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EFFECTS OF A SPECIFICALLY DESIGNED PHYSICAL CONDITIONING PROGRAM ON THE LOAD CARRIAGE AND LIFTING PERFORMANCE OF FEMALE SOLDIERS

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

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Forty-six women were studied to determine whether their ability to perform "very heavy" Army jobs could be improved by a specially designed 24-week physical training program administered within normal Army time constraints; 32 subjects remained for the entire testing and training program. The training program proved effective. The weight of boxes the women could lift to three different heights improved between 30% and 47%. After training, the average box-weight the women could lift onto a truck was 118 pounds, 81% of the Army male value. The number of 40-pound boxes the women could lift onto a truck in 10 minutes increased from 106 to 140. The number of 40-pound boxes that could be lifted off the ground, carried 25 feet and placed onto a truck increased from 53 to 62. Vertical jump and standing long jump distance increased 20% and 15% respectively. The speed at which a 75 pound backpack could be carried over a 2-mile mixed-terrain course increased from 3.4 to 4.4 miles per hour. Before the training, only 24% of the women could qualify for "very heavy" Army jobs; after the training, 78% could qualify. Body composition improved as well.

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TECHNICAL REPORT

U.S. Army Research Institute of Environmental Medicine

Title:

Effects of a specifically designed physical conditioning program on the load carriage and lifting performance of female soldiers

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BACKGROUND

The experiment described herein was undertaken with funding from the Defense Women's Health Research Program, created and funded by Congress to promote research on health and performance of women in the U.S. military. Everett Harman, Ph.D. felt there was a need for such an experiment based on reports indicating that female soldiers often had difficulty doing job tasks categorized by the Army as "heavy" and "very heavy". A 1995 USARIEM Technical Report (Westphal et al., 1995) revealed that 38% of Army MOS's open to women were categorized as "very heavy" but, even after basic training, only 40% of women assigned to such jobs could perform the lifts required of them. The report also revealed that women's physical strength or lack thereof had no influence on whether or not they selected "very heavy" MOS's. Basic training improved women's lifting capacity by 8-12%. Dr. Harman hypothesized that the ability of women to perform heavy physical tasks in the U.S. Army could be greatly improved by having them engage in a specially designed and professionally administered physical training program, under normal Army time constraints. With support from his research group (then called the Occupational Physiology Division, presently called the Military Performance Division of the U.S. Army Research Institute of Environmental Medicine), he prepared the grant application and, upon its approval, wrote the scientific protocol upon which the experiment was based. The physical training and data collection phases of the study were carried out from May through November, 1995.

LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

USARIEM	U.S. Army Research Institute of Environmental Medicine
MOS	Military Occupational Specialty
AIT	Advanced Individual Training

EXECUTIVE SUMMARY

The study was motivated by reports that female soldiers frequently had difficulty performing heavy Army jobs. To evaluate a possible solution to the problem, the experiment was designed to determine whether women's ability to perform physically heavy Army tasks, typical of a wide variety of U.S. Army military occupational specialties (MOS's), could be improved by a specially designed physical training program administered by experienced athletic strength coaches within normal Army work time constraints. The training program focussed on improving the women's ability in lifting and load carriage, the most common physically demanding tasks in the Army.

Forty-six women, all but one civilian because of a shortage of available Army female test volunteers, were tested to establish a pre-training baseline. All but one of them began the experimental physical training program. Training and testing took place at the U.S. Army Research Institute of Environmental Medicine, in Natick, MA over a seven-month period. Due to a favorable attrition rate, 32 volunteers took the pre-, mid-, and post-training test batteries.

The training proved effective in improving the physical capability of the women. The weight of boxes the women could lift to three different heights improved between 30% and 47%. By the end of training, the average box-weight the women could lift onto a 2½-ton Army truck was 118 pounds, 81% of that averaged by samples of active duty Army males previously tested. The number of 40-pound boxes the women could lift onto a truck in 10 minutes increased from 106 to 140. The number of 40-pound boxes that could be lifted off the ground, carried 25 feet and placed onto a truck increased from 53 to 62. Vertical jump and standing long jump distance increased 20% and 15% respectively. The speed at which a 75 pound backpack could be carried over a 2-mile mixed-terrain course increased from 3.4 to 4.4 miles per hour. Before the training, only 24% of the women could qualify for "very heavy" Army jobs; after the training, 78% could qualify. Body composition improved as well, as evidenced by reduced body fat and increased muscle mass.

In conclusion, a specially designed training program, within normal Army time-constraints, can be very effective in improving the ability of women to perform physically demanding military jobs. Desirable body composition changes result as well.

INTRODUCTION

The lifting and/or carrying of moderate-to-heavy loads by soldiers are tasks essential to the accomplishment of military objectives, particularly by combat ground forces. Eighty-three percent of U.S. Army Military Occupational Specialties (MOS's) involve lifting and/or carrying. At least 175 MOS's require occasional lifts in excess of 100 pounds (Headquarters, Department of the Army, 1994). Some examples of MOS's requiring heavy lifting are: 91B - Medical Specialist, 55D - Explosive Ordnance Disposal Specialist, 33R - Aviation Systems Repairer, and 74C - Record Telecommunications Center Operator (the latter must occasionally lift 150 lbs as part of a two person team and carry it 3 feet).

Women have, on average, considerably less lifting strength than do men (Myers, Gebhardt, and Crump, 1984; Vogel, 1985). Trials of simulated military lifting tasks have shown that female soldiers cannot lift as much weight as can male soldiers (Sharp, 1993). In addition, in trials of maximum speed repetitive lifting of moderately heavy loads, women cannot lift as rapidly as can males (Sharp, 1994).

Women have been minimally tested as to their ability to carry heavy backpack loads. Yet the small amount of available information suggests that, at a given walking speed, the average female soldier cannot carry a load as heavy as can the average male soldier. Also, with a given load, female soldiers cannot walk as fast as male soldiers (Patton, unpublished observations).

It is conceivable that many military tasks and pieces of equipment could be redesigned so that the amount of weight a soldier must lift and/or carry could be considerably reduced. All previous attempts to do so have failed, mainly because of technical advances which have resulted in additional devices the soldier must carry and the increased ammunition needed for fully automatic weapons. Thus, the soldier's load has risen steadily throughout recorded history (Knapik, 1989). The reduction in weight of individual military equipment would represent a very daunting challenge, requiring great financial outlays over many years.

Even though women are congressionally prohibited from entry into Army direct combat MOS's, many women have expressed the desire to be allowed to compete for such positions. Operations such as Desert Storm/Desert Shield in the Persian Gulf region have shown that women in all branches of the military service are allowed into some specialties that place them within the range of enemy weaponry, definitely "in harm's way". Some previously closed specialties, such as combat aviation, have recently been opened to women in some services. From a human performance perspective, it is critical to know whether women are capable of meeting the physical demands of combat MOS's and, if they are not generally able to meet such demands upon initial entry into the service, whether they can be physically trained to do so. While any decision on whether to allow women into, or exclude them from, combat MOS's is likely to be based primarily on political and emotional factors, experimental results on the physical capabilities of women and their response to training can provide a portion of the data upon which the logical aspect of decisions could be based.

In order to allow women to function effectively in a wide variety of Army MOS's, it is desirable to improve their ability to lift and carry moderate-to-heavy loads. Thus, it was the objective of this study to determine if a specially designed women's physical conditioning program could lessen the gap between the performance of male and female soldiers in lifting and load carriage, and thereby enable women to meet the requirements of most if not all Army MOS's.

As a result of resistance exercise programs, women have improved proportionally in strength at least as much as men (Cureton, et al. 1988; Gettman at al., 1982; Hunter 1985; Wilmore 1974; Wilmore et al. 1978). However, while it has been shown that males can improve task performance by engaging in progressive resistance exercise (Genaidy et al. 1994; Genaidy 1991; Genaidy et al. 1990; Genaidy et al. 1990; Genaidy et al. 1989; Guo et al. 1992; Sharp et al., 1993), there has been little research on the effects of physical conditioning programs on the physical work capacity of women. Two such studies were performed by the U.S. Army Research Laboratory. In the first one (Murphy and Nemmers, 1978) 13 female soldiers were able to meet prescribed rates of fire for 105 and 155 mm howitzers after only three weeks of running and resistance training. In the second (Knapik, 1996), female soldiers showed a 16-19% improvement in the manual material handling capability after a 14 week long, 5 day per week program of weightlifting and running.

The present study was intended to build on the previous studies by using a 24-week, professionally designed and administered training program specifically developed to improve lifting and load-carriage ability, and a very comprehensive set of work-oriented pre- and post-training performance tests. The exercises included weightlifting, walking, running, load-carriage, and specificity drills. The daily amount of time allocated for the physical training (1½ hours per day maximum) was compatible with a soldier's normal schedule; U.S. Army Regulation 350-41 (Headquarters, Department of the Army, 1993) requires vigorous exercise 3-5 times per week during duty hours. A group of males also underwent the test battery a single time to compare male and female performance. Magnetic resonance imaging, dual energy x-ray absorptiometry, and other anthropometric measures were used to quantify training-induced improvement in body composition.

MILITARY RELEVANCE OF THE STUDY

Women have been permitted to enter regular Army units since 1978, and engage in an increasing number of physically demanding MOS's (Moden, 1989; Myers, Gebhardt, and Crump, 1984). Because the Army has been part of the nationwide trend towards gender equality of work opportunity, and benefits by recruiting the most qualified individuals regardless of gender, and because an increasing number of women have sought opportunities in careers previously occupied mainly by men, the proportion of women in the Army has increased from 9.6% in 1983 (Defense Almanac, 1983) to 11.3% in 1992 (Defense Almanac, 1992). In 1994, 19% of Army recruits were women (Morganthau, Bogert, Barry, and Vistica, 1994). It has become apparent that women in the Army, as in the civilian world, want the opportunity to enter whatever career interests them and to function well within those careers.

Several MOS's in the Army involve difficult lifting and load carriage tasks (Teves, 1985). Even after basic training, only 40% of women assigned to jobs categorized as "very heavy" can perform the lifts required of them (Westphal et al., 1995). Female soldiers' physical strength or lack thereof has no apparent influence on whether or not they select "very heavy" MOS's, and basic training has been shown to improve women's lifting capacity by only 8-12%, too small an increase to prepare a majority of women for "very heavy" MOS's. Basic training has succeeded in bringing up to the "very heavy" strength standard only 15% of the women who were below the standard before basic training. Thus it is desirable to develop a physical training program capable of improving in a major way the level of lifting and load carriage of female soldiers. If such a physical training program were developed, Army leadership might not have to consider gender when assigning soldiers to occupational specialties and tasks, thus simplifying the assignment process.

METHODS

RESEARCH VOLUNTEERS

Sample Size Estimation

We wished to have a sample size adequate for statistically detecting performance changes made as a result of the physical training program. In addition, we wished to have a large enough sample so that lifting and load carriage performance could be predicted from regression equations using anthropometric and/or other screening variables as input.

For repeated measure sample size estimation (the same volunteers were tested pre-, mid- and post-training) a nomogram developed by Carter et al. (1981) was used to determine the necessary sample size for the pre-mid-post comparisons. It required knowledge of effect size (in standard deviation units) and the test-retest correlation coefficient for the variable of interest. The smallest improvement in occupational lifting performance we wished to detect was 5%. For maximal dynamic strength testing, standard deviations had been about 16% of the mean for both male and female Army research volunteers (Sharp 1993). Therefore, we sought an effect size of about 5/16 = 0.3 standard deviation units. Test-retest reliability for strength of muscles involved in lifting among women has been shown to exceed 0.80 (Christ, 1994). Entering the nomogram with an effect size of 0.3 and test-retest correlation of 0.80 produced an estimated sample size of 17. Because female Army research volunteers were shown to have a relatively high attrition rate in experiments which were physically demanding or in which pregnancy resulted in mandatory withdrawal, 20 research volunteers were needed to begin the experimentation. In addition, establishing a valid regression-based prediction model to predict physical performance from two independent variables requires about 20 research volunteers. Therefore, the minimum size for the experimental training group was set at 20. However, the experimental results could be considered more valid, and the conclusions more widely applicable with a larger experimental group. It was thus decided that at least 40 experimental volunteers would be recruited.

Source of Research Volunteers

As in the past, it was difficult to recruit female research volunteers. An effort was made to obtain those who were U.S. Army active duty females. However, since several experiments using female volunteers, under the Defense Women's Health Research Program, were scheduled for USARIEM, only one female military volunteer was available. Thus, local civilian women were recruited. Such volunteers were motivated by the chance to improve their physical strength and muscularity under the supervision of a professional trainer and receive modest financial remuneration. In addition, several of them indicated a desire to prove that women can be strong and capable of heavy physical work. The volunteers included civilian personnel working at the U.S. Army Natick Research, Development, and Engineering Center, the facility at which USARIEM is located. Any such research volunteers obtained their supervisor's consent in writing for participation in the experiment. Only potential subjects who were in good health and had no physical problems which could limit their ability to train heavily or make maximal exertions during testing were accepted for the experiment. However, no volunteer was excluded based on level of physical fitness. The upper age limit for the research volunteers was 37 years.

Research Volunteer Briefing

The principal investigator or an assisting investigator briefed all potential research volunteers. Informed consent was obtained from those who chose to volunteer.

Time Commitment of Research Volunteers

The physical training lasted 24 weeks. An additional two weeks was allocated for pre-tests and two weeks for post-tests, for a total commitment of 28 weeks (196 days). Volunteers spent a maximum of 1½ hours per day, 5 days per week physically training or testing. In addition, the volunteers spent between ½ and 1½ hours per day travelling to and from the training site and showering. Occasional absence during the training period, for a total of 10 missed training days was deemed acceptable. As a means of measuring test-retest reliability, female control volunteers underwent only pre- and post-testing but not the training. In order to establish male comparison values for the various physical performance and body composition tests, male control volunteers only underwent pre-testing.

SITE OF TESTING AND TRAINING

The volunteers were trained and tested in and around the U.S. Army Research Institute of Environmental Medicine located on the grounds of the U.S. Army Natick Research, Development and Engineering Center in Natick, MA.

THE PHYSICAL CONDITIONING PROGRAM

Program Overview

The training program began with the following weekly schedule:

Monday:	Lift weights:	50 minutes, 21 sets
	Rest:	10 minutes
	Run:	2 miles
Tuesday:	Lift weights:	50 minutes, 21 sets
	Rest:	10 minutes
	Varied drills:	0-30 minutes
Wednesday:	Backpack	5 miles at minimum of 4 mph pace (load selected by trainer)
Thursday:	Lift weights:	50 minutes, 21 sets
	Rest:	10 minutes
	Varied drills:	0-30 minutes
Friday:	Lift weights:	50 minutes, 21 sets
	Rest:	10 minutes
	Run:	2 miles

Weight Training

The primary goal of the physical training program was to increase the strength and endurance of the muscles involved in lifting and load carriage. This was accomplished by selecting exercises which involved the particular body movements used in those activities (Harman, 1992). A body-part approach, common to body building, was not used, as its main purpose is to affect physical appearance. The movement-oriented approach is most appropriate for improving physical performance.

The major body movements in which force must be exerted for lifting are:

ankle plantar flexion
knee extension
hip extension
back extension
shoulder extension (sagittal plane)
shoulder flexion (sagittal plane)
elbow flexion
shoulder shrug
abdominal compression (using deep abdominal muscles to generate
intra-abdominal pressure to reduce spinal compressive forces
and protect the spinal discs)

For load carriage the relatively forceful movements are the same as for lifting except that elbow and shoulder rotations aren't essential, but the following movements are:

shoulder forward displacement
back flexion (using the abdominal muscles)

Based on the importance of the above movements in lifting and load carriage, exercises employing these movements were most emphasized within the context of a total body strengthening program which, in order to achieve balanced physical development and reduction of injury risk, included the following body movements as well:

shoulder transverse adduction

shoulder frontal plane adduction
shoulder frontal plane abduction
knee flexion

Drills simulating occupational tasks, such as lifting and carrying sand bags, and backpack load carriage, were also used in training, especially in the last few weeks of the program.

In order to keep the amount of physical training within a soldier's schedule, each volunteer trained no more than 1½ hours per day (with an additional half-hour for changing and showering), 5 days per week. On a given day, each research volunteer performed between 21 and 52 exercise sets per day for a maximum of 104 sets of weightlifting exercises on a given day. In all cases the resistance was individually selected so that each volunteer could do the prescribed number of repetitions with the weight but no more.

The volunteers' actual workouts varied from day to day and week to week, in part because variety within an exercise program has been shown to be the most effective means of improving strength (Stone, 1987), and also to select exercises which each individual could perform with proper technique and to which each individual responded positively from both a physical and psychological point of view.

The exercise program was adjusted every 4 weeks so as to: vary repetitions and weight used in a periodization model (Wathen, 1994); provide variety so as to avoid physical and psychological stagnation; progress from simple exercises to those requiring greater physical coordination; and respond to the progress and needs of the experimental group. All volunteers did the same exercises in a given week. However, each group of women exercising together was split according to the days of the week and the order in which specific exercises were done, thus avoiding delay at the various exercise stations.

