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Can You Be Large and Not Obese? The Distinction Between Body Weight, Body Fat, and Abdominal Fat in Occupational Standards

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ABSTRACT

Weight control is an important early intervention in diabetes, but the nature of the association between weight and disordered metabolism has been confused because fat mass and its distribution are only partly associated with increasing body size. Weight, fat, and regional fat placement, specifically in the abdominal site, may each have distinctly different associations with diabetes risk. Abdominal circumference may be the common marker of poor fitness habits and of increased risk for metabolic diseases such as diabetes. This is an important question for public health policy as well as for occupational standards such as those of the military, which are intended to promote fitness for military missions and include strength and aerobic capacity, as well as military appearance considerations. U.S. soldiers are heavier than ever before, reflecting both increased muscle and fat components. They also have better health care than ever before and are required to exercise regularly, and even the oldest soldiers are required to remain below body fat limits that are more stringent than the current median values of the U.S. population over age 40. The body fat standards assessed by circumference-based equations are 20–26% and 30–36%, for various age groups of men and women, respectively, and the upper limits align with threshold values of waist circumference recommended in national health goals. The basis and effects of the Army standards are presented in this paper. U.S. Army body fat standards may offer practical and reasonable health guidelines suitable for all active Americans that might help stem the increasing prevalence of obesity that is predicted to increase the prevalence of Type 2 diabetes.

INTRODUCTION

JUST BEFORE the United States invaded Iraq last year, the *Times* observed that more than half of U.S. soldiers were overweight by national health goals, *i.e.*, body mass index (BMI) of >25 kg/m^2, and from this they speculated that the Army was too fat to fight.[1] This writer took advantage of a common mix-up between large and fat to spin a simple statistic into a perhaps predetermined conclusion about combat readiness. They were wrong about performance ca-

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pabilities; today's Army is stronger and fitter than ever before. Even the quality of recruits has not yet been compromised by the growing epidemic of adolescent weight gain and sedentary habits.[2] The truth is that soldiers who are large are ideal performers of many of the Army's common tasks, which depend largely on carrying and lifting strength.[3] They are larger than ever before, a desirable Army trait—"large and in charge"—with appearance of fitness and formidable size serving an important psychological advantage. Improved nutrition and medical care has added an average of 30 pounds of lean mass to the soldier, compared with Civil War soldiers over a century ago (Table 1).[4,5] All of this revives a very interesting question of what it means to health and performance to be large but lean. Body weight surrogates of fatness such as BMI, long used in epidemiology, are inadequate expressions of obesity-related definitions today, but size undoubtedly has significance as well.[5] Even proper assessments of overall fatness or "adiposity" may be far less important to health outcomes than the distribution of the body fat to the abdomen.[6,7] Waist circumference (WC) is clearly emerging as an important marker of chronic fitness and nutrition habits,[8] a predictor of visceral fat,[9] and it may play a direct role in disease pathology.[10] WC is central to the current Army standards that protect large but lean soldiers.

This paper reviews the basis of the Army body fat standards, the method of body fat estimation that is a part of the standard, and some of the apparent effects of these standards on soldier characteristics. Whether or not these body fat standards can reduce lifetime health risks for soldiers remains to be discovered.

OCCUPATIONAL STANDARDS FOR BODY COMPOSITION

The dilemma of competing goals

For the past 20 years (since 1984), the Army has strictly enforced body fat standards for soldiers. The purpose of these standards is to motivate good fitness and nutrition habits so that soldiers are prepared to conduct their mission anywhere in the world on short notice. Obese and poorly conditioned individuals are predictably a hazard to themselves and their units in a combat environment, and they are unlikely to have time to become physically conditioned when they are called up for a military deployment. The stated primary objective of the Army body fat standards is to ensure combat readiness, but this has multiple facets, some of which may dictate different thresholds of acceptable body fat or even conflict with each other. Since many soldier job specialties require strength for tasks such as lifting and carrying, a big (and perhaps fat) individual may be a good performer but does not necessarily have the expected image of a ready and capable deterrent force (trim military appearance), or satisfy health goals including reduced risk for Type 2 diabetes and other obesity-related diseases. The method of fat estimation could also unintentionally thwart the intent of the standards. For example, a typical male pattern of upper body fat distribution, *i.e.*, a shift to more abdominal and less gluteofemoral fat, in a

TABLE 1. AVERAGE BODY COMPOSITION ESTIMATES OF MALE SOLDIERS IN FIVE ERAS

	Year				
Variable	*1864*	*1919*	*1946*	*1984*	*2000*
Sample size	23,624	99,449	85,000	869	966
Age (years)	25.7	24.9	24.3	26.3	26.3
Height (in)	67.2	67.7	68.4	68.6	69.6
Body weight (lbs)	141	145	155	167	178
Abdominal circumference (in)	31.5	31.4	31.3	32.7	33.7
Body fat (%)	16.9	15.7	14.4	17.3	17.0
Fat-free mass (lbs)	117	122	133	138	148

Adapted from Friedl[4] with new data from Leu and Friedl.[5]

woman may signify both greater strength capacity as well as increased male-type health risks.[11–13] Too much emphasis on the WC for female soldiers might eliminate some of the best performers in favor of a putative reduction in health risk.[14] Thus, body fat estimation methods are as much a part of the standard as the percent body fat limits because every practical method of assessment is based on a set of assumptions that apply variably to individuals. Ideally, a method will be selected that best corresponds to the intent of the standards. The Army continuously reevaluates the standards (and method) to fine-tune these standards on the basis of any relevant new research.

Where is the Army's health benefit?

Although health risk is only one of several reasons for the Army body fat standards, and not even one of the most important ones to the Army mission of winning battles, disease risk provides the most definitive outcome in which to anchor fat standards. The current Army standards are specifically linked to thresholds of health risk. The Army standards intentionally favor large but muscular soldiers, but it is currently unknown if larger size, independent of adiposity, increases the prevalence of certain health risks such as Type 2 diabetes compared with the general population, and if the body fat standards provide an added health benefit. Incidence of Type 2 diabetes in the Army has been estimated at 1.7 cases per 1,000 person-years, based on data from the 1998 Defense Medical Surveillance System, with an average age at diagnosis of 35 years, after 14 years of Army service.[15] Very similar notes have been reported for the U.S. population ages 20–44.[15] This is surprising because of the factors that would predict lower diabetes risk in soldiers. Health standards for entry into the Army are restrictive, excluding obese individuals. Soldiers are tested for physical fitness on a semiannual basis, and this reinforces regular fitness habits; regular physical activity is measurably higher in the Army than some of the other military services and the general American public. The existing body fat standards based on waist girth are strictly enforced. Soldiers have access to excellent health care and are required to undergo periodic physical exams. This preliminary finding that Type 2 diabetes is not lower in the U.S. Army suggests other occupational risk factors (body size?), the occurrence in only a discrete group of susceptible individuals, or failure to detect a health benefit that is more noticeably accrued only later in life after retirement from the military.

