AD-A190 233 PREDICTION OF PHYSICAL FITNESS: ESTIMATED PERCENT BODY FAT USING BODY CIR.. (U) NAVAL HEALTH RESEARCH CENTER SAN DIEGO CA K A PETERSON ET AL. 30 JUN 87 NHRC-87-25 1/1

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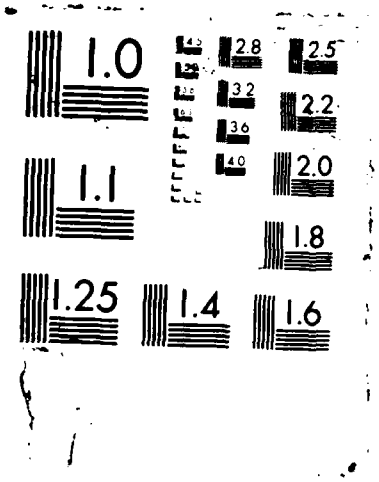
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Prediction of Physical Fitness: Estimated Percent Body Fat Using Body Circumferences Versus Weight-Height Measures

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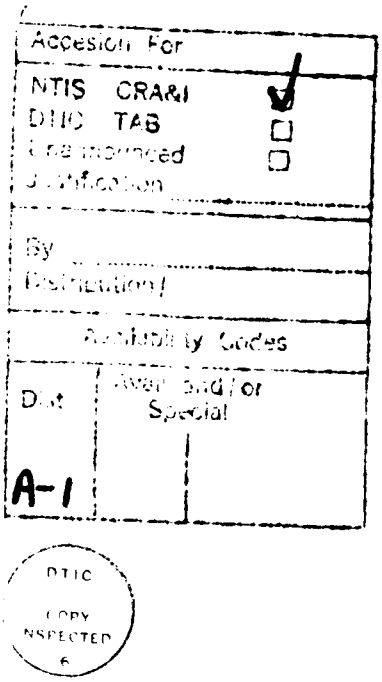

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SUMMARY

Problem

The Navy is concerned about obesity and overfatness because it is associated with a variety of health problems and may be a limiting factor in physical work capacity. All Navy personnel are currently required to undergo screening for obesity prior to participating in required physical fitness tests. While the simplest methods of estimating overfatness involve weight-height measures, the Navy has implemented an alternative method using estimates of percent body fat derived from circumference measurements. This technique is slightly more complicated than weight-height indices; however, previous research suggests it provides a more accurate reflection of body fat. A practical question is whether the amount of improvement justifies the use of this slightly more complex method.

Objective

The purpose of this study was to determine whether percent body fat estimated from circumference measures predicted physical fitness more accurately than weight-height indices.

Approach

Demographic and physical fitness data were collected for 5710 men and 477 women stationed primarily in the San Diego area. Measures included a 1.5-mile run/walk, number of sit-ups completed in two minutes, a sit-reach flexibility test, an average fitness score, and estimated percent body fat using body circumference measures. Various weight-height indices were also calculated.

Results

For men, percent body fat estimated from circumference measures predicted all four of the physical fitness measures significantly better than did any of the weight-height indices. For women, the percent body fat estimate predicted two of the four physical fitness measures significantly better than any of the weight-height measures. Overall, the pattern of associations between physical fitness and both the percent fat estimates and the weight-height measures were similar for men and women; however, the correlations between the fitness measures and the percent fat estimates were stronger for men than women.

Conclusions

Percent body fat estimated from circumference measures may be a better predictor of physical fitness because it assesses body fat more reliably than weight-height indices. While circumference measurements require slightly more time and training to administer, the "cost" appears worthwhile as a screen for physical fitness testing. Future research might assess the usefulness of the circumference technique in predicting health outcomes.

Prediction of Physical Fitness: Estimated Percent Body Fat Using Body Circumferences Versus Weight-height Measures

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The Department of Defense has instituted standards to curtail excess fatness among military personnel because obesity is associated with a variety of health problems (National Institute of Health, 1985) and overfatness may be a limiting factor in physical work capacity (Buskirk & Taylor, 1959; Cureton & Sparling, 1980; Cureton, Sparling, Evans, Johnson, Kong, & Purvis, 1978; Leon, Jacobs, DeBacker, & Taylor, 1981; and Montgomery, 1982). The Navy currently requires personnel to undergo screening for obesity prior to taking required physical fitness tests. Obesity assessment is based on a method for estimating percentage of body weight attributable to fat from several body circumferences. This method of identifying obese individuals is slightly more complicated than the use of common weight-height tables or indices. Thus, a question of practical interest to the Navy is whether there is justification for using the slightly more difficult circumference methods over simpler weight-height methods.