All exercise sessions were directly supervised by trained personnel. USARIEM employees who were certified as Strength and Conditioning Specialists by the National Strength and Conditioning Association oversaw the entire program, monitored research volunteer progress, and modified workouts as needed. The amount of weight used in the exercises was increased as the volunteers become stronger, so as to maintain the training stimulus.

The following table shows the initial weightlifting workout schedule:

Table 1. Initial weightlifting workout schedule.

Monday and Thursday set	exercise	Tuesday and Friday exercise
1	squat	underhand medicine ball toss
2	bench press	wide-grip barbell press
3	squat	underhand medicine ball toss
4	bench press	wide-grip barbell press
5	squat	underhand medicine ball toss
6	bench press	wide-grip barbell press
7	squat	underhand medicine ball toss
8	bench press	wide-grip barbell pulldown
9	squat	underhand medicine ball toss
10	bench press	wide-grip barbell pulldown
11	squat	underhand medicine ball toss
12	bench press	wide-grip barbell pulldown
13	back hyperextension	situp
14	medium grip barbell press	leg curl
15	row with elbows high	row with elbows low
16	back hyperextension	situp
17	medium grip barbell press	leg curl
18	row with elbows high	row with elbows low
19	back hyperextension	situp
20	medium grip barbell press	leg curl
21	row with elbows high	row with elbows low

One can see from the table that the volunteers did not perform consecutive sets of an exercise. Rather, they performed exercises in groups of two or three, rotating between the exercises within the group before going on to the next group. An exercise set commenced about every two minutes, translating to about 30 seconds of exercise and 1½ minutes of rest. Because the exercises were performed in groups, there was only 1½ minutes rest between sets of adjacent exercises, but 3½-5½ minutes rest between sets of the same exercise. The whole body was worked at a fairly rapid pace, while the individual muscles had enough rest to enable high levels of effort in all exercise sets. This type of exercise is called "multiple mini-circuits" (Harman, 1992). The advantage of this type of training is that it allows a high volume of exercise to be done in a relatively short time, but gives each muscle group enough recovery time to allow high repeated levels of exercise. It also provides some training effects to the aerobic and glycolytic energy systems in addition to providing the resistance necessary to stimulate increases in muscle strength. While conventional circuit training provides some of these benefits, it has the disadvantage of providing excessively long rest periods between sets of the same exercise.

Over the 24 weeks of training, some changes were made to the exercise routine monthly, using a "periodized" (Stone, 1987) exercise model. In the beginning, the volunteers performed 10-12 repetitions per exercise set. As they learned the exercise techniques and became stronger, the number of repetitions were reduced and the weight increased. After the midpoint of the training program, the repetitions were increased and the weights reduced. From then until the end of training, the number of repetitions per set were progressively reduced while the weights were increased.

As the training progressed, exercises which were more physically demanding and those requiring more physical coordination were substituted for simpler and less physically demanding ones employing the same body movements. For example, in the "explosive lift" category, the initial exercise was one in which a pair of volunteers underhandedly tossed a 15-pound medicine ball back and forth to each other. They were instructed to use as much knee and hip extension as possible to throw the ball up, while keeping the back somewhat arched. This is the classic safe-lifting posture. The exercise was designed to develop the ability to lift "ballistically", using rapid contraction of the knee and hip muscles. After the volunteers learned this exercise well, they progressed to an exercise in which they underhandedly threw the 15-pound ball as high as possible. This required greater force and coordination than the medicine ball toss and catch. After performing the exercise for a few weeks, and developing good form the volunteers progressed to the "high-pull" exercise, in which they rapidly lifted a barbell from the ground to face-level and then returned it to the ground. The latter exercise required more force and coordination than did the medicine ball exercises. In similar manner, back extension exercise progressed from back hyperextension to Romanian dead lift to standard dead lift.

Regular change in the exercise routine was seen as essential for avoiding physical and psychological stagnation. The periodized progression of repetitions and weight, as well as the regular substitution of exercises, largely fulfilled the need for change. However, after 19 weeks of training, it was felt that a greater change in the routine would be beneficial. Towards that end, the training routine changed from 21 weightlifting sets 4 days per week to 51 sets two days per week. Because the lifting volume per weightlifting day more than doubled, the weekly weightlifting volume increased from 84 to 102 sets per week, all compressed into two days. Also, the exercises used were even closer to work activities than were the previous ones. For example, most of the lifts in the latter phase employed a grip-width on the barbell which was similar to that of a box of supplies. The 51-set workouts are shown in Table 2. No running or drills were performed on the expanded lifting days. However, the two days per week that were freed up were used for added specialized drills. The remaining two days per week were devoted strictly to running.

Running

Monday and Friday, after the weightlifting workout and a 10-minute rest, the volunteers performed a run. Initially the run distance was two miles, which the volunteers were instructed to run at a physically demanding pace. After the initial 14 weeks of training, to avoid physical and psychological stagnation, the trainers were given the option of varying the run workout, and they did. Some of the variety in running workouts included:

Interval running:

Run a mile at a fast pace, walk for 5-10 minutes, then run another mile at a fast pace.

Indian run:

Run single-file in a group. The runner last in line must sprint to the head of the line. When that runner reaches the front of the line, the newly last runner must begin sprinting up to the front. Keep cycling this way until the group covers two miles.

Table 2. Two day per week 51-set workout used during weeks 20-24.

1. medicine ball situp
2. step-up
3. pull-up
4. medicine ball situp
5. step-up
6. pull-up
7. medicine ball situp
8. step-up
9. pull-up
10. incline bench press
11. lunge
12. incline bench press
13. lunge
14. incline bench press
15. lunge
16. row with elbows high
17. back hyperextension
18. row with elbows high
19. back hyperextension
20. row with elbows high
21. back hyperextension
22. side-to-side jumps
23. dumbbell clean and jerk
24. medicine ball chest pass
25. side-to-side jumps
26. dumbbell clean and jerk
27. medicine ball chest pass
28. side-to-side jumps
29. dumbbell clean and jerk
30. medicine ball chest pass
31. military press, medium grip
32. row with elbows low
33. military press, medium grip
34. row with elbows low
35. military press, medium grip
36. row with elbows low
37. leg press/calf push
38. upright row
39. leg press/calf push
40. upright row
41. leg press/calf push
42. upright row
43. dips
44. lateral dumbbell raise
45. high arm curl
46. dips
47. lateral dumbbell raise
48. high arm curl
49. dips
50. lateral dumbbell raise
51. high arm curl

Backpacking

Backpack training occurred every Wednesday. The fundamental training strategy was to start by having the volunteers walk at 4 miles per hour without any load, and then increase the weight of the backpack each week while having the volunteers maintain the 4 mile per hour hiking speed.

In order to keep track of hiking speed, a handwheel distance measurement device was modified by affixing to it a bicycle speedometer and several extra wheel magnets, giving it a resolution of 0.1 miles per hour. During the first several hikes, the trainer walked with the handwheel at exactly 4 miles per hour. The volunteers were asked to stay with the trainer or go faster if they felt they could. After several weeks, the volunteers knew when they should be at various checkpoints in order to maintain the 4 mile per hour speed. Thus, the wheel was no longer necessary.

At 4 miles per hour, the hike took 75 minutes. Therefore, all volunteers were expected to finish each hike in 75 minutes or less. The amount of weight added to an individual's backpack each week depended on the time in which and the ease with which the previous week's hike was accomplished. By the last week of training, the amount of weight that the volunteers carried for the 5-mile hike ranged from about 25-75 pounds.

As training progressed, it was felt that the increased variety of training was needed to maintain the rate of progress. Thus, after about 12 weeks, the trainers were given the option of modifying the backpack routine, and they did so. Occasionally they would have the volunteers carry heavier packs for a shorter distance. At other times they would have the volunteers travel at a faster than usual pace for a mile, then walk without any pack for a mile before putting the pack back on for another fast mile.

Individuals who had transient foot problems or other minor injuries which precluded them from hiking on a particular day could do other types of aerobic exercise such as cycling or rowing. During severely inclement or extremely hot and humid weather, indoor aerobic exercise was substituted for the hikes for all training group volunteers.

Specialized Drills

It was intended that, on Tuesday and Thursday, following the weightlifting workout and a 10 minute rest, the volunteers would train with specialized drills if they weren't too fatigued from their weightlifting and running program. As it turned out, for the first several weeks, most of the volunteers appeared fatigued enough from the lifting and running program so that implementing the drills might result in overtraining, with loss in motivation and physical strength. Therefore the drills weren't introduced until about two months into the program, when the volunteers had become physically and psychologically adapted to the weightlifting and running program. When the four day per week lifting program was compressed into two days per week, the two freed up days were then devoted strictly to the drills. Some examples of the drills are:

Hill running:

Stand at the bottom of a fairly steep hill. Sprint 30-100 feet up the slope. Walk slowly to the bottom of the hill. Repeat several times. This drill was performed on both paved and grassy hills, both with and without a special vest loaded with 0-20 pounds of steel rods enclosed in custom pouches.

Interval running:

Run between 200 yards and 1/2 mile on a fairly level surface at a high level of exertion. Walk until recovery. Repeat work/rest cycle several times. This drill was performed both with and without a backpack loaded according to the volunteer's physical fitness level.

Box jumping:

Don the weighted vest loaded with 0-40 pounds. Jump 6-10 times up onto a 12-18" high box.

Sandbag lifting and carrying:

Several different drills were performed using 40-pound sandbags. One involved moving a stack of 6-8 sandbags from the ground to a 52" high platform 25-40 feet away by running back and forth shuttling sandbags from the pile to the platform. Another was a team competition in which partners repeatedly passed sandbags back and forth to each other after running 25-40 yards with it.

Heavy box lifting:

Lift a box onto a platform. Add weight to the box. Lift again. Increase weight in the box until it is difficult to maintain good lifting form.

Sprint component drills:
High knee lifts, bounding, butt kicks, walking on toes, forward and lateral skipping, and other standard drills used by sprinters.

TEST BATTERY

The following tests were administered before the strength-training program, 14 weeks into the program, and following the program. Mid-experiment testing was initially scheduled for the twelfth week, which would have been the exact midpoint of training. However, unforeseen events unrelated to the study necessitated a rescheduling of the mid-experiment testing.

Occupational Task Testing

The following occupational lifting tests were administered to determine the volunteers' maximal lifting capacity, maximal speed of repetitively lifting boxes of moderate weight, maximal speed of repetitively lifting and carrying for short distances boxes of moderate weight, and maximal speed of transporting moderately heavy loads over different types of terrain using both a backpack and an individual towed load-carriage cart.

Tests of Maximal Occupational Lift Capacity. In a military setting, heavy equipment and supplies must often be lifted. In order to determine how much the volunteers could lift, they were tested for the maximal amount of weight they could raise in a metal box with handles from:

1. the floor to a 30" (table height) surface
2. the floor to a 52" (truck bed height) surface
3. a 30" high surface to a 60" high surface (to simulate lifting from a work surface onto a high shelf).

Tests 1 and 3 were generally conducted on the same day with at least 15 minutes rest between them. In no case was a test conducted if a research volunteer did not feel physically rested and prepared to lift. For each test, the volunteer was instructed to use proper lifting technique to include maintenance of a smooth lifting motion, left-right body symmetry, an arched back, and use of the legs in preference to the back.

The maximum lift testing was conducted in groups of 7-15 volunteers so that individuals could rest while others made their attempts. The volunteers generally rested about 2 minutes between attempts and took as much time as needed to feel fully recovered from the previous attempt and ready for the next attempt. Each group member lifted the box in turn, and several rounds were performed as box weight was increased. For the first round the box was loaded lightly. In each successive round the box weight was increased by 5-20 pounds, depending on the difficulty evidenced on the previous lift. When a volunteer failed to lift a weight, after a rest she was given one more attempt with a weight lighter than that used in the failed attempt, but heavier than her last successful lift. Test resolution was within ±5%

Test of Repetitive Lifting. In times of military conflict, Army personnel often have to rapidly load supplies onto trucks; artillery shells must be rapidly moved and loaded into field pieces. A repetitive lifting test, performed in accordance with the USARIEM Type Protocol (November 1993), was used to measure the ability to lift rapidly over several minutes. Industrial-type skate-wheel ramps, typically used to load boxes from tractor trailer trucks into stores, were arranged so that a volunteer would place a box at the top of a ramp, 52" above the ground (the height of a 2½-ton truck bed), and the box would glide down and around ready to be lifted again onto the ramp. In order to accommodate maximal lifting speed of the volunteers, two such ramps were set up face-to-face (Figure 1). The volunteer would lift a box onto one ramp, then run 8 feet to the base of the other ramp and lift another box, while the first box was rolling around to its starting position. The volunteer would thus run back and forth, alternately lifting boxes onto the two ramps. The setup could feed at least 25 boxes per minute to the volunteers, enough for even the fastest lifter. The score for this test was the number of times the volunteer could lift 40 lb boxes from the floor onto the ramp in 10 minutes. The volunteers were instructed to maintain good lifting form, and to lift at a steady rate rather than in spurts.

Test of Repetitive Lift-Carry-Lift. Military personnel often have to pick up boxes of supplies, and carry them some distance before loading them onto trucks. To simulate such a task, the volunteer repeatedly lifted a 40 lb box, walked 25 feet, and lifted the box onto a 52" high surface. An experimenter pushed the box down a 25-foot long skate-wheel ramp so that the box was waiting for the volunteer when she went back to pick it up again (Figure 2). For safety reasons, the volunteers were not

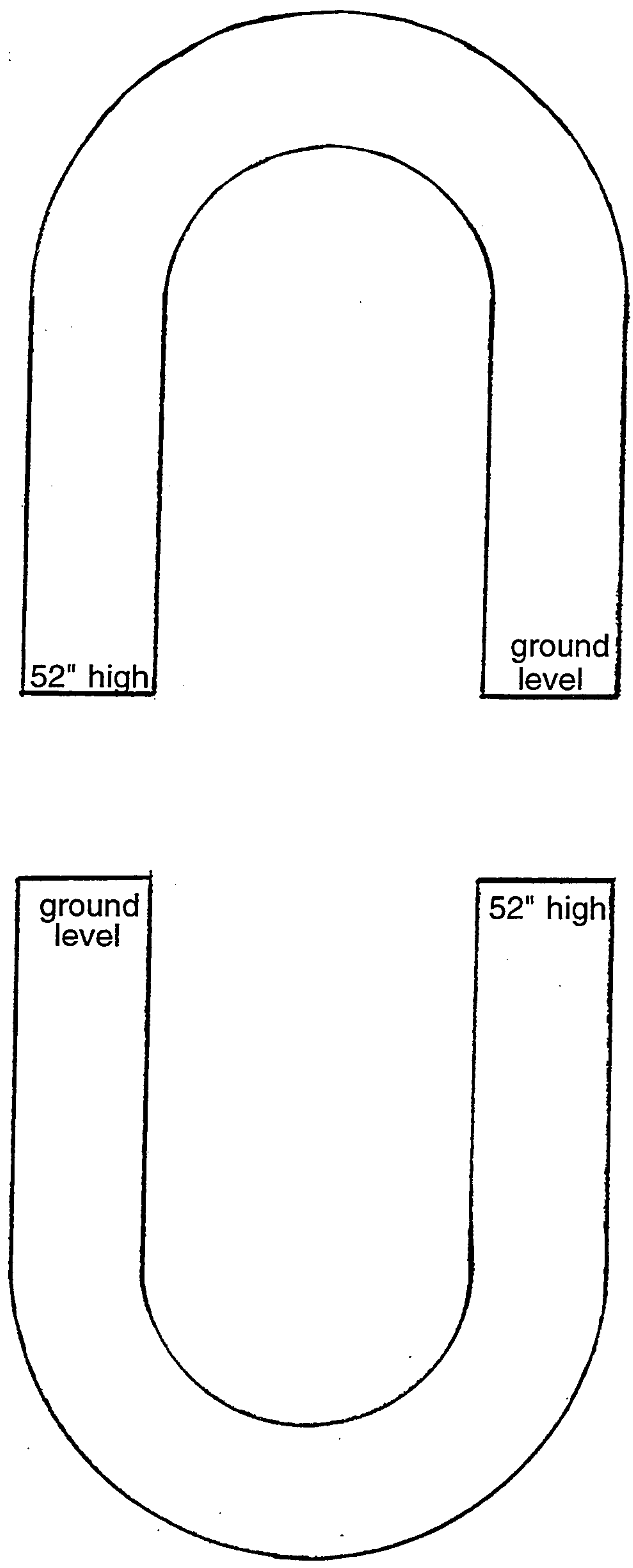

Figure 1. The repetitive lift test setup consisting of two U-shaped roller ramps.

