the sum of four skinfold sites using the age appropriate regression equation of Durnin and Womersley (12). Body fat was also calculated from circumferences according to the current method in AR 600-9. Using metric units (centimeters & kilograms), the equations for these tables are:

<u>For males:</u>
percent body fa = 43.74-(68.68*log(height))+(76.46*log(abdominal circumference - neck circumference)), and

<u>For females:</u>
percent body fat = (105.33*log(weight))-(0.20*wrist circumference)-(0.53*neck circumference)-(1.57*forearm circumference)+(0.17*hip circumference)-(0.52*height)-35.60.

Waist-to-hips ratio was calculated as abdominal circumference (at the navel) divided by hip circumference.

Biochemical assays. All assays were performed on serum except for the erythrocyte folate which was measured in blood preserved as described above. Serum lipids (cholesterol, HDL-cholesterol, and triglycerides), serum iron, and serum total iron binding capacity (TIBC) were measured colorimetrically using an automated chemistry analyzer with reagents provided by the manufacturer (Synchron CX5, Beckman Instruments, Inc., Brea, CA). Cholesterol esters were hydrolyzed with cholesterol esterase and free cholesterol was then oxidized with cholesterol oxidase and converted to a quinoneimine product. The reagent and calibrator values for this assay are directly assigned with the CDC Cholesterol Control. HDL-associated cholesterol was measured by the same method following precipitation of LDL and VLDL with phosphotungstic acid. LDL-cholesterol was calculated by the Friedewald equation (10), appropriate for mass units. Triglycerides were hydrolyzed to glycerol and subsequent enzymatic degradation of glycerol resulted in a colored formazan product; samples were not glycerol blanked.

Serum iron was measured by the change in absorbance following liberation of iron from transferrin, reduction to the ferrous state, and complexing with FerroZine Iron Reagent. TIBC was measured by release of ferric ion from saturated transferrin, which is then reduced to the ferrous state with hydroxylamine and thioglycolate and complexed with FerroZine Iron Reagent. Serum apolipoprotein-A1 and apolipoprotein-B levels were measured using

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turbidometric assays (Sigma Chemical Co., St. Louis, MO).

Ferritin was measured using an immunoradiometric assay (IRMA) (BioRad, Hercules, CA). Serum vitamin B12 and folate concentrations were measured in one assay using a doubly-labelled radioimmunoassay (RIA) procedure (BioRad). Red cell folate was measured in the same RIA following dilution of the stored ascorbic acid diluted solution with folate free human serum albumin; serum folate was ignored as negligible in the calculation of erythrocyte folate by the red cell concentration/hematocrit/100. Serum sex hormone binding globulin (SHBG) was assayed by IRMA (Farmos Diagnostica, Oulunsalo, Finland). Serum testosterone, 17beta-estradiol, insulin, and dehydroepiandrostenedione sulfate were measured using specific RIA procedures (Diagnostic Products Corporation, Los Angeles, CA). The analyses using these latter hormone measurements will appear in a separate report on the determinants of HDL_2-cholesterol levels.

Throughout this report averages are reported as arithmetic means, plus or minus one standard deviation.

RESULTS & DISCUSSION

ANTHROPOMETRY & BODY COMPOSITION

Comparison of 1990 measurements to results of the 1979 study

The comparisons of 1990 anthropometric measurements and measurements obtained in the 1979 study are shown in Table 2.[1] The values are similar and within the range of variability which would be expected for different observers from different laboratories. The mean values for body fat estimated from skinfold thicknesses are remarkably similar between 1979 (obtained from reference 3) and 1990. There is an apparent variation in the height measurements between the two studies, however, a difference of similar magnitude was reflected even between average measurements in two separate phases of the 1979 study. The median value for height in the Army is 175.5 cm for men and 162.7 cm for women; our mean values fall at approximately the 55th and 65th percentiles for all Army males and females, respectively (13).

Comparison to the Army standards of body composition

Based on the U.S. Army standards for ages 21-27 years, 18% of male and 29% of female USMA cadets exceeded the screening weight tables in Army Regulation 600-9 (dtd 1 Sept 1986).[2] When percent body fat was estimated for all cadets, irrespective of screening weights (Figure 2), no men and 13% of the women exceeded the upper limits of body fat allowed for 21-27 year old Army males (22% body fat) and females (30% body fat). The mean estimated body fat for males (12% body fat) was well below the male upper limit of 22% body fat, while the measurements for women were clustered much closer to

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[1]The comparison of anthropometric measures is made to data from the 1979 study breakout of male and female cadets in the junior class (class of 1980). This is done because measurements in the 1979 report were summarized only by class, although no statistical differences were detected between class samples.

[2]This is the age category applicable to cadets by the time of graduation, when they will be held to AR 600-9 standards. The standards for the younger age category (17-20 years) are more stringent for screening weights and for the upper limit of allowable percent body fat.

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Table 2. Comparison of anthropometric measurements of male and female cadets obtained in 1979 (second class) and in 1990 (all classes) at the U.S. Military Academy.				
	Male cadets		Female cadets	
Parameter	1979	1990	1979	1990
	Mean±SD (n=39)	Mean ±SD (n=123)	Mean ±SD (n=27)	Mean ±SD (n=88)
Height (cm)	178.9 ±6.6	176.5 ±6.9	167.5 ±6.5	165.5 ±6.5
Weight (kg)	77.0 ±10.5	77.1 ±10.0	61.2 ±7.9	61.6 ±5.7
BMI (kg/m²)	----	24.7 ±2.3	----	22.5 ±1.7
%BF (skinfolds)	14.6 ±3.9	14.0 ±3.3	23.4 ±4.8	23.8 ±3.4
%BF (AR 600-9)	----	12.2 ±3.0	----	26.5 ±3.2
Triceps SF (mm)	8.0 ±2.7	7.3 ±2.4	13.4 ±3.7	13.8 ±2.7
Biceps SF (mm)	3.7 ±1.2	4.1 ±1.2	5.9 ±2.5	6.0 ±1.7
Subscap SF (mm)	10.5 ±2.7	10.4 ±2.6	10.7 ±3.6	11.0 ±3.5
Suprail SF (mm)	13.5 ±5.1	12.6 ±6.3	12.3 ±5.1	11.6 ±5.5
Sum of skinfolds	----	34.4 ±10.4	----	42.4 ±11.5
Neck C (cm)	37.9 ±2.2	38.2 ±2.1	31.9 ±1.5	32.3 ±1.5
Abdominal C (cm)	79.7 ±5.1	80.1 ±5.8	69.6 ±6.1	73.2 ±5.0
Hip C (cm)	96.9 ±5.1	97.0 ±5.2	95.8 ±5.3	95.8 ±4.2
R. Thigh C (cm)	57.6 ±4.3	----	56.6 ±3.4	56.4 ±3.2

