Physical Fitness of Soldiers Entering and Completing Basic Combat Training

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20000309 048

DTIC QUALITY INSPECTED 3

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
March 2000

3. REPORT TYPE AND DATES COVERED
USARIEM Technical Report

4. TITLE AND SUBTITLE
Physical Fitness of Soldiers Entering and Leaving Basic Combat Training

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute of Environmental Medicine, Natick, MA
U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen, MD
Moncrief Army Community Hospital, Ft Jackson, SC

8. PERFORMING ORGANIZATION REPORT NUMBER
T00-13

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This study examined the effectiveness of basic combat training (BCT) in improving the physical fitness of incoming soldiers and compared the physical fitness and trainability of current trainees to those measured in previous years. 350 soldiers (182 men and 168 women) were recruited from those entering two BCT battalions at the Ft Jackson Reception Station during May 1-14, 1998. Volunteers performed the following procedures before BCT: 1) continuous uphill treadmill running test of peak oxygen uptake (VO2peak); 2) one-repetition maximum (1-RM) isometric strength test of the lower body, upper torso and upright pulling strength; 3) 1-RM test of dynamic lifting strength; 4) dual-energy X-ray absorptiometry (DEXA) assessment of body composition; 5) anthropometric measurements (skinfolds and circumferences); 6) vertical jump; 7) photometric measurement of limb length and joint diameters; and 8) joint mobility measures. A subset (99 men and 101 women) of the original 350 soldiers were tested on procedures 1-6 during the last week of BCT. The mean $\pm$ SD age, height and body mass pre-BCT for men was 21.8 $\pm$ 3.4 yrs, 176.5 $\pm$ 7.0 cm, and 78.9 $\pm$ 12.8 kg and for women was 21.4 $\pm$ 3.4 yrs, 163.0 $\pm$ 6.1 cm and 63.6 $\pm$ 9.8 kg. The pre-BCT VO2peak of men was equivalent to that seen in previous years while that of women was higher than those tested 20 years ago ($p<0.05$). VO2peak increased following BCT (3.6% in men and 6.3% in women). Although only lower body strength increased with training, the strength of todays recruits was comparable to, or greater than, the strength of recruits measured 15-20 years ago. Women lost 3% body fat (%BF) and gained 2.5 kg of FFM. Men lost 2%BF and gained 0.8 kg FFM. The body mass of men measured in 1998 was significantly greater pre- and post-BCT than men measured 15-20 years ago. Pre-BCT, the women measured in 1998 had more body mass than women measured 15-20 years ago (9,20), but there was no difference post-BCT. In conclusion: 1) BCT resulted in improvements in aerobic capacity and body composition; 2) increases in muscle strength were minimal; 3) while body mass and %BF are higher now, aerobic capacity, muscle strength and FFM of today's trainees was comparable to, or better than trainees 15-20 years ago.

14. SUBJECT TERMS
Basic combat training, physical fitness, aerobic capacity, muscle strength, body composition, percent body fat, fat free mass, male, female, military, lifting strength, physical training

15. NUMBER OF PAGES
44

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

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BACKGROUND

In 1997, the U.S. Army Center for Health Promotion (USACHPPM) and Preventive Medicine, in conjunction with Moncrief Army Community Hospital and the U.S. Army Training Center, Ft. Jackson, SC established a center for the study of training-related injuries at Ft. Jackson. Two projects were proposed to demonstrate the potential of this center. The first was a records review of injuries associated with Army Basic Combat Training (BCT). It was designed as a pilot study to assist collaborators in understanding the training environment and to improve data collection techniques. This pilot study was completed in December 1997 (6). The second study was designed to further investigate injury incidence and risk factors and to study special BCT populations such as discharges and newstarts. The collaboration of the U.S. Army Research Institute of Environmental Medicine (USARIEM) was requested by COL Bruce H. Jones (USACHPPM) to assist in the injury risk factor analysis. In addition to providing this assistance, participation in this study provided USARIEM the opportunity to assess the physical fitness of incoming trainees and to examine the effectiveness of the physical training portion of BCT in improving physical fitness. The physical fitness results are reported here. The training injury data were published in a USACHPPM technical report (7).

ACKNOWLEDGMENTS

This major undertaking would not have been possible without the help and support of numerous individuals. First and foremost we would like to thank the soldiers who volunteered to participate. They were embarking on a new and challenging experience and agreed to accept yet another challenge.

The non-commissioned and commissioned officers at the 120th AG Replacement Battalion-Reception, (LTC Mark McAuley), the 3-13th (LTC Robert Redfern) and the 1-28th Infantry Training Battalions (LTC James Helis and LTC David Green) were instrumental in re-organizing the jam-packed training and in-processing schedules to allow the soldiers to be briefed, medically screened and participate in this study. A special thanks goes out to SFC Sandra Upshaw of the 120th AG Replacement Battalion. The study placed an additional burden on her coordination of troop movement through the reception station. Not only did she rise to meet the challenge of coordinating the subject briefings and testing, she also helped motivate the soldiers to participate in the study. Her positive, "can-do" attitude was truly invaluable.

We thank the Drill Sergeants Academy for allowing us to conduct our testing in their ballroom even though it meant re-scheduling classes, for entrusting us with the keys and for providing convenient access to a phone.

There were a number of hospital staff members who helped us get the job done: CW3 Jack Rosario, who conducted the electrical safety checks, oversaw installation of the 220 volt outlets needed for the DEXA device, had the air conditioning in the Drill Sergeants Academy fixed and provided a space in a warehouse for us to store our equipment between testing sessions; SGT Daniel Sugarman, who not only drove the truck to move our equipment in and out of storage, but also pitched in and carried the equipment; MAJ Daniel Harms, Chief, Moncrief Army Community Hospital Clinical Laboratory, whose personnel rapidly processed our samples, allowing the female subjects to be cleared for testing, COL Dale A. Carroll and COL Stephen G. Oswald, our medical monitors who spent many a late night clearing subjects for the next day's testing, and to USARIEM's own CPT Jonathan J. Canete, who medically cleared over 100 subjects in 2 days and briefed COLs Carroll and Oswald on our screening procedures.

An individual who deserves special recognition is Mr. Howard MacCollum. Mr. MacCollum, or "Mac", was there to fulfill our every request. He knew who to call for everything and, like most good NCOs (now ex-NCO), was able to call in a number of favors owed. He was cheerful and tireless in his assistance to us and was in many ways responsible for the success of this study.

Mr. Charlie Hansen, Mr. Joe Regan and Mr. Ed Moore, the DEXA team from Palmetto Imaging Services, were always on time, pleasant to work with and extremely efficient in their operation.

The authors would like to thank the USARIEM team that worked long hours (starting as early as 0430) under sometimes miserably hot conditions (over 100° during post-BCT) to collect the data (alphabetical order): SGT Rebecca Gregg, SPC Greg Loomis, Mr. Clay Pandorf, SPC Ty Smith, SSG Roberta Worsham, and SGT Tanya Zigmont. SPC Smith, SPC Loomis and SGT Gregg graciously agreed to drive the equipment back and forth to Ft. Jackson. SGT Gregg, SGT Zigmont and SPC Smith were instrumental in rapidly loading the data into a useable format. MAJ Joseph Creedon prepared the Epi-Info data entry process, instructed SSG Worsham and SGT Gregg in modifying it and oversaw the clean-up of the data file.

Without the hard work and dedication of the above mentioned individuals, as well as many others who were not mentioned by name, the study would not have been possible.

EXECUTIVE SUMMARY

This study examined the effectiveness of Basic Combat Training (BCT) in improving the physical fitness of incoming soldiers and compared the physical fitness and trainability of current trainees to those measured in previous years. 350 soldiers (182 men and 168 women) were recruited from those entering two BCT battalions at the 120th AG Replacement Battalion-Reception, Ft. Jackson and tested during May 1-13, 1998. Volunteers performed the following procedures before BCT: 1) continuous uphill treadmill running test of peak oxygen uptake ($\dot{V}O_2$peak); 2) one-repetition maximum (1-RM) isometric strength test of the lower body, upper torso and upright pulling strength; 3) 1-RM test of dynamic lifting strength; 4) dual-energy X-ray absorptiometry (DEXA) assessment of body composition; 5) anthropometric measurements (skinfolds and circumferences); 6) vertical jump; 7) photometric measurement of limb length and joint diameters; and 8) joint mobility measures. A subset (99 men and 101 women) of the original 350 soldiers were tested on procedures 1-6 during the last week of BCT. Two-way analysis of variance (ANOVA) with Tukey HSD post-hoc tests of significant time-by-gender interactions were used to examine changes pre- to post-BCT in this subset of soldiers. ANOVAs and comparison of means tests were used to compare the current soldiers with those tested 15-20 years ago. The mean ± SD age, height and body mass pre-BCT for men was 21.8 ± 3.4 yrs, 176.5 ± 7.0 cm, and 78.9 ± 12.8 kg and for women was 21.4 ± 3.4 yrs, 163.0 ± 6.1 cm and 63.6 ± 9.8 kg. The pre-BCT $\dot{V}O_2$peak of men (50.6 ± 6.2 $ml \cdot kg \cdot min^{-1}$) was equivalent to that seen in previous years, while that of women (39.7 ± 5.2 $ml \cdot kg \cdot min^{-1}$) was higher than those tested 20 years ago ($p<0.05$). $\dot{V}O_2$peak increased following BCT (3.6% in men and 6.3% in women), which was similar to increases in a previous study of basic trainees (17). Of the four strength measures, only lower body strength increased significantly at the end of BCT. Although the other strength measures did not increase, the strength of today's trainees was comparable to, or greater than, the strength of trainees measured 15-20 years ago (9,20). There was no change in body mass for the group as a whole, but a post-hoc Tukey test of the time-by-gender interaction revealed that men lost 1.2 kg ($p<0.05$), while the body mass of women did not change significantly (+0.8 kg). There were significant time, gender and interaction effects for percent body fat (%BF) and fat free mass (FFM) estimated using DEXA. Women lost 3% body fat and gained 2.5 kg of FFM. Men lost 2% body fat and gained 0.8 kg FFM. The body mass of men measured in 1998 was significantly greater before and after BCT than men measured 15-20 years ago. Pre-BCT, the women measured in 1998 had more body mass than women measured 15-20 years ago (9,20), but there was no difference post-BCT. It is concluded that 1) BCT resulted in improvements in aerobic capacity and body composition; 2) the increases in muscle strength were less than expected; 3) the aerobic capacity, muscle strength and body composition of today's trainees appear comparable to trainees tested 15-20 years ago, with the exception of a tendency for men to weigh more.

INTRODUCTION

The purpose of Army Basic Combat Training (BCT) is to begin the process of turning civilians into soldiers. There are rigorous physical and mental challenges presented during the 8 week course. Some of the physical challenges include loaded road marching, obstacle courses, confidence courses and 3-5 days per week of physical training. The objective is to prepare the soldier physically and mentally for further training in a military occupational specialty. The physical training is designed to raise the level of physical fitness of the least fit soldiers to a minimal acceptable standard. This standard is defined in terms of the Army Physical Fitness Test (APFT). Much of the physical training in BCT is devoted to the three elements of the APFT: sit-ups, push-ups and a 2-mile run for time.

A thorough evaluation of the strength, body composition and aerobic fitness of a large number of men (n=948) and women (n=496) entering and completing BCT was conducted in 1978 (9, 17). A four site skinfold estimate of body composition revealed significant improvements in body composition following BCT. These included decreases in percent body fat (%BF), and increases in fat free mass (FFM [9]). Isometric muscle strength of the upper and lower body improved between 4% and 16% ($p<0.01$) from pre- to post-BCT (9). $\dot{V}O_2max$ (ml•kg•min^{-1}) for uphill treadmill running, a measure of aerobic fitness, increased 3%-6% from pre- to post-BCT in a sub-sample of the 1978 population ($p<0.01$, [17]). When the data were grouped by aerobic fitness levels, only the lowest fit men and women showed a significant increase in $\dot{V}O_2peak$.

In 1983, the physical fitness of a large group of basic trainees (980 men, 1004 women) was assessed as a follow on to the 1978 study. Predicted aerobic fitness, body composition and muscle strength were measured before BCT. Ninety men and 113 women were also tested at the end of BCT and demonstrated improved aerobic fitness (9%-13%), increased muscle strength (8%-14%), decreased %BF (1.3%-2.3%) and increased FFM (2.4-2.6 kg, [20]). These changes were consistent with the 1978 study (9, 17).

In 1993, a study conducted by Westphal et al. (24) examined the physical performance and body composition of female basic trainees. Although no measure of aerobic capacity was made, the strength, vertical jump and body composition of 174 female soldiers were measured before and after BCT. Muscle strength increased 8-16% ($p<0.01$) and vertical jump increased 10% ($p<0.01$). Percent body fat decreased 2.2%, while FFM increased by 2 kg.

Data from these studies provide a historical comparison of the level of physical fitness of soldiers who entered the Army during the period 1978-1993. In addition, these BCT studies all measured the physical fitness of trainees before and after BCT. Thus the change in physical fitness achieved by the current trainees can be compared to them.