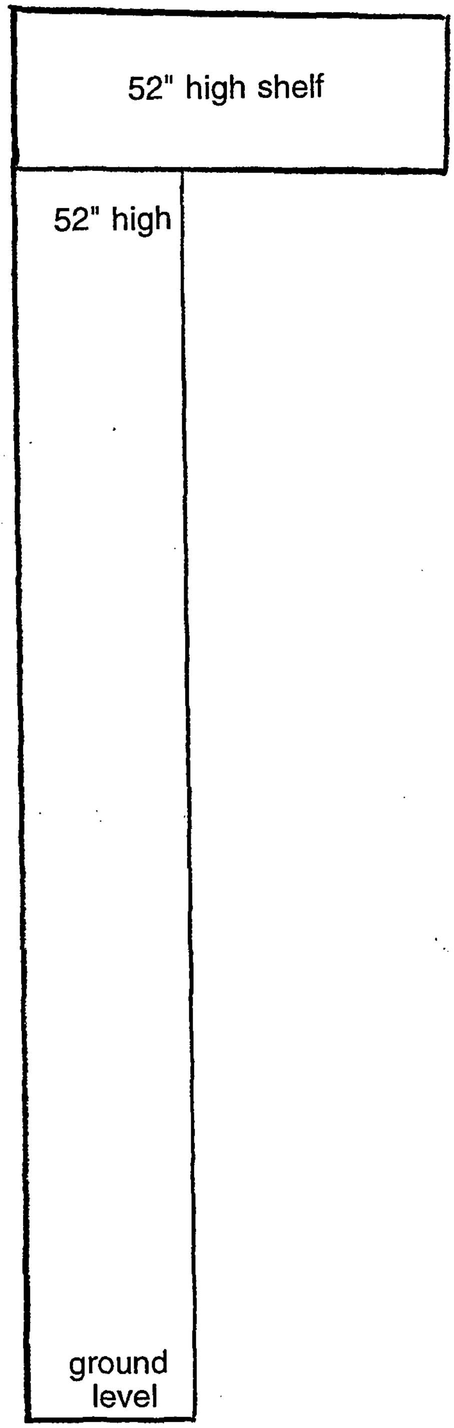

Figure 2. The repetitive lift-carry-lift test setup.

allowed to run while carrying a box, but were allowed to run back to get the next box. The score for this test was the number of times the volunteer could repeatedly transport the 40 lb box in 10 minutes. The volunteer was instructed to transport as many boxes as possible while maintaining good lifting form. Volunteers were encouraged to perform at a steady rate rather than in spurts.

Tests of Maximal Load Transport Speed. The transport of loads in backpacks is an activity frequently performed by infantry soldiers. Even though they are not assigned to combat units, women must also carry backpacks during training. In order to assess their backpack load carriage ability, the research volunteers traversed a 2-mile course as rapidly as possible while carrying a 75-pound external-frame backpack. The 75 pound load is standard for approach marches (Foot Marches, 1990). The course included a paved section with one short moderately steep hill, a relatively flat dirt-road, a rough, unmowed field, and a rough trail with short moderate-to-steep hills. The load-carriage course was used in previous experimentation in our laboratory.

An individually-towed load-carriage trailer was developed at USARIEM to determine if it could facilitate transport of heavy loads by soldiers. In order to test the ability of women to tow a loaded trailer rapidly, the research volunteers traversed at maximal speed the same 2-mile course used for the backpack test. The load-carriage trailer weighed 110 pounds, representing a 75 pound load in a 35 pound trailer.

Weather considerations: In order to avoid heat injury during load carriage, testing was postponed if weather conditions were considered hazardous for the planned type of testing. Such precautions also prevented confounding of experimental results by ambient weather conditions. Any day's postponement caused the testing schedule to be extended by one day.

Dr. Richard Gonzalez and Leander Stroschein of the Biophysics and Biomedical Modelling Division of the U.S. Army Research Institute of Environmental Medicine were consulted concerning allowable ambient conditions for the maximal speed load transport testing. As per their recommendation, their heat strain model was used to determine if ambient conditions were acceptable for testing. If the model indicated research volunteers would exceed a core body temperature of 38.5°C, testing was postponed. To lessen the likelihood of heat-related problems, research volunteers wore shorts and t-shirt during warm weather, and were encouraged to be fully hydrated before each trial. Ample drinking water was available to the volunteers during all test trials and during training.

Leander Stroschein used the heat strain model to estimate the weather conditions appropriate for testing. During the maximal-speed load transport testing, volunteers were expected to self-pace at about 425 watts when asked to go as fast as they could, based on past experience. Assuming a wind speed of 1 m/s, full sunlight, and acclimatized research volunteers, the ambient temperature limit for the maximal performance testing ranged from 30°C (86°F) at 80% humidity to 31.5°C (88.7°F) at 20% relative humidity. The testing took place in Massachusetts from spring to fall during a year when summer temperature was unusually moderate, so there were no tests postponed due to heat and humidity.

Upon consultation with Dr. Murray P. Hamlet, authority on cold injury at the U.S. Army Research Institute of Environmental Medicine, it was decided that to avoid possible frostbite, load carriage trials would be postponed if the ambient temperature were below -2°C (28°F). Because testing began in May and ended in November, there were no instances when it was necessary to postpone testing due to the cold.

Insecure footing can result in increased risk of falls, strains and sprains, and likely decrease the speed at which a course can be negotiated. Therefore, load carriage testing was postponed when the ground was muddy, puddled, or slippery for any other reason.

Non-Occupational Testing

The following additional tests were included in the pre-mid-post test battery in order to characterize the structural and functional changes that resulted from the physical conditioning program, and to help determine which physical characteristics contributed to effective performance of physically demanding occupational tasks. Maximal oxygen uptake testing was done to show the effects of the training program on basic aerobic capability, and to allow examination of the association between the increase in aerobic capability and improvement in task performance. The muscular strength/endurance testing provided similar information in regard to strength/endurance of the muscles of the hip and thigh. Estimation of percent fat and lean body mass, magnetic resonance imaging, and other anthropometric measurements did likewise for body composition. The vertical jump and standing long jump helped identify training-induced changes in rapid, forceful muscular exertions.

Maximal Oxygen Uptake Testing. Oxygen uptake was measured using a continuous, uphill, stepwise, treadmill protocol and a computerized system developed at the U.S. Army Research Institute of Environmental Medicine. The volunteer, connected to the analysis apparatus by mouthpiece and flexible tubing supported by headgear and overhead support-arm, first warmed up by running for 5 minutes at 5 mile/hr on the flat. After a 5 minute rest, the volunteer started running on the treadmill at 5% grade and a speed determined to be easy-to-moderate based on the volunteer's heart rate during the warmup run. Every two minutes, the treadmill speed was increased by 0.5 mile/hr without changing the treadmill grade. A volunteer was considered to be at maximal oxygen uptake if, one minute after a speed increase, the volunteer had not increased oxygen uptake by at least two $ml \cdot min^{-1} \cdot kg^{-1}$. The volunteers generally reached maximum oxygen uptake on the treadmill within 10-14 minutes.

Muscular Strength/Endurance Testing. The volunteers underwent a test of strength/endurance, developed in our laboratory, and used in previous experimentation. The test required the volunteer to squat with a 45.5 kg (100 lb) barbell, lifting the weight .36 m per repetition, at a rate of 37.5 repetitions/min (.625 repetitions/s), cued by a custom-made light system, resulting in a power output of 100 watts exerted by the lifter on the bar. The test score was the number of repetitions the volunteer could perform. Experimenters exhorted the volunteers to stay on the pace and perform full repetitions as they began to tire, and the test was stopped when the volunteer could no longer perform full repetitions at the required pace. The test conditions had been empirically chosen as those for which the test took no longer than a few minutes, even for a large, fit, male research volunteer. Yet the weight was light enough for even smaller, less fit male volunteers to do at least a few repetitions. The weight was not reduced for the females in this study in order to allow comparison of the female scores to the previously established male norms. Thus, on the pre-test, some of the females could not do any repetitions. However, after training, all the females were able to do at least 13 repetitions with the standard weight at the standard pace. The following shows the calculation of external power output for the test:

$$\begin{aligned} power_{W} &= force_{N} \times velocity_{m/s} \\ &= (bar\ mass_{kg} \times accel\ of\ gravity_{m/s2}) \times (meters/rep \times rep/s) \\ &= (45.36_{kg} \times 9.80368_{m/s2}) \times (.360\ m/rep \times .625\ rep/s) \\ &= 100\ watts \end{aligned}$$

The acceleration of gravity used in the equation is specific to the site of testing.

Vertical Jump Test. Vertical jumping ability is important for hurdling obstacles and getting up and over walls. It is also a basic component of general athletic ability.

For the vertical jump test, the research volunteer stood on a force platform and jumped as high as possible, touching a Vertec jump meter at the high point of the jump. The meter provided the vertical distance jumped.

Standing Long Jump Test. Long jumping ability is important for leaping over holes in the ground and other obstacles. For the standing long jump test, the research volunteer stood on a force platform and jumped horizontally as far as possible. A tape measure was used to measure the horizontal distance jumped.

Estimation of Percent Fat and Lean Body Mass. Dual-energy x-ray absorptiometry (DEXA) was used to estimate percent body fat. The DEXA system (LUNAR, Madison WI) also was used to determine bone mineral density and bodily content of bone, fat, and non-bone lean tissue. For the procedure, the volunteer, dressed in shorts and T-shirt, lay face-up on a DEXA scanner table (Mazess 1990). The body was carefully positioned so that it was laterally centered on the table with the hands palm-downward. Velcro straps were used to keep the knees together and support the feet so they tilted 45° from the vertical. Scanning was in 1 cm slices from head to toe using the 20 minute scanning speed. Lunar software version 3.6 provided estimates of percent body fat, bone mineral density and bodily content of bone, fat, and non-bone lean tissue. All female research volunteers underwent DEXA testing only after receiving a negative serum pregnancy test within the prior 48 hours.

Other Anthropometric Measurements. As a means of ascertaining what combination of physical traits were associated with the ability to lift and/or carry heavy loads effectively and quickly, and to describe changes due to training, various body measurements were made including:

body weight:
height:

widths:	knee, elbow
circumferences:	neck, chest, upper arm, waist, hips, thigh, and calf
skinfolds:	subscapular, triceps, biceps, suprailiac, abdominal, thigh, and calf

muscle cross-sectional area: Measurements of the training-induced changes in the volunteers' muscle cross sectional area of the upper arm and upper leg were made using the magnetic resonance imaging (MRI) facilities at West Suburban Imaging in Wellesley, MA. The magnetic field strength of the MRI unit was 1.5 Tesla. Repetition and echo times were 300 and 17 msec respectively and the image was T_1 weighted. Female research volunteers underwent MRI testing no more than 2 days after receiving a negative serum pregnancy test.

In order to obtain the cross-sectional images, the volunteer lay on a sliding table. An RF coil was placed over her right arm or leg such that the image slice was at the midpoint of the elbow and shoulder joint centers for the upper arm and between the hip and knee joint centers for the upper leg. Because the gradient coils generated noise as they were pulsed on and off, the volunteers wore hearing-protective earphones. They were asked to remain as still as possible during the imaging, which took no more than 15 minutes for each of the two limbs.

RESULTS

RELIABILITY OF THE TESTS

To ascertain the reliability of the test battery, five female control subjects underwent most of the tests on two occasions, separated by about five months. A greater number of reliability subjects would have been preferable. However, it did not appear warranted to expose a large number of subjects to the rigors and risks of maximal testing for the purpose of reliability testing. Table 3 shows the reliability of those tests for which at least 3 of the control subjects were tested twice.

Table 3. Pre-post test score correlations of female control subjects and the number of subjects upon which each correlation is based.

Test score	pre-post r	n
Maximal oxygen uptake (l/m)	0.96	5
Maximal oxygen uptake ($ml \cdot min^{-1} \cdot kg^{-1}$)	0.92	5
Heart rate at maximal oxygen uptake ($beats \cdot min^{-1}$)	0.98	5
40-lb 52" lift (max reps in 10 minutes)	0.99	5
30-60" box lift (max weight)	0.92	5
30" box lift (max weight)	0.98	5
2-mile 110-lb trailer tow (max speed)	0.73	4
standing long jump (max distance)	-0.21	4
vertical jump (max distance)	0.84	4
2-mile 75-lb pack hike (max speed)	0.82	3

For the tests in which less than 3 control subjects completed pre- and post-tests, pre-post correlations were run on the women's training group. The rationale is that the reliability of the tests themselves should be at least as great as the pre-post correlations of the training group, because the latter would be reduced by differential training effects among the test subjects. The training group pre-post correlations for the variables not in Table 3 were: 52" maximal box lift r = 0.88, maximum lift-and-carry repetitions in 10 minutes r = 0.82, maximum repetitions squatting with 100 pound barbell r = 0.73. The training group pre-post correlation for the vertical jump was 0.92, which suggests greater reliability than indicated by the control subject testing, and the pre-post correlation for the standing long jump was 0.92, obviously much better than the control group pre-post correlation shown in Table 3. As a whole, the test battery can be characterized as quite reliable, especially considering the 5-6 month time span between pre- and post- tests.

EXPERIMENTAL GROUP ATTRITION

In previous physically demanding U.S. Army Research Institute of Environmental Medicine studies that have taken place over a period of weeks, volunteer attrition has typically been in the range of 25% for males and 50% for females (Marilyn Sharp, USARIEM, personal communication). Because this study involved heavy physical exertion by women over a six month period, it was anticipated that attrition could be well over 50%, threatening the integrity of the study. An effort was made to minimize attrition by: starting the exercise program at a low level of intensity and increasing the intensity gradually, providing consistent encouragement to volunteers and recognition for effort and achievement, varying the training program to avoid tedium, being attentive and responsive to volunteer concerns, and promptly providing treatment for study-related injuries. That effort was rewarded in that total attrition was only about 30%. The reasons for volunteer attrition are shown in Table 4.

The fact that only two of the volunteers discontinued the study for motivational reasons indicated success of the efforts to maintain volunteer morale. One of the two was a mother of four children who had to drive 50 minutes from her home to the training facility. The two women who changed employment had not anticipated doing so at the beginning of the study. Both pregnancies were unplanned. The woman who left because of heavy work and family commitments expressed deep disappointment that she was not able to continue the study. The volunteer who experienced the idiopathic laryngospasm, which made it difficult to breathe, was an avid bicyclist who competed in long-distance bicycle races. While the USARIEM physician who examined her felt that the problem might never recur, and nothing was likely to come of it, the possibility of a fatal episode mandated that she be withdrawn from the study. Fortunately, during the year following her withdrawal, she continued to be exceptionally physically active and continued to compete in 100-mile bicycle races with no further problems. The woman who developed a tumor had initially reported a persistent abdominal ache that she thought was a result of the exercise program. It was later diagnosed as a uterine tumor requiring surgery.

The most severe of the study-related reasons for volunteer withdrawal was the anterior cruciate ligament tear, which occurred as the volunteer tried to lift a weighted box onto a 52" high shelf while undergoing the pre-training test battery. The volunteer later reported having previously torn her other anterior cruciate ligament in a skiing accident. Apparently, to keep pressure off that knee, which had never been surgically repaired, she swung the box to the other side as she attempted to lift it, placing excessive force and torque on the uninjured knee, rupturing the ligament on that knee as well. The way in which the volunteer lifted was directly contrary to the instructions given by the experimenter to lift symmetrically without twisting.

Table 4. Reasons for experimental group volunteer attrition.

Reason for failure to complete study	number of volunteers
Non-study-related reasons:	-
loss of motivation	2
new job, schedule conflict	1
new job, moved outside of commuting range	1
pregnancy	2
heavy work and family commitments	1
idiopathic laryngospasm	1
tumor requiring surgery	1
Study-related reasons:	-
sciatica	1
anterior cruciate ligament tear	1
knee pain	1
back strain	1
hip pain	1

The hip problem was diagnosed as a possible stress-fracture. The volunteer revealed that she had had the problem for some time before the study but hadn't divulged that to the screening physician. The problem resolved itself following the study.

The sciatica was evaluated via magnetic resonance imaging and was shown not to involve spinal disc malformation.

During the study, there were other injuries requiring treatment that necessitated only temporary withdrawal from training or temporary modification of the training program. These problems included foot blisters, shin pain, backache, calf pull, stiff neck, and bruises from falling during a run or hike. A substitute exercise was provided if possible for any exercise that caused an ache or pain.

TRAINING-INDUCED CHANGES IN FEMALE PHYSICAL PERFORMANCE

The effects of the training on the physical performance of those volunteers who made it through the whole program, including the pre-training, mid-training, and post-training testing phases are shown in Table 5 and Figures 3 to 14. The results from those volunteers who missed any of the three testing phases are not shown in the table. However, over the first 14 weeks of training, the improvement in performance of those volunteers who only took the pre- and mid- tests was quite similar to that of volunteers who continued on to complete the whole program. Results for the various performance tests are detailed in the following paragraphs.

Table 5. Performance changes (mean±SD) over the 24-week training period. The mid-test was administered after 14 weeks of training and post-test after 24 weeks of training.