note: **%BF (skinfolds)** = percent body fat estimated by the Durnin & Womersley equations (12) using the sum of 4 skinfolds and age;
%BF (AR 600-9) = percent body fat estimated using the Army circumference equations, as detailed in AR 600-9, "The Army Weight Control Program."
SF = triceps, biceps, subscapular, & suprailiac skinfolds;
C = neck, abdominal, hip, & right thigh circumferences.
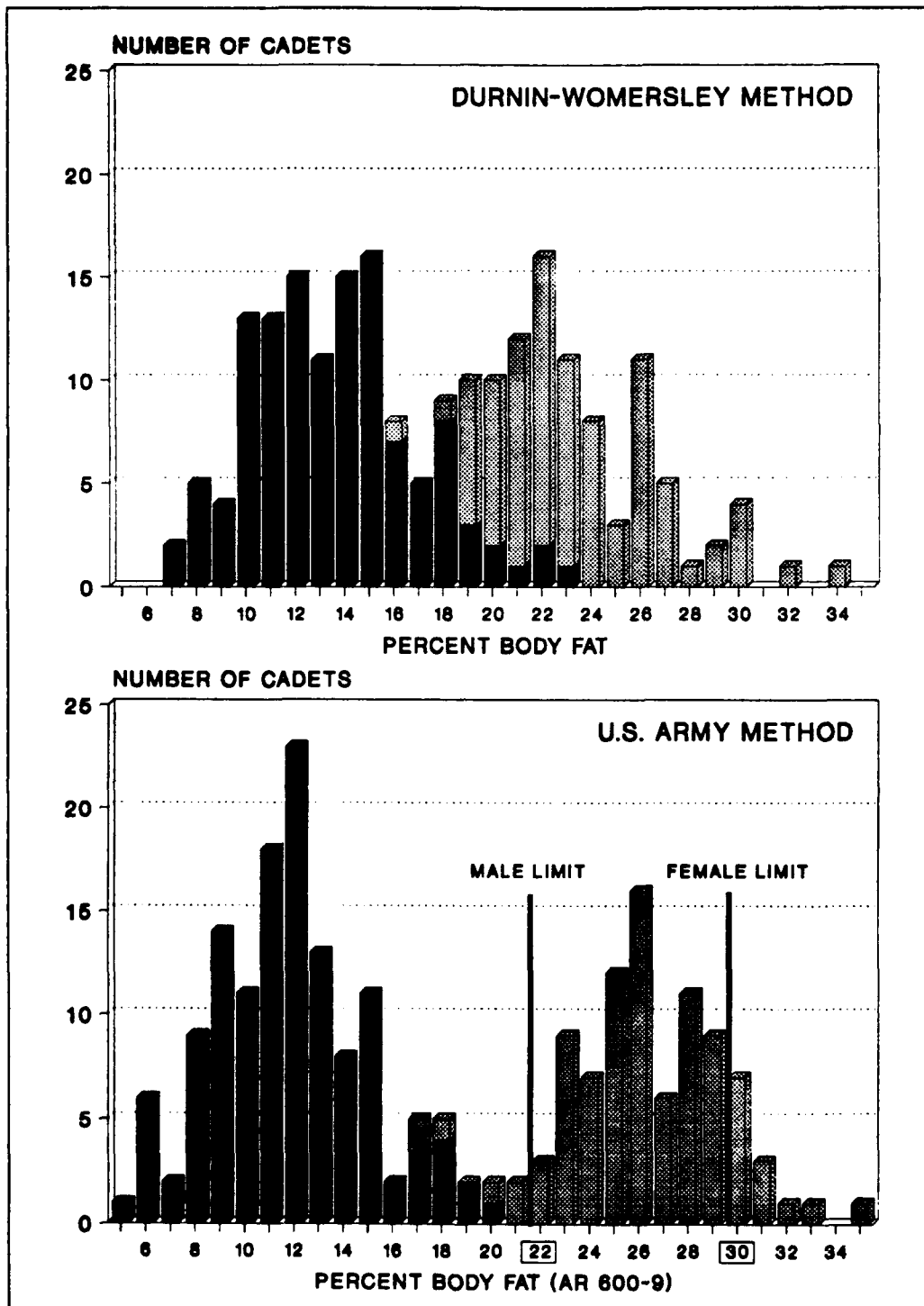
Figure 2. Distribution of male (solid bars) and female (shaded) cadets by percent body fat estimated from skinfold (upper graph) and circumference (lower) equations. The lower graph shows upper limits of fatness IAW AR 600-9 for ages 21-27.

their upper limit of 30% and had a mean value of 26.5% body fat.

By the current Army standards of AR 600-9 (for the age category: 21-27 years), no males and 12 females (13%) would exceed screening tables and would then also exceed body fat limits (Figure 3). Thus, all women who were overfat were captured by the weight screening tables.

The cadet values can be compared to 1988 data on Army recruits in their first week of basic training (14). In that sample, 1483 males averaged 16.1% body fat, compared to 12.2% for male cadets in this study. Female recruits (n=1159) averaged a very similar 26.8% body fat (compared to 26.5% in female cadets) but averaged 3 kilograms less in body weight. This suggests that the female cadets carry a greater lean body mass than the average female recruit.

Our observed distribution of fatness in the highly select population of the Military Academy suggests that the current standards in AR 600-9 are *physiologically* more stringent for women than for men. It was also our subjective impression that few, if any, female cadets were carrying excess fat.

Although the circumference method is the Army standard for estimating body fat, the skinfold method of Durnin & Womersley was the interim method used by the Army while the circumference equations were being developed. Figure 2 illustrates why methods of body fat assessment should not be used interchangeably. Each "generalized" equation estimates body fat differently and this is largely dependent on which specific measurement sites the method relies on. Thus, the Durnin & Womersley method which estimates body fat from subcutaneous fat in four upper body sites for both males and females yields different estimates than the Army circumference methods which emphasize abdominal fat (internal and subcutaneous) in males and gluteofemoral fat and body weight in females.

Each of the services has different methods of body fat estimation and the results are compared against different limits of body fat. As an example, all cadets in this study would be well in compliance with the Army fat standards if assessed by the original Marine Corps equations (15,16). However, the Marine Corps upper limits of body fat calculated by these equations are also more stringent at 18% and 26% for all men and women (17). Using the Marine Corps standards with the Army method of estimation, *half* of the female cadets

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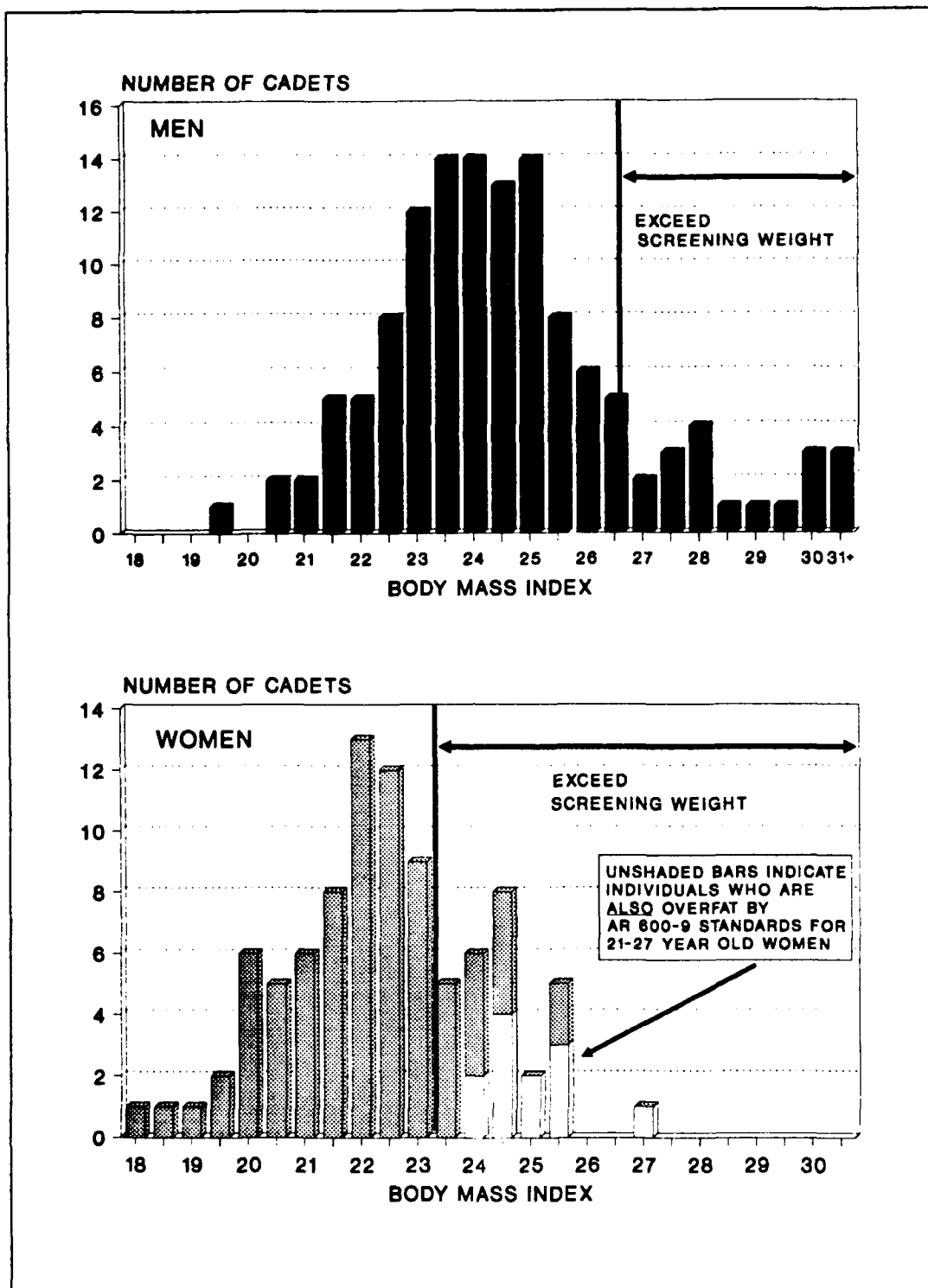
Figure 3. Distribution of cadet weight-for-height represented as body mass index (wt/ht², in kilograms and meters). Soldiers exceeding the screening weights are assessed for body fat by the Army circumference methods.

(averaging 26.5% body fat) would be classified as overfat.[3] Clearly, it would be inappropriate to measure cadets by one method and hold them to a body fat standard which has been set for a different method of assessment.