The BCT course at Ft. Jackson has undergone changes over the last 20 years. Two important changes that may affect the comparability of studies over the years are gender integration or segregation during BCT and the requirement to pass a physical fitness screening test before entering BCT. Prior to 1976, all BCT was conducted separately for men and women. From 1976-1982, men and women trained together. From 1983-1993 gender segregation was re-instituted. Training the genders together was resumed in mid-1993 and continues to the present time. Of the studies mentioned above, Knapik et al. (9) and Patton et al. (17) were gender integrated, while Teves et al. (20) and Westphal et al. (24) were gender segregated. During gender segregation, the program of instruction was identical for men and women, with the exception of medical exams and personal hygiene training. A study by Mottern et al. (16) has shown gender integrated training to be at least as effective as gender segregated training in developing soldierization skills.

A second major change to BCT was institution of the Fitness Training Unit (FTU) at Ft. Jackson in 1985. This program required trainees to physically qualify for BCT at the reception station. To enter BCT, male trainees had to perform at least 13 push-ups, and females had to perform at least one. In 1997, the entry criteria were changed to include sit-ups and a one-mile run. Entry to BCT and exit from FTU criteria in effect during the summer of 1978 are shown in Table 1.

Table 1. Passing scores in effect during this study for initial physical fitness screening test and score required to exit FTU to begin BCT.

	Men		Women	
	Minimum to enter BCT	Minimum to exit FTU	Minimum to enter BCT	Minimum to exit FTU
Push-ups (reps)	13	20	3	6
Sit-ups (reps)	17	21	17	21
1 mile run (min)	9	9	11	11

The purposes of the study reported here are 1) to examine the changes from pre- to post-BCT in aerobic capacity, muscle strength and body composition to evaluate the effectiveness of the physical training during BCT; and 2) to compare the physical fitness of a large sample of men and women entering Basic Combat Training in 1998 to data collected on similar populations between 1978 and 1993.

METHODS

SOURCE OF VOLUNTEERS

Volunteers were recruited from the 3-13th and 1-28th Infantry Training Battalions. Soldiers were briefed on the procedures and voluntary nature of the study at the Ft. Jackson 120th AG Replacement Battalion (Reception). Those who chose to participate were asked to read the volunteer affidavit agreement and sign it. Volunteers were medically cleared by a medical monitor prior to participation in any physiological testing procedures. Table 2 summarizes the number of soldiers briefed; who volunteered; who were not tested because they failed the initial physical fitness screening test, the medical screen or were not available for testing; and who were tested pre- and post-BCT. There was a 57% volunteer rate (53% of men volunteered, while 63% of women volunteered). Of the population briefed, 42.3% was tested pre-BCT (38% of men briefed and 47.5% of women briefed). 11% of the total number of volunteers did not participate in phyisological testing because they failed the initial physical fitness screening test. 4% of male volunteers failed the initial physical fitness screening test, while 16.1% of women volunteers failed. The racial distribution of the volunteers tested is in Appendix A, Table A-1.

Table 2. Soldiers (number) who were briefed, volunteered, tested and not tested.

	Men	Women	Total Sample
Briefed	474	354	828
Volunteered	251	224	475
Failed PT screen	18	36	54
Failed medical screen	10	5	15
Not tested other*	45	36	81
Tested pre-BCT	182	168	350
Tested pre- & post-BCT	99	101	200

*Scheduling conflicts or withdrew consent.

Pre-BCT testing of 350 soldiers was conducted in late May 1-13, 1998. Soldiers then began the 8 week Basic Combat Training Course with either the 3-13th or the 1-28th Infantry Training Battalion. Soldiers in the 3-13th attended BCT from 8 May-1 July. Soldiers in the 1-28th attended from 15 May-8 July. Both battalions followed the same program of instruction and were required to meet the same physical fitness standards. Two hundred of the same soldiers who participated in the pre-BCT testing were tested again during the last week of BCT (27 June- 5 July 1998).

MEASUREMENTS

Peak Oxygen Uptake

Aerobic power was measured using open circuit spirometry during a continuous uphill treadmill running protocol. The protocol was similar to the interrupted protocol used by Patton et al. in 1978 (17). The initial 5 min warm-up was at 0% grade and 2.68 $m \cdot sec^{-1}$ (6 mph) for men and 2.24 $m \cdot sec^{-1}$ (5 mph) for women. If the heart rate was less than 150 bpm by minute 5 of the warmup, treadmill speed was increased 0.45 $m \cdot sec^{-1}$ (0.5 mph) for the remainder of the test. Following the warm-up, the treadmill grade was increased by 2% every 3 minutes until there was an increase of less than 2 $ml \cdot kg \cdot min^{-1}$ (or 0.15 $l \cdot min^{-1}$) with an increase in treadmill grade, or until voluntary exhaustion. Volunteers wore a nose clip and were connected to the oxygen uptake measuring device via a low resistance non-rebreathing valve (Hans Rudolf, Inc, Kansas City, MO) and a mouthpiece. The on-line oxygen uptake system consisted of an Applied Electrochemistry S-3A oxygen analyzer (AEI Technologies, Pittsburgh, PA), a Beckman LB-2 carbon dioxide analyzer (Sensormedics, Inc., Yorba Linda, CA) and a K.L. Engineering flowmeter turbine (K.L. Engineering Turbine Company, Northridge, CA), interfaced with a Hewlett-Packard computer (model 9122, Hewlett-Packard, Palo Alto, CA). A single-lead EKG (model 1511B, Hewlett-Packard, Palo Alto, CA) was monitored by trained personnel during the test to determine heart rate and ensure the safety of the volunteer.

Muscle Strength

Three measures of maximum voluntary isometric strength were made. Upper torso strength (UT) was measured in a secured, seated position with the upper arms parallel to the floor and the elbow flexed to 90 degrees. The volunteer grasped a suspended 45.7 cm long piece of 3.2 cm diameter aluminum tubing and pulled maximally downward. Lower body (LB) strength was measured in a seated position with the knee angle set at 90 degrees. The volunteer pushed maximally against a stationary foot rest (9). 38 cm upright pulling strength (UP) was measured in a semi-squat position with the knees bent, the head up and the back straight (8). Volunteers grasped a taped aluminum bar 38 cm high attached via aircraft cable to a load cell mounted on a wooden platform and pulled vertically. For all three measurements (UT, LB, UP), force was applied smoothly, without jerking, reaching maximum within a 1-2 sec period and was held for 5-6 sec. The maximum force was measured by a Baldwin, Lima, Hamilton (BLH, Waltham, MA) load cell and displayed on a BLH model 450A transducer indicator. The mean of two of the highest of three trials within 10% of one another was recorded as the score for each test. Additional trials (to a maximum of five) were performed if the highest trial was more than 10% greater than the second highest trial. A minimum 1-min rest period was provided between trials.

Lifting strength was measured using the incremental dynamic lifting device (IDL). The test simulates lifting a box with handles from ground level onto a 2-1/2 ton truck. Volunteers lift handles attached to the carriage of a weight stack machine vertically from 20 cm to 152 cm. The carriage moves vertically between two guide rails. The lift begins with the subject grasping the handles of the weight carriage and assuming a bent-knee, straight back position with the head up and feet shoulder width apart. The load is accelerated upward by straightening the legs and pulling up on the handles of the weight carriage, which are held in an overhand grip. The wrists are simultaneously rotated under the handles and the load is pressed to the 152 cm mark on the vertical guides. The initial load is 18.2 kg and is increased in 9 kg increments for men and 4.5 kg increments for women until the volunteer begins to experience difficulty. At this time the increments are reduced by half (4.5 kg for men and 2.3 kg for women) until the volunteer is unable or unwilling to complete the lift using a safe technique. Volunteers were provided detailed instruction on lifting technique, adequate practice trials and inter-trial rest periods of a minimum of 1-min at near maximum loads (14, 19).

Leg Power/Vertical Jump

Leg muscle power was measured by vertical jump ability using a Vertec vertical jump meter (Sports Imports, Inc, Columbus, OH). The Vertec vertical jump meter consists of a 24 inch vertical, comb-like array of 48 evenly spaced horizontal vanes. These vanes easily pivot out of the way when they are touched. This array is atop a support that allows positioning from 6 to 12 feet above the floor. The subject stands immediately beneath the Vertec with heels together and reaches as far overhead as possible with one hand without lifting either heel off the floor. The technician adjusts the Vertec such that the bottom measurement vane just touches the subject's outstretched hand. The subject is instructed to jump as high as possible and to tap the measurement vanes at the top of the jump with the upward reaching hand. By touching the vanes the subject leaves a temporary, resettable record of the jump and reach. Because the vanes serve as a target for the jumpers they also serve as a motivator to encourage better performance. The subject performs three countermovement jumps, the maximal jump height is recorded and the measurement vanes are reset. A 45 sec rest is given between each jump. Leg power was estimated using the following equations (4) :

$$\text{Peak Power (W)} = 61.9 * \text{Jump height (cm)} + 36 * \text{Body mass (kg)} - 1822$$

$$\text{Average power(W)} = 21.2 * \text{Jump height (cm)} + 23 * \text{Body mass (kg)} - 1392$$

Body Composition

A four-site skinfold (biceps, triceps, subscapular, and supra iliac) estimate was made of body composition (3). Three measurements were made at each site by a trained technician using Harpenden calipers (Country Technology, Inc., Gays Mills, WI).

The U.S. Army circumference estimate of %BF was also made using a Gulik measuring tape (Lafayette Instruments, Lafayette, IN). For men, abdominal and neck circumference were measured. For women hip, forearm, neck and wrist circumferences were measured (2, 21). Subjects were asked their age. Height was measured using a stadiometer (Model GPM, Seritex, Inc, Carlstadt, NJ) and body mass was measured using a digital scale (Model 770, Seca Corp, Columbia, MD).

Dual energy X-ray absorptiometry (DEXA) was also used to estimate %BF (12). The volunteer was placed supine on a DEXA scanner table (Model DPXL, Lunar Corp, Madison, WI). The body was positioned so the head, trunk and pelvis were aligned and laterally centered on the table. The hands were rotated palm-downward. Approximately 45° of femoral external rotation was maintained through the placement of Velcro straps around the knees and forefeet. Scanning began at the head and progressed in 1 cm intervals to the toes with the machine set to the fast 10 min scanning speed. LUNAR software version 4.3 IQ provided an estimate of %BF, fat and non-bone lean tissue. Women volunteers were required to have a negative pregnancy test within 96 hours of testing.

Hamstring Flexibility

Hamstring flexibility was obtained using Well's sit and reach test and a "bender box" (23). The subject sat on the floor with their legs out straight in front of them. The stockinged feet were dorsiflexed with the soles flat against a wooden box. Attached to the top of the box was a moveable marker and a ruler measured in centimeters. The subject placed one hand over the other, and pushed the marker as far away as possible without bending the knees. Two practices were allowed and three trials followed. The best trial was the final score. Additional measures were also made, which are described in the Appendices (B. Joint Mobility and Anthropometric Measurements; C. Photometric Measurements) and will be reported separately.

Order of Testing

There were four testing stations, as follows: Station 1-$\dot{V}O_2$peak test; Station 2-flexibility, anthropometry, and photometric testing; Station 3- muscle strength and vertical jump; Station 4-DEXA. When a group of 16 volunteers arrived, four were assigned to each station. Volunteers proceeded to the next station immediately upon completing the previous station. Testing was conducted such that an inactive station was interspersed between two physically demanding stations.

Data Analysis

Descriptive statistics were calculated for the total group, as well as for each gender. Data were analyzed using a repeated measures analysis of variance (RM-ANOVA) design (pre- to post-BCT), with gender as a grouping factor. Tukey's HSD for unequal sample sizes was used to examine significant interaction effects. Multivariate analysis of variance was used to compare the outcomes from the three body composition estimation methods. SPSS (SPSS Inc, Chicago, IL) and Statistica (Statsoft, Tulsa, OK) software packages were used. Comparison of means tests (26) were used to compare the current sample to previous samples in cases where the previous data were not available. When previous data were available, one way and RM-ANOVAs were run separately for each gender. Where necessary, Tukey's HSD post-hoc tests for unequal sample sizes were used to examine the significance of differences between means.

RESULTS

DESCRIPTIVE DATA

The age, height and weight of the pre-BCT sample are listed by gender in Table 3. Men were significantly taller and heavier than women ($p<0.01$), but there was no difference in age between the genders.

Table 3. Descriptive data for pre-BCT sample.

	Women (n=168) Mean ± SD	Range	Men (n=182) Mean ± SD	Range
Age (yrs)	21.4 ± 3.4	18-33	21.8 ± 3.4	18-35
Height (cm)*	163.0 ± 6.1	149.6-179.3	176.5 ± 7.0	159.0-195.3
Weight (kg)*	62.6 ± 9.8	44.3-101.1	78.9 ± 12.8	48.2-126.5

* Men significantly different from women ($p<0.01$).