Variables	Pre	%PM	Mid	%MP	Post	%PP	pval
52" box lift (lbs)	90.1±16.9	20.3	108.4±21.1	10.1	117.5±21.2	30.4	<.001
30" box lift (lbs)	132.0±25.3	21.8	160.8±22.3	11.1	175.4±25.0	32.9	<.001
30-60" box lift (lbs)	59.4±12.7	29.1	76.7±15.1	17.8	87.3±17.1	47.0	<.001
40-lb 52" box lift (reps)	105.8±19.3	27.9	135.3±18.0	4.1	139.6±18.3	31.9	<.001
40-lb 52" lift, 25' carry (reps)	52.5±6.5	11.2	58.4±6.8	6.3	61.7±5.9	17.5	<.001
vertical jump (in)	12.3±2.8	17.1	14.4±3.1	3.3	14.8±3.0	20.3	<.001
standing long jump (ft)	4.97±.76	8.2	5.38±.77	7.0	5.73±.88	15.3	<.001
100 lb barbell squat (reps)	15.8±13.6	143.7	38.5±21.1	149.4	62.1±29.4	293.0	<.001
2-mile 110-lb trailer tow (min)	28.0±3.5	-11.8	24.7±3.3	-1.4	24.3±2.7	-13.2	<.001
2-mile 75-lb pack hike (min)	36.2±3.4	-18.5	29.5±4.3	-5.2	27.6±4.1	-23.8	<.001
VO2 (ml/kg)	40.8±5.0	13.2	46.2±5.7	0.7	46.5±5.5	14.0	<.001
2-mile 110-lb trailer tow (mph)	4.35±.54	13.6	4.94±.65	1.6	5.01±.56	15.2	<.001
2-mile 75-lb pack hike (mph)	3.35±.35	24.2	4.16±.64	8.4	4.44±.69	32.5	<.001

Pre = test results obtained before the physical training program
Mid = test results obtained after 14 weeks of training
Post = test results obtained after 24 weeks of training
%PM = percent change from the pre-test to the mid-test
%MP = percent change from the mid-test to the post-test
%PP = percent change from the pre-test to the post-test
pval = probability that pre-post change in mean score occurred by chance.

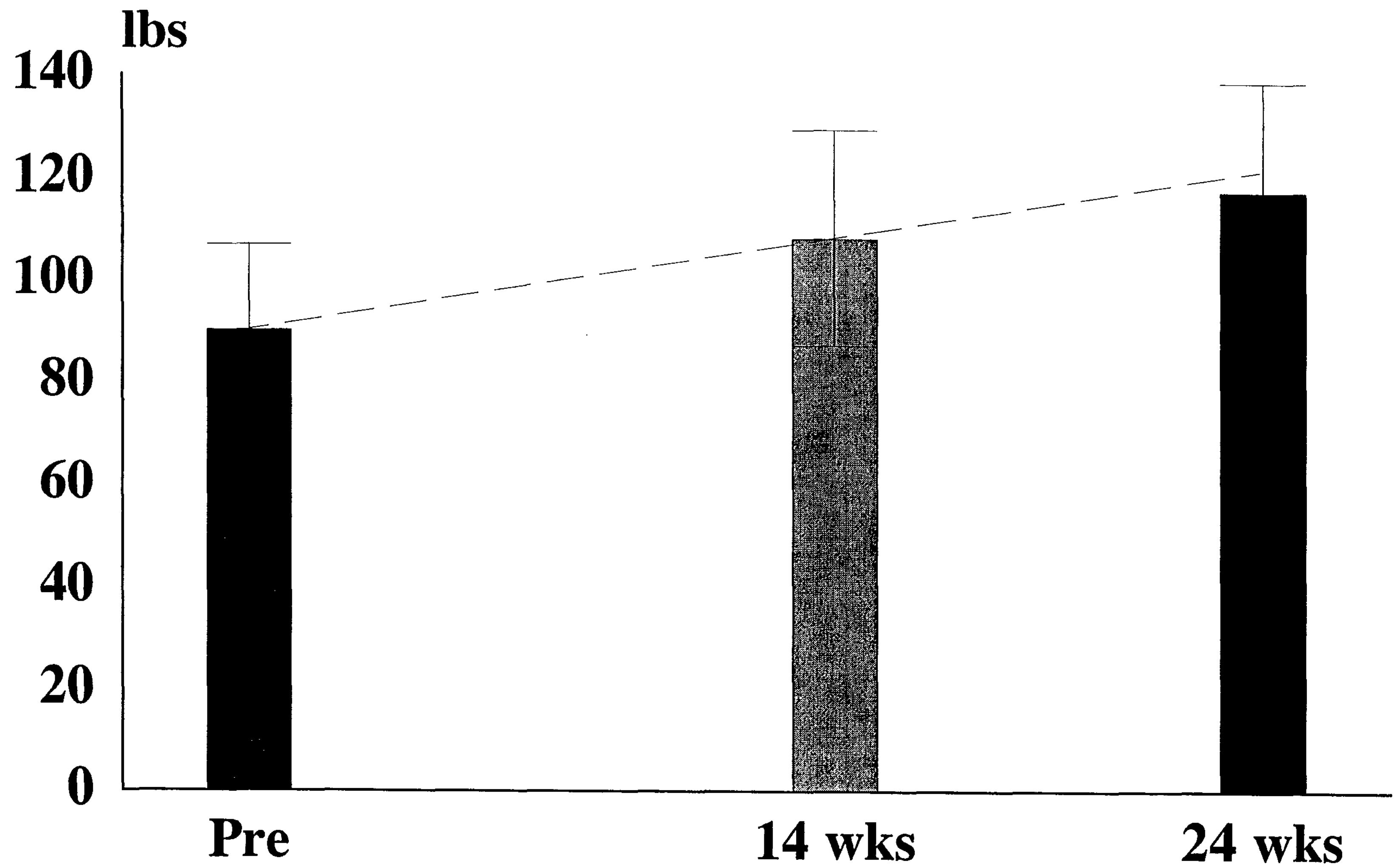

Figure 3. Maximal box weight lifted from the floor to a 52" height (mean±SD).
Probability that pre-post difference occurred by chance <0.001

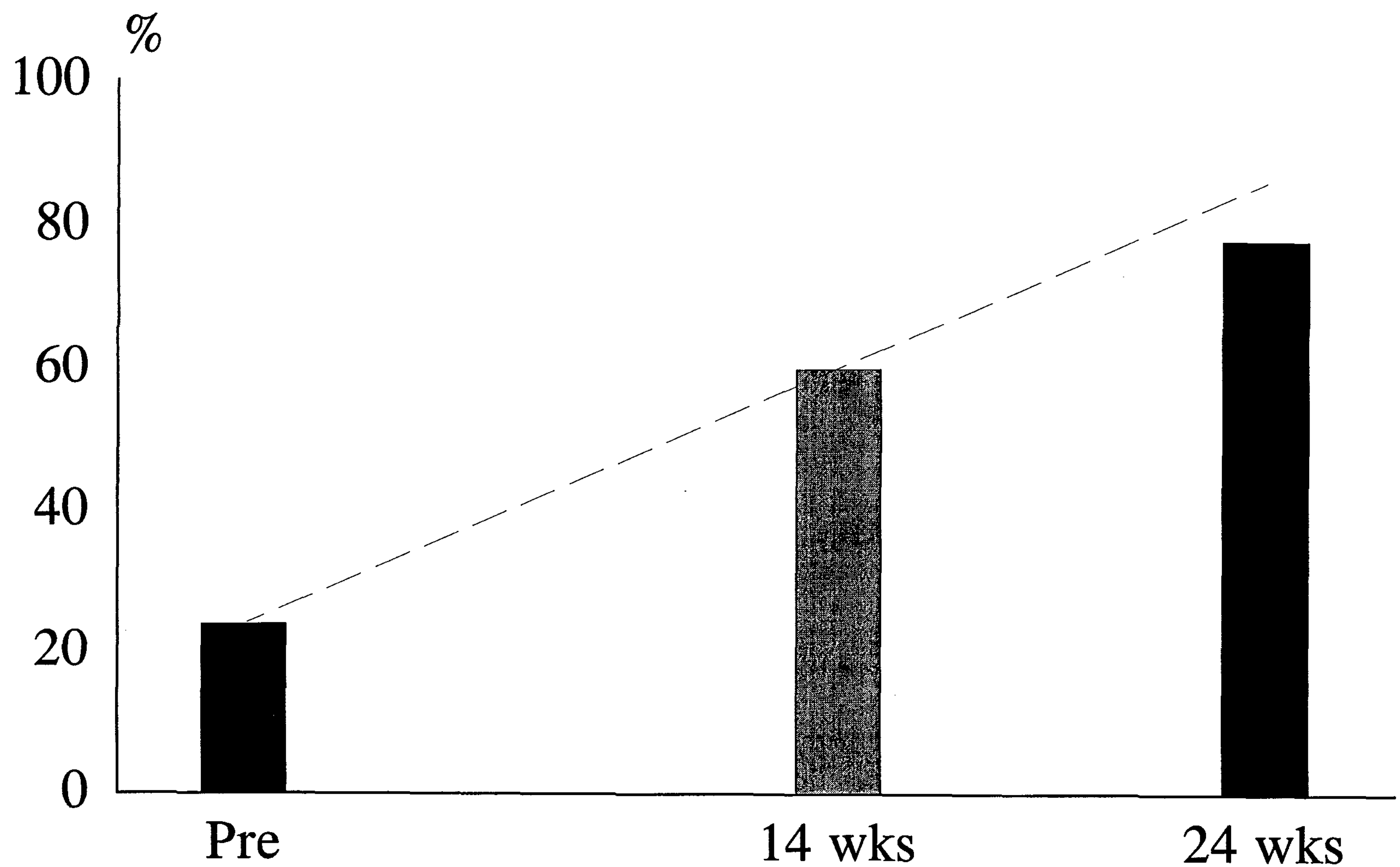

Figure 4. Percentage of female volunteers meeting "very heavy" job criterion (mean±SD). Probability that pre-post difference occurred by chance <0.001

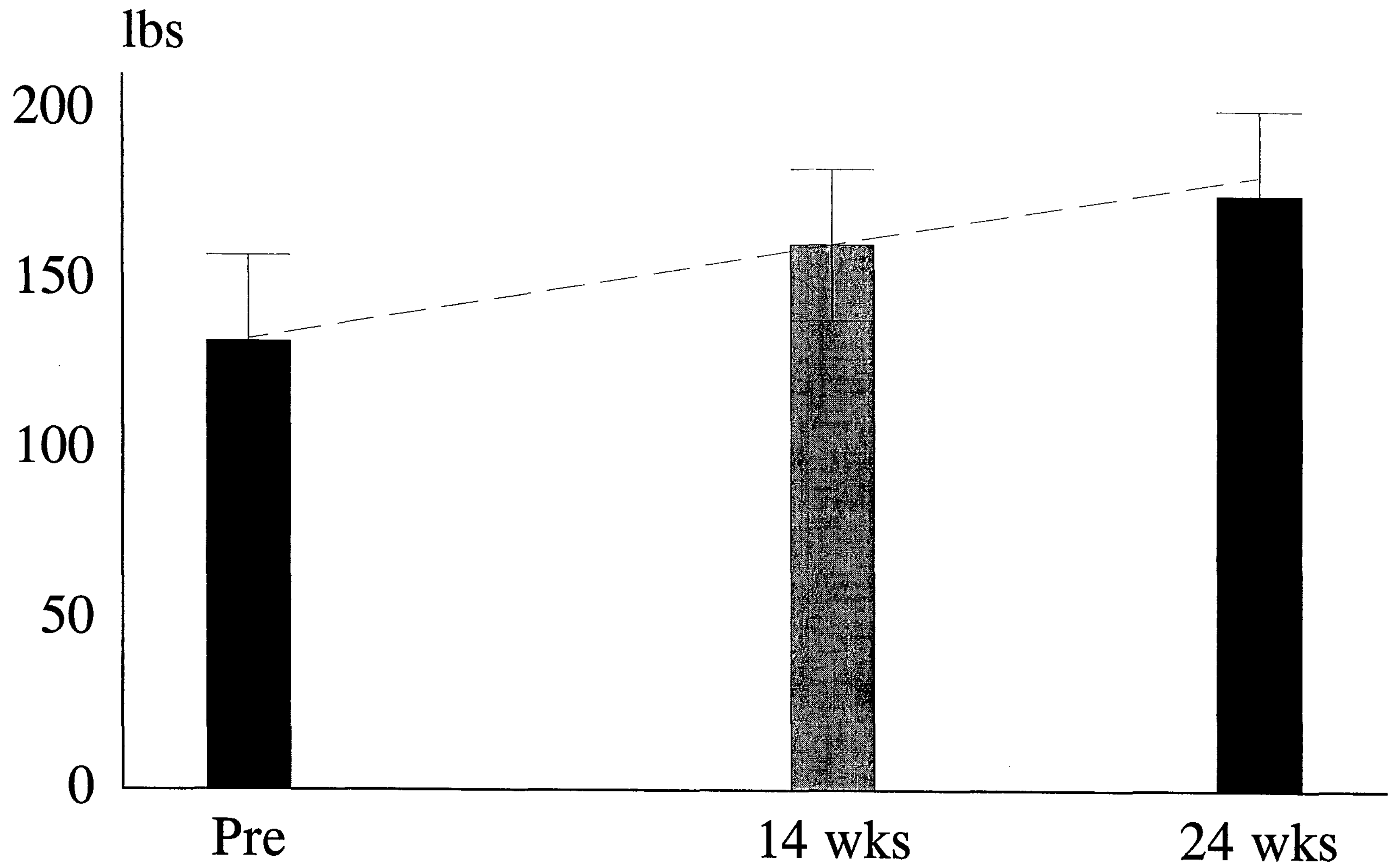

Figure 5. Maximal box weight lifted from the floor to a 30" height (mean±SD).
Probability that pre-post difference occurred by chance <0.001

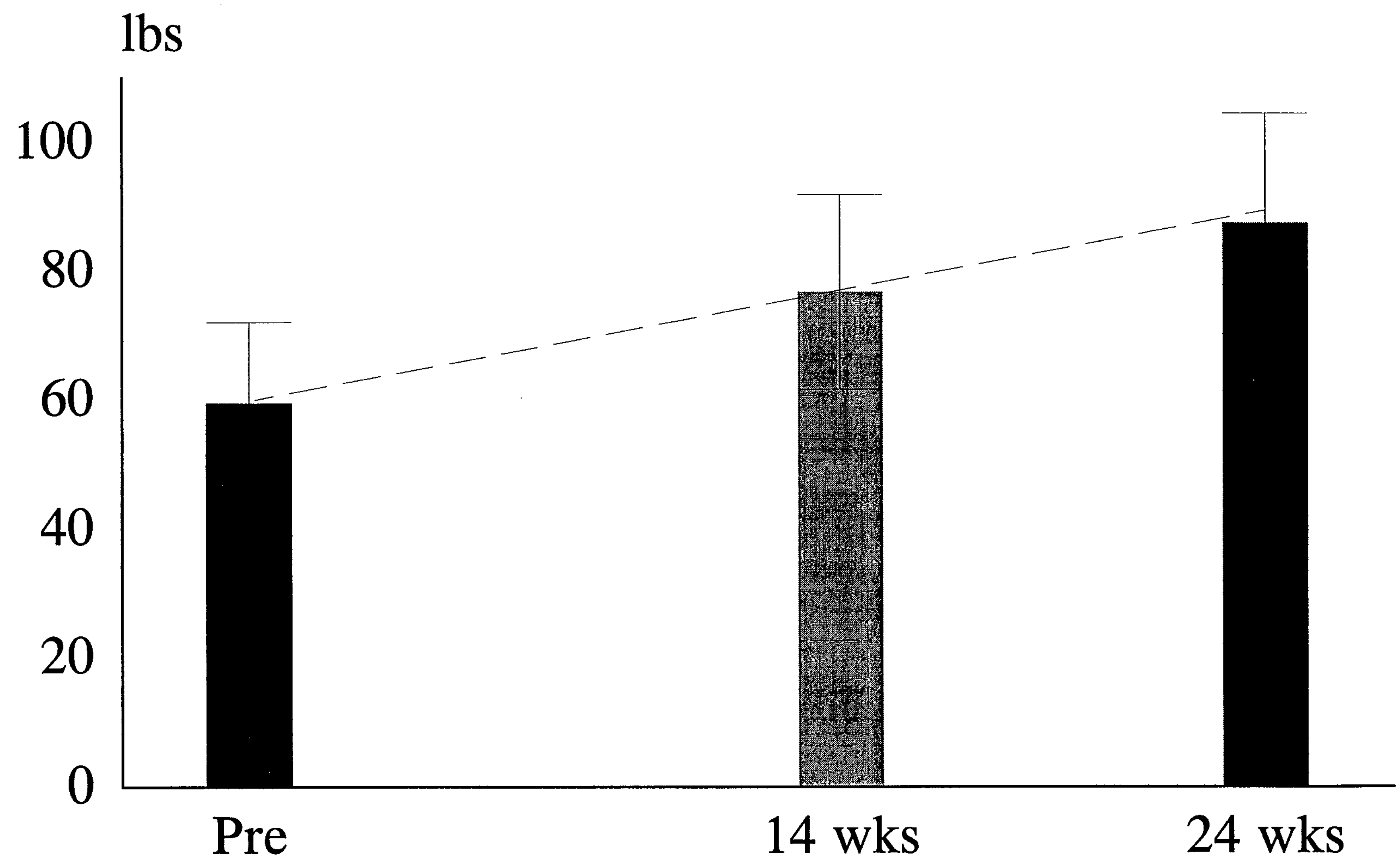

Figure 6. Maximal box weight lifted from a 30" height to a 60" height (mean±SD).
Probability that pre-post difference occurred by chance <0.001