Comparison to recommended health standards

Few studies have examined the relationship between health endpoints and percent body fat; thus, the relation between health risk and fatness is generally based on epidemiological studies using height and weight. The Surgeon General of the Public Health Service states that "people are considered overweight if their body mass index exceeds the 85th percentile for young American adults...and are at increased risk for diabetes mellitus, high blood pressure and stroke, coronary heart disease, some types of cancer, and gallbladder disease" (18)[4]. No female cadets fell into this category of excess weight while 18 male cadets (14%) exceeded the recommended limits.

An alternative method of assessing health risk from excess fatness is the waist-to-hips circumference ratio (WHR). This has been extensively used in epidemiological studies to demonstrate clear associations between high levels of abdominal fat (high WHR) and heart disease, stroke, and diabetes (19). The principal difficulty with the application of this index is the variety of sites which are used as "waist" and "hips" measurements and other differences between populations studied.

In our study, average WHR values were 0.83±0.04 (men) and 0.76±0.02 (women). One woman exceeded a ratio of 0.85 and also registered the highest body fat measurement, but demonstrated no metabolic abnormalities (cholesterol was less than 150 mg/dl). In contrast, the highest male ratio of 0.93 was associated with a high LDL-cholesterol level even though estimated body fat was only 15% (by skinfolds and by circumferences).

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[3]U.S. Military Academy Cadets are encouraged to meet the more stringent limits of 18% and 26% body fat or be enrolled in the Cadet Weight Control Program. There appears to be some flexibility in the method of measurement.

[4]The 85th percentile for young men and women is generally derived from the National Health and Nutrition Examination Survey, 2nd phase (NHANESII). The 85th percentile values are 27.2 kg/m^2 (men) and 26.9 kg/m^2 (women).

Distribution of cadets attempting to change their weight

In their questionnaires, a majority of female cadets (79.5%) answered "yes" to the question, "Are you trying to lose weight?"; no women indicated that they were attempting to gain weight. There was no clear relation between this response and estimated fatness or proximity to fat limit standards (Figure 4). A smaller proportion of male cadets (37%) were also attempting to lose weight, while 25% were trying to gain weight.

Changes with respect to physical maturation

Male anthropometric values demonstrated a trend for an age-related increase (e.g. height, weight, abdominal circumference) and these

Figure 4. Distribution of cadets by percent body fat showing the subpopulation of cadets attempting to lose weight (unshaded bars).

seemed to level off at about age 21 (Table 3). Although these differences between age groups were not statistically significant, the trend is consistent with physical maturation still occuring for many male cadets under age 21. For women, no trend is discernable (Table 4), consistent with their earlier physical maturation. In the 1979 anthropometric study (1), the cadet measurements were compared by class and no statistically significant differences emerged.

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Table 3. Male anthropometric measurements classified by age.						
Age	**18**	**19**	**20**	**21**	**22**	**23+**
Sample size	7	23	39	28	17	9
Height (cm)	173.1	174.0	177.5	177.8	177.0	176.5
Weight (kg)	70.3	74.5	78.8	78.5	77.2	79.7
BMI (kg/m^2)	23.5	24.5	24.9	24.8	24.6	25.6
%BF (sknflds)	13.6	13.6	13.8	14.1	14.1	15.1
%BF (600-9)	11.4	12.0	12.0	11.7	12.8	14.4
Abdom C (cm)	76.2	78.5	80.4	80.4	81.1	83.5
Hip C (cm)	93.5	96.0	97.8	97.0	97.2	97.7
WHR	0.81	0.82	0.82	0.83	0.83	0.85

Table 4. Female anthropometric measurements classified by age.						
Age	**18**	**19**	**20**	**21**	**22**	**23+**
Sample size	11	23	20	19	10	5
Height (cm)	168.7	166.2	163.4	166.0	164.6	164.5
Weight (kg)	61.4	62.7	61.2	61.5	61.7	61.7
BMI (kg/m^2)	21.6	22.7	22.9	22.3	22.8	22.8
%BF (sknflds)	22.3	24.7	23.8	23.5	24.8	22.5
%BF (600-9)	24.6	26.2	27.0	26.8	27.6	26.6
Abdom C (cm)	73.1	74.2	73.2	72.5	73.0	72.1
Hip C (cm)	96.3	96.3	95.2	96.7	94.6	94.6
WHR	0.76	0.77	0.77	0.75	0.77	0.76

note: WHR=waist-to-hips ratio

SERUM LIPIDS AND OTHER CARDIOVASCULAR RISK FACTORS

Comparison of 1990 measurements to measurements in 1979

Serum lipid levels were very similar to the measurements a decade ago (Table 5) and any differences fall within the expected range of inter-laboratory variation. A variation of 5% is considered "acceptable" for clinical lab measurements of total cholesterol traceable to Centers for Disease Control standards (20). The difference in cholesterol between the two West Point studies is about 5%. In the 1990 study, total cholesterol, the LDL-cholesterol fraction (Figure 5), and it's associated apolipoprotein-B were not different between male and female cadets but the distribution of serum triglycerides and HDL-cholesterol (Figure 6) were different between genders. The higher triglycerides and lower HDL-cholesterol range in males is associated with the increased risk of coronary artery disease attributed to male sex.

National Cholesterol Education Program (NCEP) guidelines

Specific guidelines for detection, evaluation, and treatment of high blood cholesterol in adults (age 20 and over) were established by an NCEP panel in 1988 (10). The recommendations were that unfasted serum cholesterol should be measured in all adults every five years. Less than 200 mg/dl is considered a desirable blood cholesterol; other experts add that even below this level, the lower the cholesterol, the lower the risk of ischemic heart disease. The range between 200 and 240 mg/dl is considered a "borderline-high" blood cholesterol which, in younger (20-39 year old) adults, should be evaluated along with the individuals with "high" blood cholesterol (>240 mg/dl). In clinical screening, the first step is to repeat the cholesterol measure in a second blood sample to confirm high or borderline-high status. In this study, 11 of the men (9%) and 7 of the women (8%) had cholesterol levels greater than 200 mg/dl (Figure 5).

The next step in the NCEP recommended evaluation relies primarily on LDL-cholesterol levels. LDL-cholesterol values of >160 mg/dl or >130 mg/dl and the presence of at least two risk factors calls for treatment. Eight men (6%) and three women (3%) exceeded levels of 130 mg/dl; all of these individuals also exceeded total cholesterol concentrations of 200 mg/dl.

Table 5. Comparison of serum lipid, lipoprotein, and insulin values observed in male and female cadets in 1979 (shaded columns) and in 1990 at the U.S. Military Academy.

Parameter	Male cadets		Female cadets	
	1979	1990	1979	1990
	Mean±SD (n)	Mean ±SD (n)	Mean ±SD (n)	Mean ±SD (n)
Cholesterol (mg/dl)	164 ±25 (158)	157 ±29 (127)	170 ±26 (70)	162 ±25 (90)
HDL-cholesterol (mg/dl)	45 ±9 (158)	48 ±10 (127)	55 ±10 (70)	59 ±12 (90)
Cholesterol/ HDL-cholesterol	3.8 ±0.9 (158)	3.4 ±0.8 (127)	3.2 ±0.6 (70)	2.8 ±0.5 (90)
LDL-cholesterol (mg/dl)	95 ±24 (156)	93 ±26 (127)	98 ±25 (70)	88 ±22 (90)
Triglycerides (mg/dl)	122 ±77 (156)	82 ±35 (127)	93 ±46 (70)	71 ±26 (90)
Apolipoprotein-A1 (g/l)	----	119 ±24 (124)	----	127 ±25 (88)
Apolipoprotein-B (g/l)	----	67 ±20 (118)	----	64 ±17 (90)
Insulin (ng/ml)	----	13 ±3 (124)	----	12 ±3 (86)