THE SHIFTING EMPHASIS IN MILITARY WEIGHT STANDARDS

The U.S. Army has had weight standards in place for over a century, but the original emphasis on underweight has flipped to concern about obesity.[4] Originally, weight standards were used to screen out recruits who were chronically malnourished or had chronic illnesses such as tuberculosis. The Army wanted large soldiers who might therefore be healthy, strong, and looked like formidable opponents.[4] Congress was prompted to start the School Lunch program because so many potential recruits were turned away for underweight in World War II. However, by the post-Vietnam era, there was a perception that soldiers were becoming obese and had a poor level of fitness, calling into question both their deterrent value (they didn't *look* fit to fight) and the level of military readiness (the capability to conduct the military mission). In 1976, this became a crisis, reportedly precipitated after news services panned their cameras across a line of ample bellies in a military formation during a nationally televised military ceremony. This led to a new Army regulation with strict weight standards, but the regulation included a significant loophole that required a military physician to assess overweight soldiers to determine if they needed to lose weight or were just large. In 1980, President Carter ordered a review of the fitness of the military services. This resulted in a Department of Defense Instruction that mandated new fitness and body composition standards for all military services.[16]

It was innovative to replace unenforceable body weight standards and a subjective appraisal of adiposity with circumference-based body fat estimations. These occupational standards remain unique to the U.S. military. After

some adjustments based on new research, the military Services have agreed to a single set of equations for body fat assessment (Fig. 1),[17–19] but each of the four military services still set its own body fat thresholds according to its mission requirements. The 1980 panel concluded that the upper limits of body fat could be reasonably set at 20% and 30% for men and women, respectively.[16] However, the final instruction to the services called for Department of Defense-wide goals for body fat to be 20% for all men and 26% for all women, apparently guided by the thinking that women were essentially men with too much fat and that female physical performance could be improved by simply legislating a lower body fat. Subsequent data from multiple studies and reviews, including the Defense Women's Health Research Program, have corrected deficiencies in Army health, fitness, and nutrition regulations to account properly for the physiology of the female soldier rather than provide "accommodations" in existing male standards.[20] The 1980 panel also suggested older age standards at 30% and 37% body fat for men and women, but with no data to guide standards for physiological changes with age, they were concerned that average population values, rather than physiologically based values, might become accepted as normal.[16]

ARMY BODY FAT STANDARDS

How the standards were set

The Army regulation uses weight screening tables to identify soldiers who may be at risk for exceeding the body fat standards. These are based on BMI, and the most recent revision uses a range between 25 to 27.5 kg/m^2. If a soldier exceeds his or her gender- and age-related weight limits, he or she is measured for body fat. If they also exceed their body fat limits (Table 2), they are placed on the Army weight control program and must successfully achieve their body fat standards or face dismissal for failure to meet weight control standards. Army weight tables for men are traceable to the 1912 Medico-Actuarial tables, with male upper limits set at 125% of the desirable weight of young men.[4] This value of 27.5 kg/m^2 proved to be

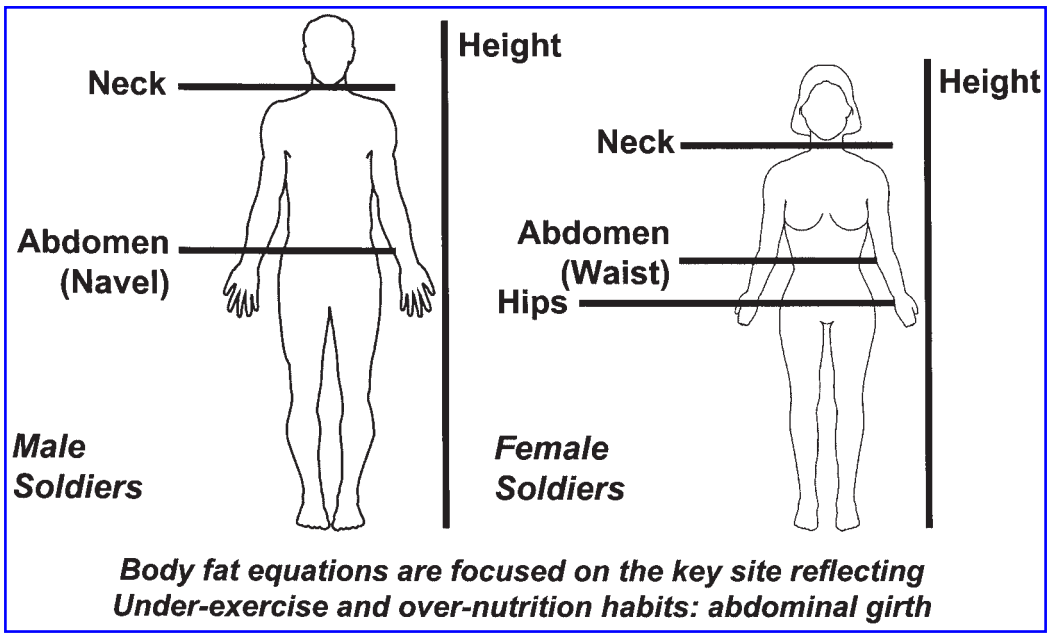

FIG. 1. Method of circumference-based body fat measurements. The equation for men is % body fat = 86.010 × $\log_{10}$(abdomen II circumference − neck circumference) − 70.041 × $\log_{10}$(height) + 36.76. The equation for women is % body fat = 163.205 × $\log_{10}$(abdomen I + hip − neck) − 97.684 × $\log_{10}$(height) − 78.39.[19] Abdomen I is measured at the thinnest part of the waist, Abdomen II is measured at the level of the navel. Both sites are measured with stomach muscles relaxed.

TABLE 2. ARMY WEIGHT CONTROL STANDARDS

	Age categories (years)			
	17–20	21–27	28–39	40+
Men				
Screening table weights	25.9	26.5	27.2	27.5
% body fat limits	20	22	24	26
Women				
Screening table weights[a]	25.0	25.3	25.6	26.0
% body fat limits	30	32	34	36

[a]Pending change from more stringent screening weights originally set with more stringent fat standards for female soldiers.

very similar to the upper limit for men in 1988 national health guidelines (BMI 27.8 kg/m^2, based on the 85th percentile of BMI for young men and women in the U.S. population).[21] Along with data on the average adiposity of older fit soldiers,[22] this formed the basis for the upper limit of acceptable body fat in men, with an estimated equivalence of 26% body fat (Fig. 2). Department of Defense goals of 20% body fat for males were revalidated with the observation that in a sample of soldiers, 20% body fat corresponded to an acceptable average fitness level of 46 mL/kg/min in maximal aerobic capacity.[23] Arbitrary increments in body fat and the screening table weights to predict overfat were established between this upper and lower bound to avoid an equally arbitrary and illogically large jump in allowable body fat at one birthday. The tables and the standards for women were then established in parallel to the male standards but have been adjusted several times, along with an evolving appreciation for physiologically appropriate female standards. Most recently, the female screening weights