It is relatively easy to use various tables or indices of weight and height to identify obese people. The Metropolitan Life Insurance tables of "ideal" weights are often used (Metropolitan Life Foundation, 1983). Commonly used ratios of weight (W) to height (H) include: W/H, W/H^2 (body mass index or Quetelet's index), $W/H^{1.5}$, W/H^3 (the Rohrer index), $W^{0.33}/H$ (the Ponderal index), and $H/W^{0.33}$ (an inversion of the Ponderal index). Several studies have found that Quetelet's index is the best weight-height predictor of body fat in men (Goldbourt & Medalie, 1974; Keys, Fidanza, Karvonen, Kimura, & Taylor, 1972; Knapik, Burse, & Vogel 1983); whereas, $W/H^{1.5}$ has been suggested as the best index for women (Knapik et al. 1983).

One of the problems with common weight-height tables and indices is that they do not discriminate between muscle and fat weight in individuals. They are based on an "ideal" proportion of weight to height. When people exceed certain cut-off points, it is assumed that they are overly fat. However, this assumption can be inaccurate for relatively lean individuals who are especially muscular and, therefore, weigh more than average people of

equivalent height (e.g., football players or body builders). Conversely, weight-height indices may not identify some individuals who fall within acceptable weight ranges but truly have excess body fat relative to their lean mass.

Circumference methods such as those used by the Navy probably better estimate the percentage of body weight attributable to fat than do weight-height measures (Hodgdon, 1987; Pollock & Jackson, 1984). Estimates of percent body fat are made with equations based on circumference measures typically involving areas prone to excess fat accumulation, such as the upper and lower arm, waist, hip, and thigh (Hodgdon & Beckett, 1984a, 1984b; Wright, Dotson, & Davis, 1980, 1981). If excessive fatness rather than greater weight per se is the critical factor limiting physical work capacity, the accuracy of the technique used (i.e., circumference versus weight-height method) to measure overfatness could make an important difference for predicting physical work capacity. Such a difference might be especially important to the Navy, as physical fitness is a critical component of overall military readiness.

The Navy is concerned about obesity among its personnel because of the impact of excess fat on work capacity and because of the health implications of overfatness. For medical safety, individuals identified as obese during pre-test screening are not allowed to take the Navy's required physical fitness test. Furthermore, individuals judged obese over three test cycles (1.5 years) are subject to administrative discharge from the service. Thus, it should be of particular interest to the Navy to identify the most accurate yet efficient method for measuring obesity. The present study compared the associations between physical fitness and several indicators of overfatness to provide information about which technique might better serve the needs of the Navy.

METHOD

Participants

Participants included 5710 men and 477 women stationed at ship and shore commands located primarily in the San Diego area. All were active duty Navy personnel participating in an ongoing evaluation of the Navy's Health and Physical Readiness Program (Conway & Dutton, 1985; Nice, Dutton, & Seymour, 1984). Participants for the current study were selected if they had height,

weight, and body circumference data. The subjects ranged in age from 17 to 57 years (Mean = 27.35, SD = 6.74).

Measures

Height-Weight Indices. The various weight-height indices were calculated after converting the weight and height data to metric units (kilograms and meters). The following equations were used: W/H, $W/H^{1.5}$, W/H^{2} (Body mass index or Quetelet's index), W/H^{3} (Rohrer index), $W^{0.33}/H$ (Ponderal index), $H/W^{0.33}$ (Sheldon's inversion of the Ponderal index).

Percent Deviation from Ideal Weight. The difference between the subject's weight and ideal weight (Metropolitan Life Foundation, 1983) was calculated for a person of medium frame and a given height. The Metropolitan Life Height and Weight Tables range from 158 cm to 193 cm for men, and from 148 cm to 183 cm for women. Therefore, this measure was calculated only for participants within these height ranges. Percent deviation from ideal weight was then defined as: IdealW = [(Weight - Ideal Weight) / Ideal Weight] x 100.