note: There were no significant differences in any of these parameters for female cadets comparing those using oral contraceptives and those who did not.
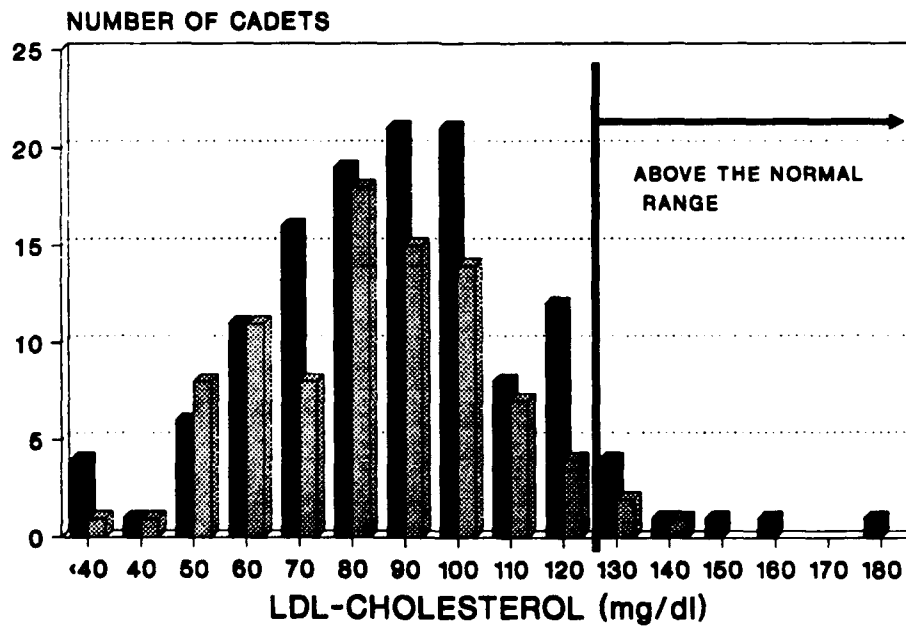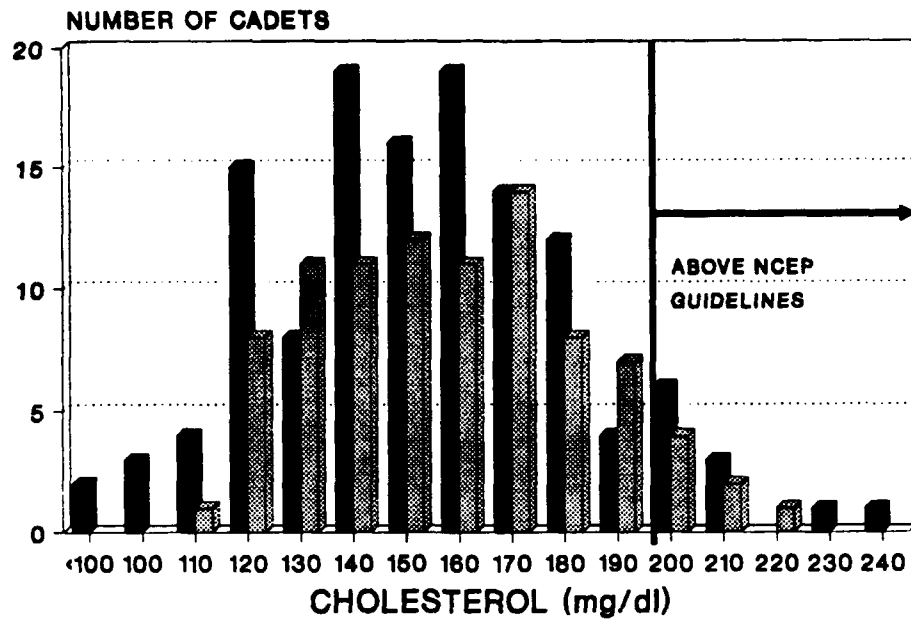
Figure 5. Distribution of male (solid bars) and female (shaded) cadets by total cholesterol and LDL subfraction values. The National Cholesterol Education Program (NCEP) recommended upper limits are shown.
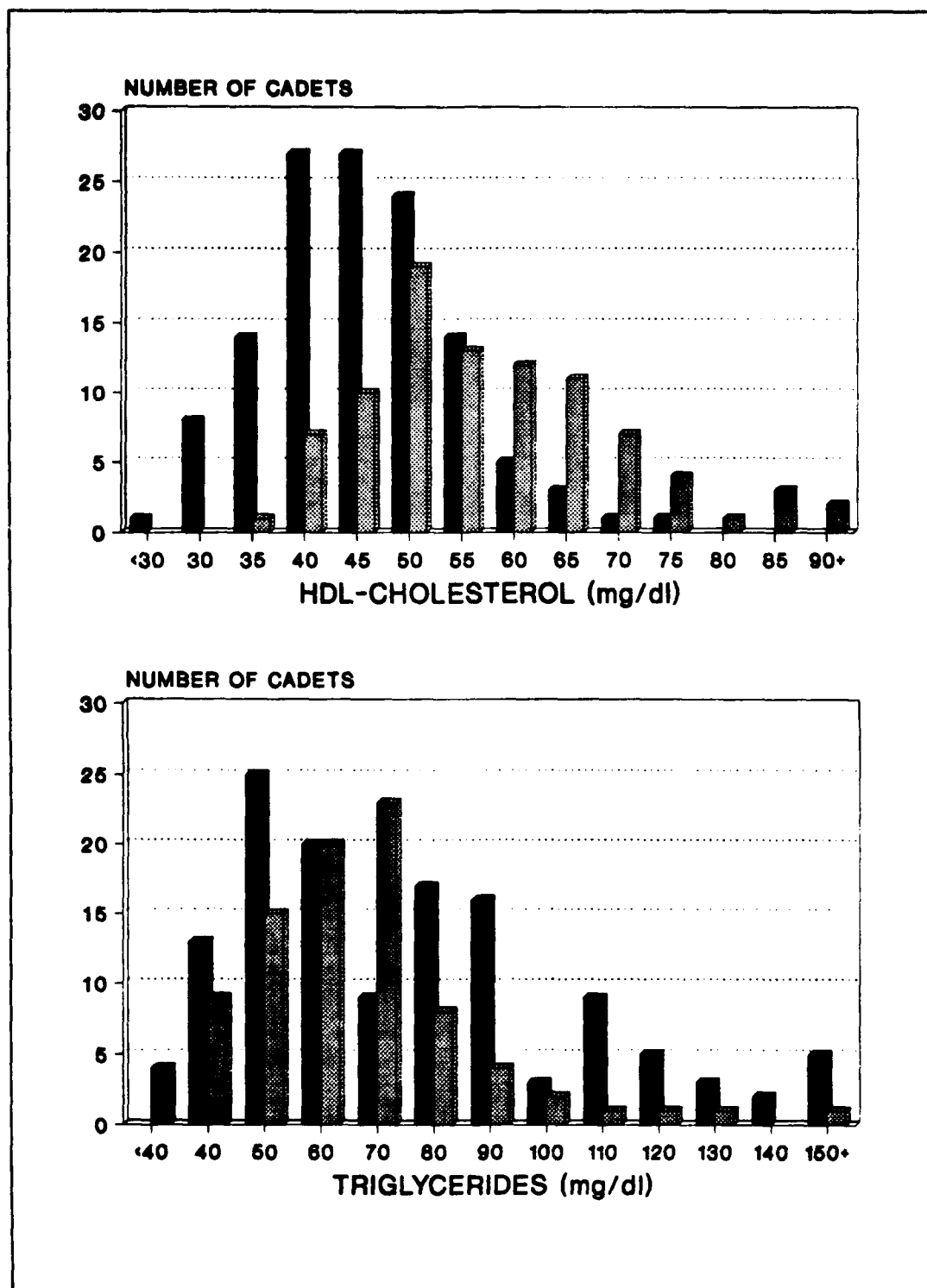
Figure 6. Distribution of male (solid bars) and female (shaded) cadets by HDL-cholesterol and triglycerides. Low HDL-cholesterol (<35 mg/dl) is associated with increased heart disease risk even if total cholesterol is <200 mg/dl.

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Risk factors in the NCEP algorithm include:

- o male sex
- o HDL-cholesterol of <35 mg/dl
- o cigarette smoking (>10 cigarettes/day)
- o family history of premature (before age 55) coronary heart disease
- o severe obesity (>30% of ideal body weight)
- o hypertension
- o diabetes

Four of the eight men may have had at least one other risk factor in addition to being male with either recent smoking or family history of heart disease; however, no one in this study currently smoked more than 10 cigarettes per day and a family history of *premature* coronary heart disease was uncertain. No cadets were severely obese and there were no known diabetics. Two cadets (1 male, 1 female) stated that they had known high blood pressure but neither one had an elevated total cholesterol. No risk factors, other than elevated LDL-cholesterol, were known to be present for the three women.

The first step of recommended treatment for this group (at least for the four men with probable risk factors) is dietary intervention involving a reduction of dietary fat intake to <30% of total calories and of saturated fats to <10% of total calories. This limit of dietary fats is also recommended for all individuals as part of the NCEP guidelines.

Comparison to values from the Army Health Risk Appraisals (HRA)

The cadet cholesterol values were comparable to the active Army, under age 25, as assessed in the second quarter of the 1990 Health Risk Appraisal (21). Mean values in that report were 167.0 mg/dl (9,548 men) and 175.9 mg/dl (1,510 women), with 4% of all men and women over 200 mg/dl.

Lipid and lipoprotein ratios as indices of heart disease risk

In the 1979 study of USMA cadets, the ratio of cholesterol/HDL-cholesterol was used as an expression of relative cardiovascular disease "risk." This value has not changed in the intervening decade although the previous study reported more individuals at the upper limits. In 1979, fifteen men (9.5%) and two

women (2.9%) had ratios of 5.0 or greater. In contrast, we found only seven men and no women in this range of increased risk for heart disease (Figure 7).