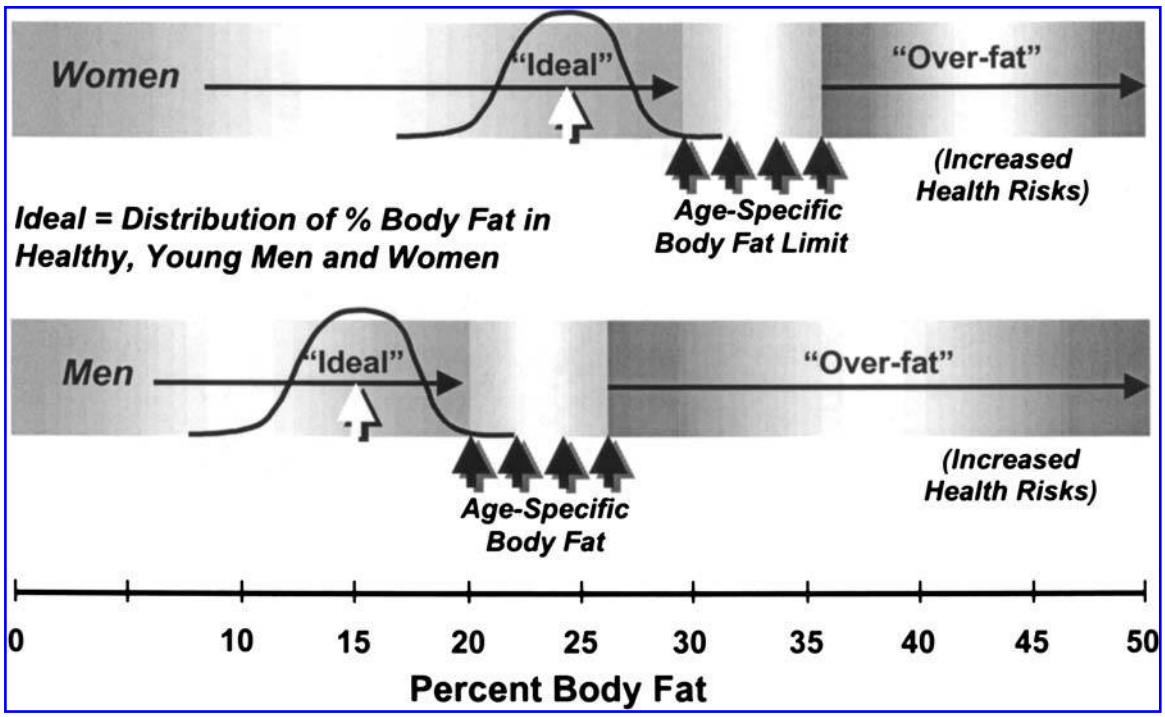

FIG. 2. The basis of the Army body fat standards. Arbitrary age-related increments in allowable upper limits of body fat are bracketed by upper limits of the body fat distribution around the average of fit young men and women (15% and 25%, respectively) and by thresholds of increased health risk traceable to BMI and abdominal circumference values (see text).

have been raised to a minimum of BMI of 25 kg/m^2 (Table 2), as women were attempting to meet more stringent weight tables to avoid being labeled as overweight even if they met the fat standard; this was, in effect, holding female soldiers to healthier than "healthy" weights while also not identifying any additional women exceeding the fat standard. Body fat standards based on a distribution above the average body fat of fit young men (15%) and women (25%) have stood up well over time as reasonable and appropriate limits for fat gain before any physiological changes with aging occur along with the accumulation of the effects of career-long health and fitness habits (Fig. 2).

Equating BMI thresholds to percent body fat

The health-related upper limits of body fat for men (26%) and women (36%) have also withstood comparisons to new data on health risk thresholds, easily remaining within the relatively broad target range that results from the imprecision inherent in biological and measurement variations. The best available methods for body fat measurement typically vary by 0.5–1.0% in reproducibility and daily biological variation, and 2.5–3.0% body fat in accuracy against a criterion method.[24] The actual significance of any health risk threshold is not more precise than at least several percent body fat units because of the soft linkage to health outcomes in different populations. There can also be large variation between population means for different methods of body fat estimation; these are not readily interchangeable, and the methods must be specified.[25,26] On top of this variation, trying to relate BMI-based health guidelines [previous guidelines, BMI of <27.8 kg/m^2 for men and <27.3 kg/m^2 for women; current National Heart Blood and Lung Institute (NHBLI) goals, BMI <25 kg/m^2] to percent body fat is a moving target that depends on habits and traits that might influence the balance of lean and fat in individuals in any given population.[21,27] Even within Army populations, selective pressures and physical training regimens vary the lean–fat relationship between groups such as West Point cadets, new Army recruits, and soldiers in various types of units. Nevertheless, the current limits hold up well with new data. Gallagher *et al*.[27] reported that a BMI of 25–30 kg/m^2 corresponded to body fats of 20–24% in men and 32–36% in women, based on data from a large civilian sample of various ages and ethnicities tested by dual energy x-ray absorptiometry (DXA) and using a four-compartment model. At the higher end of BMI in an older population, the values also remain consistent. For example, in the Third National Health and Nutrition Examination Survey (NHANES III), where body fat was estimated from bioelectrical impedance measurements, average BMI of around 27.3 kg/m^2 and 26.6 kg/m^2 for 40–49-year-old men and women, respectively, corresponded to average body fat of 24–26% (men), and 35–40% (women).[28] In a recent Army survey, men and women over age 40 averaged 26.9 kg/m^2 and 25.5 kg/m^2, respectively, corresponding to military WC-based body fat of 19.5% and 29.5%.[5] These examples illustrate some of the variations in population characteristics and methods and still bracket a rough equivalence between BMI-based health risk thresholds and the Army standards.

Relating WC to percent body fat

The relationship between military body fat and WC thresholds established in the NHLBI guidelines is easier to demonstrate, as the military's method of body fat estimation is essentially a calibrated WC. It should be cautioned that there are methodological differences between standards applied, with a wide range of measurements representing abdominal circumferences that may fall anywhere from the bottom of the rib cage to the top of the pelvis; the military equations use the navel as the landmark for measurement in men and the thinnest portion of the waist for women. Using average values for height, neck circumference, and hip circumference (women only) of active duty soldiers in the military equations, the male upper limit of 26% body fat is predicted by a WC of 38.5″ (NHLBI guidelines: WC <40″); the female upper limit of 36% body fat is predicted by 35″ (NHLBI guidelines: WC <35″). Sixty percent of the male soldiers and 40% of female soldiers exceed a BMI of 25 kg/m^2; very few soldiers

below this BMI threshold exceed waist circumferences of 35″ or 40″, and only 7% of all female soldiers and 4% of all male soldiers exceeded these girths, compared with 12% of men and at least 12% of women exceeding body fat standards.[5] Thus, the Army WC-based body fat standards are more stringent than the health threshold-based NHLBI guidelines, and very few individuals exceeding the WC thresholds are missed by the Army standards.

