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EFFECT OF INTENSE MILITARY TRAINING ON BODY COMPOSITION

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ABSTRACT

Individuals in a structural physical training program can show beneficial changes in body composition, such as body fat reduction and muscle mass increase. This study measured body composition changes by using 3 different techniques–skinfold thickness (SF) measurements, air displacement plethysmography (BOD-POD), and dual-energy x-ray absorptiometry (DXA)–during 9 months of intense training in healthy young men engaged in military training. Twenty-seven young men were recruited from a special faction of the Italian Navy. The program previewed three phases: ground combat, sea combat, and amphibious combat. Body composition was estimated at the beginning, in the middle, and at the end of the training. After the subjects performed the ground combat phase, body composition variables significantly decreased: body weight ($P < 0.05$), fat-free mass (FFM) ($P < 0.001$), and fat mass (FM) ($P < 0.03$). During the amphibious combat phase, body weight increased significantly ($P < 0.01$), mainly because of an increase in FFM ($P < 0.001$) and a smaller mean decrease in FM. There was a significant difference ($P < 0.05$) in circumferences and SF at various sites after starting the training course. Bland–Altman analysis did not show any systematic difference between FM and FFM measured with the 3 different techniques on any occasion. On any visit, FFM and FM correlation measured by BOD-POD ($P = 0.90$) and DXA was significantly greater than measured by SF. A significant difference was found in body mass index (BMI) measured during the study. BOD-POD and SF, compared with DXA, provide valid and reliable measurement of changes in body composition in healthy young men engaged in military training. In conclusion, the findings suggest that for young men of normal weight, changes in body weight alone and in BMI are not a good measure to assess the effectiveness of intense physical training programs, because lean mass gain can masquerade fat weight loss.

KEY WORDS fat mass, fat-free mass

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INTRODUCTION

Individuals in a structural physical training program can show beneficial changes in body composition, such as body fat reduction and muscle mass increase (21). Body weight is not a suitable measure for assessing body changes because an increase in weight related to an increase in fat-free mass (FFM) can be misinterpreted as an increase in body fatness. Values of body weight adjusted for height, referred to as body mass index (BMI), greater than 25 and 30 are considered to indicate being overweight and obese, respectively (7). This measure is also not able to disentangle fat and FFM. The main assumption of the BMI is that body mass is correlated with body fatness and consequently to morbidity and mortality (5,8,13,17,25). Although some individuals who are overweight have no excess fat (e.g., bodybuilders and military recruits) (4,12,21,24), others have BMIs within the normal range with a high percentage of their body weight as fat (e.g., the elderly or adolescents) (18,28). These peculiar misclassified people are uncommon relative to the population as a whole (6), but the difficulty arises as to how they may be evaluated appropriately according to body fatness content.

To detect changes and provide precise measurements, it is fundamental to use techniques that are able to estimate total body fat and FFM change. In studies with few subjects (6,10), noninvasive and simple techniques to measure body fat percentage and FFM, such as bioelectrical impedance analysis, seem to be less accurate and precise than in epidemiologic studies (26). Previous studies have indicated the validity of air displacement plethysmography for measuring body composition (2) and excellent agreement with hydrostatic weighing (19). A simple method for assessing fat mass (FM) loss and FFM increase could be useful for individuals who engage in a fitness program. This is particularly important for individuals engaging in occupations in which weight, FM, or FFM

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standards are needed to improve their job. For example, in AU2 the Army, all soldiers are weighed regularly to ensure compliance with weight control regulations and management (27).

There are special groups in the Army in which physical performance, agility, and speed, among other characteristics, are fundamental. There is a unique group of Italian Navy Seals called the underwater military navy, in which physical strength, resistance, and obstinacy are unique components for being part of this special and highly selective group.

The aim of this study was to measure body composition changes by using 3 different techniques–skinfold thickness (SF) measurements, air displacement plethysmography (BOD-POD; Life Measurement, Inc., Concord, CA), and dual-energy x-ray absorptiometry (DXA)–used as reference methods (22,23) during 9 months of intense military training in healthy young men.

METHODS

Experimental Approach to the Problem

Young men were recruited for this special program in the Italian Navy. The subjects were informed of the purposes and benefits of the study, and all volunteered to participate in the study.