A more recent approach to assessing risk of heart disease is to directly measure some of the specialized proteins which define the cholesterol subfractions. In this study, we measured apolipoprotein-A1 (associated with HDL-cholesterol) and apolipoprotein-B (associated with LDL-cholesterol). A ratio of these two expressed as apo-A1/apo-B has been used in some recent epidemiological studies to estimate risk of coronary artery disease (22). Eight male and 2 female cadets had ratios of less than 1.0, suggesting increased risk for heart disease (Figure 7). This index yields estimates very similar to the other ratio; thus, the average cholesterol/HDL-cholesterol ratio for these ten individuals averaged 4.3, with none less than 3.5.

Lipid associations with other cardiovascular disease risk factors

Six male cadets (5%) and 4 female cadets (4%) admitted to cigarette smoking within the past 6 months, while 88% of male and female cadets had never smoked (Table 6). Family history of high blood pressure was present in nearly half of the cadets while one quarter of cadets had family histories of heart attack and diabetes. Less than 10% had a family history of stroke.

Individuals with family history of high blood pressure and heart attack were overrepresented in the group of cadets with cholesterol/HDL-cholesterol ratios greater than 4.0: 81% of the 27 individuals with risk ratios > 4.0 had a positive family history of high blood pressure and 57% of this group had a family history of heart attack (compare with overall proportions in Table 6. Five of the six males classified as recent smokers also fell in this group. Family history of high blood pressure was also a key predictors of a low HDL-cholesterol in multiple regression analysis. These findings are consistent with other reports. For example, in the Bogalusa heart study, 25% of white males had evidence of coronary heart disease by age 30 and this was predicted by factors including genetics, LDL-cholesterol, insulin levels, and smoking habits (23).

Relatively few cadets reported having one or more alcoholic drinks per week and 37% of men and 55% of women stated that they did not drink alcohol. The low prevalence of alcohol consumption was not found to be a predictor of serum lipids in this study.

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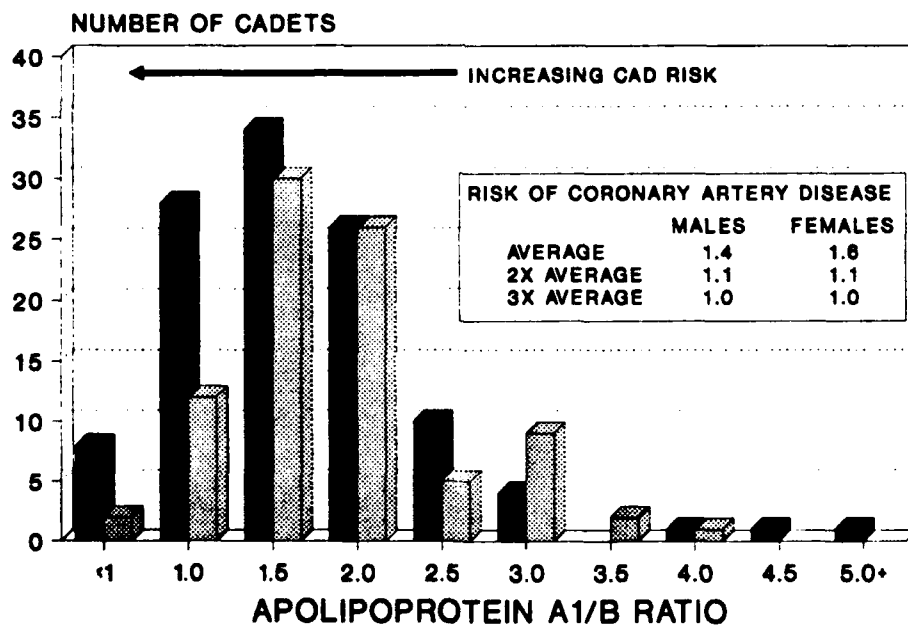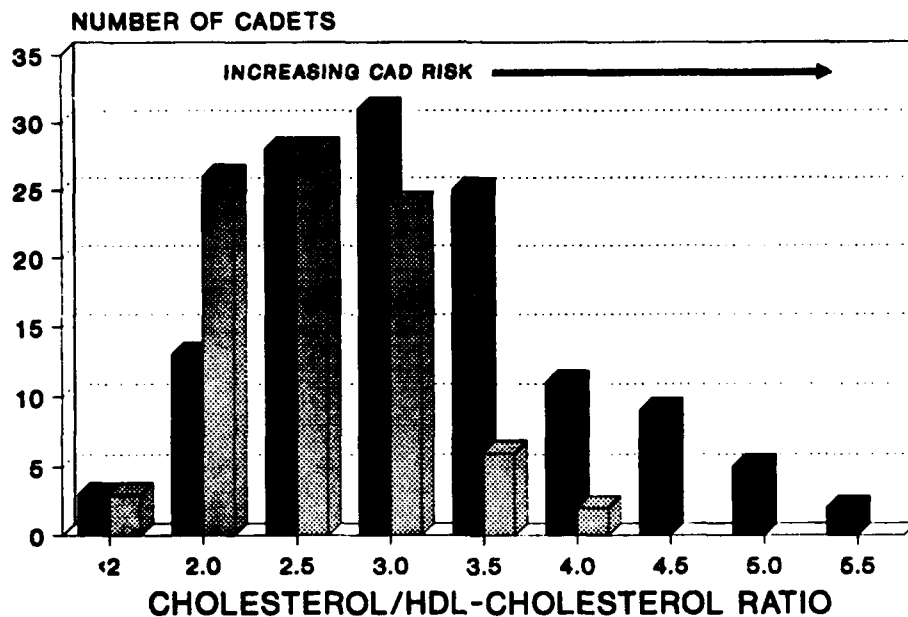
Figure 7. Distributions of male (solid bars) and female (shaded) cadets by two different cardiovascular risk indices. Cadets with a high cholesterol/HDL-cholesterol ratio were similarly predicted with a low apolipoprotein-A1/B ratio.

Table 6. Distribution of health risk factors surveyed by questionnaire (frequencies given by percent and number of cadets).			
Parameter		Men	Women
Cigarette smoking	within 6 months	5% (6)	4% (4)
	former smoker	7% (8)	8% (7)
	never smoked	88% (107)	88% (77)
Fam hist: heart attack	yes	24% (28)	18% (16)
	no	62% (74)	70% (61)
	don't know	14% (17)	11% (10)
Fam hist: high BP	yes	43% (51)	55% (48)
	no	26% (31)	20% (18)
	don't know	32% (38)	25% (22)
Fam hist: diabetes	yes	24% (29)	23% (20)
	no	66% (80)	65% (57)
	don't know	10% (12)	12% (11)
Fam hist: stroke	yes	7% (8)	6% (5)
	no	76% (92)	80% (70)
	don't know	17% (21)	15% (13)
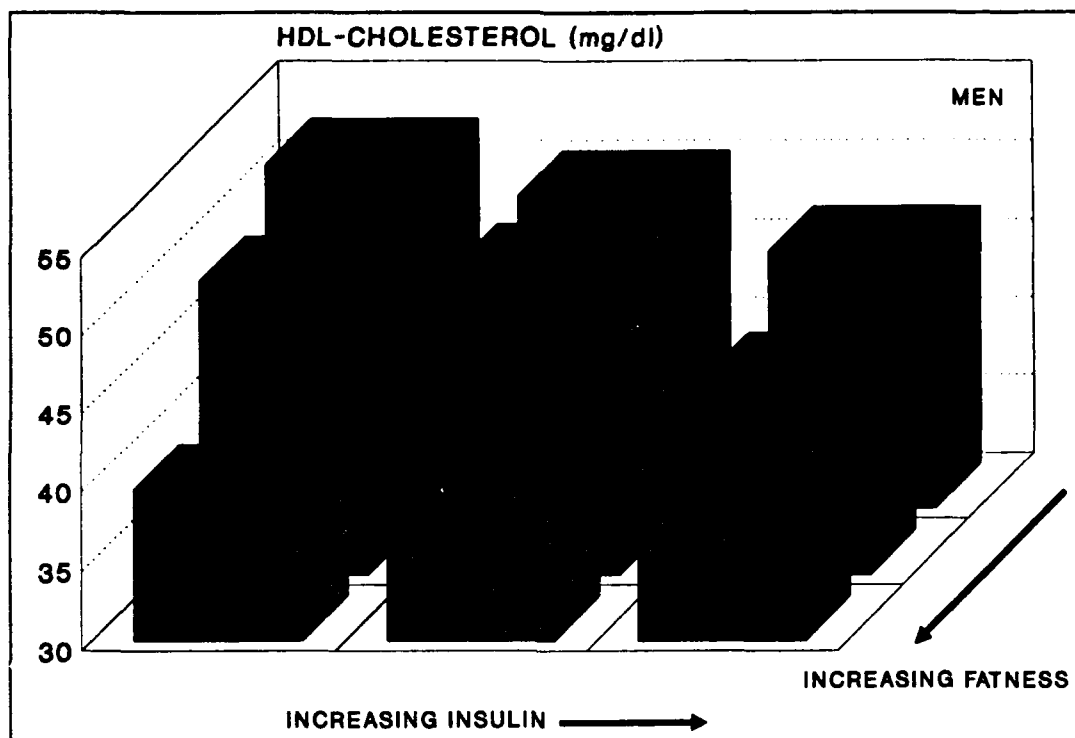
Figure 8. The effect of fasting insulin levels and skinfold-determined fatness on HDL-cholesterol levels in male cadets. Although divided into tertiles, subjects tend toward a diagonal because insulin and fatness are also related.