BODY FAT MEASUREMENT TECHNOLOGIES

Military body fat standards rely on predictive equations based primarily on WC (Fig. 1). The method has been calibrated[17,18] and validated[19,29,30] against more accurate methods of total body fat measurement, including underwater weighing (UWW), DXA, and multicompartment models. However, it is important to note that the actual use of a more accurate total fat assessment would be less suitable to the Army goals than this regional fat measurement standard. This conclusion is predicated on the view that adipose tissue does not behave as one homogeneous organ, but exhibits functional differences and is regulated differently between intraabdominal and various subcutaneous sites. A fair and appropriate application of these standards requires some assumptions concerning the lability of fat at the measurement sites in response to changes in fitness and nutrition behaviors, as well as benefits of WC reduction to health outcomes. There are data to support both assumptions.[31–34]

Practical methods of body fat estimation

Military researchers have considered many approaches to assessing body type and body composition over time, and have been involved in the development of many of these methods (Table 3). Visual assessment is the age-old standard used by commanders to choose soldiers, but this reached a high state of refinement in the now discredited eugenics movement with detailed somatotyping of 100,000 soldiers at the end of World War II to develop an occupational classification scheme.[4] Remnants of this concept of body type predicting human capabilities and behavior were still evident in Army regulations until just recently. With a skilled observer, visual assessment of fatness can be as good as many of the standard anthropometrically based assessments, but for general use the approach is too variable and subjective.[35] Body size, as generally assessed using the standard Quetelet's index (BMI), has a good correlation with adiposity in population studies but is not useful in assessing individuals, except for severe underweight where fat provides significantly less variation in the assessment of minimum lean mass. Abdominal fat based on waist girth has long been recognized to be a good predictor of health risk, with a difference of more than 2″ between waist and chest girths predicting increased mortality, especially for diabetes, based on Metropolitan Life Insurance Company reports in the 1930s.[36] In normal males, the predominant site of excess fat storage is in the abdomen; for healthy young females, this is one of the last sites of fat deposition, following subcutaneous locations ranging from thigh and hips to upper arm, with differential regulation of each depending on pregnancy, lactation, and endocrine influences associated with other normal processes.[9,37,38] Thus, the military services were able to quickly adopt circumference-based standards based on an earlier concept developed for male Marines, but each of the four Services produced different female equations,[39] which could produce wildly varied body fat values for any one woman.[40] The original concept was that the characteristics (including ethnicity) of each Service differed and equations needed to be developed that would be suitable to fat prediction for that Service; this was illogical since the goal was to produce generalized equations that would apply fairly to all individuals. Only recently, the Department of Defense has settled on one best set of equations—those developed originally by Hodgdon and co-workers for the Navy.[17–19] This followed 2 decades of studies on the best method for the military services. In the 1980s the Army briefly used skinfold measurements and the equation of Durnin and Womersley[41] for the body fat standard because this had been well established in Army research studies on physical performance and environmental stressors. However, standardization of the technique was too demanding and not practical for Army-wide

TABLE 3. STANDARD PHYSICAL AND CHEMICAL METHODS OF TOTAL BODY FAT ASSESSMENT

Technology	*Measurement*	*Theoretical premise*	*Caveats and disadvantages*
Human visual appraisal	Visual inspection (% body fat)	Practiced eye can detect relative fatness ("fat doesn't flex")	Very imprecise quantification; errors at lower levels of fat and when fat is well distributed
Body mass index (BMI)	Height and weight (kg/m^2)	Increasing weight corresponds to increasing proportion of body fat	Large errors from genetic, nutritional, and physical training variability
Skinfold thicknesses (SF)	Sum of multiple calipered skinfold thicknesses (mm)	Subcutaneous fat layer represents total body fat	Technique difficult to standardize; varies with body fat topography; considers only subcutaneous fat
Circumference-based equations (CIRCS)	Tape-measured girths at key sites (cm)	Combination of body girths can represent total body fat	Individual variations due to site-specific emphasis
Underwater weighing (UWW)[a]	Body density determined by water displacement	Constant FFM density (g/cm^3) (usually 1.100 g/cm^3 of FFM)	Requires considerable subject cooperation; large errors from variations in lean mass
Total body water (TBW)	Imbibed deuterium dilution ($\mu g/mL$)	Constant FFM hydration (usually 73% of FFM)	Specialized isotope measurement required; large errors from variations in hydration
Total body potassium (TBK)	Natural K-40 gamma emission	Constant FFM potassium (usually 2.66 g/kg)	Specialized measurement device required
Bioelectrical impedance analysis (BIA)	Body resistance to electric current (ohms)	Resistance correlates with FFM	Large errors from variations in hydration, electrolytes, and body dimensions
Dual energy x-ray absorptiometry (DXA)	Differential attenuation of two x-ray energies	Constant attenuation coefficient of fat and lean soft tissues	Body thickness affects measurements
Multicompartment models	Combined measurements, usually DXA, UWW, TBW	Bone mass, density, and body water provide key measures of body composition	Reduced variability from multiple methods is offset by added measurement errors
Neutron activation analysis (NAA)	Induced gamma emission from key elements	Constant relationship of elemental body composition	Specialized and expensive measurement; higher than minimal medical risk

Methods are listed roughly in order of historical and technological origin. Imaging methods such as magnetic resonance imaging and computed tomography, currently used in regional assessments such as estimates of abdominal fat volumes, still require further software development and validation for whole-body assessments. FFM, fat-free mass.

[a]Can also be done using air displacement to estimate density similar to UWW.

use.[42,43] Bioelectrical impedance appeared to be a sophisticated and accurate method that might be able to replace the other methods being considered, but it proved unsuitable for individual assessments because of the wide excursions in values that could be produced by relatively small changes in hydration status and other factors.[44,45]

Criterion methods of body fat estimation

The criterion method for all of the other methods that were being tested in the 1980s was body fat calculated from body density measured by UWW (or "hydrostatic" weighing). The criterion methods of UWW and total body water measurement, as well as their combination in "multicompartment models" that considered direct measurement of as many of the major components of body composition as possible, came out of a landmark meeting at Natick Army labs in 1959.[46] This group recognized the deficiencies in single methods and proposed multicompartment models combining body water measurements and density. An Air Force body composition researcher, Thomas Allen, was one of the first to propose a four-compartment model that included bone mineral,[47] but in the absence of a practical method to measure whole body bone mineral content, this had to be crudely derived from anthropometry. This changed with the advent of DXA technology, which provides good bone mineral content measurements for multicompartment models. Multicompartment models improve the accuracy of body fat assessments by including measures of several of the body compartments that contribute the greatest variability to the estimates. These usually involve body water (the largest component), bone mineral content (the densest component), and fat and the remaining lean mass components based on body density. The largest error still comes from the UWW used to measure density.[24] The current gold standard of body composition testing is *in vivo* neutron activation analysis, which involves irradiating individuals with neutrons and measuring decay products of nitrogen, chloride, and calcium isotopes. The four-compartment model approach compares well with this even more intensive elemental multicompartment model of body composition.[48] It is now possible to achieve a near-complete assessment of the composition of the living human body using combined chemical and elemental models, and this has been demonstrated for six main chemical compartments (including cellular mineral content and glycogen) and 11 elements.[49]