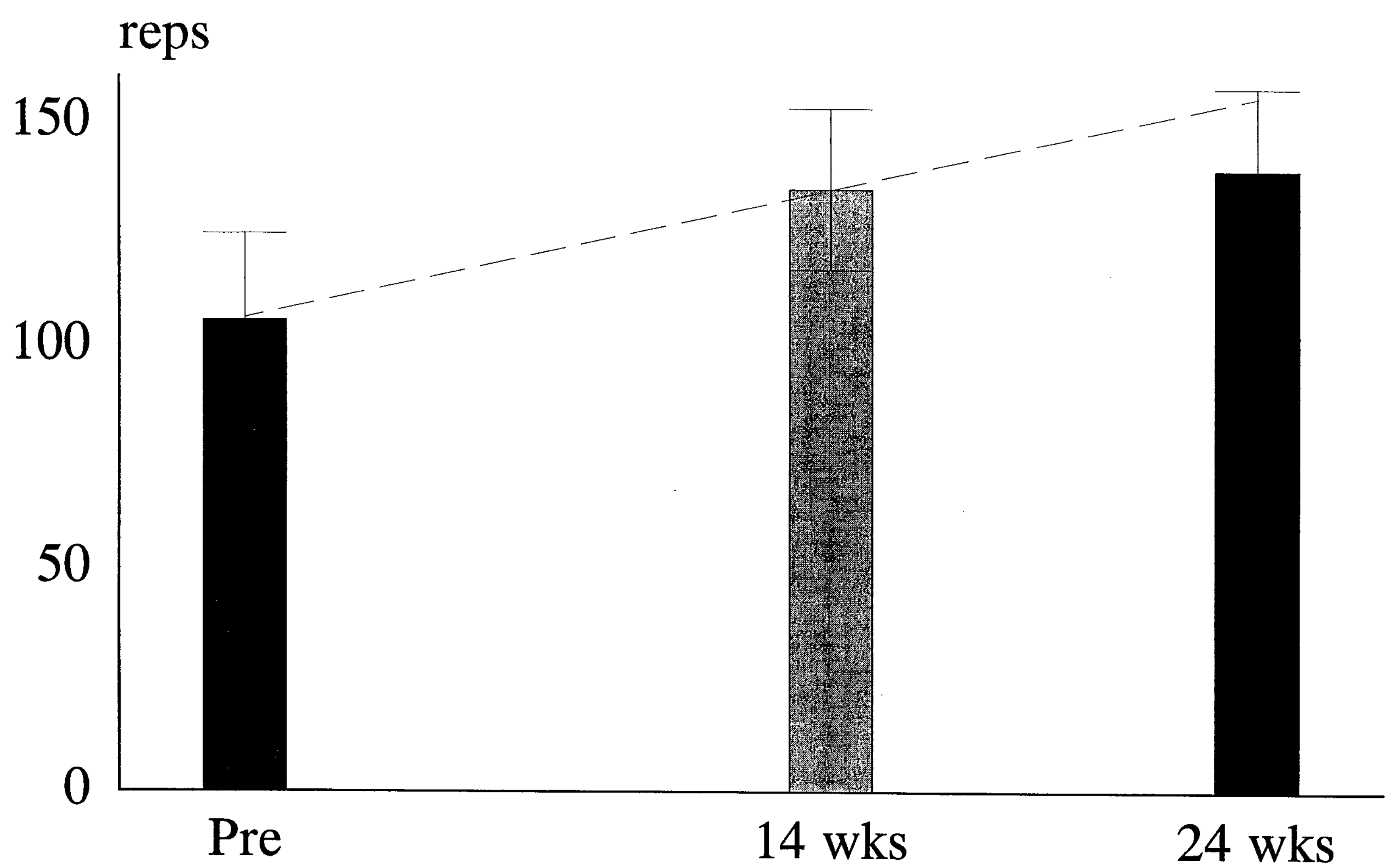

Figure 7. Number of times in 10 minutes a 40 pound box could be lifted to a 52" height (mean±SD). Probability that pre-post difference occurred by chance <0.001

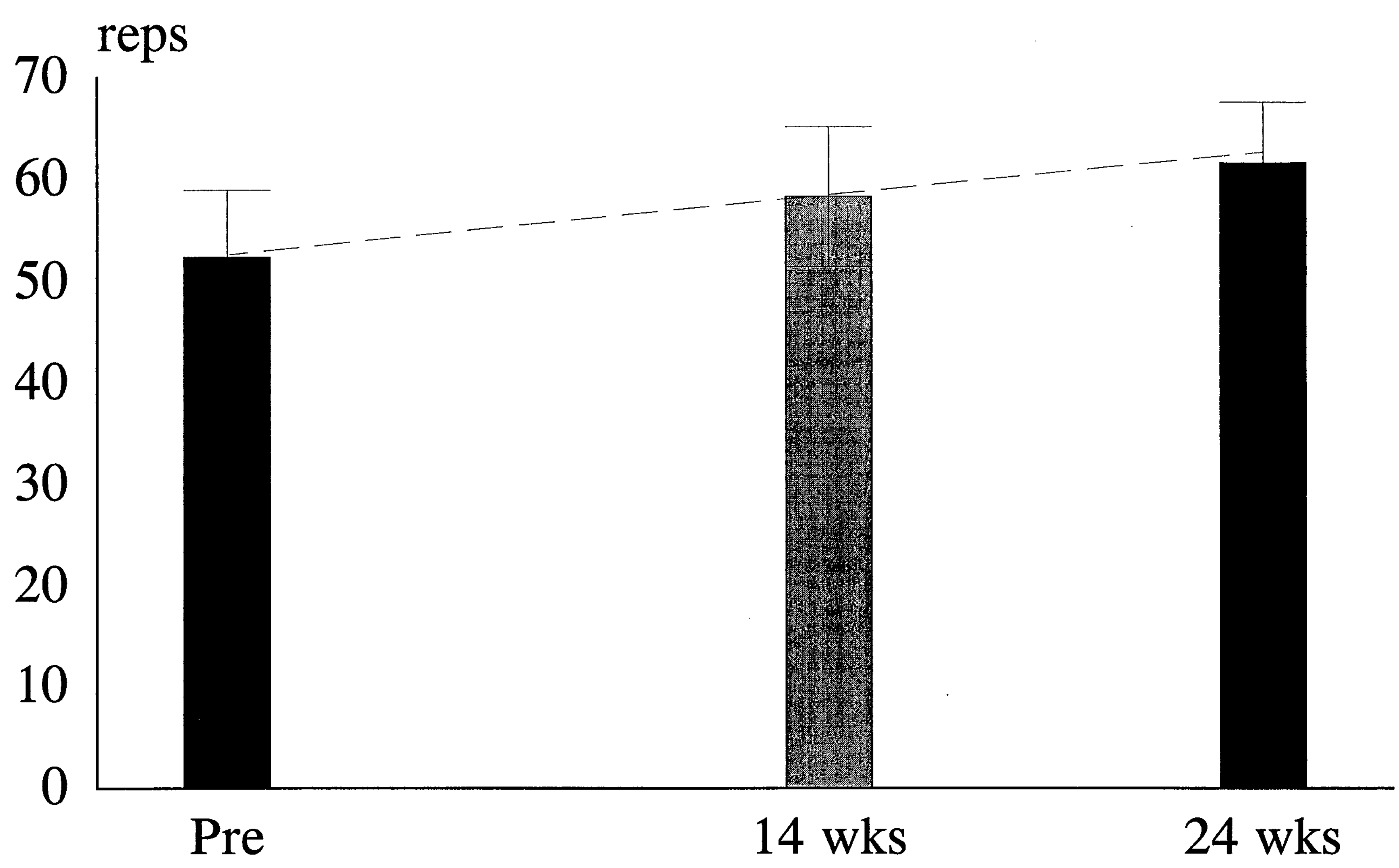

Figure 8. Number of times in 10 minutes a 40 pound box could be lifted off the ground, carried 25-feet, and lifted up to a 52" height (mean±SD). Probability that pre-post difference occurred by chance <0.001

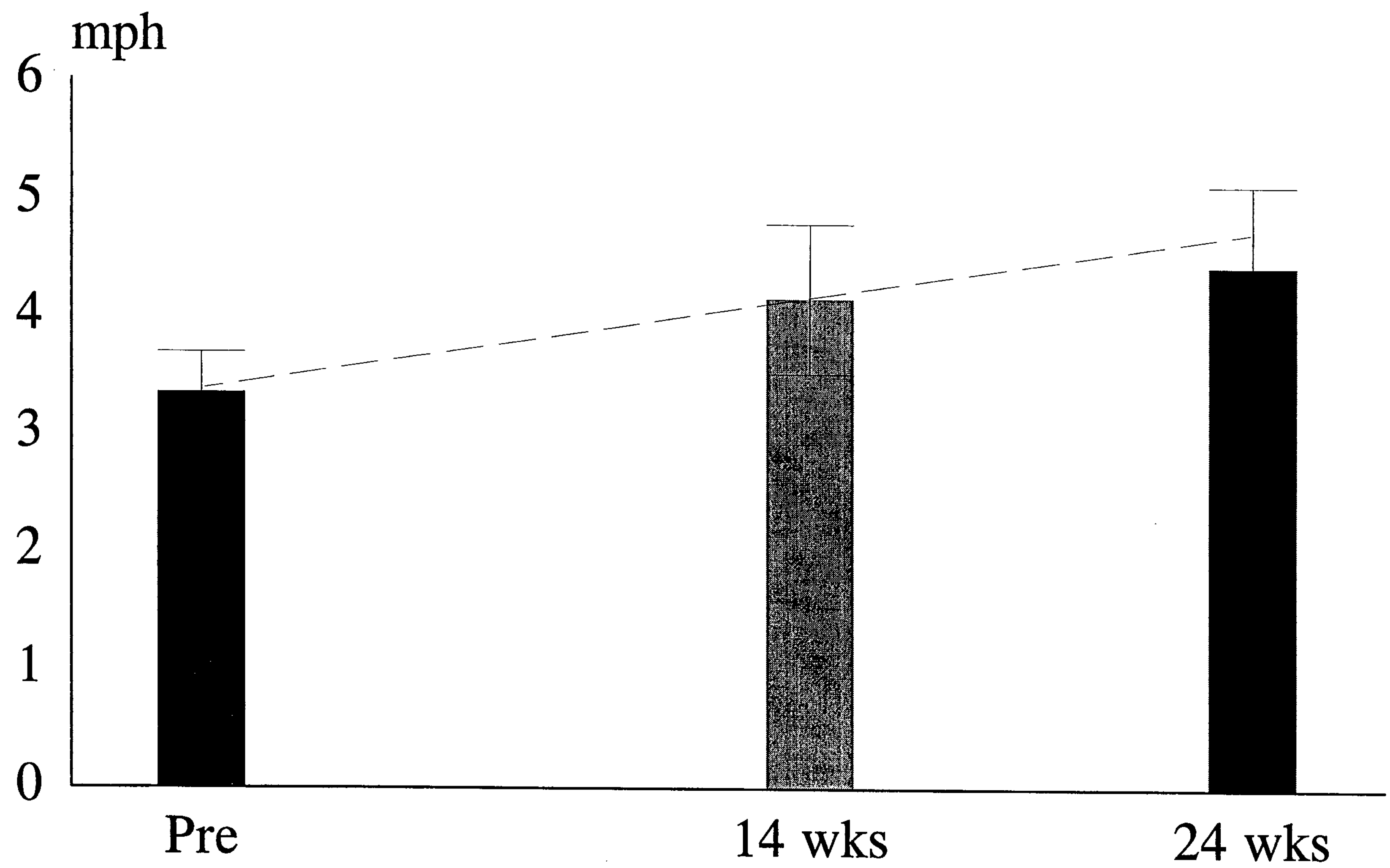

Figure 9. Average speed over 2 mile course carrying 75-pound backpack (mean±SD). Probability that pre-post difference occurred by chance <0.001

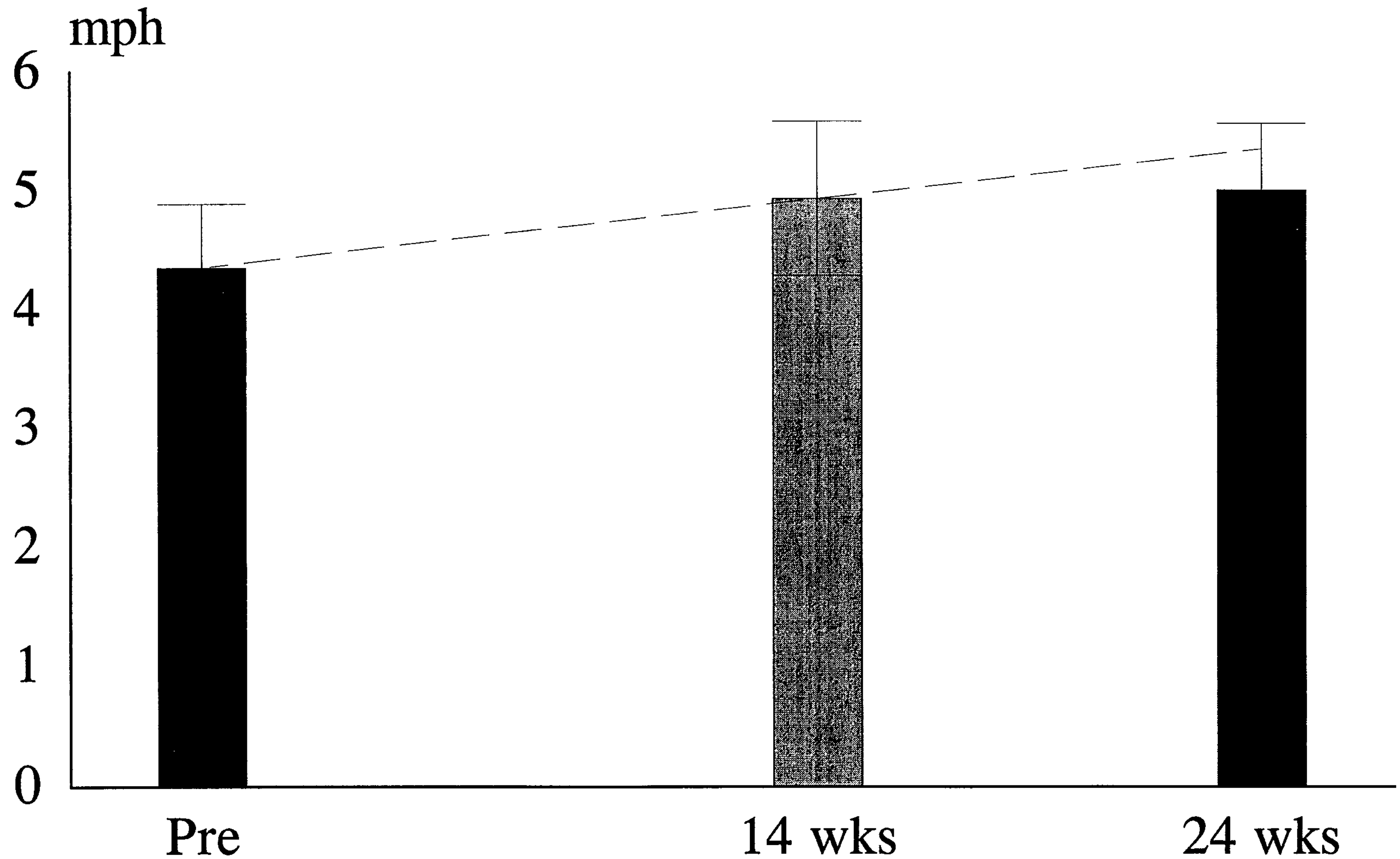

Figure 10. Average speed over 2 mile course towing 110-pound trailer (mean±SD). Probability that pre-post difference occurred by chance <0.001