PEAK AEROBIC CAPACITY

Pre-BCT $\dot{V}O_2$peak

The cardiorespiratory measures made during the pre-BCT peak aerobic capacity test are listed in Table 4 for men and women. The female-to-male ratio (F/M) is also provided. Men had a higher aerobic capacity (absolute and relative to body weight) and a higher maximum ventilatory rate than women ($p<0.01$), but there was no gender difference in maximum heart rate or ventilatory equivalent (R). Figure 1, a frequency distribution of pre-BCT $\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$) of the entire sample, is skewed to the left. Figure 2 is a frequency distribution of pre-BCT $\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$) by gender, and illustrates the gender overlap.

Table 4. Cardiorespiratory measures made during the pre-BCT $\dot{V}O_2$peak test and the female-to-male ratio (F/M).

	Women (n=155)		Men (n=171)		F/M
	Mean ± SD	Range	Mean ± SD	Range	ratio
$\dot{V}O_2$peak ($\ell \cdot min^{-1}$)*	2.45 ± 0.42	1.7-3.9	3.92 ± 0.54	2.4-5.9	0.63
$\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$)*	39.2 ± 5.1	30-57	50.6 ± 6.2	36-70	0.77
$\dot{V}E$ ($\ell \cdot min^{-1}$)*	99.6 ± 15.0	53-137	141.6 ± 20.2	70-197	0.70
Heart rate ($beats \cdot min^{-1}$)	196.2 ± 9.5	160-220	196.7 ± 8.0	170-216	1.00
R ($\dot{V}CO_2/\dot{V}O_2$)	1.21 ± 0.08	0.93-1.58	1.21 ± 0.08	1.00-1.46	1.00

*Significant difference between genders (p<0.01).

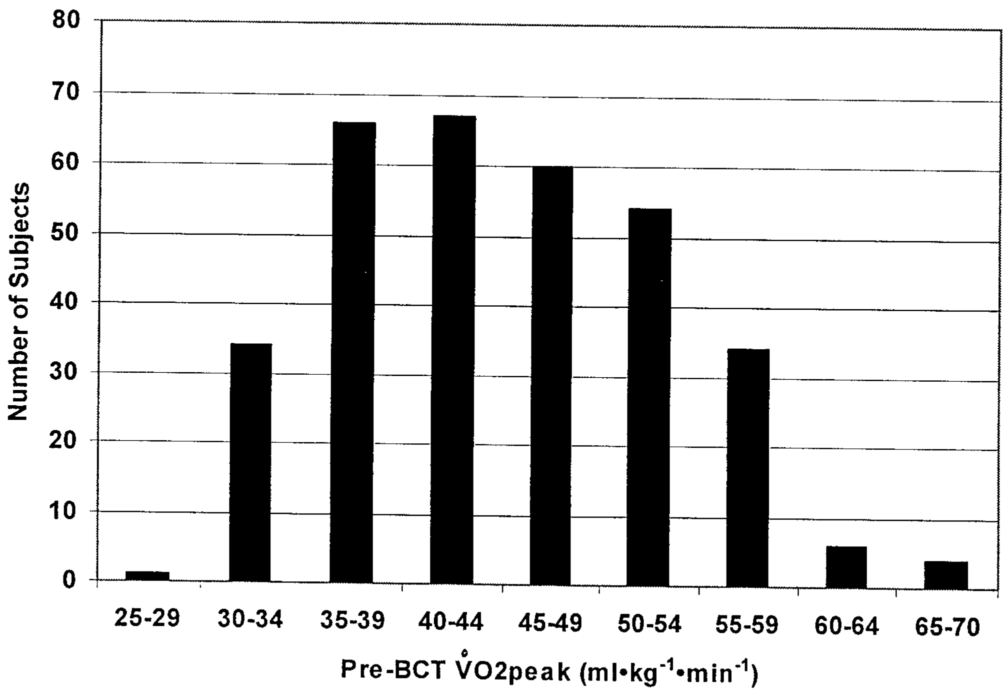

Figure 1. Pre-BCT frequency distribution of $\dot{V}O_2$peak (n=326)

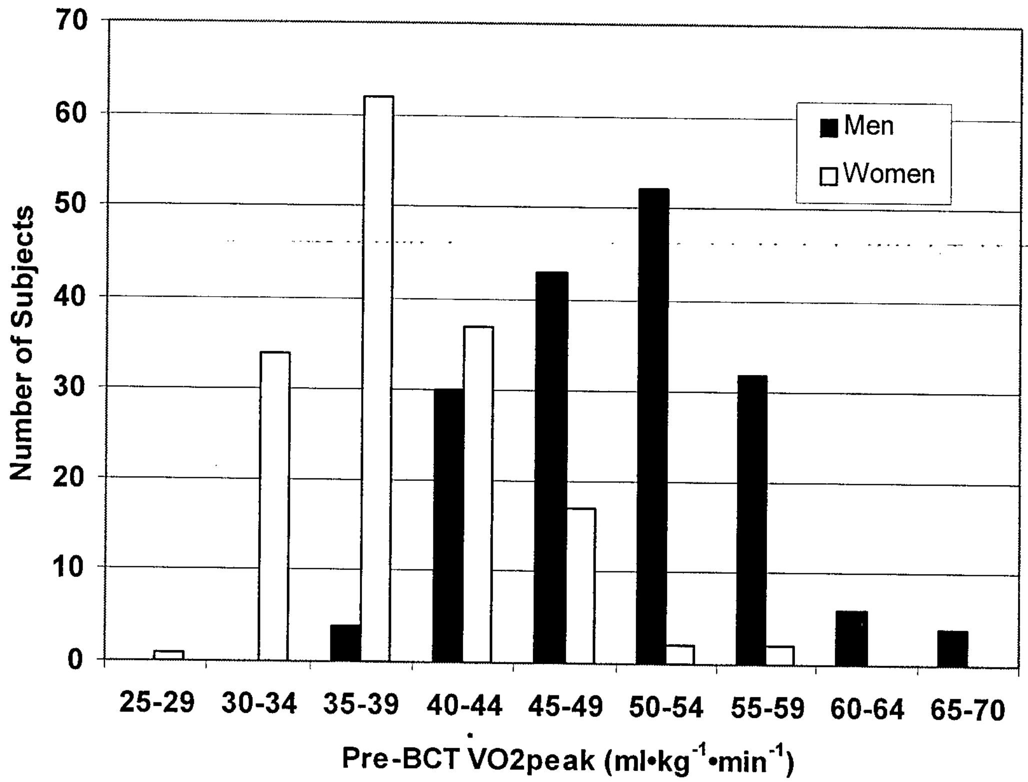

Figure 2. Frequency distribution of pre-BCT $\dot{V}O_2$peak (ml•kg^{-1}•min^{-1}) by gender

Pre- to Post-BCT Change in Aerobic Capacity

The data for peak aerobic capacity tests pre- and post-BCT are presented in Table 5. All measures changed significantly from pre- to post-BCT ($p<0.05$). $\dot{V}O_2$peak increased 2.3% and 3.6% in men and 7.3% and 6.3% in women in absolute (l•min^{-1}) and relative (ml•kg^{-1}•min^{-1}) terms, respectively. RM-ANOVAs revealed significant gender differences ($p<0.05$) for all measures except heart rate. Figure 3 depicts the change in relative aerobic capacity from pre- to post-BCT for both genders combined. The overall improvement in $\dot{V}O_2$peak is indicated by the shift of the curve to the right.

Table 5. Cardiorespiratory measures made during the pre- and post-BCT $\dot{V}O_2$peak tests (Mean ± SD).

	Men (n=91)		Women (n=80)	
	Pre-BCT	Post-BCT	Pre-BCT	Post-BCT
$\dot{V}O_2$peak ($l \cdot min^{-1}$)*	3.94 ± 0.51	4.03 ± 0.47	2.47 ± 0.43	2.65 ± 0.41
$\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$)*	50.6 ± 6.3	52.5 ± 5.6	39.7 ± 5.2	42.2 ± 4.8
$\dot{V}E_{BTPS}$ ($l \cdot min^{-1}$)*	142.5 ± 17.1	140.1 ± 17.9	99.4 ± 16.1	97.1 ± 14.6
Heart rate($beats \cdot min^{-1}$)*	196.1 ± 8.6	185.6 ± 8.1	195.6 ± 9.6	184.4 ± 7.3
R*	1.21 ± 0.08	1.14 ± 0.08	1.21 ± 0.07	1.12 ± 0.08

*Significant change pre- to post-BCT ($p<0.05$).

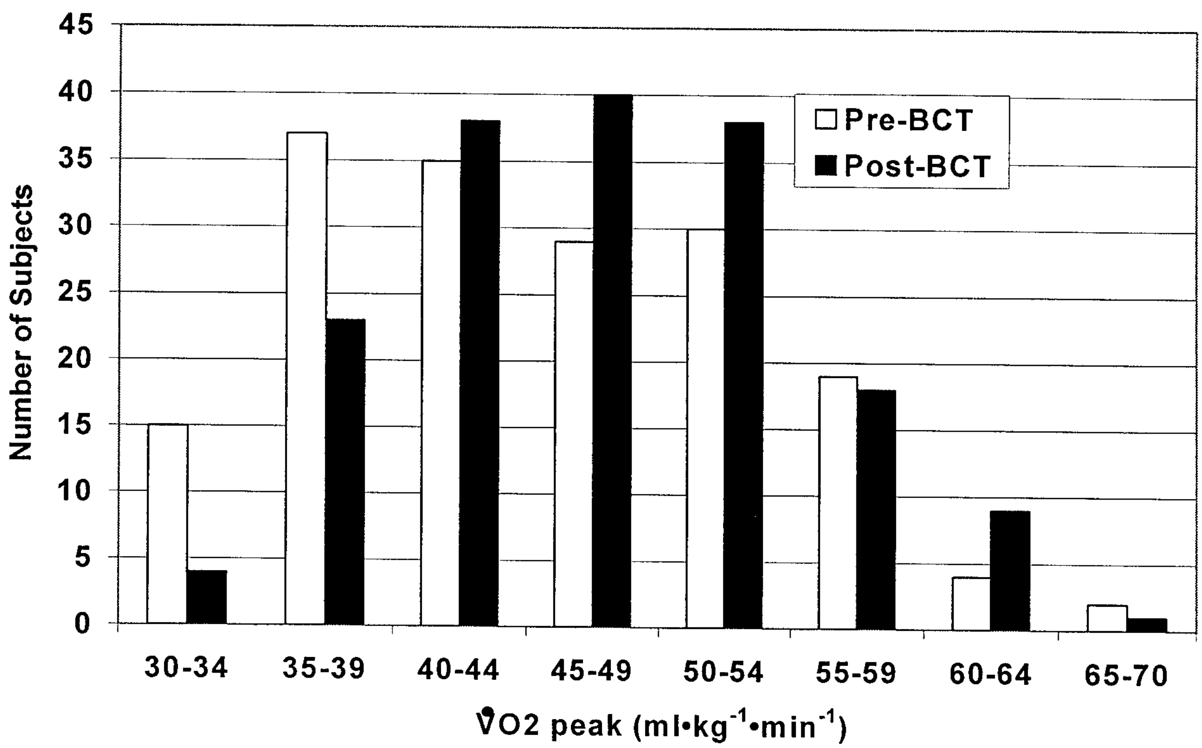

Figure 3. Pre- and post-BCT $\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$)

MUSCULAR STRENGTH

Pre-BCT Strength

The pre-BCT measures of isometric strength and IDL strength are listed by gender in Table 6. Men were stronger than women on all measures ($p<0.01$). The female to male strength ratio is also listed in Table 7. Women's UT strength was about 57% that of men's, while their LB strength was about 60% of men's.

Table 6. Muscle strength (kg) and the female to male (F/M) ratio pre-BCT.

	Women (n=168)		Men (n=182)		F/M
	Mean ± SD	Range	Mean ± SD	Range	ratio
UT *	64.9 ± 11.2	34.1-104.6	113.3 ± 17.3	81.4-174.6	.57
LB *,#	97.3 ± 24.8	45.0-201.0	158.6 ± 42.5	73.5-307.5	.61
UP *	81.9 ± 17.0	41.4-136.4	133.4 ± 24.8	69.8-200.0	.61
IDL *	40.0 ± 10.3	22.7-79.6	76.8 ± 15.6	40.9-118.2	.52

* Significant gender difference ($p<0.01$).
#The sample size for LB strength was 148 women and 148 men.

Pre- to Post-BCT Changes in Muscle Strength

The muscle strength before and after BCT is listed by gender in Table 7. There was a significant change in IDL (-1.0 kg) and LB isometric strength (+4.3 kg) from pre- to post-BCT ($p<0.05$) for both genders combined. The increase in LB isometric strength was driven by strength increases in women. A significant time-by-gender interaction effect for IDL was due to the strength decrease in men of 3.3 kg and concomitant increase of 1.4 kg in women. There were no significant changes in UP or UT isometric strength.

Table 7. UT, LB, UP and IDL muscle strength (kg) pre- and post-BCT (Mean ± SD).