Data were collected at the beginning, in the middle, and at the end of the course, with 84 to 90 days between measurements. The subjects who began this program faced a rigorous training period of 9 months, divided in 3 phases: ground combat, sea combat, and amphibious combat. Each phase of 3 months was developed with daily activities on 5 days per week and the total amount of training per week was approximately 40 hours.

The research protocol for this study was approved by the AU3 Italian Navy Head Quarter of La Spezia by the local ethical committee, and all subjects gave informed consent before entry into the study.

Subjects

Twenty-seven young men were recruited, and 10 completed the training. The subjects who began this program faced a rigorous training period of 9 months, divided in 3 phases: AU4 ground combat, sea combat, and amphibious combat. In the first phase, the subjects were subordinate to progressive and intense physical preparation with training in the race, gym, and land combat. The activities became more intense during this first period. During the second phase, the physical training continued, and the activity improved by adding underwater swimming. During the third phase, the main activity was centralized on navigation of the surface, disembarkation on land, infiltration of several types of coasts, AU5 including cliffs, and training in navigation. Subjects who succeeded in finishing the training course took part in the preparation of the final test executed in maximal realism. At every visit, the subjects completed SF, BOD-POD, and DXA measurements in this order on the same day. The subjects also performed a medical history questionnaire and physical examination before assessment of body composition.

Instrumentation and Test Procedure

All anthropometric measurements were performed by the same expert operator, according to the Anthropometric Standardization Reference Manual (16). Weight was measured to the nearest 100 g, and height was measured to the nearest 0.1 cm with an electronic balance with an incorporated stadiometer (Tanita, Tokyo, Japan). BMI was calculated as weight divided by the square of the height (kg/m^2).

Skinfold thicknesses and circumferences were measured with a caliper and an anthropometric tape, respectively (Holtain, Crymich, UK). SF (i.e., biceps, triceps, subscapular area, suprailiac area, calf, and middle thigh) was measured to the nearest millimeter with a calliper on the right side of the body (16). Circumferences (i.e., arm, waist, hip, calf, and middle thigh) were measured to the nearest millimeter with a plastic tape. All skinfold and circumference measurements were repeated 3 times, and the 3 values were averaged.

Body density was performed by air displacement plethysmography (BOD-POD). The subjects were measured in a tightly fitting swimsuit and in a swim cap to minimize the effect of the hair on body volume assessment and with all jewelry removed (9,11). Body mass was first measured to the nearest 0.01 kg on a calibrated electronic scale. Each subject was then asked to sit in the air displacement plethysmograph for body volume measurement. The subjects were instructed to sit quietly with an erect posture and normal respiration, with their hands folded in their laps and their feet placed on the floor of the device. A minimum of 2 50-second tests were conducted to ensure reliability of the measurements.

Body volume measurement was measured according to previous suggestions (9,11,19).

Dual-energy x-ray absorptiometry scanners were used to measure FM (kg) and FFM (kg). DXA scans were performed by the same operator using a Lunar DPX-L densitometer with adult software version 3.6 (Lunar Corp., Madison, WI). Accuracy of whole body lean tissue mass (LTM) and bone mineral content (BMC) was 2.5% and 1.0%, respectively, in the authors' laboratory (unpublished data).

Statistical Analyses

Descriptive statistics, including means and *SD*s of changes of measured variables, were computed. Significant tests for these changes were performed by using a paired *t*-test. Pearson correlation analyses were performed to determine relationships between FFM and FM, as measured by DXA, and FFM and FM, as measured by other techniques. The Bland–Altman bias plots (3) were created to assess the agreement or difference between the FFM and FM measurement by DXA and FFM and FM estimate by SF and BOD-POD. The Pearson correlation was used to evaluate the relationship between FM and FFM with different body composition methods. Statistical significance was set at $P \leq 0.05$. Data were analyzed by using a personal computer version of Intercooler Stata 9.0 (StataCorp, College Station, TX).

RESULTS

Anthropometric data at the beginning, in the middle, and at the end of the training are shown in Table 1 for the subjects who finished the course. According to the data collected, 35% of the subjects completed the course. The mean age of the participants was 24.9 ± 3.4 years (range, 21–29 years).