Percent Body Fat Measures. Percent body fat (%BF1) for males and females was estimated from a set of body circumference measurements using the equations of Wright, Dotson, & Davis (1980, 1981). These equations were used in the Navy's first implementation of the "Health and Physical Readiness Program" established by OPNAVINST 6110.1B in October, 1982. Two body circumferences were obtained for males: 1) neck circumference, measured around the neck with the tape passing just below the larynx, and 2) abdominal circumference, measured around the abdomen at the level of the umbilicus. In women, neck and abdomen measures were taken, plus three additional measures: 1) bicep circumference, measured at the largest circumference of the arm with the arm extended and palm facing up, 2) forearm circumference, measured at the largest circumference of the forearm, and 3) thigh circumference, measured on the left thigh just below the buttock. All circumferences were measured in centimeters. The equations are as follows:

$$\%\text{ Body Fat (men)} = (0.740 \times \text{Abdomen}) - (1.249 \times \text{Neck}) + 0.528$$

$$\%\text{ Body Fat (women)} = (1.051 \times \text{Biceps}) - (1.522 \times \text{Forearm}) - (0.879 \times \text{Neck}) + (0.326 \times \text{Abdomen}) + (0.597 \times \text{Thigh}) + 0.707$$

For males, a second estimate of percent body fat (%BF2) was derived from the same circumference measures plus height using the procedures developed by

Hodgdon & Beckett (1984a). This estimate is currently used by the Navy, as directed by OPNAVINST 6110.1C which became effective October, 1986. The circumference measures and height are used to estimate body density which in turn is used to estimate percent body fat:

a) Body Density (men) = -[.19077 × Log10(Abdomen − Neck)] + [.15456 × Log10(Height)] + 1.0324

b) % Body Fat = [(4.95/Body Density) − 4.5] × 100

Physical Fitness Tests. The required physical fitness test had three components: a 1.5-mile run, a sit-ups test, and a flexibility test. The 1.5-mile run was included to test cardiorespiratory endurance and physical stamina; performance was measured as the time to run/walk a 1.5-mile course. The sit-ups test was included as a test of muscle endurance; the measure was the number of flexed-knee sit-ups completed within a two-minute time period. In the sit-reach flexibility test, the participant sat on the ground with legs outstretched in front, then touched the ground as far forward as possible for three seconds; the distance from the heel to the fingertips was then measured. An average physical fitness score was computed for each participant by taking the mean of the standardized scores on the run, sit-up, and sit-reach data. Run time was reverse scored in this procedure so that positive Z-scores indicated better performance.

Procedures

Weight, height, body circumference measures, and scores on the three physical fitness tests for each participant were recorded as part of physical readiness testing required by the Navy. This testing was conducted by command fitness coordinators, who forwarded the data to the Naval Health Research Center.

Analysis Procedures. Two types of analyses were conducted for men and women separately. First, descriptive statistics were computed on all weight-height measures, percent body fat estimates, and physical fitness scores. Second, Pearson product-moment correlations were calculated among the various weight-height indices, body fat measures, and physical fitness scores. The significance of the differences between pairs of correlations was tested using procedures described by McNemar (1969, p. 158).

RESULTS

Descriptive statistics for men and women are presented in Tables 1 and 2, respectively. The Navy males in this study were of approximately the same height but weighed an average of 1 kilogram (kg) less than the national average for civilian males 25-34 years old (mean height = 1.76 meters; mean weight = 78.5 kg) (U.S. Bureau of the Census, 1985). Navy women were approximately the same height but weighed about 3 kilograms less than the national average for women of the same age group (mean height = 1.63 meters; mean weight = 64.4 kg).

Table 1

Descriptive Statistics for the Men

	Mean	Standard Deviation
Age	27.56	6.83
H (Meters)	1.77	.08
W (Kilograms)	77.59	12.00
%BF1	15.85	5.34
%BF2	16.48	5.81
IdealW	9.04	14.41
W/H	43.72	5.95
$W/H^{1.5}$	32.85	4.32
W/H^{2}	24.69	3.22
W/H^{3}	13.97	1.96
$W/H^{0.33}$	2.37	.11
$H^{0.33}/W$	.43	.02
1.5 mile Run (minutes)	12.60	2.21
Sit-ups (number in 2 min.)	52.21	16.89
Sit-reach (inches)	2.44	3.02
Average Score (Z-score)	.00	.76

NOTE: group size ranged from n = 5451 to 5710 because of missing data.