	Women (n=99)			Men (n=99)		
	Pre-BCT	Post-BCT	%Δ	Pre-BCT	Post-BCT	%Δ
UT	65.6 ± 11.4	67.3 ± 11.3	2.6	113.7 ± 17.3	113.2 ± 16.2	0.0
LB[#,*]	96.7 ± 24.7	103.3 ± 25.6	6.7	160.5 ± 42.6	162.3 ± 39.9	1.1
UP	81.7 ± 19.4	85.3 ± 16.9	4.4	133.3 ± 23.6	133.2 ± 22.0	0.0
IDL[*,&]	40.7 ± 10.6	42.1 ± 9.6	3.4	76.5 ± 14.8	73.2 ±13.6	-4.3

[#]The sample size was 85 men and 88 women.
[*] Significant difference pre- to post-BCT ($p<0.01$).
[&] Significant time-by-gender interaction ($p<0.05$).

VERTICAL JUMP AND POWER OUTPUT

Pre-BCT Vertical Jump

Vertical jump height was used to estimate peak and mean power output during the take-off phase of the jump (4). These data are presented in Table 8. Men scored higher than women on all measures ($p<0.01$).

Table 8. Vertical jump height, peak power and mean power output for men and women pre-BCT.

	Women (n=168)		Men (n=182)		F/M
	Mean ± SD	Range	Mean ± SD	Range	ratio
Jump height (cm)[*]	32.8 ± 5.6	17-48	51.6 ± 8.1	33-76	.64
Peak power (W)[*]	2500 ± 559	1075-4454	4248 ± 673	2475-6178	.59
Mean power (W)[*]	766 ± 284	155-1780	1539 ± 338	747-2716	.50

[*] Men significantly different from women ($p<0.01$).

Pre- to Post-BCT Changes in Vertical Jump

The changes from pre- to post-BCT for vertical jump and the peak and mean power outputs are listed by gender in Table 9. There were significant gender and time effects in jump height, peak and mean power output ($p<0.01$). Jump height decreased 1 cm or 2.4% from pre- to post-BCT. There was a time-by-gender interaction for both measures of power. Examination of the data revealed that the men decreased more from pre- to post-BCT than the women.

Table 9. Changes in vertical jump height (JH), peak power (PP) and mean power (MP) from pre- to post BCT (Mean ± SD).

	Women (n=97)			Men (n=99)		
	Pre-BCT	Post-BCT	%Δ	Pre-BCT	Post-BCT	%Δ
Jump Height (cm)*	33.2 ± 5.2	32.8 ± 5.7	-1.2	51.1 ± 8.2	49.7 ± 8.1	-2.7
Peak Power (W)*,#	2512 ± 566	2496 ± 554	0.0	4191 ± 685	4050 ± 667	-3.3
Mean Power (W)*,#	766 ± 290	765 ± 276	0.0	1511 ± 341	1446 ± 321	-4.3

*Significant main effect pre- to post-BCT ($p<0.05$).
#Significant time-by-gender interaction ($p<0.05$).

BODY COMPOSITION

Pre-BCT Body Composition

Percent body fat (Table 10) and FFM (Table 11) were derived using DEXA, skinfolds and circumferences. Men had a lower %BF and more FFM than women.

Table 10. %BF estimated using DEXA, skinfold and circumference techniques pre-BCT.

	Women (n=168)		Men (n=182)		F/M
	Mean ± SD	Range	Mean ± SD	Range	ratio
DEXA*	29.0 ± 6.3	12.2-42.0	16.7 ± 6.4	4.5-32.0	1.74
Skinfold*	29.3 ± 4.2	16.8-39.1	18.7 ± 4.8	8.1-30.5	1.56
Circumference*	28.8 ± 4.3	14.7-38.8	16.9 ± 5.6	4.9-26.7	1.70

*Significant gender difference ($p<0.01$).

Table 11. FFM (kg) estimated using DEXA, skinfold and circumference techniques pre-BCT.

	Women (n=168)		Men (n=182)		F/M
	Mean ± SD	Range	Mean ± SD	Range	ratio
DEXA*	44.1 ± 5.5	33.0-72.4	65.2 ± 8.1	44.5-94.8	.68
Skinfold*	43.9 ± 5.5	31.6-64.3	63.7 ± 8.3	42.7-92.5	.69
Circumference*	44.3 ± 5.5	34.2-67.5	65.0 ± 8.0	45.4-96.5	.68

* Significant gender difference ($p<0.01$).

Pre- to Post-BCT Changes in Body Mass and Body Composition

Body composition and body mass data are presented for the pre- to post-BCT sample in Table 12. There was no change in body mass from pre- to post-BCT for the total group (69.9 - 69.7 kg); however, there was a time-by-gender interaction effect ($p<0.01$). A Tukey post-hoc test showed the body mass of women did not change significantly from pre- to post-BCT (+0.8 kg), while men decreased (1.2 kg, $p<0.05$).

Table 12. Body mass and body composition pre- and post-BCT by gender estimated using DEXA, skinfold and circumference techniques (Mean ± SD).

	Women (n=100)		Men (n=99)	
	Pre-BCT	Post-BCT	Pre-BCT	Post-BCT
Body mass*(kg)	62.0 ± 9.8	62.8 ± 9.4	78.0 ± 12.6	76.8 ± 11.2
%BF				
DEXA*,#	28.6 ± 6.0	25.6 ± 5.2	16.5 ± 6.4	14.4 ± 5.5
Skinfold	28.9 ± 4.0	27.3 ± 3.4	18.8 ± 4.6	17.7 ± 3.9
Circumference	28.6 ± 3.8	27.9 ± 3.5	16.6 ± 5.5	15.1 ± 4.2
FFM (kg)				
DEXA*,#	43.8 ± 5.7	46.3 ± 5.7	64.6 ± 8.0	65.4 ± 8.0
Skinfold	43.8 ± 5.7	45.3 ± 5.6	63.0 ± 8.2	63.0 ± 7.9
Circumference	43.9 ± 5.4	44.9 ± 5.3	64.6 ± 8.0	64.9 ± 8.0

*Significantly main effect pre- to post-BCT ($p<0.05$).
#Significant time-by-gender interaction effect ($p<0.05$).

RM-ANOVA revealed significant time, gender and interaction effects for %BF and FFM as measured by DEXA ($p<0.01$). Tukey post-hoc analysis of the interaction effect demonstrated a significant decrease in %BF of 2.1% and 3.0% in men and women, respectively. Since the decreases were similar in quantity and direction, it is unclear why there was a significant interaction term for %BF. Based on Tukey post-hoc analysis, men and women both increased FFM from pre- to post-BCT. Women gained about three times as much FFM as men (2.5 vs. 0.8 kg), resulting in the significant time-by-gender interaction for FFM.

Body Composition Comparison of Methods

Multivariate ANOVA was used to examine differences in the estimates obtained using the three different methods of body composition assessment. With the exception of the time-by-gender interaction for %BF, significant effects were found for all main effects and all interactions for %BF and FFM. Tukey post-hoc analysis of the method main effect found all estimates of %BF and FFM were significantly different from each other ($p<0.05$). The skinfold method produced the highest %BF (23.2%) and lowest FFM (53.8 kg), followed by the circumference method (22.1%BF, 54.6 kg FFM) and DEXA yielded the lowest %BF (21.3%) and highest FFM (55.0 kg) estimates. All methods of estimation detected an increase in FFM and decrease in %BF from pre- to post-BCT ($p<0.01$), based on Tukey post-hoc analysis of the time-by-method interaction. The decrease in %BF detected by DEXA (2.5%) was larger than that found using the skinfold (1.4%) and circumference (1.1%) methods. Since there was no change in body mass for the total sample, it follows that the increase in FFM detected by DEXA (1.7 kg) was greater than those detected by skinfold (0.8 kg) and circumference (0.7 kg) methods.

HAMSTRING FLEXIBILITY

There was a significant gender difference pre-BCT in hamstring flexibility, as measured by the bender box. Women (37.3 ± 7.3 cm) were more flexible than men (33.7 ± 7.4 cm, $p<0.05$). Hamstring flexibility increased from pre- (33.1 cm) to post-BCT (35.5 cm), and there was a significant time-by-gender interaction effect ($p<0.05$). Post-hoc analysis of the time-by-gender interaction revealed that the flexibility of men improved about twice as much as that of women from pre- to post-BCT (3 cm or 9.8% vs. 1.7 cm or 4.8%).

LIMITATIONS OF THE DATA

Prior to a discussion of the results, it is important to consider the limitations of the data. Unlike soldiers tested in the past, the current soldiers were required to pass an initial physical fitness test before they began training. The test included a 1-mile run for time, sit-ups and push-ups. The requirements for passing each event are in Table 1. A trainee failed the test if they failed any one event. Overall, 6.9% of the men and 23.9% of the women failed the initial physical fitness screening test from January through August of 1998. Although these figures are not for the specific time period of this study, they are the only figures available. Soldiers failing the initial physical fitness screen would be 3 weeks behind their peers in entering BCT, and therefore did not participate in our study. This loss of the least fit of new recruits may have biased the results. For example, 2 mile run time has been shown to be correlated ($r=-0.76$ to -0.91) with peak oxygen uptake (5,15). The correlation was lower for the subjects that participated in this study ($r=-0.52$ for men, $r=-0.56$ for women (Table 13). It should be noted that these were not experienced runners, and the physical fitness screening test is a 1- rather than a 2-mile run. Of the sample who volunteered, 7 men (3.1%) and 20 women (8.9%) were unable to participate because they failed the physical fitness screening test. Of the soldiers tested between January and August 1998, only 3.6% of the men and 8.8% of the women who failed the physical fitness screen failed the run portion of the test. This means that less than six women and five men who volunteered for this study did not participate because they failed the run. It is unlikely that this small number would skew the means for $\dot{V}O_2$peak testing. The calculations used to determine this number are in Appendix D.

Push-ups and sit-ups are tests of muscular endurance rather than maximum muscular strength, as measured by the isometric and dynamic strength measures made during this study. Although a relationship between muscular strength and push-ups and sit-ups has been previously reported (5), the current correlations between the physical fitness screening test items and the strength measurements are not strong enough for the loss of volunteers to have greatly biased the strength scores. Sit-ups were not highly correlated with the measures of muscular strength made in this study (range for men r=0.04-0.14 and for women r=-0.06- 0.06, see Table 13). The correlations between push-ups and muscular strength ranged from r=0.21- 0.35 in men and from r=0.05- 0.19 in women. Although some of these relationships were statistically significant, push-ups accounted for no more than 12% of the variability in any of the strength measures performed by either gender.

Table 13. Correlations between APFT events and measures of strength and aerobic capacity pre-BCT for the combined sample and for men and women separately.

	Push-ups			Sit-ups			2 mile run		
	Both	Men	Women	Both	Men	Women	Both	Men	Women
IDL	0.64*	0.21*	0.06	0.20*	0.06	-0.03	-0.47*	-0.01	0.03
UT	0.72*	0.35*	0.17*	0.25*	0.14	0.06	-0.52*	-0.01	-0.12
LB	0.60*	0.26*	0.19*	0.18*	0.04	0.05	-0.42*	-0.08	-0.07
UP	0.62*	0.21*	0.05	0.20*	0.10	-0.06	-0.46*	-0.02	-0.05
$\dot{V}O_{2peak}$	0.63*	0.24*	0.28*	0.31*	0.20*	0.25*	-0.71*	-0.52*	-.0.56*

*($p<0.05$)

In addition to subject selection, there were several things that may have affected the post-BCT performance scores. Due to scheduling problems, the soldiers were post-tested 30-72 hours after a physically demanding field training exercise (FTX). The final night of the FTX included a 100 yard low crawl with weapons and a 12 km loaded road march. Many soldiers sustained minor injuries (blisters, contusions and lacerations). Despite receiving a full night of sleep prior to testing, most appeared mentally and physically fatigued. This is likely to have had the greatest effect on the muscle strength measurements, which require a maximum voluntary effort. To exacerbate the fatigue of the soldiers, the air conditioning at the post-BCT testing site was not functioning. Outside temperatures were above 100° F every afternoon. Large room fans circulated air on volunteers at each testing station, cold fluids were provided and most testing was conducted before noon to compensate for this. When exercising in the heat, blood is directed away from the exercising muscle to the surface blood vessels to reduce body heat. Even in this acclimatized population, it is likely that the heat attenuated the aerobic training response, since $\dot{V}O_2max$ is reduced in a hot environment (13).

DISCUSSION

The discussion will be divided into two sections. Section one compares the initial fitness level of soldiers entering the Army in 1998 to that of soldiers measured over the past 20 years. Section two compares the pre- to post-BCT changes in physical fitness observed in soldiers today with those from previous years. The previous samples for which the original data were available were measured in 1978 (9,17), 1983 (20) and 1993 (24). For section one, the analyses used were t-tests (when there were only two groups for a given variable) or one-way ANOVAs (when there were more than two groups). For section two, RM-ANOVAs were used to examine the differences between subject samples before and after BCT. For both sections, the analyses were run separately by gender and Tukey post-hoc tests for unequal sample sizes were used to determine where the differences between means lay. When the original data were not available, Comparison of Means Tests were used to assess group differences (26).

Table 14 lists the pre-BCT age, height and weight of volunteers from the four studies. The current soldier tends to be slightly older and the men tend to be taller than those measured previously. While the difference in age was statistically significant, it is of little practical significance. Of more concern is the greater body mass of today's soldiers. This potentially represents a health risk particularly in the men who were 8 kg (12%) heavier than those measured in 1978.