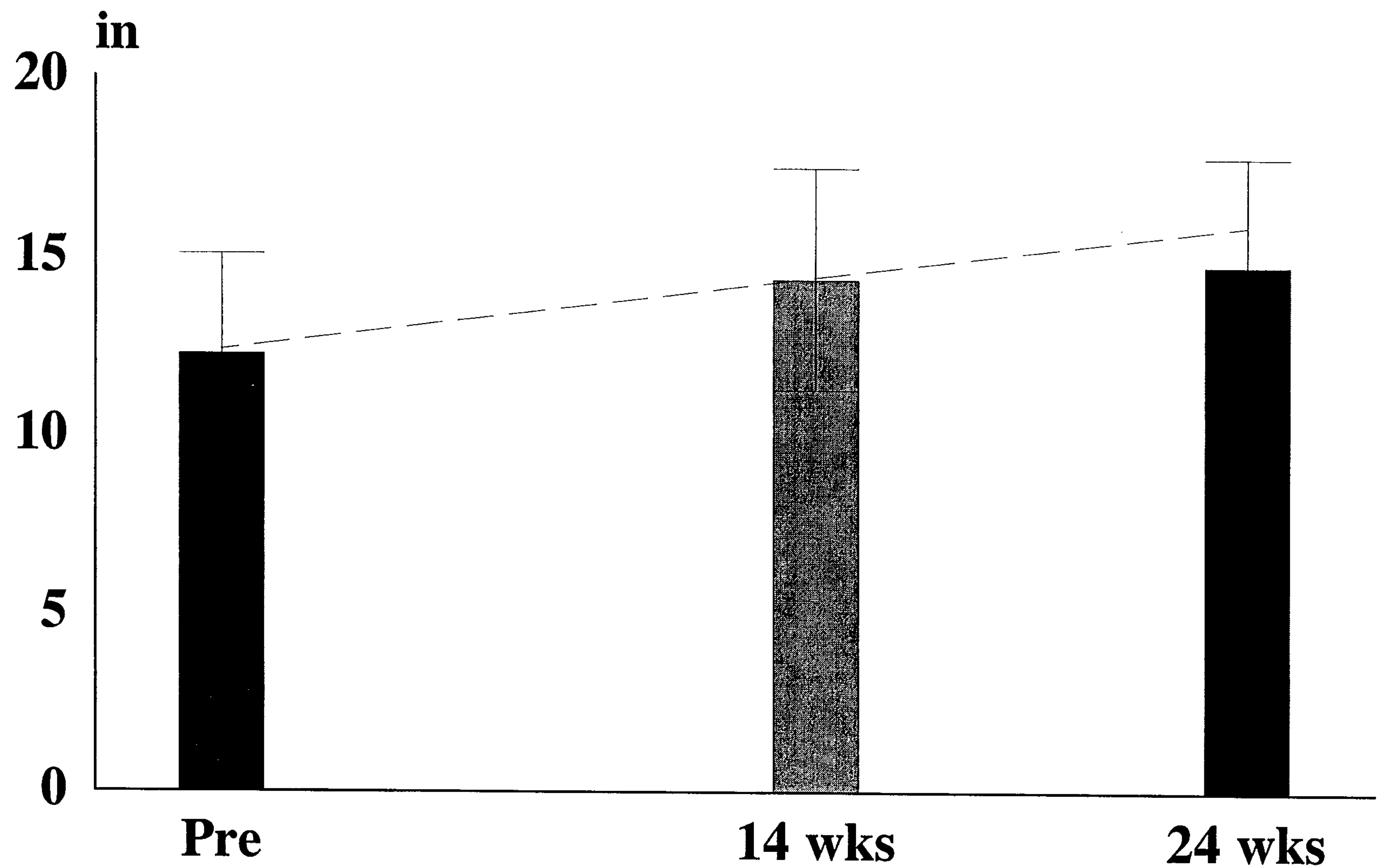

Figure 11. Maximal vertical jump height (mean±SD).
Probability that pre-post difference occurred by chance <0.001

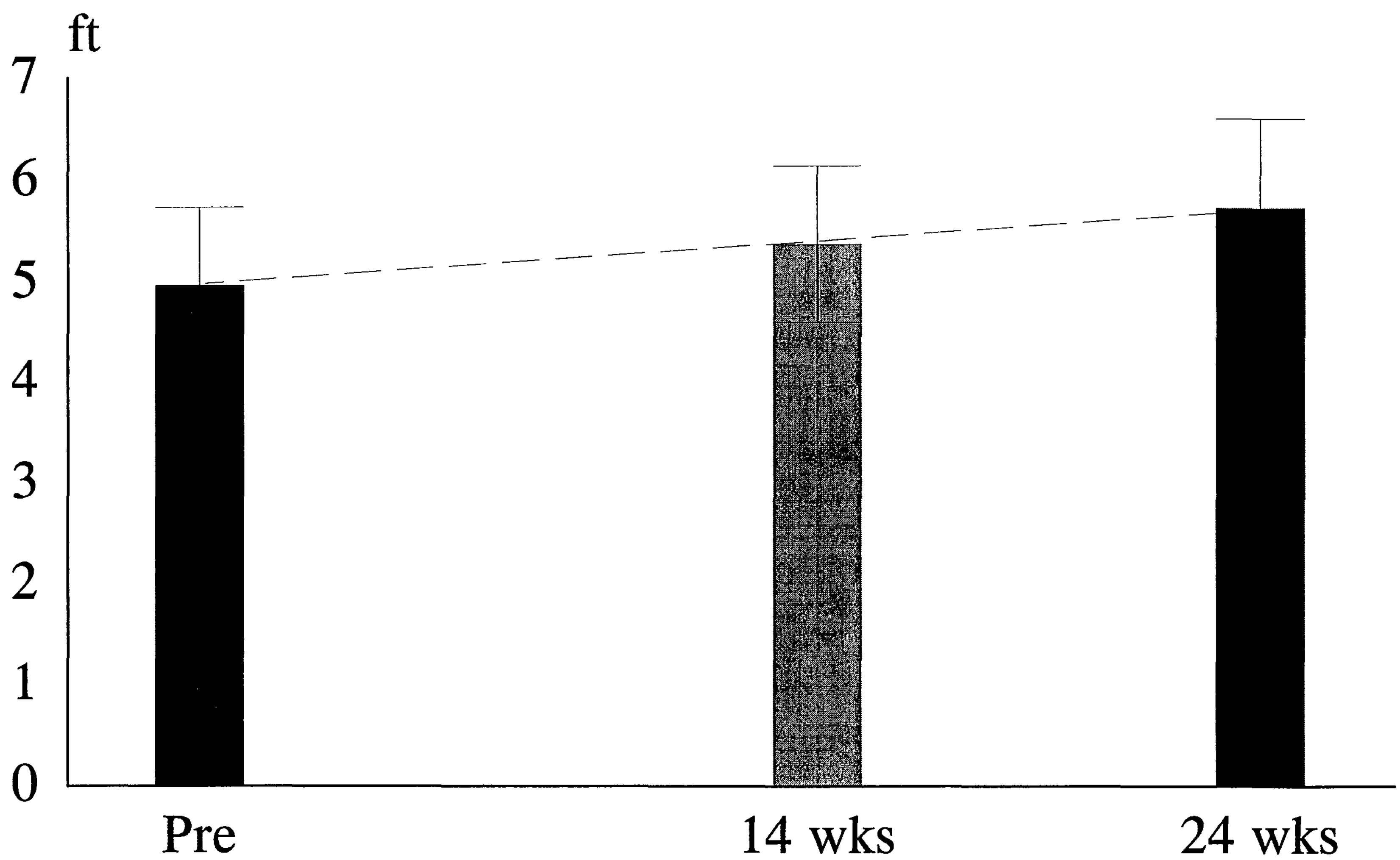

Figure 12. Maximal standing long jump distance (mean±SD).
Probability that pre-post difference occurred by chance <0.001

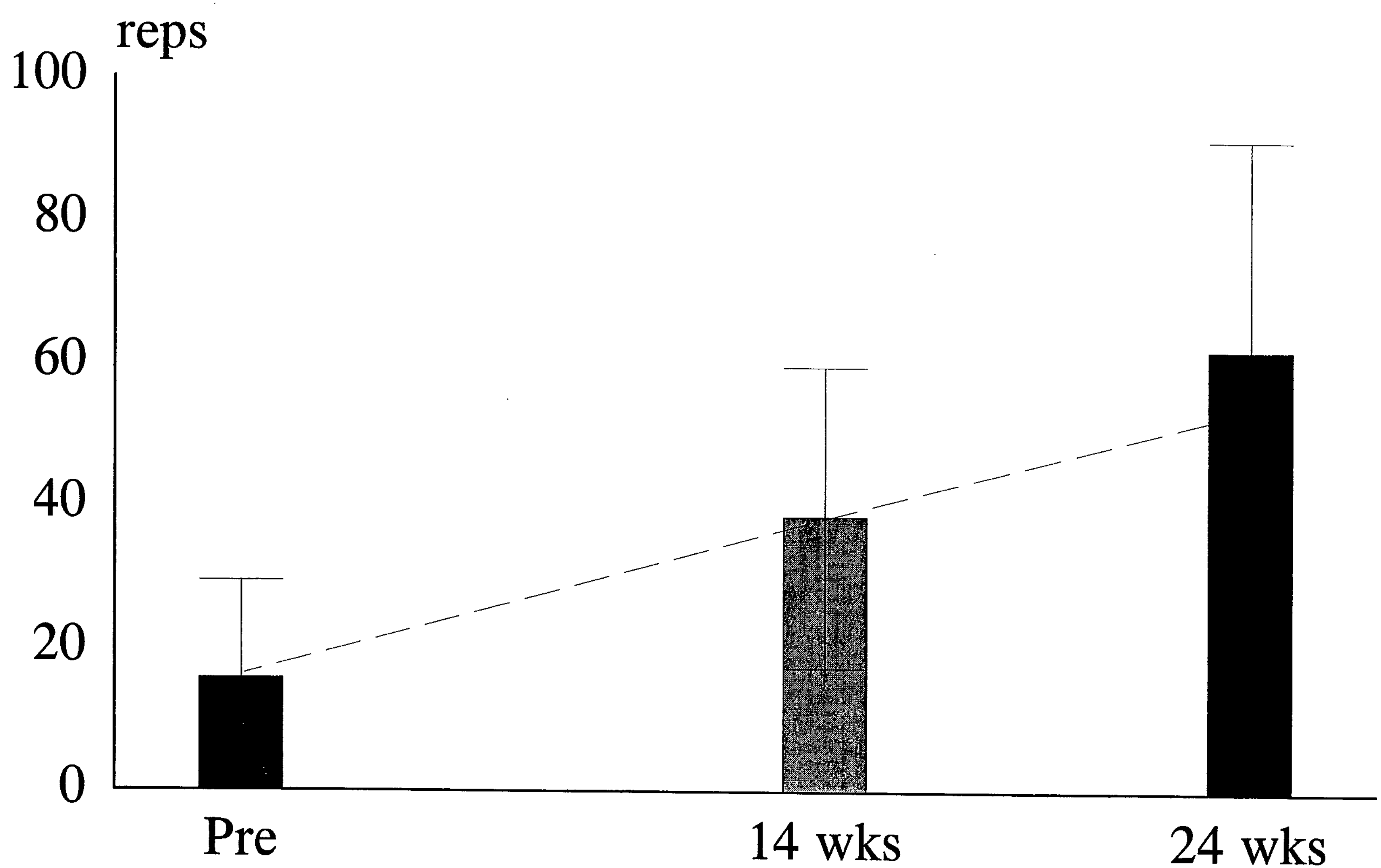

Figure 13. Maximal number of squat repetitions with 100-pound barbell (mean±SD). Probability that pre-post difference occurred by chance <0.001

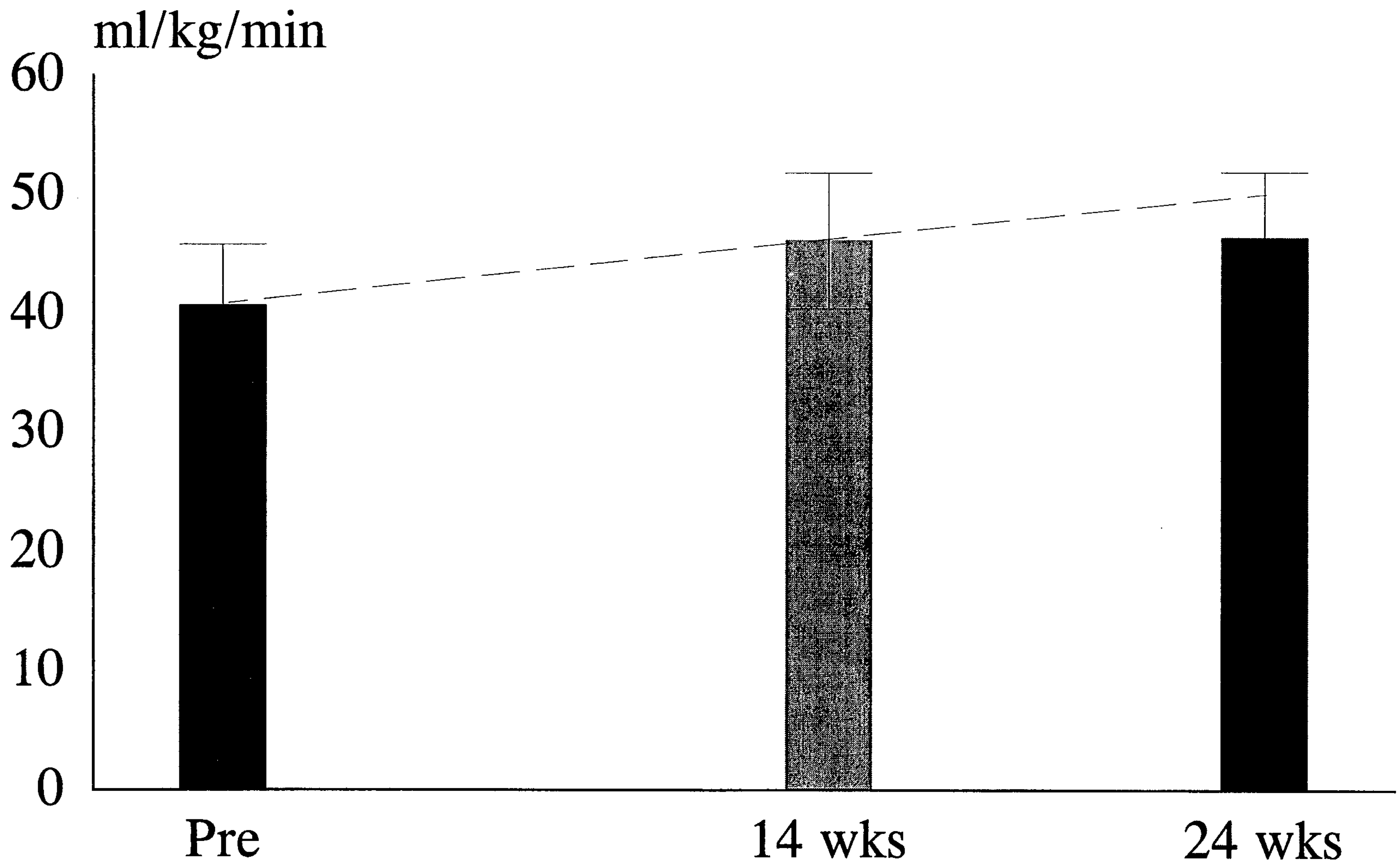

Figure 14. Maximal oxygen uptake measured on a treadmill (mean±SD).
Probability that pre-post difference occurred by chance <0.001

Maximal Lifting

It can be seen in Table 5 that the performance of the women in the three different maximal box lifts improved 30.4%, 32.9% and 47.0%. The U.S. Army considers a military occupational specialty "very heavy" if more than 100 lbs. must be lifted occasionally. However, that categorization does not specify the height of the lift. If we consider the lift to table height (30"), 38 of the 41 women who took the pre-training test were able to lift in excess of 100 lbs (Table 6). After 14 weeks of training all the volunteers were able to lift in excess of 100 lbs. If we consider the lift to truck-bed height (52", Table 7), which is a relatively high but important lift in the military context, only 24% of the women could lift over 100 lbs on the pre-training test. However, after 14 weeks of training, 60% of the women could lift over 100 lbs., and after 24 weeks of training, 78% could lift over 100 lbs. Thus, the training program could be considered quite successful in preparing women for "very heavy" military occupational specialties. The fact that in Figure 3, a relatively linear improvement in capability is evidenced over the 24 week training period suggests that, had training continued for several more weeks, an even larger percentage of women could have passed the required standard; this projection is also supported by Figure 4. Improvements in the other maximal lift tests were also quite linear (Figures 5 and 6).

A previous study of female Army personnel showed that, before basic training, only 29% of females assigned to "very heavy" MOS's could lift the amount of weight required by their jobs, while after basic training, 40% could perform the required lifts (Westphal et al., 1995). Thus, only 15% of the women who initially failed were brought to a passing level by basic training. In contrast, our training program brought 71% of those who initially failed up to a passing level, indicating a success rate of our program almost five times better than that of basic training. Seventy-eight percent of our female volunteers could qualify at the "very heavy" MOS level after training. The experimental program is clearly more effective than standard Army Basic Training programs in preparing females to perform heavy jobs. The physical training portion of Army Basic Training is not specifically designed to improve lifting ability.