Table 2

Descriptive Statistics for the Women

	Mean	Standard Deviation
Age	24.45	4.40
H (Meters)	1.66	.07
W (Kilograms)	61.36	9.01
%BF1	21.74	5.42
IDLWT	.36	12.98
W/H	37.02	4.91
$W/H^{1.5}$	28.77	3.73
W/H^{2}	22.37	2.92
W/H^{3}	13.54	1.92
$W^{0.33}/H$	2.35	.10
$H/W^{0.33}$	.43	.02
1.5 Mile Run (minutes)	14.88	2.14
Sit-ups (number in 2 minutes)	49.75	18.02
Sit-reach (inches)	3.56	3.02
Average Score (Z-score)	.00	.76

NOTE: group size ranged from n = 419 to 477 because of missing data.

For men, the correlations among the various weight-height indices ranged from /r/ = .78 to .99. The correlations between the percent body fat estimates and the weight-height measures ranged from /r/ = .58 to .79. The correlation between the two percent body fat estimates was .96. For women, the correlations among the various weight-height indices ranged from /r/ = .80 to .99 The correlations between the percent body fat estimates and the weight-height measures ranged from /r/ = .60 to .71.

Tables 3 and 4 present for men and women, respectively, the correlations between the physical fitness measures and the weight-height and body fat estimates. Also shown is the percent of variance accounted for in the relationships. Scores on the sit-ups, sit-reach, and average fitness measure were negatively correlated with the body fat and the weight-height measures, indicating that higher percent body fat and being "overweight" was associated

with poorer performance. Actual run time was positively correlated with the body fat and weight-height measures, indicating that higher percent body fat and being overweight were associated with taking longer to run the 1.5-mile course.

Table 3

Correlations of the Weight-Height and Body Fat Measures with the Physical Fitness Scores for Men

	Run(*)		Sit-ups(*)		Sit-reach(*)		Average Score(*)	
W/H	.28	(8%)	-.13	(2%)	.07	(.6%)	-.21	(4%)
$W/H^{1.5}$	.29	(8%)	-.14	(2%)	.07	(.6%)	-.22	(5%)
W/H^{2}	.29	(8%)	-.14	(2%)	.07	(.6%)	.22	(5%)
W/H^{3}	.28	(8%)	-.14	(2%)	-.07	(.6%)	-.22	(4%)
$W^{0.33}/H$	.27	(7%)	-.14	(2%)	-.07	(.6%)	-.21	(4%)
$H/W^{0.33}$	-.27	(7%)	.13	(2%)	.07	(.6%)	.21	(4%)
IdealW	.29	(8%)	-.14	(2%)	-.07	(.6%)	-.22	(5%)
%BF1	.42	(18%)	-.29	(8%)	-.16	(3%)	.39	(15%)
%BF2	.43	(18%)	-.29	(8%)	-.18	(3%)	-.40	(16%)

NOTE: Group size ranged from n = 5331 to 5604 because of missing data.

(*) Percent of variance accounted for in the relationship

For men, percent body fat estimated from body circumference measures was a significantly better predictor of physical fitness than were any of the weight-height indices ($p < .05$). Relative to the best weight-height measure, estimated percent body fat accounted for an additional 10% of the variance in run time and average fitness scores, an additional 6% of the variance in sit-up performance, and an additional 3% of the variance in sit-reach flexibility (see Table 3).

Table 4

Correlations of the Weight-Height and Body Fat Measures with the Physical Fitness Scores for Women

	Run(*)		Sit-ups(*)		Sit-reach(*)		Average Score(*)	
W/H	.29	(8%)	-.14	(2%)	-.08	(.6%)	-.22	(5%)
$W/H^{1.5}$	.32	(10%)	-.14	(2%)	-.07	(.5%)	-.23	(5%)
W/H^{2}	.33	(11%)	-.15	(2%)	-.07	(.5%)	-.24	(6%)
W/H^{3}	.33	(11%)	-.15	(2%)	-.06	(.4%)	-.23	(5%)
$W^{0.33}/H$	.33	(11%)	.14	(2%)	-.04	(.1%)	-.22	(5%)
$H/W^{0.33}$	-.32	(10%)	.13	(2%)	.03	(.09%)	.21	(4%)
IdealW	.33	(11%)	-.15	(2%)	-.07	(.5%)	-.24	(6%)
%BF1	.34	(12%)	-.21	(4%)	-.19	(4%)	-.32	(10%)

Note: Group size ranged from n = 439 to 465 because of missing data.