Table 14. Comparison of current subject descriptors with previous studies.

	Year	Men n	Men Mean ± SD	Women n	Women Mean ± SD
Age (yrs)	1978 (9)	955	19.9 ± 2.7[a]	506	20.7 ± 3.2[a,b]
	1985 (20)	980	19.5 ± 2.5[b]	1004	20.4 ± 3.3[a]
	1993 (24)	**	**	176	21.4 ± 3.4[b]
	current	182	21.8 ± 3.4[c]	168	21.4 ± 3.4[b]
Height (cm)	1978 (9)	955	174.3 ± 6.6[a]	506	162.5 ± 6.8
	1985 (20)	980	175.1 ± 6.8[b]	1004	162.6 ± 6.3
	1993 (24)	**	**	174	163.0 ± 6.5
	current	182	176.5 ± 7.0[b]	168	163.0 ± 6.1
Weight (kg)	1978 (9)	955	70.7 ± 10.8[a]	506	59.0 ± 7.2[a]
	1985 (20)	980	72.9 ± 10.8[b]	1004	58.5 ± 6.7[a]
	1993 (24)	**	**	174	62.2 ± 9.0[b]
	current	182	78.9 ± 12.8[c]	168	62.6 ± 9.8[b]

[a] Different letters represent a significant difference for that variable, within each gender ($p<0.05$).
**No men were tested during this study.

SECTION 1: PRE-BCT PHYSICAL FITNESS OF ARMY TRAINEES: PRESENT AND PAST

The anecdotal comments of experienced drill sergeants, members of the U.S. Army Physical Fitness School (personal communication), and reports in the literature for U.S. adolescents (1,10), would lead to the hypothesis that the entry level physical fitness of today's trainees is lower than in previous years. Using objective measurement techniques, this study examined three aspects of physical fitness: cardiorespiratory fitness, muscle strength and body composition. The results from soldiers measured on these three aspects will be compared to those from previous years to determine if the soldiers entering BCT today are less physically fit than those entering 15-20 years ago.

Cardiorespiratory Fitness

The pre-BCT $\dot{V}O_2$peak of the current sample of men (50.6 $ml \cdot kg^{-1} \cdot min^{-1}$) was equivalent to previous samples measured in 1975 (50.8 ml•kg^{-1}•min^{-1}, [22]) and 1978 (50.7 ml•kg^{-1}•min^{-1}, [17]). The mean $\dot{V}O_2$peak of women measured pre-BCT in 1998 (39.2 ml•kg^{-1}•min^{-1}) was slightly higher ($p<0.05$) than women in 1975 (38.1 ml•kg^{-1}•min^{-1}, [22]) and significantly different ($p<0.05$) from those measured in 1978 (36.9 ml•kg^{-1}•min^{-1}, [17]). Based on the aerobic fitness categories of Shvartz and Reibold (18), the current values for $\dot{V}O_2$peak put the incoming soldiers in the "good" category, which is third from the highest of seven categories. These data show that soldiers entering BCT today are as aerobically fit as they were 20 years ago, and the women may be in slightly better aerobic condition.

Muscle Strength

UP and LB strength were measured before and after 7 weeks of Basic Combat Training in men and women by Knapik et al. in 1978 (9). The mean UT strength of soldiers tested in 1998, was more than 15% higher before BCT ($p<.05$) than those tested in 1978 (men: 113.3 kg vs. 97.2 kg; women: 64.9 kg vs. 54.9 kg). The 1998 soldiers also performed better ($p<0.05$) on the test of LB strength pre-BCT than those in 1978 (men: 158.6 kg vs. 142.4 kg; women: 97.3 kg vs. 91.4 kg).

Isometric UP and IDL were measured in men and women pre-BCT in 1983 (20). IDL was also measured in women pre-BCT in 1993 (24). The UP strength of 1998 trainees was significantly greater ($p<0.05$) than that of the 1983 trainees upon entry to BCT (men: 133.4 kg vs. 128.4 kg; women: 82.0 kg vs. 77.1 kg). 1998 men and women lifted more weight during the pre-BCT IDL than those measured in 1983 (men: 76.5 kg vs. 61.1 kg; women: 40.7 kg vs. 30.4 kg). There was no difference in IDL strength between women in the current study and those measured in 1993 (39.7 kg, [24]). The apparent increase in IDL scores over time is likely due to differences in the testing methods. During the two later studies (24, present), the minimum increases in load were smaller (2.3 vs. 4.6 kg), adequate rest was allowed between lifting attempts and more emphasis was placed on lifting technique than during the 1983 study (20).

The initial strength levels of new trainees are comparable to, or greater than those seen in trainees 10-20 years ago. As with the initial level of aerobic fitness, these results do not support the hypothesis that young people entering the Army today are less physically fit than those who entered 15-20 years ago.

Body Composition

The third aspect of entry level physical fitness to be compared with previous groups is body composition. Body mass and composition were measured in basic trainees at Ft. Jackson in 1978, 1983 and 1993 (women only). In all samples, %BF and FFM were determined using the Durnin and Womersley (3) equation based on the sum of four skinfolds.

As illustrated in Figure 4, the body mass of soldiers was greater over time. The current trainees were heavier pre-BCT than those measured 15-20 years ago ($p<0.05$), but there was no significant difference in body mass between the women trainees measured in 1993 (24) and the current women. Increasing body mass appears to be a greater problem in men than in women. Men in the current study were 10% heavier and women were 6% heavier than those measured in 1978 (9). Although the current group of soldiers was significantly taller, this was not simply a function of soldiers getting bigger. %BF has also increased over time in male basic trainees (Figure 5). The current group of men had significantly higher %BF and more FFM pre-BCT than the previous groups. In contrast, women did not demonstrate a continuous increase over time (Figure 6). The pre-BCT %BF of the current women (29.3%, $p<0.05$) was greater than that of 1978 (9) and 1983 women (20), but less than the 1993 women (24). The current women's FFM was greater ($p<0.05$) than that of women measured in 1978 (9) or 1993 (24), but not different from those measured in 1983 (20). While the initial body mass and %BF of men and women entering the Army did not compare favorably to previous years, the level of FFM increased. This is positive, as FFM is the metabolically active tissue used to perform physically demanding tasks. More FFM is typically associated with better performance on strength demanding tasks, particularly tasks requiring movement of an external load such as lifting, carrying and loaded rucksack marches.

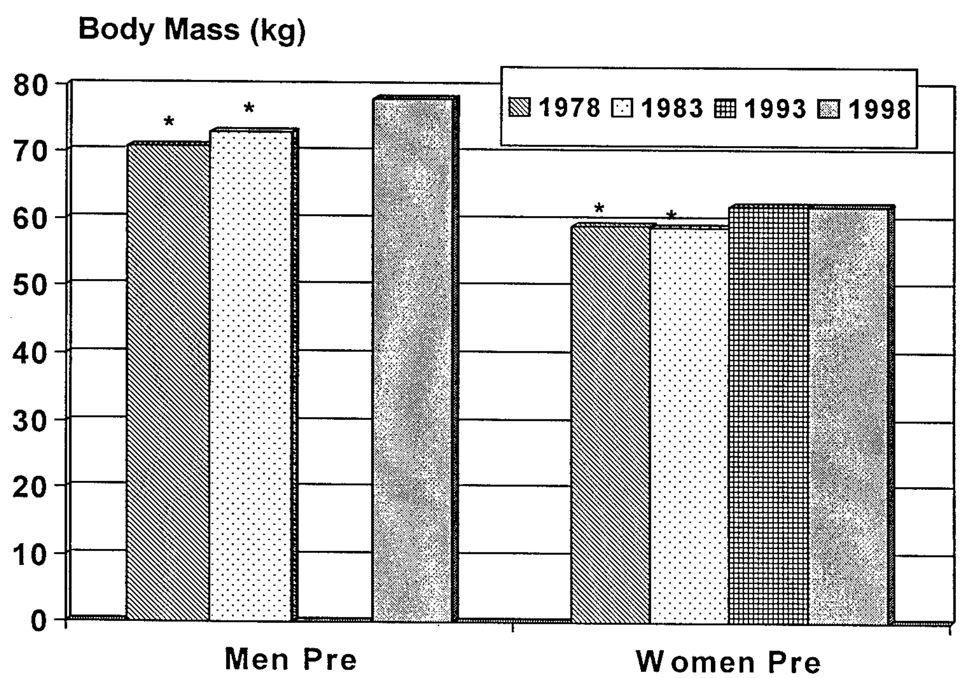

Figure 4. Body mass (kg) in male and female trainees measured at Ft. Jackson pre-BCT in 1978 (9), 1983 (20), 1993 (women only, [24]) and 1998 (present data)
*Different from 1998 ($p<0.05$)

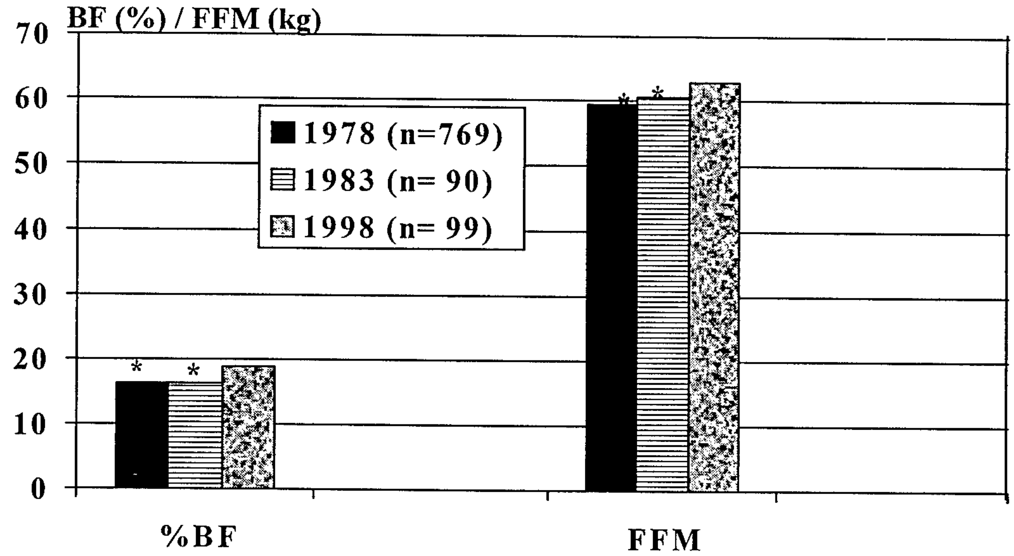

Figure 5. Percent body fat (%BF) and fat free mass (FFM) of men pre-BCT in 1978 (9), 1983 (20) and 1998 (present data). *Different from 1998, ($p<0.05$)

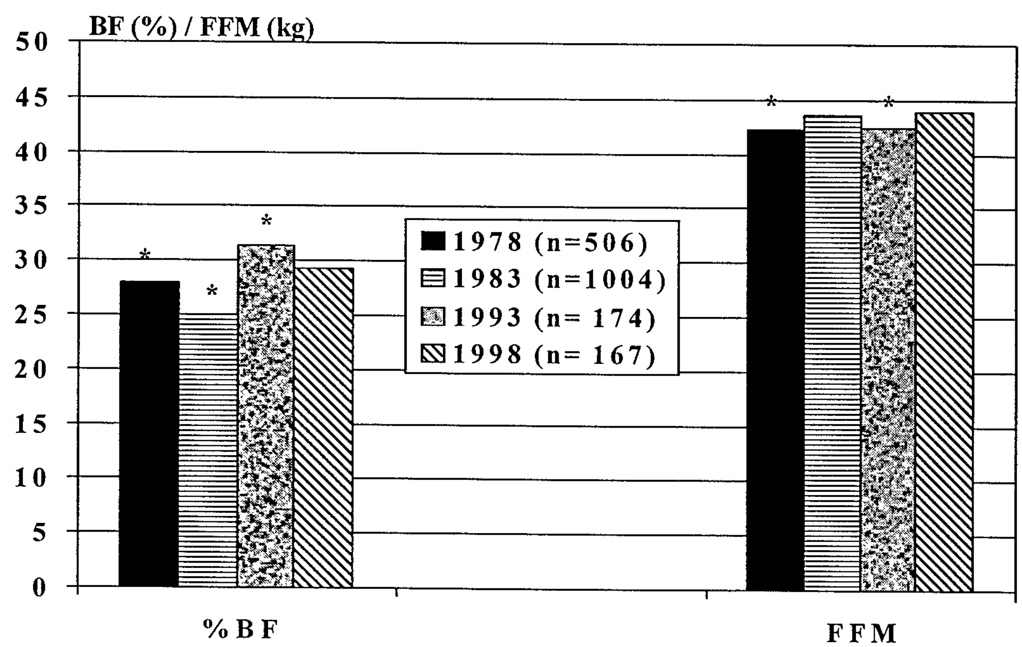

Figure 6. Percent body fat (%BF) and fat free mass (FFM) of women pre-BCT in 1978 (9), 1983 (20), 1993 (24) and 1998 (present data). *Different from 1998 ($p<0.05$)

Overall, when one compares the entry level physical fitness of soldiers measured for this study to those measured 15-20 years ago, most differences are minor. Soldiers today enter BCT with similar or higher levels of aerobic fitness, muscle strength and FFM. Unfortunately, they also enter with more body mass and body fat.