DXA also provides a method of body fat assessment as a by-product of the need to assess and correct for soft tissue in the bone analysis. This body fat measurement is based on estimates only from the soft tissue pixels, thus ostensibly eliminating the effects of variations in bone density. Percent body fat from DXA is also more reproducible than from UWW because it does not require active participation of the subject.[2] UWW was a particular problem as the criterion method for development of the Army equations as half of the Army cannot swim and many study participants were not comfortable performing maximum exhalations underwater. The radiation exposure from DXA is low enough that this method is commonly used for repeated measures in longitudinal studies; however, pregnancy testing of young women is a common safety precaution. DXA provides a new criterion method for body fat estimation that is both more reproducible and accurate than UWW, when more detailed multicompartment model methods are not practical.

The future is in visceral adipose tissue (VAT), not fat

As the technology for body composition research improves, the importance of regional fat placement to health consequences is becoming better recognized, and the emphasis is moving to imaging techniques that assess VAT. Thus, for the purpose of obesity-related health risk predictions, BMI has been improved by total body fat measurement, followed by WC, now being replaced by VAT assessment. WC alone does not distinguish subcutaneous fat and VAT, although the correlation between WC and visceral fat is stronger than that obtained between BMI and visceral fat.[50] A practical solution based on correction with the addition of a suprailiac or abdominal skinfold measurement is problematic because with increasing adiposity these skinfold sites quickly exceed the span of standard spring-loaded calipers. More likely, future clinicians, epidemiologists, and perhaps platoon sergeants will use a handheld device based on an imaging technology to obtain a rapid and accurate assessment of VAT, and perhaps even the specific lipid composition.

OCCUPATIONAL RELEVANCE OF BODY SIZE, BODY FAT, AND WC

Body size, body fat, and fat distribution each have different significance in occupational standards. Acute outcomes affecting the ability to perform the military mission today are the health and performance outcomes of greatest importance to the Army, including strength, power, aerobic capacity, environmental injury risks, and acute health risks such as Type 2 diabetes that potentially degrade soldier physical and mental performance.

Physical performance

BMI predicts lean mass at least as well as it predicts fat mass, within the range of BMI of healthy individuals. There is a direct relationship between lean mass and both strength and work capacity, since strength is predicted by the cross-sectional area of muscle[3] and work capacity is determined in large part by the amount of working muscle.[51] These relationships to the fat-free mass are gender neutral, with data for male and female soldiers falling on the same regression line (Fig. 3). Because of human sexual dimorphism, women generally have less fat-free mass and fall lower in the physical strength and aerobic capacity range. Thus, women would be most likely to be affected by standards that set minimums of fat-free mass (or minimum body mass index) to ensure a minimum level of strength for safe and effective lifting and carrying tasks. Current

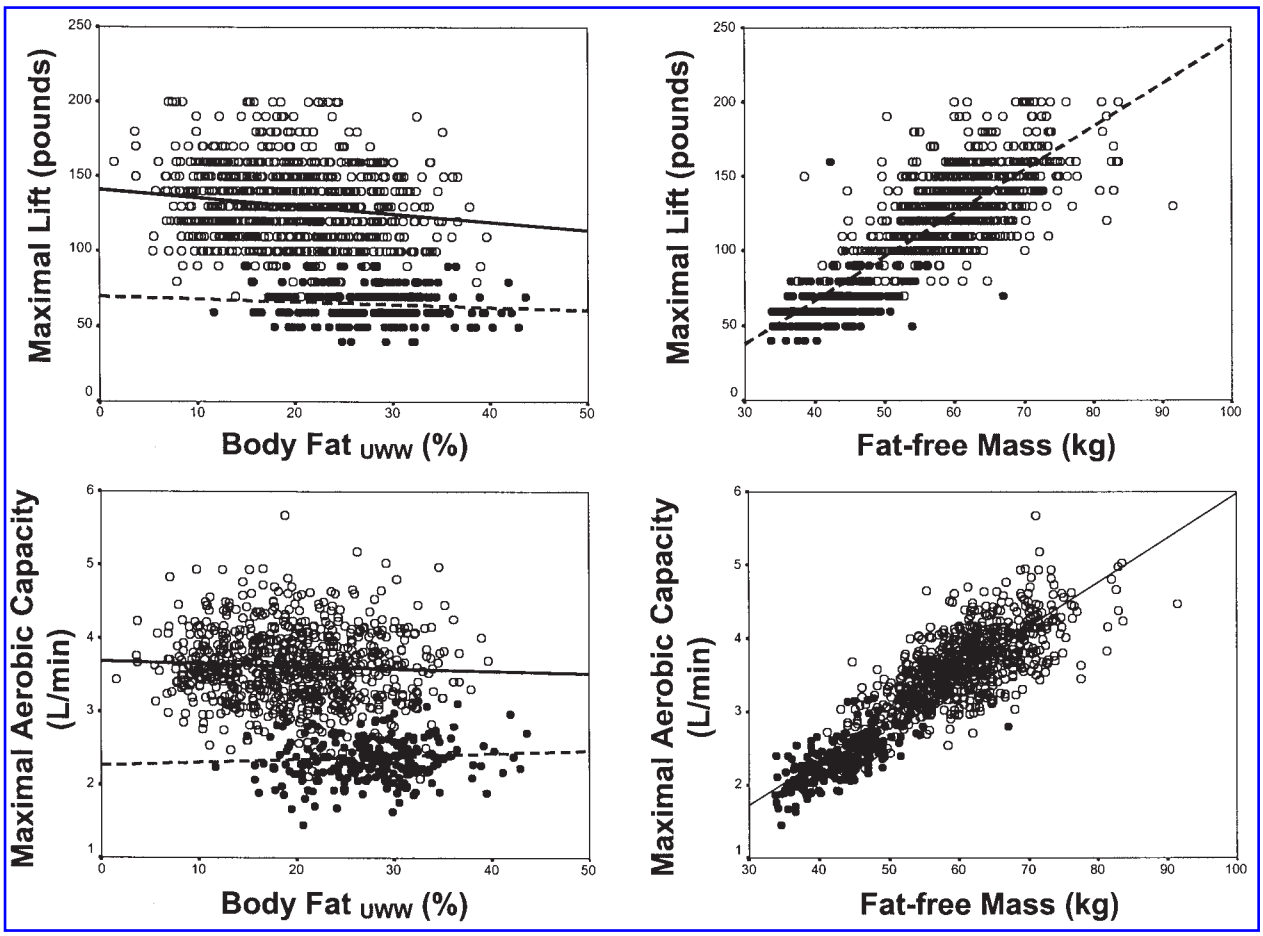

FIG. 3. Relationships between physical performance measures (maximal lift strength and maximal aerobic capacity) and percent body fat and fat-free mass (males, open circles and solid regression line; females, solid circles and dashed regression line; fat-free mass relationships fit a single regression line regardless of gender). The key to soldier physical capacity is body mass, or more specifically the fat-free mass component, not percent body fat. Data plotted are from Fitzgerald *et al.*[52]