The relationship between other factors measured in this study and serum lipid profiles is somewhat different from that observed in other studies which include a more diverse age range and greater variety in health and fitness habits. In multiple regression models the significance of a fasting insulin level to HDL-cholesterol levels was clear ($r = -0.31$, $p < 0.01$, for men; $r = -0.21$, $p < 0.05$, for women), and for males, body fat assessed by skinfolds was also important to explaining HDL-cholesterol levels (simple $r = -0.29$, $p < 0.01$) (Figure 8); however, none of the endocrine factors (testosterone, estradiol, DHEAS, and SHBG) were important predictors in this statistical approach. Thus, only increasing insulin level was associated with decreasing mean HDL-cholesterol levels and increasing fatness was independently associated with declining HDL-cholesterol. Other studies have also found fasting serum insulin concentration to be a sensitive predictor of coronary artery disease (24). Both waist-to-hip ratio and body fat demonstrated positive correlations with cholesterol, triglycerides, and apolipoprotein-B in men while only the waist-to-hip ratio and triglycerides demonstrated a significant correlation in women.

IRON STATUS

Comparison of 1990 measurements to measurements in 1979

The comparisons of hematological and iron balance measures between 1979 and 1990 are shown in Table 7. Nearly every measured parameter is different between the 1979 and 1990 studies as a consequence of the blood drive in the preceding week in the 1990 study. The effect of oral contraceptive pill (OCP) use by a portion of female cadets produced a statistically significant elevation in TIBC values only (382 $\pm$71 with OCP versus 335 $\pm$45 for nonusers). In the 1990 study, hemoglobin, hematocrit, ferritin were significantly higher and TIBC levels were significantly lower for males compared to female cadets.

The effects of blood donation and use of iron supplements

Roughly half of the cadets had donated blood in a blood drive in the week prior to our study.[5] This allowed us to make some interesting observations on the effects of phlebotomy on iron status. The most obvious consequence was that many cadets demonstrated values which were below the normal range, for example, serum iron and iron saturation values (Figure 9). Blood donation significantly shifted the range of ferritin (Figure 10) and hemoglobin (Figure 11) levels for both men and women. For the men, hemoglobin, hematocrit, serum iron, iron saturation, and ferritin were significantly lower, while TIBC and erythrocyte folate increased (Table 8). The changes for the women were more complicated because many of them were also using iron supplements. The largest differences were for those women who had given blood and used no iron supplements, compared to those who had not given blood and who used iron supplements of some kind (Table 9). Many of those using iron supplements also were taking vitamins and this explains differences such as observed for vitamin B-12 levels.

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[5]Several blood drives involve the Corps of Cadets every year. The Greater New York-Hudson Valley blood drives occur semiannually and were this year conducted 26-29 March and in late August 1989. The participation status of our cadet subjects in the August blood drive was unknown but because of its timing it would have involved primarily plebes. A third blood drive is conducted annually by the military. This year it was conducted by a blood team from Fort Knox, two months before our study (22-25 January 1990).

Table 7. Comparison of hematological values observed in male and female cadets in 1979 (shaded columns) and in 1990 at the U.S. Military Academy.				
	Male cadets		Female cadets	
Parameter	1979	1990	1979	1990
	Mean±SD (n)	Mean ±SD (n)	Mean ±SD (n)	Mean ±SD (n)
Hemoglobin (g/dl)	15.6 ±1.0 (161)	14.6 ±1.8 (125)	13.3 ±1.2 (72)	12.2 ±0.9 (90)
Hematocrit (%)	44.8 ±2.7 (161)	43.4 ±3.2 (126)	39.1 ±2.3 (72)	36.4 ±2.6 (90)
Serum iron (ug/dl)	95 ±31 (156)	68 ±32 (127)	80 ±38 (69)	62 ±43 (90)
TIBC (ug/dl)	333 ±35 (128)	327 ±44 (127)	344 ±44 (56)	347 ±57 (90)
Iron saturation (%)	28.6 ±10.2 (127)	21.3 ±10.9 (127)	23.0 ±11.2 (66)	18.9 ±13.8 (90)
Ferritin (ng/ml)	48 ±23 (63)	33 ±29 (127)	25 ±11 (30)	14 ±11 (90)
RBC folacin (ng/ml)	363 ±105 (158)	285 ±74 (56)	431 ±138 (70)	318 ±96 (36)
Serum folacin (ng/ml)	9.2 ±3.9 (158)	8.8 ±3.7 (127)	11.7 ±6.2 (70)	11.0 ±5.6 (90)
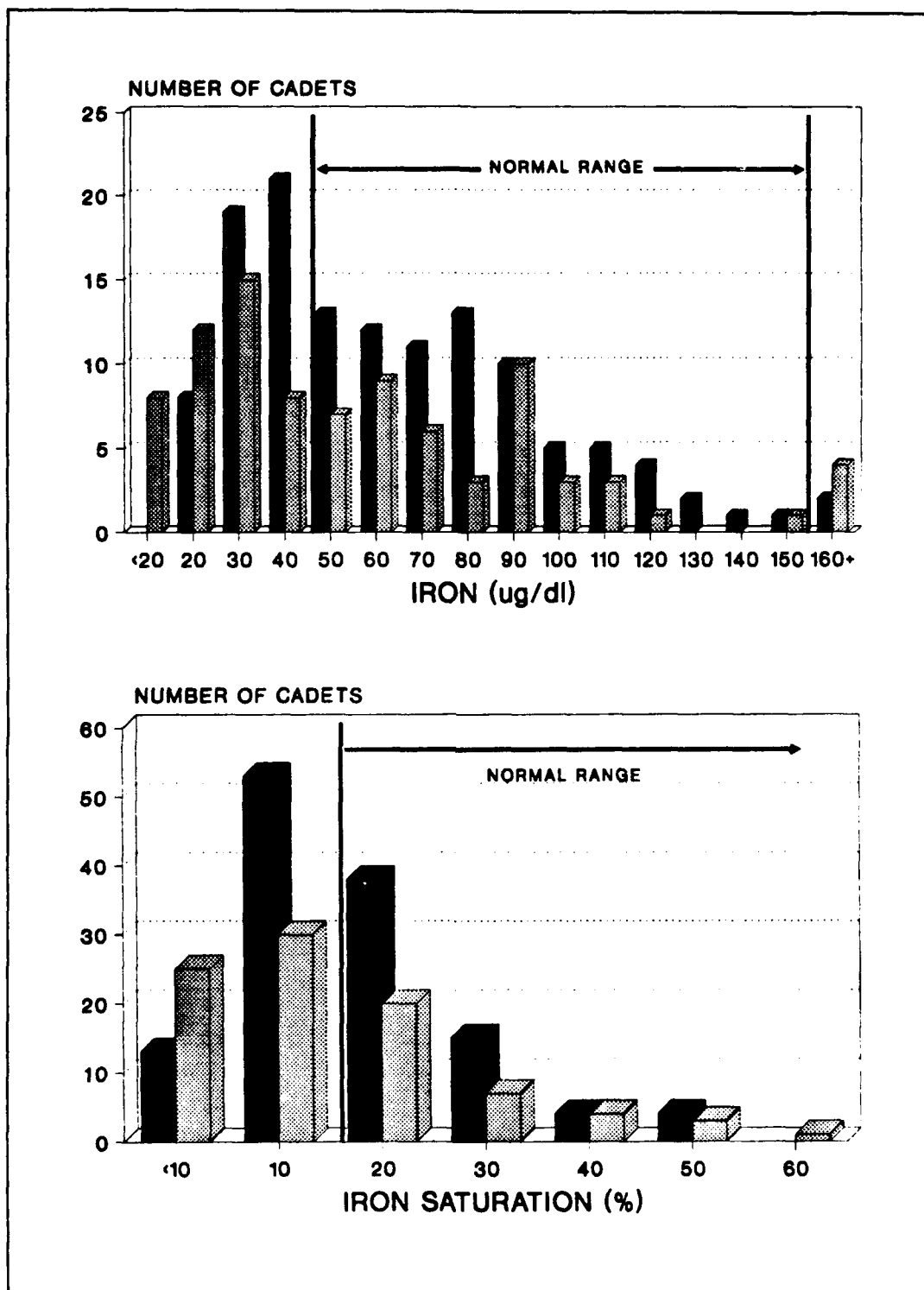
Figure 9. Distribution of male (solid) and female (shaded) cadets by serum iron and percent iron saturation. Many cadets, especially the women, had values below the normal ranges as a consequence of the blood drive.