Repetitive Lifting

The training increased by 31.9% the number of times the female volunteers could lift a 40 lb box to a 52" height in 10 minutes. It also increased by 17.5% the number of times in 10 minutes that a 40 lb box could be lifted off the ground, carried 25 feet and lifted onto a 52" high shelf. These improvements are illustrated in Figures 7 and 8. An

Table 6. Floor to 30" box lift. The number (%) of female volunteers who could lift within the indicated range before training, after 14 weeks of training, and after 24 weeks of training.

	less than 80 lbs	80-100 lbs	over 100 lbs
before training	0 (0%)	3 (7%)	38 (93%)
after 14 weeks of training	0 (0%)	0 (0%)	29 (100%)
after 24 weeks of training	0 (0%)	0 (0%)	32 (100%)

Table 7. Floor to 52" box lift. The number (%) of female volunteers who could lift within the indicated range before training, after 14 weeks of training, and after 24 weeks of training.

	less than 80 lbs	80-100 lbs	over 100 lbs
before training	11 (27%)	20 (49%)	10 (24%)
after 14 weeks of training	1 (3%)	13 (37%)	21 (60%)
after 24 weeks of training	1 (3%)	6 (19%)	25 (78%)

apparent reason that the repetitive lift-carry-lift test didn't show as much improvement as the repetitive lift test is the stipulation that, for safety reasons, the volunteers not run while carrying the box. Since the walking segment of the activity took up more than half the time, overall room for improvement was limited.

Backpacking Speed

The 2-mile 75 lb backpacking speed of the female volunteers improved 32.5% over the 24 weeks of training to 4.44 mph (Figure 9). According to the Army field manual on foot marches, "the fighting load for a conditioned soldier should not exceed 48 lbs and the approach march load should not exceed 72 lbs" (this weight includes the soldiers clothing, boots, etc). In addition, the manual states that a normal rate of march on a road during the day is 2.5 mph. Thus, after training, the female volunteers in our study carried a heavier pack than prescribed at a considerably greater speed. While our test distance was only 2 miles, the fact that the women were able to average 78% faster than the normal Army march speed strongly suggests that they would be able to readily maintain the standard speed with heavy packs for long distance marches. Additional supporting evidence is that their weekly backpack training hikes were five miles long at a minimum of four miles per hour.

Trailer Tow Speed

The speed at which the volunteers towed a 110-pound trailer two miles over the mixed-terrain course improved by 15.2% to 5.01 miles per hour (Figure 10). One reason the volunteers didn't improve in trailer towing speed as much as in backpacking speed is that the highest priorities of the training program were to improve lifting and load carriage ability. Thus exercises were selected that were less specific for load towing than for load carriage.

Jumping Ability

Vertical jump improved by 20.3%. Standing long jump improved by 15.3%. These improvements can be seen in Figures 11 and 12.

Muscular Strength/Endurance

The maximal number of times the experimental volunteers could squat with a 100 lb barbell on their shoulders almost quadrupled, from 16 to 62 repetitions (Figure 13). This indicates a great increase in strength/endurance of the hip and thigh muscles. It is not surprising that this test showed the greatest percentage of improvement of any of the tests since the squat was one of the core training exercises.

Aerobic Ability

The maximal oxygen uptake relative to body mass of the female volunteers, determined on a treadmill, increased an average of 14% with training (Figure 14), a considerable improvement in aerobic fitness. Improvement of this magnitude would be expected of an endurance-training program (McArdle, Katch, and Katch, 1996). Even though the women in our study only ran a maximum of four miles per week, the combined effect of the weekly runs, the five-mile backpack hike, and the four day per week fast-paced weight training was enough to bring about this relatively large increase in aerobic power. The mean of the females after training was similar to that of average American males in the same age range (McArdle, Katch, and Katch, 1996).

Individual Differences in Response to Training

Because considerable variation was observed among the women in responsiveness to physical training, an effort was made to identify factors accounting for the differences. Correlational analysis determined that the major predictor of improvement was pre-test performance, with those women starting out less capable improving by the greatest percentage. Table 8 shows that on several of the tests, poorer pretest performance was a good predictor of greater responsiveness to training. The negative correlations of lift improvement with pre-test strength were even stronger when lifts were expressed as percentage of lean body weight, indicating a decline in a muscle's trainability as it's strength potential is approached. In a notable exception to the overall trend, the percentage change in backpacking speed showed no association at all ($r = -0.09$) with initial performance. While body fatness was unrelated to improvement in maximum weight lifted or number of repetitions performed in endurance tests, the initially fatter women improved less in backpacking speed but more in the vertical and long jumps, even though both the fatter and the leaner women lost similar percentages of their body fat. All other anthropometric factors (height, weight, lean body mass, circumferences, diameters, etc.) were poor predictors of responsiveness to training. Thus pre-test performance was the best predictor of responsiveness to physical training among the women.

Table 8. Statistically significant (p<0.05) correlations of pre-test performance with percent improvement (the negative r's indicates greater improvement with poorer pre-test performance).

Test	r
maximal box weight lifted from floor to 76 cm height	-0.69
maximal box weight lifted from floor to 132 cm height	-0.38
maximal box weight lifted from 76 cm height to 152 cm height	-0.42
lift 18 kg box to 132 cm height - maximal reps in 10 min	-0.71
lift 18 kg box, carry it 8 m, lift it to 132 cm height - maximal reps in 10 min.	-0.65
maximal oxygen uptake - treadmill	-0.39
maximal vertical jump	-0.63
maximal standing long jump	-0.35

TRAINING-INDUCED CHANGES IN FEMALE BODY COMPOSITION

Even though improvement in physical performance was the major object of the training program, Table 9 and subsequent graphs show that the women also improved their body composition profiles. Despite losing an average of only 1.4 kg. in body weight (Figure 15), they lost 2.8 kg. of body fat (Figure 16), and gained about 0.9 kg. of muscle (Figure 17), resulting in a decreased percent body fat (Figure 18). The thickness of skinfolds in various parts of the body, an indicator of fat deposits under the skin, decreased by a mean 16% (Figures 19 to 25). Chest circumference increased by 12% (Figure 26) presumably because of development of muscles of the chest and back, and improved posture. The average waist and hip circumferences dropped by about two cm. (Figures 27 and 28), but the thigh circumference increased about one cm. (Figure 29) even though the fat thickness dropped by 17%, indicating that thigh muscularity increased. Memers of the research team as well as several friends and family members of the volunteers, remarked that the female volunteers had greatly improved their appearance over the course of the study. Bone mineral density increased less than one percent (Figure 30), a change that was not significant. However, if such increases would continue to occur over an extended training period, it would lead to major increases in bone mineralization. Current scientific opinion is that weight-bearing exercise can increase bone mineralization and decrease the likelihood of osteoporosis in later life (Grimston et al., 1993; Haliova and Anderson 1989).

Thirty-one test volunteers underwent MRI scans before and after training to assess upper-arm and upper-leg muscle cross-sectional area. Table 10 shows the changes resulting from training. One can see that the muscle cross-sectional area of both the upper-arm and upper-leg increased about 5% with training. The ratio of arm to leg cross-sectional area was not affected at all by training; arm cross-sectional area remained at about a fourth of leg cross-sectional area.

Table 9. Body composition changes (mean±SD) over 24-week training period. Mid-test was administered after 14 weeks of training and post-test after 24 weeks of training.

Variables	Pre	%PM	Mid	%MP	Post	%PP	pval
body mass (kg)	69.5±11.7	-0.7	69.0±11.1	-1.3	68.1±11.2	-2.0	.05
DEXA percent fat (%)	36.3±7.8	-4.4	34.7±7.6	-8.0	31.8±7.7	-12.4	.0001
fat mass (kg)	24.9±9.1	-5.6	23.5±8.6	-5.6	22.1±8.4	-11.2	.0001
lean body mass (kg)	41.7±4.0	1.4	42.3±4.2	0.7	42.6±4.2	2.2	.0001
bone mineral density (g/cm)	2.71±.34	-0.4	2.70±.34	1.1	2.73±.33	0.7	.08
chest circumference (cm)	82.3±8.2	10.0	90.6±5.6	2.2	92.4±6.4	12.3	.0005
upper arm circumference (cm)	29.8±3.4	-0.3	29.7±2.8	-0.7	29.5±3.0	-1.0	.63
waist circumference (cm)	80.4±10.8	-1.2	79.4±10.3	-1.2	78.4±10.3	-2.5	.005
hip circumference (cm)	104.2±8.4	-1.6	102.5±7.5	-0.9	101.6±7.7	-2.5	.0005
thigh circumference (cm)	55.6±5.2	-0.5	55.3±4.9	2.0	56.4±5.2	1.4	.05
calf circumference (cm)	36.9±3.3	0.8	37.2±3.2	-1.1	36.8±3.3	-0.3	.11
suprailiac skin/fat fold (mm)	17.5±8.6	-8.0	16.1±8.6	-7.4	14.8±8.2	-15.4	.001
subscapular skin/fat fold (mm)	23.0±10.4	-14.8	19.6±8.7	-6.1	18.2±7.8	-20.9	.0005
biceps skin/fat fold (mm)	14.0±7.4	0.0	14.0±7.1	-18.6	11.4±7.0	-18.6	.002
triceps skin/fat fold (mm)	28.0±8.8	-7.5	25.9±7.3	-13.2	22.2±6.9	-20.7	.0005
abdominal skin/fat fold (mm)	28.2±9.6	-2.1	27.6±9.5	-6.0	25.9±10.8	-8.2	.05
thigh skin/fat fold (mm)	37.6±9.7	-9.0	34.2±8.2	-7.7	31.3±9.2	-16.8	.0005
calf skin/fat fold (mm)	30.5±9.8	-13.4	26.4±7.3	0.3	26.5±7.1	-13.1	.0005
height (cm)	164.1±6.1	0.4	164.7±7.1	-0.2	164.3±6.2	0.1	.30

Table 10. Changes in muscle cross-sectional area with training (mean±SD).

n=31	Muscle cross-sectional area (cm^2)		Pre to Post p-value	Pre to Post % Change
	Pre	Post		
Arm	28.6±4.5	29.8±5.0	.0026	5.09±7.6
Leg	118.5±14.3	124.2±16.1	.0015	4.89±7.8
Arm/Leg ratio	.241±.028	.241±.027	-	-

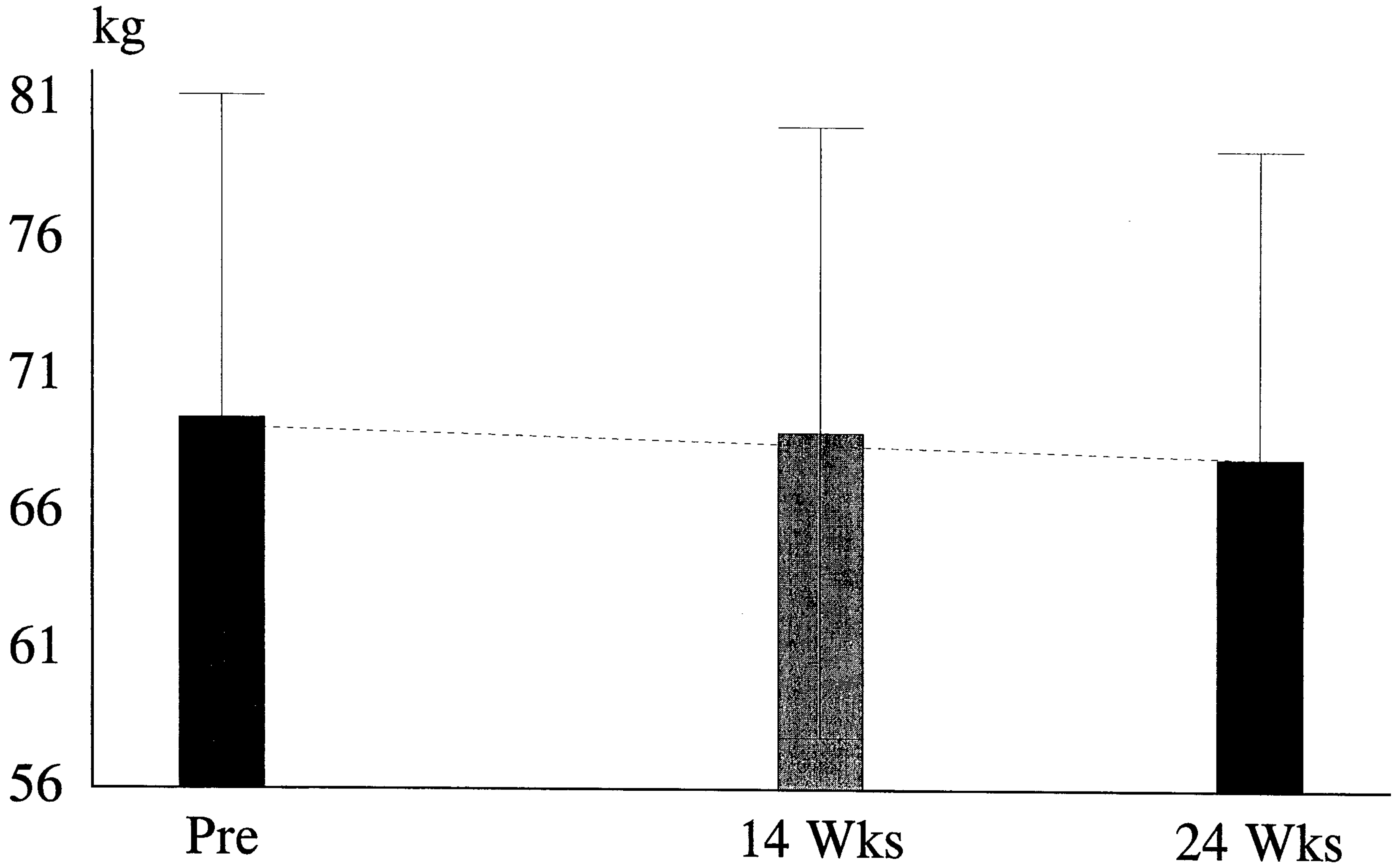

Figure 15. Body mass (mean±SD). Probability that pre-post difference occurred by chance <0.05

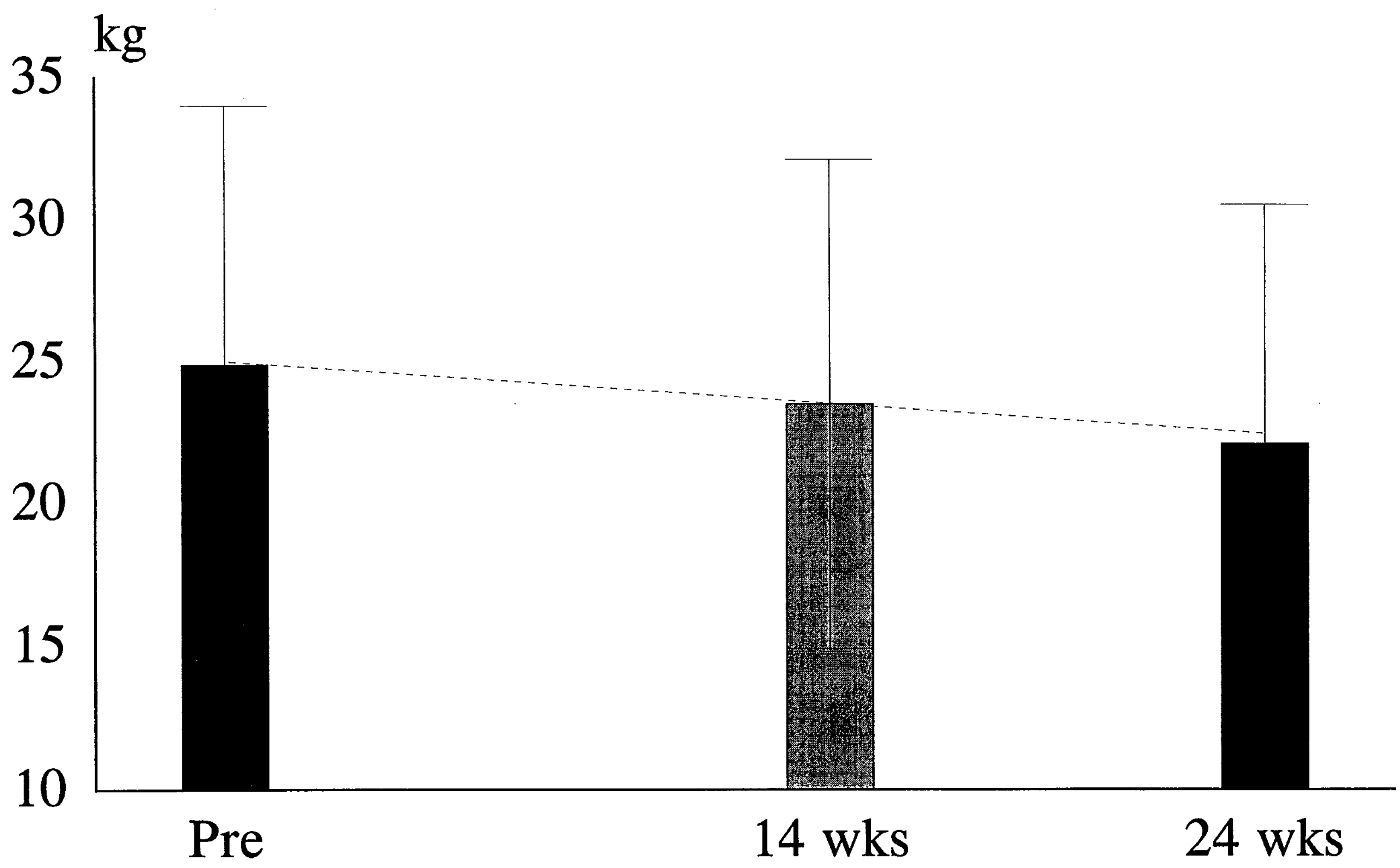

Figure 16. Fat mass (mean±SD). Probability that pre-post difference occurred by chance <0.00005