SECTION 2: CHANGES IN PHYSICAL FITNESS PRE- TO POST-BCT

Aerobic Fitness

Examination of the change in aerobic fitness for the present group compared to previous groups of soldiers in BCT indicates a similar training effect was achieved (Table 15). The range of increase reported in previous Basic Combat Training studies of directly measured $\dot{V}O_2$peak was 3.2%-8.0% for men, compared to the current 3.6%, and 3.7%-6.5% for women compared to the current 6.3% (17,22). BCT was as effective in improving the aerobic fitness of trainees in this study as it was 15-20 years ago. RM-ANOVA comparing the current data to that from Patton et al. (17) showed no between group differences in men. There was a significant group effect for women, with 1998 women achieving a higher $\dot{V}O_2$peak than those of Patton et al. ($p<0.05$). The men measured by Vogel et al. in 1975 (22) had two times the increase in $\dot{V}O_2$peak of other groups of men, while the 1975 women had half the increase of 1978 and 1998 women. This may be partially explained by differences in BCT. BCT was gender-integrated in 1978 and 1998, but gender-segregated in 1975. In addition, the physical training program was minimal for 1975 women. These results suggest that gender-integrated training might be better for improving aerobic capacity in women, but not optimal in men. This theory is not supported by the data of Mottern et al. (16) who reported that men and women in gender-integrated companies tended to perform better on the APFT. The only exception to this was push-ups in men, where gender-segregated companies proved superior. The physical training intensity for women was relatively less than that for men in 1975 and this, rather than gender integration or segregation, probably accounts for the reduced training effect in 1975 women (22). While the increases in $\dot{V}O_2$peak of the current sample were similar to those of Patton el al., it is probable that the increases would have been greater had the temperature of the post-BCT testing facility been lower and the soldiers more rested.

Table 15. Comparison of directly measured $\dot{V}O_2$peak ($ml\bullet kg^{-1}\bullet min^{-1}$) of 1998 and previous year trainees (Mean ± SD).

Reference	year[1]	n	$\dot{V}O_2$peak pre-BCT	$\dot{V}O_2$peak post-BCT	% Δ
Men					
Vogel et al. (22)	1975	186	50.8 ± 6.1	54.9[2]	8.0
Patton et al. (17)	1978	78	50.7 ± 4.7	52.3 ± 4.0	3.2
Present study	1998	91	50.6 ± 6.3	52.5 ± 5.6	3.6
Women					
Vogel et al. (22)	1975	159	38.1 ± 3.5	39.5*	3.7
Patton et al. (17)	1978	62	36.9 ± 3.6[3]	38.9 ± 3.5*	6.5
Present study	1998	80	39.7 ± 5.2	42.2 ± 4.8	6.3

[1] Year of data collection.

[2] Extrapolated from % Change data reported by Vogel et al. (22).

* Different from present study using comparison of means test ($p<0.05$).

The $\dot{V}O_2$peak of untrained, young adults would be expected to increase 10%-20% following a well designed, 6-8 week aerobic training program (25). This is greater than the improvement seen here of 3.6% in men and 6.3% in women, and greater than that seen in previous studies of basic trainees. It should be remembered, however, that the main purpose of BCT is not to create aerobic athletes, but to raise the fitness of all soldiers to a minimum acceptable level. Patton et al. (17) divided subjects into five fitness categories for men and four for women. Only men and women in the lowest two fitness categories (men below the range of 49-52 $ml\bullet kg^{-1}\bullet min^{-1}$ and women below the range of 38-41 $ml\bullet kg^{-1}\bullet min^{-1}$) showed a significant increase in aerobic capacity from pre- to post-BCT. When the current data were analyzed using the same categories, the results were similar. Figure 7 illustrates that only men in the lowest aerobic fitness category (<46 $ml\bullet kg^{-1}\bullet min^{-1}$) improved significantly (9.8%, $p<0.05$). As shown in Figure 8, women in the lowest two categories (<35 $ml\bullet kg^{-1}\bullet min^{-1}$ and 35<38 $ml\bullet kg^{-1}\bullet min^{-1}$) improved (16.7% and 14.5%, respectively, $p<0.05$). This indicates that BCT is raising the aerobic fitness level of soldiers most in need of improvement, thus increasing the likelihood of success in their assigned jobs. The less positive aspect of this finding is that the ability group running does not appear to result in improved fitness for the most fit ability groups.

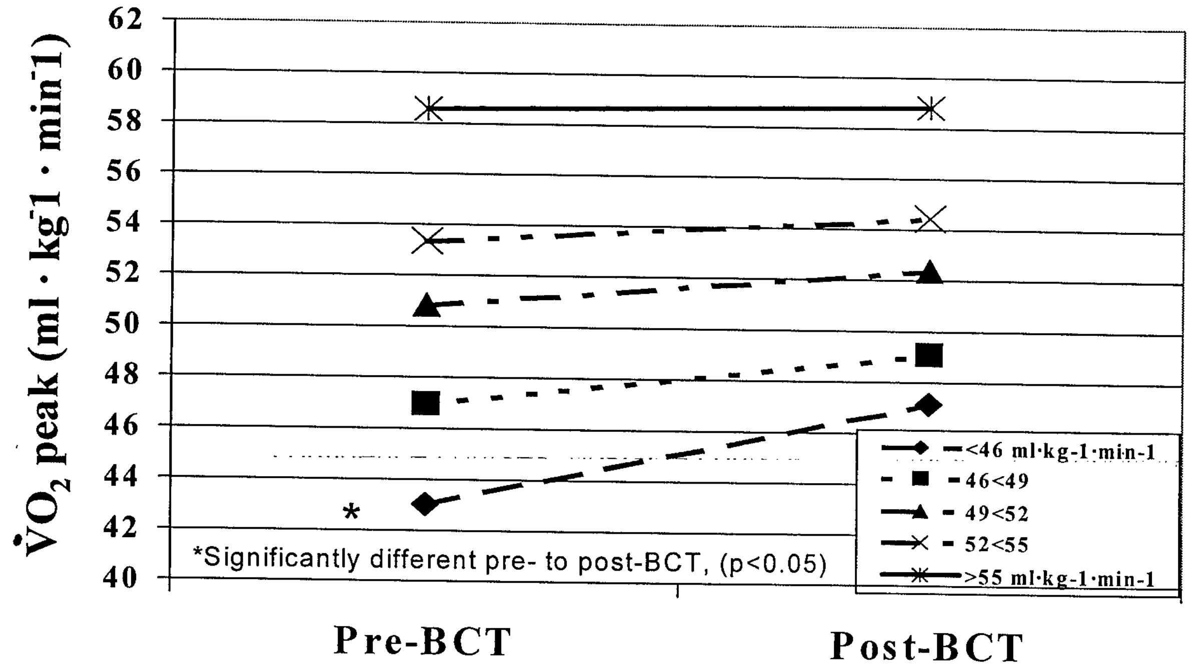

Figure 7. Change in $\dot{V}O_2$peak pre- to post-BCT in men grouped by the aerobic fitness categories of Patton et al. (17)

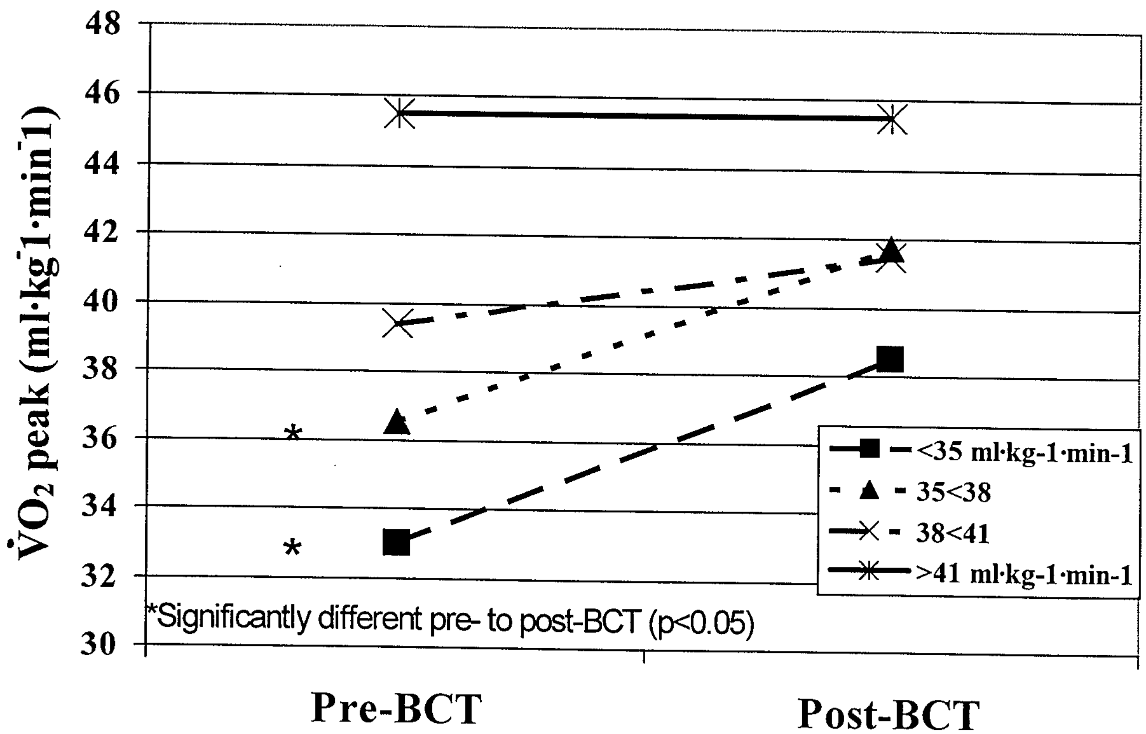

Figure 8. Change in $\dot{V}O_2$peak pre- to post-BCT in women grouped by the aerobic fitness categories of Patton et al.(17)

Muscle Strength

Although changes in muscle strength with progressive resistance training vary with the type of training program implemented, an untrained young adult would be expected to increase 1-RM strength 5%-15% during an 8 week period (25). The physical training which occurs during BCT typically does not include progressive resistance training exercises or equipment. Rather, the "strength" portion of morning physical training consists mainly of exercises involving the movement of body weight such as sit-ups, push-ups, jumping jacks and squat thrusts. Other training such as confidence courses, obstacle courses, net climbing and repelling would likely involve strength, but are not done frequently enough to exert a strong effect on the strength development and testing. This training would not be expected to produce dramatic increases in muscle strength. As mentioned in the results section, no large increases in strength were found. The men showed no increase in any of the strength measures, and decreased in IDL strength. The women had small increases in strength ranging from 2.6% in UT strength to 6.7% for LB strength.

The changes observed in UT and LB strength were smaller in 1998 than in 1978 (Tables 16 and 17, [9]). RM-ANOVA for UT strength revealed significant ($p<0.05$) group (1998 > 1978), time (increase pre- to post-BCT) and time-by-group interaction effects in both genders. Tukey post-hoc analysis of the interaction effect showed 1998 men and women had more UT strength before and after BCT than 1978 men and women, but did not significantly increase from pre- to post-BCT as seen in 1978 men and women. As the pre-BCT UT strength of 1998 soldiers was greater than those measured in 1978, the initial strength level may have left less room for improvement.

Table 16. Comparison of UT strength (kg) of 1998 and 1978 trainees (Mean ± SD).

Reference	Year[1]	n	pre-BCT	post-BCT	% Δ
Men					
Knapik et al. (9)	1978	733	97.8 ± 18.2*	102.1± 16.2*	4.2
Present study	1998	98	113.7 ± 17.3	113.2 ± 16.2	0.0
Women					
Knapik et al. (9)	1978	359	55.3 ± 11.8*	61.0 ± 9.6*	9.3
Present study	1998	99	65.6 ± 11.4	67.3 ± 11.3	2.6

[1] Year of data collection

*Significantly different from present study at same time of measurement ($p<0.05$).

RM-ANOVA for LB strength also resulted in significant group (1998>1978), time (increase pre- to post-BCT) and interaction effects for the men ($p<0.05$). There was no group difference for women; however, the time and interaction effects were significant ($p<0.05$). The change in LB strength in 1998 men was negligible (1.1%) compared to that of the 1978 men (11%), and 1998 women increased about half as much as the 1978 group (7% vs. 14%). While 1998 men had greater LB strength at the beginning of BCT, they were not different from the 1978 soldier at the end of BCT. Legg and Duggan (11) reported a 4.2% decrease in LB strength of British male trainees after 3 months of basic training. The reason given for this decrease in strength was that half of the sample had finished a fatiguing road march 6 hours prior to post-basic training testing. Since 1998 women did not have higher pre-BCT LB strength than those measured in 1978 (9), it is likely that the lesser training response observed in 1998 women was mainly due to the fatiguing FTX. In 1998 men, the diminished training response for LB strength may be attributed to both a higher initial strength level and the fatiguing effect of the FTX.