Body composition changes at the 3 points are summarized in Table 2. From the beginning until the subjects performed the ground combat phase (time 1–2), the body composition variables significantly decreased: body weight (1.65 ± 2.3 kg) ($P < 0.05$), FFM (4.02 ± 1.41 kg) ($P < 0.001$), and FM (1.7 ± 2.12 kg) ($P < 0.03$). During the amphibious combat phase (time 2–3), body weight increased significantly (–2.13 ± 2.15 kg) ($P < 0.01$), mainly because of an increase in FFM (–3.93 ± 1.57 kg) ($P < 0.001$) with a nonsignificant decrease in FM (–0.24 ± 2.5 kg) ($P =$ nonsignificant). There was a significant difference ($P < 0.05$) in circumferences and SF at various sites after starting the training course.

No significant difference was found between FM and FFM during all 3 visits according to the different techniques. The correlation coefficients between FM and FFM measured with the different techniques are summarized in Table 3.

At any visit, FFM and FM correlation measured by BOD-POD ($P = 0.90$) and DXA was significantly greater than that measured by SF (Table 4).

Bland–Altman analysis did not show any systematic difference between FM and FFM, as measured with the 3 different techniques on any occasion.

A significant difference was found in BMI measured during the study. BMI decreased after the land combat phase (0.7 ± 0.8) ($P < 0.02$), and this decrease could be explained by a decrease in body weight, as a reflection of a decrease in FFM and FM. Conversely, there was a significant increase in BMI (0.69 ± 0.7) ($P < 0.01$) during the amphibious combat phase, which was related to an increase in weight (–2.13 ± 2.15) ($P < 0.01$) because FFM increased (3.93 ± 1.57) and FM remained stable.

DISCUSSION

This study used 3 different methods to evaluate FM and FFM in healthy young men. DXA has not been established yet as a gold standard, but it accurately evaluates changes in body composition and it could be considered as a reference method because of its precision and accuracy (15). According to Houtkooper et al. (14), DXA is the most sensitive method for assessing small changes in body composition over time.

This study found a significant positive correlation between all 3 methods of FFM and FM assessment and no meaningful difference between DXA and the other 2 methods. For this reason, it may be suggested that FM and FFM, as measured by SF and BOD-POD, could serve as good alternative methods in daily clinical practice.

The data showed that body weight is not an effective or accurate tool to assess body composition changes during

TABLE 1. Body composition and anthropometric measures at the start, in the middle, and at the end of the training.

Variable	Start	Middle	End
Body composition			
Weight (kg)	79 ± 9.6	77.3 ± 9.4	79.4 ± 9.5
Height (cm)	176.8 ± 7.8	176.8 ± 7.8	176.8 ± 7.8
Body mass index (kg/m^2)	25.4 ± 1.9	24.7 ± 1.5	25.4 ± 1.7
Skinfold thickness (mm)			
Subscapular area	13.4 ± 4.0	12.2 ± 3.0	12.2 ± 3.0
Biceps	4.2 ± 1.0	4.3 ± 1.0	4.2 ± 0.8
Triceps	9.4 ± 2.6	8.8 ± 1.9	8 ± 2.0
Suprailiac area	12.6 ± 4.6	11.2 ± 3.4	11 ± 3.0
Thigh	10 ± 3.0	10 ± 2.0	8 ± 2.0
Calf	7 ± 3.0	6.8 ± 1.5	6.6 ± 1.0
Circumference (cm)			
Arm	32.3 ± 2.0	31.6 ± 1.6	32.2 ± 1.6
Waist	82 ± 4.7	79.8 ± 7.1	82 ±5.5
Hips	98 ± 5.0	96 ± 5.0	97.9 ±5.0
Middle thigh	57 ± 3.0	58 ± 3.0	57 ± 3.0
Calf	39 ± 1.0	39 ± 1.0	39 ± 1.0
Waist-to-hip ratio	0.83 ± 0.02	0.82 ± 0.04	0.83 ± 0.02
Fat-free mass (kg) measured by DXA*	68.8 ± 7.6	64.8 ± 6.6	68.7 ± 6.9
Fat mass (kg) measured by DXA	10.3 ± 4.0	8.6 ± 3.6	8.9 ± 2.8

*Dual-energy x-ray absorptiometry.

TABLE 2. Changes in body composition in training period.