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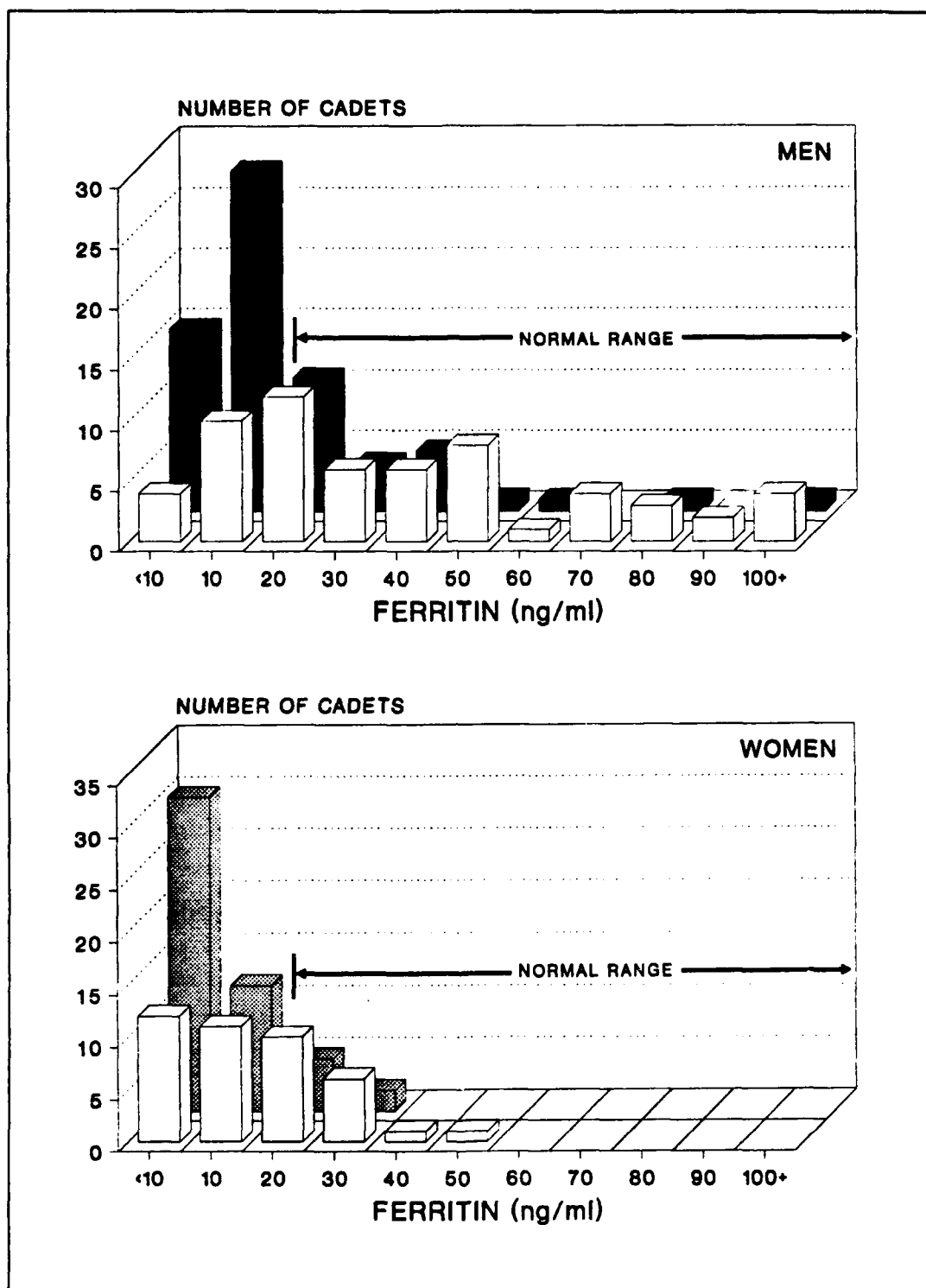
Figure 10. Distribution of male (top) and female (bottom) cadets by ferritin concentrations, divided into those who participated in the blood drive (filled bars, back) and those who did not (open bars, front).
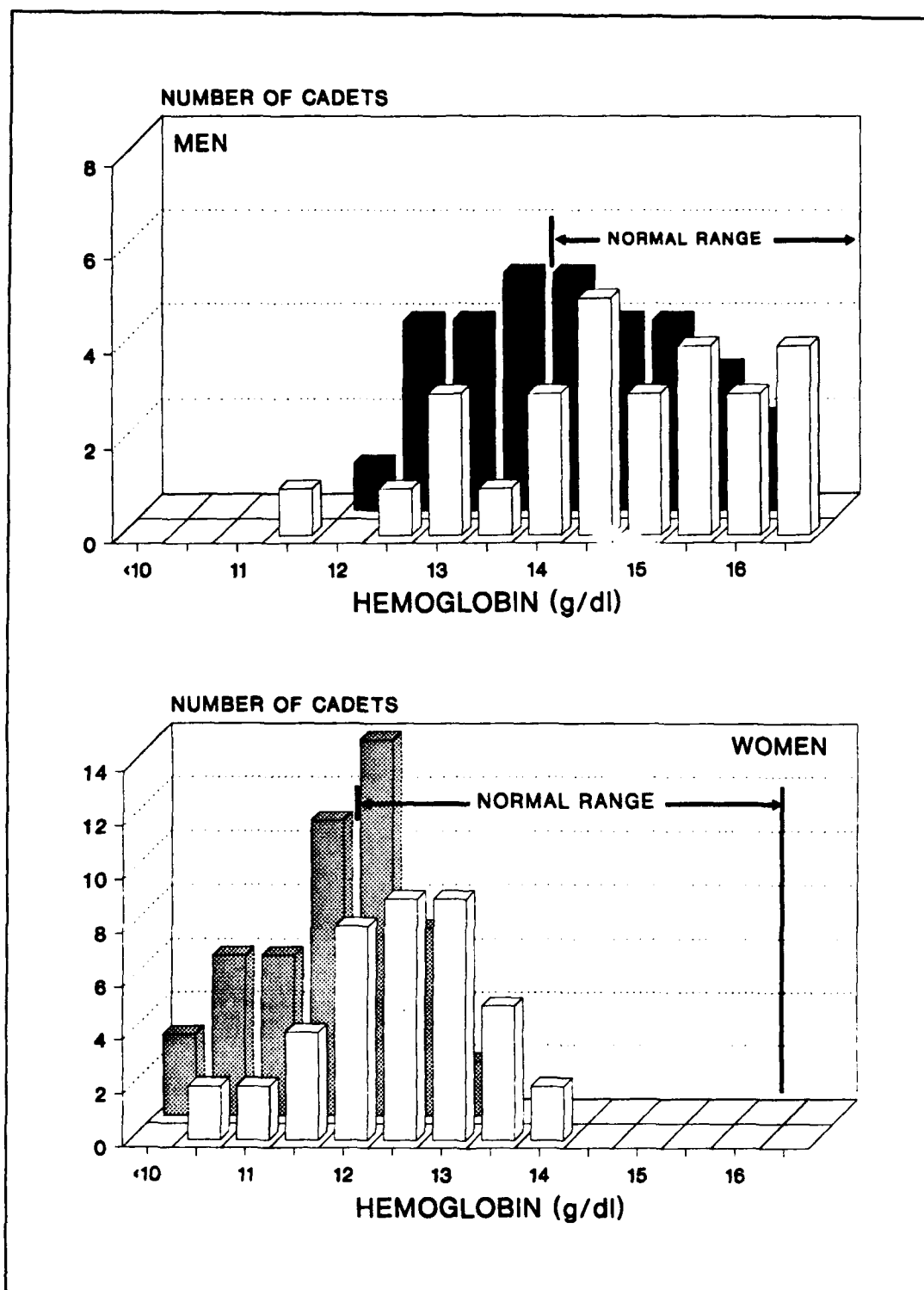
Figure 11. Distribution of male (top) and female (bottom) cadets by hemoglobin concentrations, divided into those who participated in the blood drive (filled bars, back) and those who did not (open bars, front).