lower limits for BMI of 19 kg/m^2 mark a lower limit of fat-free mass below which no individuals are expected to be able to lift 100 pounds to the height of a standard Army truck bed.[53] Strength and aerobic capacity are not significantly impaired by increasing relative fatness, and there is no correlation between percent body fat and either of these outcomes for male or female soldiers (Fig. 3). Although fatness does not appear to impair performance, there is also no association that implies fatter soldiers do better. However, in the absence of Army body fat standards, some of the strongest soldiers would likely be among the fattest as typically observed in elite strength athletes such as power lifters, football players, and sumo wrestlers in whom deliberate overnutrition to increase lean mass also tends to increase relative fatness.

An entirely different relationship is observed if one considers physical performance that requires moving the body mass through space, as in distance running. Aerobic capacity, expressed in terms of body weight, falls off with increasing relative fatness. Fat weight counts exactly the same way as weight added into a carried backpack, and, in fact, to equate running performance between men and women requires adjustment for higher levels of gender-specific body fat in women.[54] The relationship between percent body fat and aerobic performance has a wide variability, with some fatter but fit soldiers able to outpace thinner soldiers; thus, percent body fat has a strong relationship but is not a suitable predictor of aerobic performance (expressed in terms of body weight). Although the correspondence between 20% body fat in young soldiers to a reasonable fitness level of 46 mL/kg/min aerobic performance helped to guide the current standards, there is no aspect of militarily relevant physical performance that can be used to set body fat standards. The Army even considered recognizing this gray zone of percent body fat within which an individual may exceed age-specific standards (but below the health-based upper limits of 26% and 36% body fat for the oldest men and women), but still demonstrate superior physical fitness.[5] This also acknowledges the loose and somewhat arbitrary significance of absolute thresholds, since individuals do not go from being excellent soldiers to unfit and unhealthy as they cross a threshold value from, for example, 20% to 21% body fat. At present, a sliding standard for "fit-fat" is too complicated to administratively manage.

The insulative properties of the subcutaneous fat layer can moderate ability to withstand environmental heat and cold, either of which can impair performance and present important environmental injury risks to soldiers. Very lean and thinner soldiers are more susceptible to cold, but the converse does not necessarily hold true, as individuals who are fat as a reflection of their poor fitness habits may not have optimal thermoregulatory responses appropriate to a cold or heat challenge.[55,56] In the heat, large soldiers with greater mass to body surface area ratios are at greater risk for heat injury than smaller soldiers, even if they lack additional insulating fat; addition of a thick subcutaneous fat layer is an independent risk.

Military appearance

The emphasis on appearance in the military is much maligned as empty ceremonial show, but a military that looks fit and intimidating has deterrent value. It also meets the general expectation of taxpayers to *see* a fit and ready force. The practiced eye can predict percent body fat with accuracy comparable to reputable objective methods.[35] More significantly, a team of Army headquarters staff personnel rating standardized photographs of over 1,000 male and 250 female soldiers for military appearance sorted individuals with disproportionately large abdominal girths into the unacceptable categories (Fig. 4). For women, the abdominal measures were not as strong but still predominated as the primary discriminator of military appearance (Fig. 4).[25] It was also noted that for a given appearance rating, percent body fat of the women was 8.7% greater than for men,[35] suggesting the complexity of factors involved in visual assessments. Thus, WC-based methods of body fat estimation are consistent with military appearance goals, although body composition assessments of any kind have little merit as the objective metric for military appearance. Military appearance is not purely defined by estimates of obesity or its