Variable	Time 1–2	Time 2–3
Body composition		
Weight (kg)	1.65 ± 2.3*	−2.13 ± 2.15*
Body mass index (kg/m^2)	0.7 ± 0.8*	−0.69 ± 0.7*
Skinfold thickness (mm)		
Subscapular area	1.2 ± 2.5	−0.5 ± 2.3
Biceps	−0.1 ± 0.3	0.08 ± 0.35
Triceps	0.27 ± 0.88*	−0.05 ± 2.1
Suprailiac area	1.35 ± 2.5	0.69 ± 4.28
Thigh	0.00 ± 2.35	2.2 ± 2.2*
Calf	0.35 ± 2.62	0.2 ± 1.39
Circumference (cm)		
Arm	0.7 ± 0.97*	−0.6 ± 0.96
Waist	2.2 ± 4.35	−2.15 ± 4.28
Hips	2.7 ± 1.71*	−1.75 ± 2.92
Middle thigh	−1.4 ± 0.45*	1.7 ± 2.33*
Calf	0.2 ± 0.25*	0.55 ± 1.11
Waist-to-hip ratio	0.0007 ± 0.04	−0.0007 ± 0.03
Fat-free mass (kg) measured by DXA†	4.02 ± 1.41*	−3.93 ± 1.57*
Fat mass (kg) measured by DXA	1.7 ± 2.12*	−0.24 ± 2.5

*Significantly different from 0 ($P < 0.05$).
†Dual-energy x-ray absorptiometry.

a physical training program. The data raise the possibility that exercise only performed at a very high intensity contributes to changing effectively the human body. Usually, a decrease in body weight is accomplished by exercising and following a hypocaloric diet, and it is associated with significant decreases in fat and FFM. All subjects did not follow a diet and gained weight at the end of the intense training program.

Body composition change in the subjects could be related to lost body fat; an increase in FFM averaged 2.5 kg between the second and third controls. Conversely, by comparing the first and third controls, no change was found on FFM. If BMI at the first visit is compared with BMI at the third visit, the values appear exactly the same and, again, with no capacities of showing the FFM increase and FM decrease. Evaluation of physical training effects based only on body weight or BMI could be misinterpreted because of conventional reasoning that an increase in weight is an increase in fat (8,21,24).

The results indicated sensitivity and specificity of BOD-POD in detecting changes in body composition. According to the data, BOD-POD showed better capacity than SF in FM and FFM assessment. This difference may suggest that BOD-POD estimates of FM and FFM should be preferred to SF in this specific population.

PRACTICAL APPLICATIONS

This study highlights the challenges faced by the military in evaluating body composition. Even if BMI proved to be a satisfactory estimate of being overweight in a population, modest success in weight loss programs would not be adequately reflected in body weight changes. More studies are needed to confirm these results. One limitation of this study is the relatively small sample size. However, most of the studies conducted on a selected population who followed a very intense fitness program, such as the current one, also included

TABLE 3. Correlation matrix of fat mass and fat-free mass measured by dual-energy x-ray absorptiometry (DXA), skinfold thickness (SF), and air displacement plethysmography (BOD-POD).

	DXA/SF (1)	DXA/BOD-POD (1)	DXA/SF (2)	DXA/BOD-POD (2)	DXA/SF (3)	DXA/BOD-POD (3)
Fat-free mass	0.96	0.97	0.96	0.98	0.95	0.98
Fat mass	0.88	0.93	0.77	0.93	0.81	0.94

Table 4. Fat mass (FM) and fat-free mass (FFM) measurements by dual-energy x-ray absorptiometry (DXA), air displacement plethysmography (BOD-POD), and skinfold thickness (SF) at the beginning, in the middle, and at the end of the training period.

Variable	Start	Middle	End
Body composition			
FFM (kg) measured by DXA	68.8 ± 7.6	64.8 ± 6.6	68.7 ± 6.9
FM (kg) measured by DXA	10.3 ± 4	8.6 ± 3.6	8.9 ± 2.8
FFM (kg) measured by BOD-POD	67.9 ± 7.1	68.4 ± 8	70 ± 2.4
FM (kg) measured by BOD-POD	11 ± 3.7	8.9 ± 3.1	9.2 ± 2.9
FFM (kg) measured by SF	66 ± 7.2	65.4 ± 7.2	67 ± 6.8
FM (kg) measured by SF	12.7 ± 3.6	11.8 ± 3	12.4 ± 3.4

few subjects (1,20) because of the difficulty to complete the program. The particular training followed by the subjects in this study was difficult to perform and required a strenuous discipline. In this study, 27 men started the program and only 10 completed it. This ratio underlines the intensity and difficulty of the training. In conclusion, the findings suggest that for young men of normal weight, changes in body weight alone and in BMI are not a good measure to assess the effectiveness of intense physical training programs because lean mass gain can masquerade fat weight loss.

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