Table 17. Comparison of LB strength (kg) of 1998 and previous year trainees (Mean ± SD).

Reference	Year[1]	n	pre-BCT	post-BCT	% Δ
			Men		
Knapik et al. (9)	1978	737	143.2 ± 38.4*	158.2 ± 41.1	10.6
Legg & Duggan (11)	1987	57	132.6 ± 25.8#	127.0 ± 17.4#	-4.2
Present study	1998	85	160.5 ± 42.6	162.3 ± 39.9	1.1
			Women		
Knapik et al. (9)	1978	348	93.4± 30.0	106.6 ± 31.1	14.0
Present study	1998	88	96.7 ± 24.7	103.3 ± 25.6	6.8

[1]Year of data collection
*RM-ANOVA: significantly different from pre-BCT men in present study ($p<0.05$).
#Comparison of Means Test: significantly different from present study ($p<0.05$) at same time of measurement.

There were no group differences (1983 vs. 1998) in UP strength, but both time and interaction effects were significant ($p<0.05$) in men and women. As shown in Table 18, the UP strength of 1998 men was not significantly changed from pre- to post-BCT. This is in contrast to the 10.7% increase in strength ($p<0.05$) achieved by the 1983 men (20). While both groups of women increased UP strength from pre- to post-BCT, the 1983 women (20) had a greater increase (12.5%) than the current women (4.4%).

Since initial strength levels of men and women were similar to those from previous studies, the reduced training effect in UP strength may be primarily attributed to the fatiguing effect of the FTX.

Table 18. Comparison of UP strength (kg) of 1998 and 1993 trainees (Mean ± SD).

Author	Year[1]	n	pre-BCT	post-BCT	% Δ
Men					
Teves et al. (20)	1983	90	128.4 ± 18.7	142.2± 21.4*	10.7
Present study	1998	99	133.3 ± 23.6	133.2± 22.0	0.0
Women					
Teves et al. (20)	1983	113	79.1 ± 10.9	89.0± 19.3	12.5
Present study	1998	99	81.7 ± 19.4	85.3± 16.9	4.4

[1] Year of data collection.
*Significantly different from present study at same time of measurement ($p<0.05$).

Table 19 contains the IDL data from the current and previous studies. Since the testing method was different in 1978, it is inappropriate to compare the IDL strength pre- and post BCT. The pre- and post-BCT testing methodology was consistent within studies; therefore, the training effect can be compared by ignoring the absolute load lifted and comparing the change in IDL strength from pre- to post-BCT. The 1998 sample did not demonstrate the same increase as the 1983 soldiers (20). The current men lifted less post-BCT than pre-BCT, as opposed to a small increase in 1983 men (3%). The increase in IDL in previous women (1983=12.4%, 1993=8.4%) was two to three times that found in the current women (3.4%), again suggesting a blunted training effect due to the FTX.

Table 19. Comparison of IDL strength (kg) of 1998 and previous year trainees (Mean ± SD).

Author	Year[1]	n	pre-BCT	post-BCT	% Δ
Men					
Teves et al. (20)	1983	90	61.1 ± 10.0*	63.0 ± 9.9*	3.0
Present study	1998	99	76.5 ± 14.8	73.2 ± 13.6	-4.3
Women					
Teves et al. (20)	1983	113	30.4 ± 6.1*	34.7 ± 8.2*	12.4
Westphal et al. (24)	1993	124	40.4 ± 8.8	43.8 ± 9.4	8.4
Present study	1998	99	40.7 ± 10.6	42.1 ± 9.6	3.4

[1] Year data collected

*Significantly different from present study at same time of measurement ($p<0.05$).

In 1998, trainees were as strong or stronger than previous groups post-BCT in all but one measure of strength i.e., UP. Most of the changes in muscle strength from pre- to post-BCT were smaller than those seen in previous studies. The smaller than expected increases in muscle strength may be attributed to residual fatigue from the FTX, a high ambient temperature in the testing area and, for some variables, higher levels of strength pre-BCT.

Body Composition

As mentioned earlier, the most dramatic difference between the current trainees and those measured 15-20 years ago was the difference in body mass. These data can be seen for pre- and post-BCT in Table 20. Based on RM-ANOVAs, there were significant group and time-by-group interaction effects in both men and women. Tukey post-hoc analysis of the main effect for group revealed the current men were heavier ($p<0.05$) than the previous two samples. The three groups of men responded differently to BCT, as illustrated in Figure 9. The 1978 men (9), who had the lowest pre-BCT body mass, gained +0.9 kg ($p<0.05$), the 1983 men (20) did not change significantly (+0.6 kg), while the current sample of men, who were heaviest pre-BCT, lost 1.2 kg ($p<0.05$). In women, the group main effect was due to a difference between the 1993 sample (24) and the 1978 sample (9). The interaction effect in women (Figure 10) was significant because women with lower pre-BCT body mass (1978 and 1983) had a greater increase in body mass (nearly 4%, $p<0.05$) pre- to post-BCT, compared to women with higher pre-BCT body mass (1993 and 1998) who only had a 1% gain in body mass.

Table 20. Comparison of body mass (kg) of 1998 with previous year trainees.

Source	Year[1]	n	pre-BCT	post-BCT	% Δ
Men					
Knapik et al. (9)	1978	769	70.9 ± 10.6*	71.7 ± 8.8*	1.1
Teves et al. (20)	1983	90	72.9 ± 9.6*	73.5 ± 7.6*	0.8
Present study	1998	99	78.0 ± 12.6	76.8 ± 11.2	-1.5
Women					
Knapik et al. (9)	1978	393	59.1 ± 7.1*	61.3 ± 6.7	3.7
Teves et al. (20)	1983	113	58.9 ± 6.5*	61.2 ± 6.3	3.9
Westphal et al. (24)	1993	150	62.1 ± 8.7	62.9 ± 8.1	1.1
Present study	1998	101	62.0 ± 9.8	62.8 ± 9.4	1.3

[1] Year of data collection
*Significantly different from 1998 sample at same time in training ($p<0.05$).

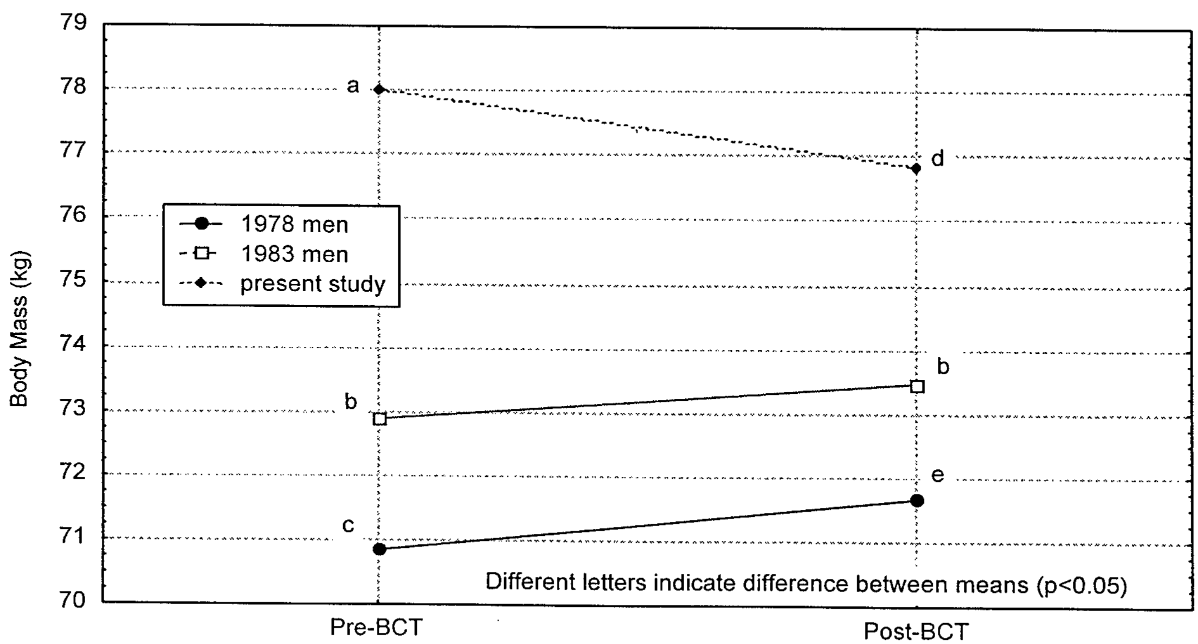

Figure 9. Time-by-group interaction for body mass in men

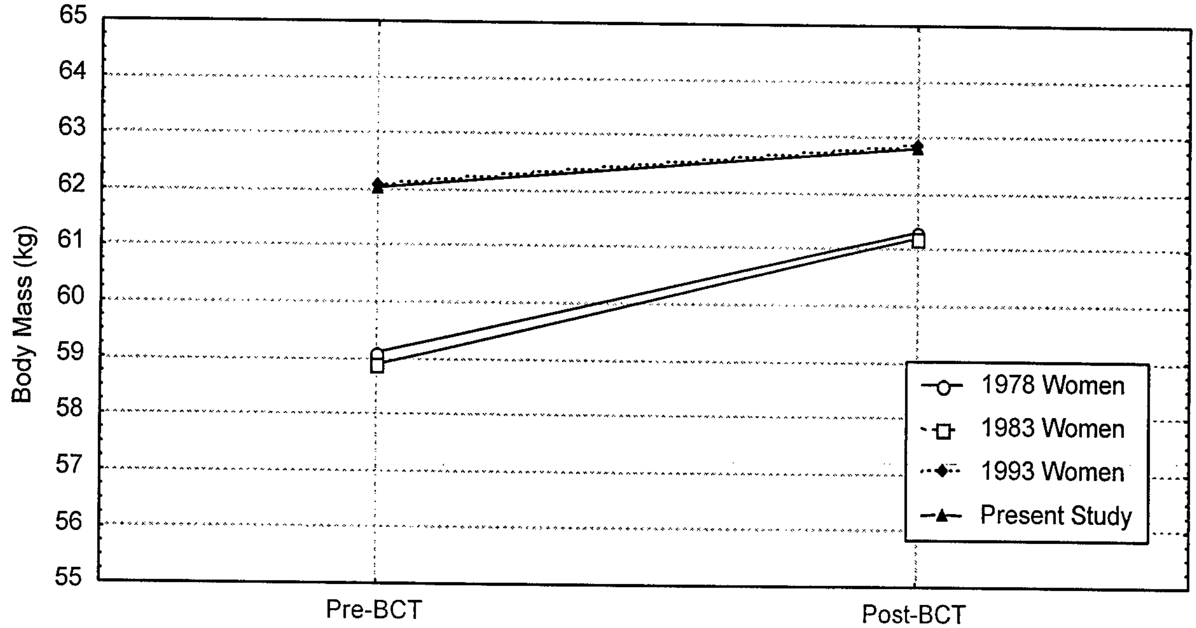

Figure 10. Time-by-group interaction for body mass in women

The skinfold determined %BF and FFM for each of the groups can be found in Appendix E in Tables A-4 and A-5, respectively. The current men had the highest %BF pre- and post-BCT($p<0.05$), and significantly more FFM than the 1978 men (9). One might expect the group with the highest %BF to have the greatest decrease pre- to post-BCT, but this did not occur. As can be seen in Figure 11, the current sample of men had the smallest decrease in %BF of the three groups. Also unlike the previous two groups (9, 20), the current men did not exhibit an increase in skinfold determined FFM.

The body composition changes in the current sample of women were similar to those of previous samples. The 1993 women (24) tended to have the highest %BF and the lowest FFM. As can be seen in Figure 12, the pattern of change (increase in body mass and FFM with a decrease in %BF) was similar for all groups, but the changes in body mass and FFM in the current and 1993 samples were not as large as those found in 1978 (9) and 1983 (20).