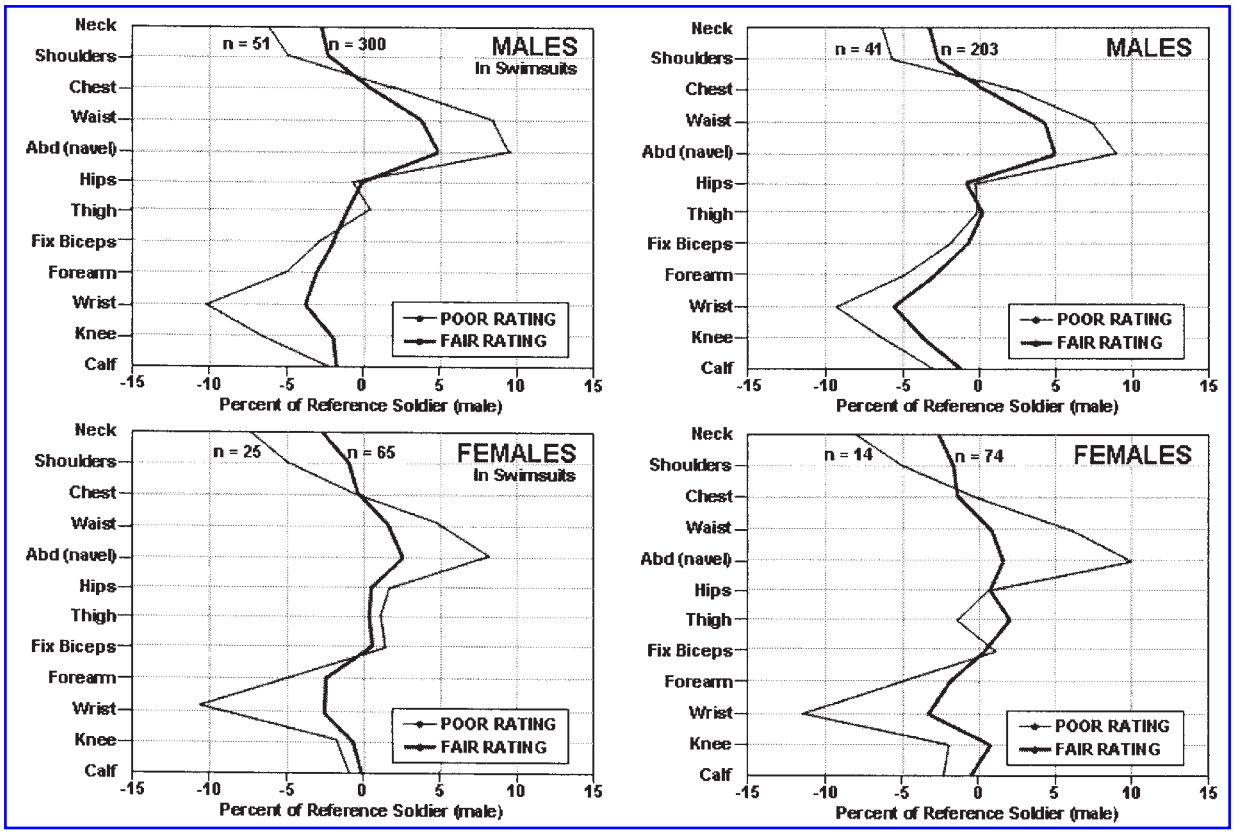

FIG. 4. "Somatograms" of male and female soldiers rated as "poor" or "fair" for military appearance, compared with all others receiving "good" or better ratings (reference male and reference female soldier). Plotted points show average deviation from the proportions of the reference soldier body circumferences. Disproportionately large abdominal circumferences were the principal discriminators of military appearance for men and women, in swimsuits and in dress uniforms. Data analyzed are from Fitzgerald *et al.*[52]; reference data are from Vogel and Friedl.[25]

suggestive markers such as the WC, but includes posture, wear of the uniform, and other complex psychosocial and cultural factors.

Health risks

Acute impairment of soldier performance by some undiagnosed obesity-related diseases, notably Type 2 diabetes, may actually be more important than currently recognized, and this is currently a focus of military medical research. A wide range of physiological functions such as physical endurance, cognition and mood, and compensatory responses in extreme environments might be affected by less than optimal glucose regulation, and might make the difference in success or failure in a military mission. The current scanty data that suggest no difference in the incidence of Type 2 diabetes in soldiers compared with the young U.S. population may highlight the fact that most soldiers are young (under age 30) and may not yet reflect the effects of long-term health habits; a detailed comparison of the health outcomes in older soldiers is needed. The greatest benefit of these standards may be in preventing health and performance decrements in the older soldiers who are also the leaders and key decision-makers. WC appears to be an important predictor of diabetes risk,[57–59] although the basis for this association remains to be defined and may be a direct effect of elevated fatty acids impairing hepatic function,[10] a reflection of overall body composition affecting insulin clearance,[60] or simply a consequence of deranged metabolism reflecting the effect of other stress responses including corticosteroids or interleukins.[61–63]

The 1980 panel on fitness in the military concluded that military appearance would be the likely driver for setting body fat standards because "the level of obesity which detracts from

health is generally greater than that required for a trim appearance, and performance is a relative factor, dependent on what is required of the individual."[16] Ultimately, the standards have been anchored by health risk thresholds because the relationship between percent body fat and physical performance is too variable and military appearance is too subjective.

CHANGES IN RESPONSE TO ARMY BODY FAT STANDARDS

WC increases along with other body dimensions and body weight in men until about age 21. Thus, in U.S. Military Academy cadets followed during their 4 years from ~18 to 22 years, abdominal measures increased in the men by an average of 2″, as weight increased by 10 pounds, and bone mineral content and other dimensions continued to increase; comparable measures for women were more stable, suggesting that they have achieved physical maturity before age 18.[64] Beyond this point of early maturation, it is unclear how much more WC, adiposity, and BMI should be expected to change with physiological changes such as the decline in sex steroids and other somatotrophic influences in men and women as they age. Clearly, in the U.S. population there is a shift in body composition with reduction in bone and muscle and an increase in fat mass,[28] and this can occur within stable weights. What is least understood is the interaction with nutrition and exercise habits and how much of the changes attributed to ageing can be practically prevented or reversed. Data from the military cannot adequate address this question because soldiers move to increasingly sedentary jobs as they progress in their careers, decreasing their total daily energy expenditure even as they continue to maintain voluntary fitness habits.

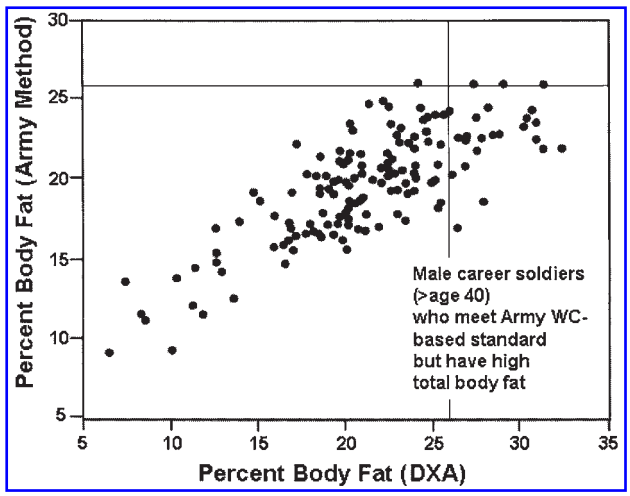

FIG. 5. Relationship between percent body fat in older male soldiers estimated by DXA and by the Army circumference equation. The linear relationship plateaus at the upper limit of acceptable body fat for men >40 years (26% body fat), demonstrating a preferential retention of career soldiers who maintain thin waists. Data plotted are from Marchitelli *et al.*[69]

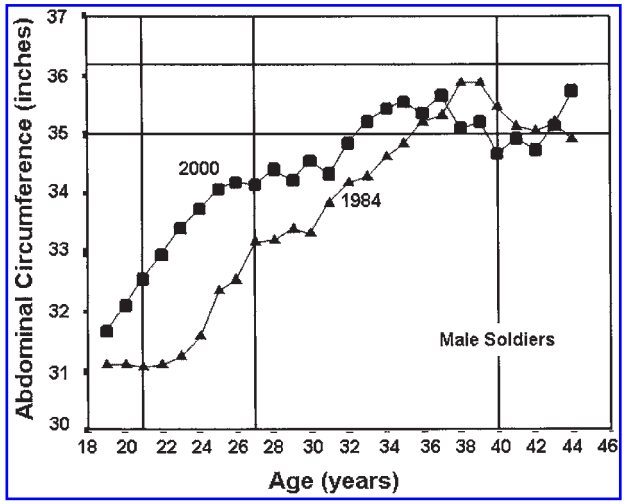

FIG. 6. Average abdominal measurements in male soldiers by age. The Army began enforcing body fat standards in 1984, but the standards have not been strict enough to prevent a 1–2″ increase in the second age category (21–27 years). Data analyzed are from Fitzgerald *et al.*[52] and Leu and Friedl.[25]

Secular trends for young and old soldiers

The WC appears to reflect the most labile site of fat storage and is readily influenced by exercise and nutritional influences.[8] This is important for occupational standards that require reasonably attainable goals through modification of individual exercise and nutrition habits, and provide a solid basis as a marker of chronic habits. Even in very lean young men undergoing an intensive Army training program with limited food intake and other combined stressors, abdominal girth was the most affected, with an average decline of 10 cm over