(*) Percent of variance accounted for in the relationship

For women, percent body fat estimated from body circumference measures predicted sit-reach flexibility and average physical fitness scores significantly better than did any of the weight-height indices ($p < .05$). Relative to the best weight-height measure, estimated percent body fat accounted for an additional 4% of the variance in both the sit-reach flexibility and the average fitness scores, and an additional 2% of the variance in sit-up performance. There was essentially no difference between the best weight-height indices and the estimated percent body fat measures in their ability to predict run performance (see Table 4).

DISCUSSION

Although physical fitness is not strongly related either to body fat estimates or weight-height measures, percent body fat estimates predicted performance on the Navy's physical fitness tests better than commonly used weight-height indices. Relative to the best weight-height measure, estimated percent body fat accounted for an additional 3 to 10 percent of the variance in men's physical fitness test scores and 0 to 4 percent of the variance in women's scores. The correlations between the weight-height indices and the

physical fitness scores were very similar across the sexes: however, the correlations between the percent body fat and the fitness scores were generally higher for men than for women. On the whole, percent body fat estimated from circumference measures was a better predictor of performance on the Navy's physical fitness tests than were any of the weight-height indices; however, this finding was stronger for men than for women.

Estimates of percent body fat from circumference measures may be better predictors of physical fitness because they are more reliable estimates of actual body fat than weight-height measures (Hodgdon, 1987; Pollock & Jackson, 1984). While the weight-height indices are relatively simple measures of body proportion, equations which use body circumferences should more accurately predict fat because they include measures of body locations commonly associated with obesity, such as the abdomen and hips (Bjorntorp, 1985). If fat is truly an important underlying factor limiting physical work capacity and general fitness, a more accurate measure of body fat should be more strongly associated with specific tests of physical fitness.

Accuracy of the measurement technique might also explain why the strength of the relationships between percent body fat and physical fitness differed slightly for men and women. Both Wright et al. (1980, 1981) and Hodgdon & Beckett (1984b) reported slightly larger standard errors of measurement (SEM) for women than men. Thus, it is possible that the somewhat lower correlations with physical fitness scores in women may be attributed to slightly higher measurement error associated with the women's equations.

One possible limitation of this study is that the Navy sample may be more physically fit than the general population and, thereby, limit the generalizability of the findings. The Navy men and women were of approximately the same height as an age matched national sample but weighed somewhat less (U.S. Bureau of the Census, 1985). The weight differences may be related to the physical fitness requirements of the Navy. However, it seems unlikely that the relatively minor weight differences or possible differences in average fitness levels would markedly affect the generalizability of this study's findings regarding the association between physical fitness and percent body fat or weight-height measures. If anything, the restriction of range in percent body fat and physical fitness because of Navy regulations may result in an underestimate of the relationship between these variables in the general population.

In summary, the results from this study indicated that circumference estimates of body fat provide a better prediction of physical fitness than do common weight-height indices. Future research might examine the relationship between body circumference measures and various health outcomes. This research may provide information useful for predicting specific types of morbidity and mortality, which would have important implications for diagnosis and treatment in health care settings.

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)
This study compared several weight-height indices with an estimate of percent body fat based on a few circumference measurements. The utility of alternative obesity/overfatness measures was assessed by comparing the strength of their associations with several measures of physical fitness, including a 1.5-mile run/walk, 2-minute sit-ups test, sit-reach flexibility test, and an average fitness score. Study participants included 5710 Navy men and 477 Navy women. For men, percent body fat estimated from circumference measures predicted all the components of physical fitness significantly better than any of the weight-height indices. For women, estimated percent body fat was a significantly better predictor of two of the four fitness measures. Overall, the pattern of associations between physical fitness and both the estimated percent body fat and the weight-height measures was similar for men and women; however, the correlations between the percent fat and the fitness measures were stronger for men than for women. These findings suggest that the Navy's procedure for estimating fatness using circumference measures provides a better screen for physical fitness testing than would any of the commonly used weight-height indices.

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