Table 8. Comparison of male hematological values between recent blood donors and non-donors.			
Parameter	Did not give blood	Gave blood in the previous week	Significance (t test)
Hemoglobin (g/dl)	15.0 ±1.3 (59)	14.2 ±0.9 (66)	$p < 0.001$
Hematocrit (%)	44.7 ±3.0 (59)	42.1 ±2.8 (67)	$p < 0.001$
Serum iron (ug/dl)	79 ±33 (60)	58 ±29 (67)	$p < 0.001$
TIBC (ug/dl)	313 ±34 (59)	337 ±43 (67)	$p < 0.001$
Iron saturation (%)	25.4 ±11.1 (60)	17.6 ±9.4 (67)	$p < 0.001$
Ferritin (ng/ml)	45 ±33 (60)	22 ±20 (67)	$p < 0.001$
RBC folacin (ng/ml)	268 ±72 (32)	307 ±72 (24)	$p < 0.05$
Serum folacin (ng/ml)	8.1 ±2.7 (60)	9.3 ±4.3 (67)	not significant
Vitamin B-12 (pg/ml)	440 ±126 (60)	450 ±142 (67)	not significant

Iron status for the sample population was assessed following the algorithm of Cook & Finch (25) (Table 10). The least severe form of iron deficiency, a reduction in stored iron, is accurately marked by low ferritin levels (<12 ng/ml). By this criterion, 25 men (20%) and 49 women (54%) had some level of iron deficiency. This would be expected in blood donors (26) and, indeed the majority of these individuals (80% of the men and 70% of the women) in this category had given blood. At the next level, the iron deficit begins to encroach on essential iron. This is reflected by a decreased level in the proportion of iron bound by transferrin (<16%) and many subjects with low ferritins also had these

Table 9. Comparison of hematological values between recent female cadet blood donors and non-donors, with and without iron supplementation. (Shaded blocks indicate values which are significantly different from the means of women who took iron supplements and had not given blood.)

Parameter	Did not give blood		Gave blood (prior week)	
	Used iron supplement	No iron supplement	Used iron supplement	No iron supplement
Hemoglobin (g/dl)	12.7 ±0.8[a] (14)	12.5 ±1.0[a] (22)	11.7 ±0.6[b] (15)	11.8 ±0.8[b] (29)
Hematocrit (%)	38.0 ±1.7[a] (14)	37.8 ±2.4[a] (22)	34.9 ±2.1[b] (15)	34.9 ±2.1[b] (29)
Serum iron (ug/dl)	79 ±24[a] (14)	72 ±41[a] (22)	77 ±67[a] (14)	42 ±28[b] (30)
TIBC (ug/dl)	332 ±42 (14)	326 ±46 (21)	332 ±41 (14)	354 ±52 (30)
Iron saturation (%)	24.2 ±8.7[a] (14)	22.1 ±13.3[a] (22)	23.4 ±19.3[a] (14)	12.9 ±10.4[b] (30)
Ferritin (ng/ml)	20 ±10[a] (14)	18 ±13[a] (22)	14 ±9[a,b] (14)	10 ±8[b] (30)
RBC folacin (ng/ml)	327 ±65[a] (4)	309 ±65[a] (9)	396 ±63[a] (6)	244 ±65[b] (12)
Serum folacin (ng/ml)	13.9 ±7.4[a] (14)	9.3 ±3.7[b] (22)	14.4 ±5.7[a] (14)	8.7 ±3.1[b] (30)
Vitamin B-12 (pg/ml)	527 ±166[a] (14)	392 ±131[b,c] (22)	459 ±149[a,c] (14)	356 ±124[b] (30)

n=81 female cadets with known iron supplementation/nonsupplementation status. Same letters denote groups which are not significantly different from each other by Duncan's multiple range test. TIBC demonstrated no differences between groups by an initial one way analysis of variance.

Table 10. Proportion of cadets with increasing levels of iron deficiency.				
	Males		Females	
	Did not give blood	Gave blood	Did not give blood	Gave blood
Total sample	59	66	41	49
Ferritin < 12 ng/ml	5 (8.4%)	20 (30.3%)	15 (36.6%)	34(69.4%)
+ Iron sat'n < 16%	3 (5.1%)	17 (25.8%)	9 (22.0%)	28(57.1%)
+ Hemoglobin < 12 g/dl	1 (1.7%)	0	2 (4.9%)	18(36.7%)

low iron saturation levels. The most severe level of iron deficiency results in anemia, with hemoglobin levels of less than 12 g/dl. Only one male subject fell into this category and he had not given blood (as an obvious outlier, this subject was referred to the Cadet Health Clinic for further examination, along with two women who also had not given blood). Twenty women (22%) fell into this category of iron deficiency anemia and this was clearly related to the recent blood drive since 18 out of the 20 had given blood.

There was no effect on the values with respect to the day of study which might be construed as recovery from the phlebotomy. This is consistent with other reports which suggest that the average time to complete blood replacement following a 500 ml phlebotomy is about 40 days (27). This time to recovery can be significantly reduced if iron supplementation is used. Very few males used iron supplements, nor is there any apparent need for such supplementation. However, the benefits of iron supplementation for the female cadets are clear from the results in Table 9, where both ferritin and iron saturation levels were significantly lower for women who gave blood but did not use iron supplements, compared to those who also gave blood but did use supplements. Women using iron were also slightly less likely to fall in the category of iron deficiency anemia: only four of these women (20%) used supplements, compared to one third of all women who gave blood.

The recommendation of the Surgeon General of the Public Health Service (18) is that young women in their childbearing years (and frequent blood donors) are at increased risk for iron deficiency anemia and "these individuals

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should be monitored and should receive special counsel on preventing iron deficiency." For patients with anemia, it is recommended that they "receive counseling and assistance to develop diets that have adequate amounts of bioavailable iron, folate, or vitamin B12 from dietary or supplemental sources."

Although some parameters ranged above their statistical upper limits of the normal range, there was no reason to suspect serious iron overload in any of these subjects as a result of their use of iron supplements. The five highest ferritin levels ranged from 100 to 176 ng/ml; all were males who had not given blood in the blood drive and none were known to be using iron supplements.

CONCLUSIONS

1. The body composition of U.S. Military Academy cadets participating in this study is no different than that of cadets studied a decade ago. This includes comparisons of female cadets to the first group of female cadets to attend the Academy (studied in their junior year). Mean weights, circumferences, and skinfold thicknesses were nearly identical.

2. No men, but 14% of the women, exceeded the body fat limits of 22% (male) and 30% (female) as determined by the Army circumference equations, the Army standard which will be applied to these cadets when they graduate. Subjective observations by the study team were that few, if any, female cadets were carrying excess fat, attesting to the stringency of current Army female body fat standards. Nevertheless, the Cadet Weight Management Program encourages cadets to meet even more stringent standards.

3. A majority of female cadets indicated they were trying to lose weight. The distribution of this group was across all levels of body fat. The second report from this study will include information on which of these cadets were actually restricting their caloric intake, the appropriateness of their weight loss efforts, and how this relates to fatness and to iron balance.

4. Serum lipid profiles suggested low cardiovascular disease risk status of most cadets. However, this is appropriate for this young group of highly fit individuals, where serum lipid profiles do not reflect a longer duration of poor lifestyle habits. Cadets with borderline-high LDL-cholesterol levels who are at increased risk for cardiovascular disease would be advised to decrease their intake of fats to less than 30% of total calories and of saturated fat to less than 10%, but this is also recommended as a healthful lifestyle change which will have long-range benefit to young men and women even if they currently do not have elevated LDL-cholesterol.

5. The most significant determinants of elevated cholesterol and reduced HDL-cholesterol in males were skinfold-determined fatness and fasting serum insulin levels while family history of high blood pressure was also significantly associated. In women, the waist-to-hips ratio was significantly related to triglycerides and insulin was also associated with reduced HDL-cholesterol; however, estimates of total fatness had no demonstrable relationship with

increased health risk in these women.

6. Iron supplementation seems to be appropriate, especially for many of the female cadets. Nearly half of the female cadets used some kind of iron supplement as recommended in the 1979 hematologic study report. Iron supplementation produced an especially marked effect in the cadets who gave blood in a blood drive just prior to the study. The data also suggest that some iron compromised cadets should not have donated blood. The second report from this study will be able to detail the adequacy of dietary iron for these cadets.

7. Body fat is associated with a more atherogenic profile even in this group of within-Army standards males, while there was no association between fatness measures and any lipid parameters for the women (in the range of fatness observed). This suggests marked differences in the relationship between fatness and cardiovascular health consequences between sexes, with greater importance of fatness to male disease risk. The health risk to the women appears to come from the opposite direction, with their poor hematological status (compared to the males) possibly related to the large proportion of women who are restricting caloric intake to ensure that they meet stringent body composition standards. Iron status was more likely to be compromised in women than in the men, whether or not they had given blood or were taking iron supplements. From the standpoint of health, these observations provide reasons to liberalize the female Army body fat standards.

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