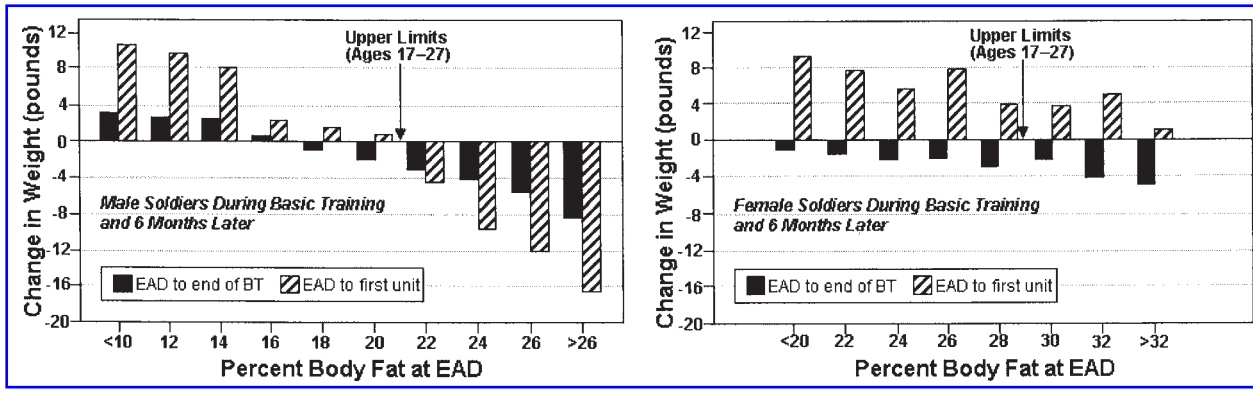

FIG. 7. Changes in body weight according to initial adiposity during 8 weeks of basic training (BT) [entry to active duty (EAD) until end of BT] and 6 months later (EAD until 6 months in first unit) for 1,048 male and 816 female soldiers. The fattest men lost and continued to lose weight in the Army, while all women lost weight in basic training and promptly regained and added additional weight after basic training.[70] The body fat standards for female soldiers were more stringent by 2% units for each age group at the time these data were collected (see text).

8 weeks of training in men averaging 15% body fat (by DXA) at the start of their training.[65] Other sites are less under environmental control, including gluteofemoral fat and upper arm fat, which appear to be more under control of genetic and endocrine changes, *e.g.*, pregnancy, lactation, virilization.[66–68] One consequence of the Army standards is a cadre of senior soldiers with relatively low abdominal girths, even if total fat may be relatively high (Fig. 5).[69] Whether this is a result of exercise and nutrition habits reinforced by the Army program, highlighting the susceptibility of the abdominal site to individual control, or whether this represents selection of individuals with small WCs and elimination of those who cannot achieve the standard cannot be determined from the available data. Fewer data are available for senior female soldiers, although representation of women in higher ranks continues to increase and will provide more information in the future.

Even while waist girth in older soldiers appears to plateau, the average girth of young soldiers has increased by nearly 2″ for men in the third decade, compared with men nearly 20 years ago (Fig. 6).[5,52] These values still fall within the accepted male upper limit for young men and presumably reflect an increasing prevalence of overweight in young soldiers. This calls into question whether the body fat standards for young men are stringent enough and whether more stringent standards would have a significant impact on this measurement. The data for females soldiers have remained closer to their upper limit for entry into the military as well as their body fat standards for retention in the Army, so a different effect may be seen in data from female soldiers that could confound any true gender differences.

TABLE 4. WC CORRESPONDENCE TO HEALTH AND PERFORMANCE

Outcome	*WC correlation*
Adiposity	Best single anthropometric predictor of overall fatness in men[17]; weaker correlation in women[18,38]
Visceral fat	Better correlation with visceral fat than other practical measures[9,50]
Type 2 diabetes	Strong association with disease risk[12,57–59]
Physical activity habits	Labile fat site more closely associated with regular aerobic training[8,31–34,68]
Aerobic performance	Weak inverse correlation reflecting excess fat weight and reduced levels of regular physical activity[23]
Strength performance	Poor correlation[23]
Appearance	Identifies site of greatest offense—the "pot belly"[25,35]
Chronic stress	May reflect chronic stress hormone exposure[61,62]

Effects of basic training

A recurring proposal to liberalize entry ("accession") standards to ease the restrictions on eligible recruits calls for Army medical researchers to develop a program that will help soldiers achieve and maintain the standards. While some men appear to be able to lose and continue to lose weight if they are over-fat, female soldiers appear to lose weight during basic training but regain it all and then add some (Fig. 7). This gender differential remains unexplained but is likely related to the more stringent female fat standards that may have been physiologically less appropriate; the upper limit for the youngest group of women was 28% body fat at the time these data were collected, and female recruits were clearly pushed up against the limit in a non-normal distribution, compared with the male recruits that distributed normally below their upper limit of 20%.[70] Individuals with the highest body fat consistently lose the greatest amount of weight in military training programs, and WC is a key marker of the change.[30,70,71] Women with an upper body (abdominal) fat distribution are more likely to lose weight and reduce WC in response to physical training (similar to men) than women with lower body (hips and thighs) fat distribution.[68] However, the distinction between fat patterning and overall adiposity in nonobese young women is confounded by the increasing prevalence of abdominal fat with increasing adiposity.[30] A current major challenge is to devise programs to prevent recidivism with return of abdominal fat and overall fatness, especially where the most profound reductions tend to produce the largest rebound fatness in the "recovery" from training.

This leads to the very important and interesting but so far unanswered question of what proportion of retired soldiers maintain fitness and health habits when standards are no longer enforced. Conceivably, a sudden reduction in physical activity and significant fat weight gain is more dangerous to metabolic disorders than a lifetime of sedentary balance.

CONCLUSIONS

The Army WC-based standards attempt to balance competing goals of combat readiness, military appearance, and health, while preventing obesity in the Army. There is a clear performance distinction between large and fat that was recognized even when Commander Behnke tested all-American football players for body fat using his new method of UWW more than 60 years ago and found an average weight of 200 pounds in men with average body densities of 1.080 g/mL (<10% body fat). He noted that "according to standard height-weight tables the majority of football players could be classified as unfit for military service and as not qualified as risks for first class insurance by reason of overweight."[72] The focus on WC is especially relevant to Type 2 diabetes risk,[57–59] and this includes related benefits from its application in motivating health behaviors such as regular physical activity,[73] and includes other important correlates previously discussed (Table 4). The payoff of a reduced disease incidence remains to be demonstrated for soldiers, perhaps to be tested in the military "Framingham" study, the Millenium Cohort Study.[74]

NOTE ADDED IN PROOF

The screening table weights and body fat measurement method described for Army women in this paper were previously approved but implementation by the Army is still pending coordination of the revised Army Regulation (AR 600-9).

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