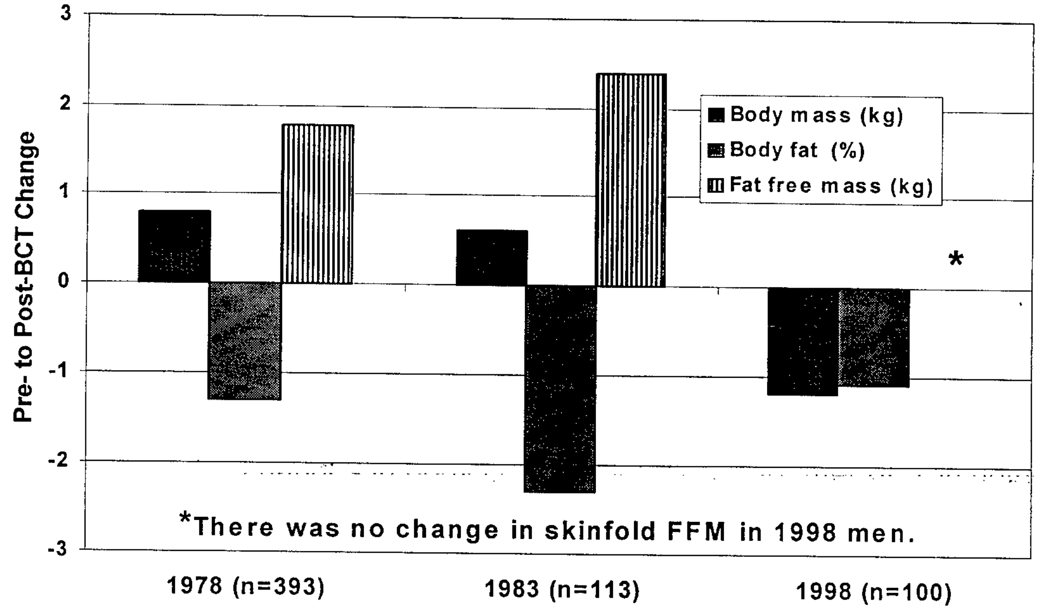

Figure 11. Pre- to post-BCT changes in body composition in men measured in 1978 (9), 1983 (20) and 1998 (present data)

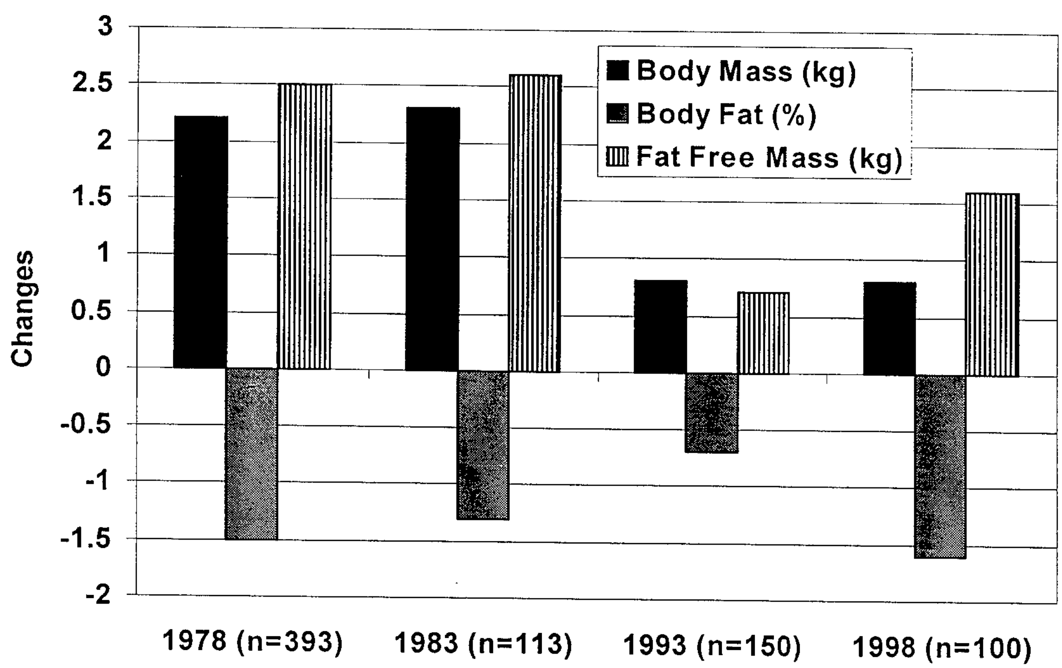

Figure 12. Pre- to post-BCT changes in body composition in women measured in 1978 (9), 1983 (20), 1993 (24) and 1998 (present data)

To summarize, two of three indicators of physical fitness (aerobic fitness and muscle strength) are encouraging in that the trainees of 1998 enter BCT at a fitness level equal to or greater than those entering 15-20 years ago. As mentioned earlier, some of the least fit trainees were not tested, because they were sent to the FTU. Based on the number of volunteers lost, it is not likely to have greatly affected the data. The trainees we tested made gains in aerobic fitness pre- to post-BCT comparable to those in BCT 15-20 years ago. Muscle strength at the end of BCT was comparable to or better than that of earlier samples, but the increases observed were not as great. Although the increasing levels of body mass and %BF are a cause for concern, positive changes in body composition occurred after BCT in both men and women. Basic Combat Training is effective in physically preparing today's recruit for an Army career.

CONCLUSIONS

1. Trainees entered BCT with levels of aerobic fitness and muscle strength that were equal to or better than that of soldiers 15-20 years ago.

2. Trainees entered BCT with more body mass, FFM and a higher %BF than trainees 15-20 years ago.

3. BCT was as effective in improving the aerobic fitness of trainees as it was 20 years ago.

4. BCT did not result in large increases in the muscle strength of the current trainees.

5. Unlike previous trainees the current men tended to lose, not gain body mass, and did not gain FFM.

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APPENDICES A-E

CONTENTS:

APPENDIX A

Racial Distribution of Sample

Table A-1. Racial distribution of pre-BCT sample.

	Women (n=169) n	%	Army-wide %	Men (n=182) n	%	Army-wide %
Black	56	33.3	26.4	42	23.1	39.6
Caucasian	84	50.0	59.1	111	61.0	46.6
Hispanic	20	11.9	7.8	20	11.0	6.8
Other	8	4.8	6.7	9	4.9	7.0

[1] Demographic data as of Sept 98, personal communication from Headquarters, Dept of Army Office of the Deputy Chief of Staff for Personnel.

APPENDIX B

Joint Mobility and Anthropometric Measurements

1. Measurements of lower extremity joint passive range of motion were performed using standard goniometric techniques. The measures were made to examine their influence on training injuries. The following flexibility measurements were made:

    1. Hip internal and external rotation
    2. Knee hyperextension
    3. Ankle dorsi flexion and plantar flexion with knee extended
    4. Ankle plantar flexion with knee flexed

The joint mobility measurements made pre-BCT are presented in Table A-4. These data will be analyzed in a separate report.

2. In addition to the above measurements, mid-thigh, and mid-calf circumferences were measured with a standard flexible anthropometric tape. Arch height at the navicular of the foot was measured with a rigid scale in the weight bearing position. Mid-tibial and femoral condyle width were measured with calipers. The anthropometric measurements are presented in Table A-5.

Table A-2. Joint mobility (Mean ± SD) pre-BCT for all subjects combined and by gender.

	Total Sample (n=349)		Women (n=167)		Men (n=182)	
	Right	Left	Right	Left	Right	Left
Knee Hyperextension (°)	1.6 ± 4.1	2.0 ± 4.0	2.1 ± 4.2	3.0 ± 4.0	1.2 ± 3.9	2.0 ± 4.0
Ankle dorsi-flexion, knee extended (°)	15 ± 5	16 ± 8	15 ± 5	16 ± 10	16 ± 5	15 ± 6
Ankle dorsi-flexion, knee flexed (°)	21 ± 6	20 ± 6	21 ± 6	20 ± 6	21 ± 6	20 ± 6
Ankle plantar-flexion, knee extended (°)	47 ± 7	44 ± 10	49 ± 7	46 ± 10	45 ± 7	42 ± 9
Hip external rotation (°)	47 ±10	44 ± 10	46 ± 8	44 ± 9	48 ± 10	45 ± 10
Hip internal rotation (°)	29 ± 11	34 ± 11	37 ± 10	41 ± 10	23 ± 8	28 ± 8

Table A-3. Anthropometric measurements made pre-BCT for all subjects combined and by gender.

	Total Sample (n=349)		Women (n=167)		Men (n=182)	
	Right	Left	Right	Left	Right	Left
Thigh circumference (cm)	55.2 ± 5.5	56.0 ± 5.6	54.2 ± 5.0	55.3 ± 5.2	56.2 ± 5.8	56.7 ± 5.9
Calf circumference (cm)	36.1 ± 3.1	35.9 ± 3.0	35.1 ± 2.8	34.9 ± 2.8	36.9 ± 3.2	36.8 ± 3.0
Femoral condyle width (cm)	9.4 ± 0.7	9.4 ± 0.8	8.9 ± 0.6	8.9 ± 0.7	9.7 ± 0.6	9.8 ± 0.8
Mid-tibial width (cm)	3.6 ± 0.5	3.5 ± 0.5	3.3 ± 0.4	3.2 ± 0.4	3.8 ± 0.4	3.8 ± 0.4
Arch height (cm)	3.7 ± 0.7	3.9 ± 0.7	3.5 ± 0.7	3.7 ± 0.7	3.9 ± 0.7	4.1 ± 0.7

APPENDIX C

Photometric Measurements

Although none of the data will be included in this report, photometric techniques were used to enable rapid collection of anthropometric data on a large number of individuals. A physical therapist identified and placed reflective markers on seven bony landmarks on both sides of the lower body (medial and lateral malleoli, head of the fibula, tibial tuberosity, midpoint of the patella, greater trochanter, and anterior superior iliac spine). In preparation for the photographs, socks and shoes were removed, t-shirts rolled up above the umbilicus and the sides of the shorts tied to reveal the greater trochanter and anterior superior iliac spine. Once outfitted with reflective markers, volunteers were positioned on a raised platform with heels 3" apart and the forefeet at a 60° angle. Mirrors were mounted at 45° angles to the photographic line of site, to provide an image of the lateral aspects of the lower limbs. A 0.75 m rod was mounted to the right of the volunteer, perpendicular to the floor, to provide a known length to calculate distances. A 35 mm camera with a 200 mm telephoto lens using color transparency film was used to photograph the volunteers from the waist down. Flood lamps were positioned to provide maximum illumination with minimum glare. The camera was located on a tripod at the volunteers' knee height 15 m away. Photographs were digitized, and a computer program used to derive the following measurements on both sides of the body:

1. Leg length (greater trochanter-lateral malleoli)
2. Tibial length (tibial tuberosity-medial malleoli)
3. Femoral length (greater trochanter-patella)
4. Femoral condyle width
5. Bitrochanteric width
6. Pelvic width (distance between right and left anterior superior iliac spines)
7. Q-angle (acute angle formed by a line from the tibial tuberosity through the midpoint of the patella and a line from the anterior superior iliac spine through the midpoint of the patella
8. Knee width (distance from right to left patella mid-points)

This technique has been shown to produce inter- and intra-rater reliability correlations ranging from r=0.90-0.99.

Cowan, D.N., B.H. Jones, P.N. Frykman, D.W. Polly, E.A. Harman, R.M. Rosenstein, and M.T. Rosenstein. Lower limb morphology and risk of overuse injury among male infantry trainees. Med Sci Sports Exerc, 28(8):945-954, 1996.

APPENDIX D

Calculation of Volunteers Lost to the FTU

Calculation of number of subjects lost to the pre-BCT physical fitness screening test items:

Number of volunteers who failed at least one test item=12 men, 20 women
The total percentage failing at least one test item=8.4% men, 30.3% women
The percentage failing each event is shown below (can fail more than one event):

	Men	Women
push-up	3.6	13.8
Sit-up	1.7	7.7
1 mile run	3.1	8.8

To determine the approximate number failing each event the ratio of the percentage failing a specific event to the total percentage failing at least one event that event was multiplied by the total number of soldiers failing the test within gender:

	Men	Women
push-up	(3.6/8.4) x 12=5.16	(13.8/30.3) x 20=9.2
Sit-up	(1.7/8.4) x 12=2.4	(7.7/30.3) x 20=5
1 mile run	(3.1/8.4) x 12=4.4	(8.8/30.3) x 20=5.8

APPENDIX E

Skinfold Determined Body Composition

Table A-4. Comparison of skinfold determined %BF of 1998 and previous year trainees.

Source (yr data collected)	Year[1]	n	pre-BCT	post-BCT	Δ
Men					
Knapik et al. (9)	1978	769	16.3 ± 5.1*	14.5 ± 3.8*	-1.8
Teves et al. (20)	1983	90	16.3 ± 4.7*	14.0 ± 3.3*	-2.3
Present study	1998	99	18.8 ± 4.6	17.7 ± 3.9	-1.1
Women					
Knapik et al. (9)	1978	393	28.0 ± 4.7	26.5 ± 3.7	-1.5
Teves et al. (20)	1983	113	25.6 ± 3.9*	24.3 ± 3.4*	-1.3
Westphal et al. (25)	1993	150	31.3 ± 4.5	30.6 ± 4.5	-0.7
Present study	1998	100	28.9 ± 4.0	27.3 ± 3.4	-1.6

[1] Year of data collection.

*Significantly different from 1998 sample at same time in training ($p<0.05$).

Table A-5. Comparison of skinfold determined FFM (kg) of 1998 and previous year trainees.

Source (yr data collected)	Year[1]	n	pre-BCT	post-BCT	% Δ
Men					
Knapik et al. (9)	1978	769	59.3 ± 6.8*	61.1 ± 6.4*	3.0
Teves et al. (20)	1983	90	60.6 ± 5.7*	63.0 ± 5.7	4.0
Present study	1998	99	63.0 ± 8.2	63.0 ± 7.9	0.0
Women					
Knapik et al. (9)	1978	393	42.4 ± 4.3*	44.9 ± 4.5	5.9
Teves et al. (20)	1983	113	43.6 ± 3.9	46.2 ± 4.1	6.0
Westphal et al. (25)	1993	150	42.5 ± 4.8	43.5 ± 4.9	2.4
Present study	1998	100	43.7 ± 5.7	45.3 ± 5.6	3.7

[1] Year of data collection.
*Significantly different from 1998 sample at same time in training ($p<0.05$).