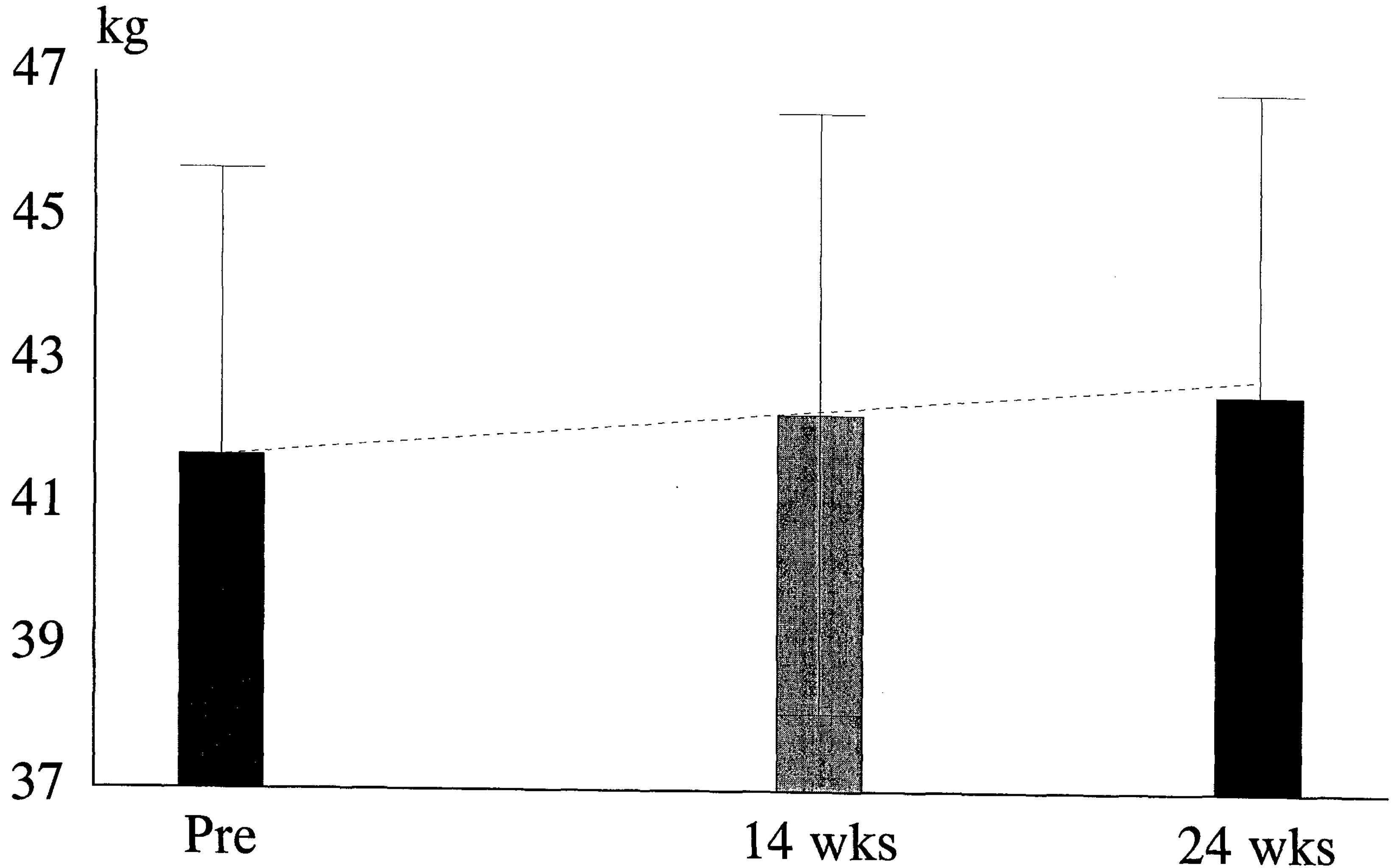

Figure 17. Lean body mass (mean±SD). Probability that pre-post difference occurred by chance <0.0001

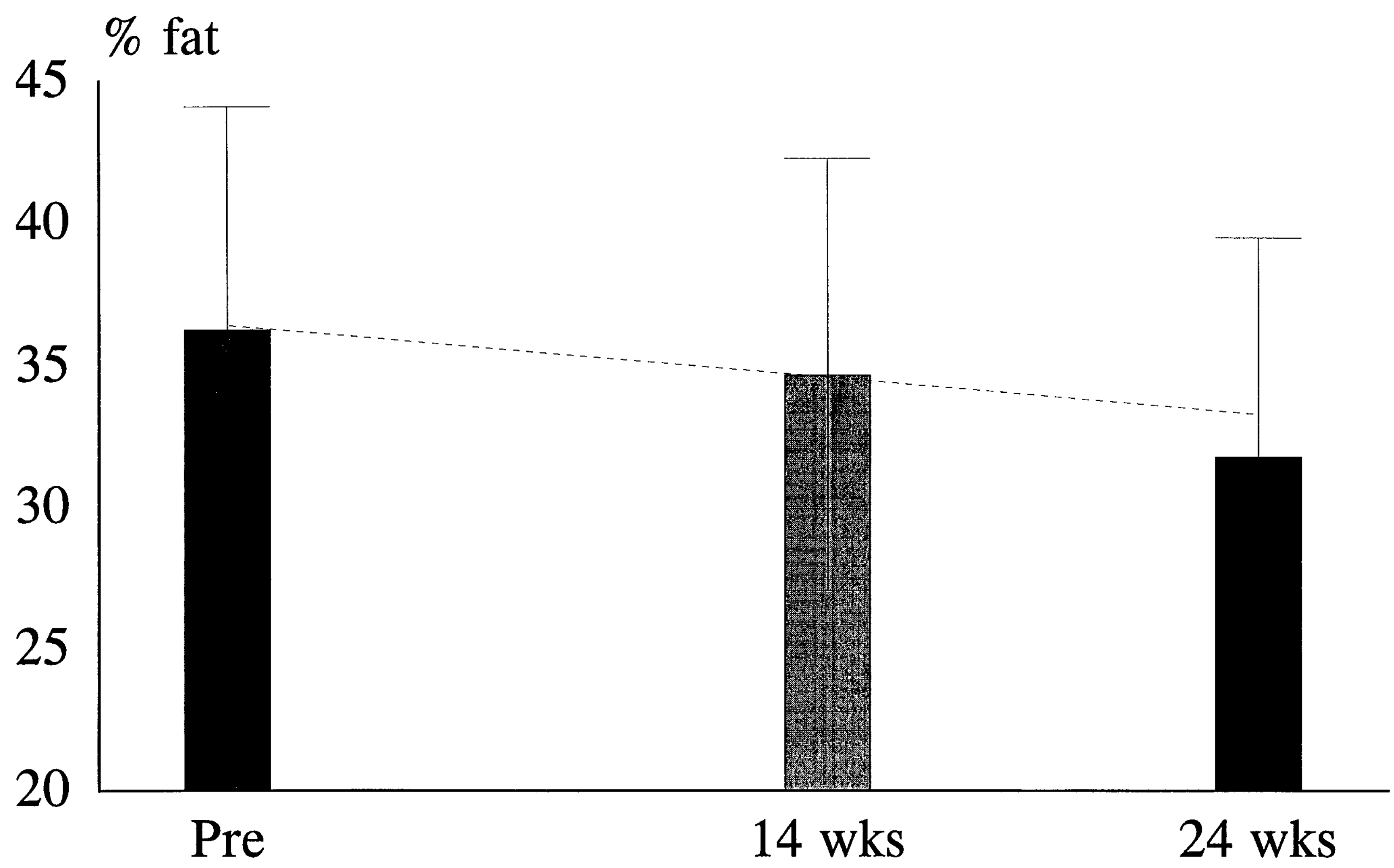

Figure 18. Percent body fat measured by DEXA (mean±SD).
Probability that pre-post difference occurred by chance <0.00005

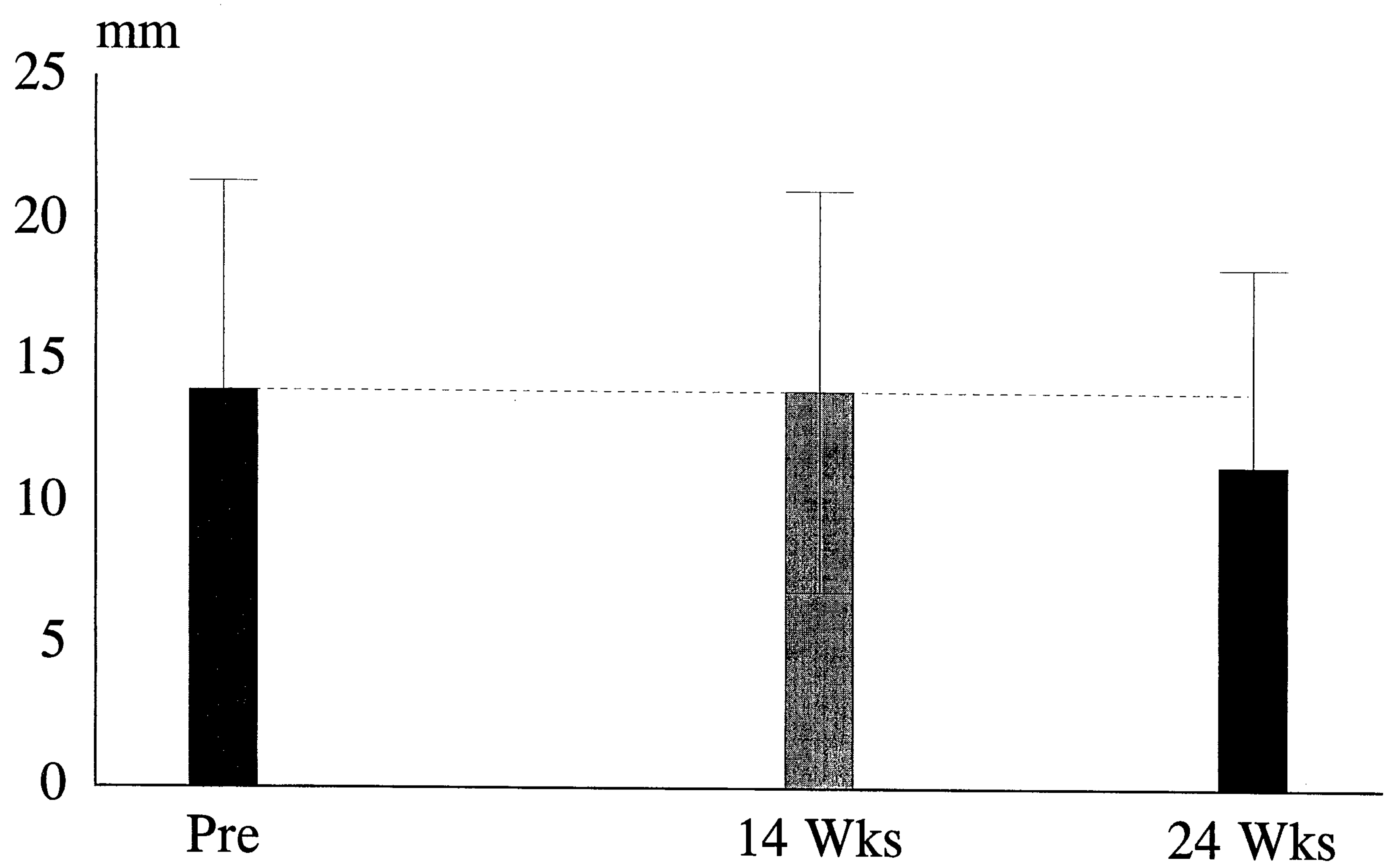

Figure 19. Biceps skinfold (mean±SD). Probability that pre-post difference occurred by chance <0.002

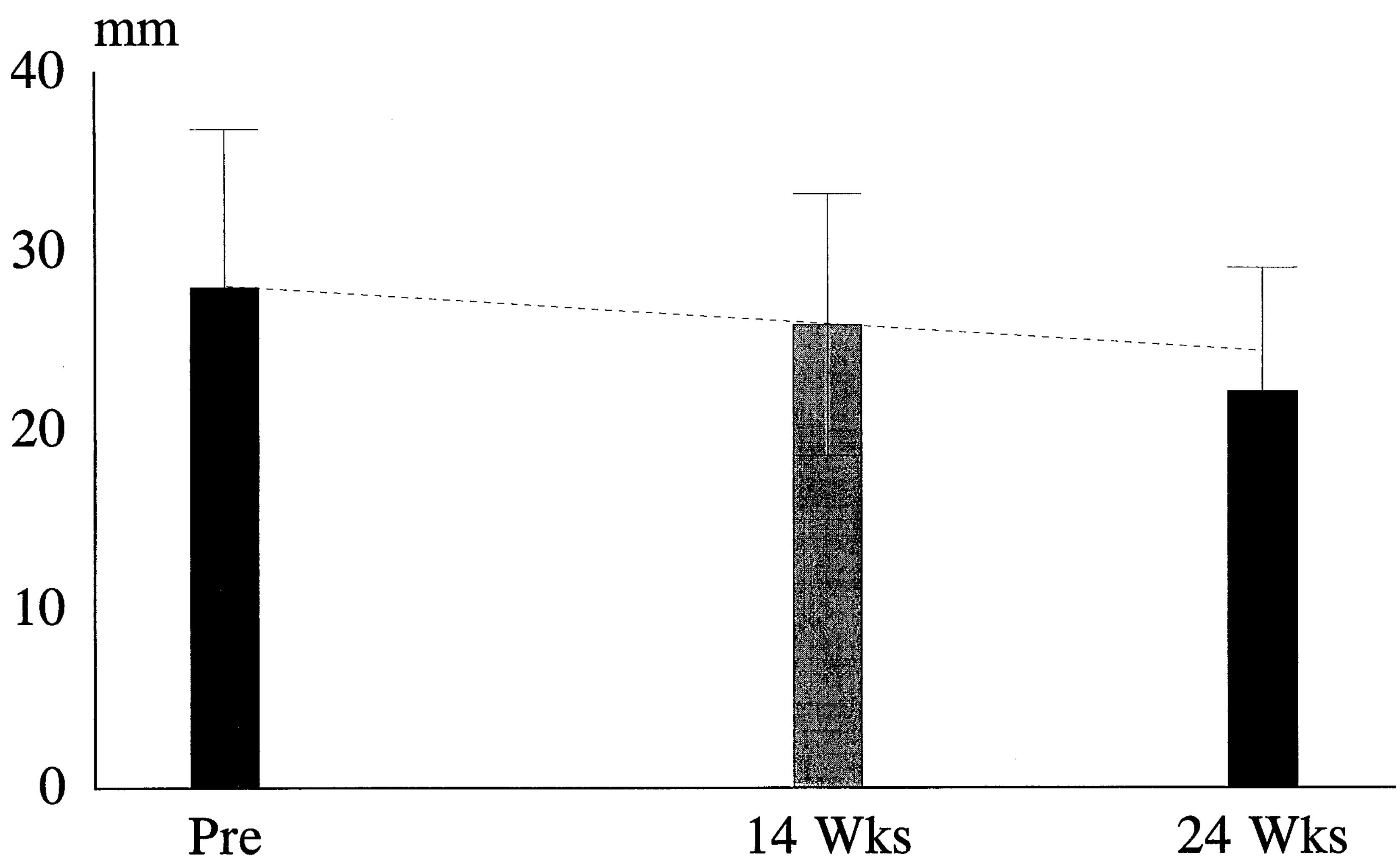

Figure 20. Triceps skinfold (mean±SD). Probability that pre-post difference occurred by chance <0.0005

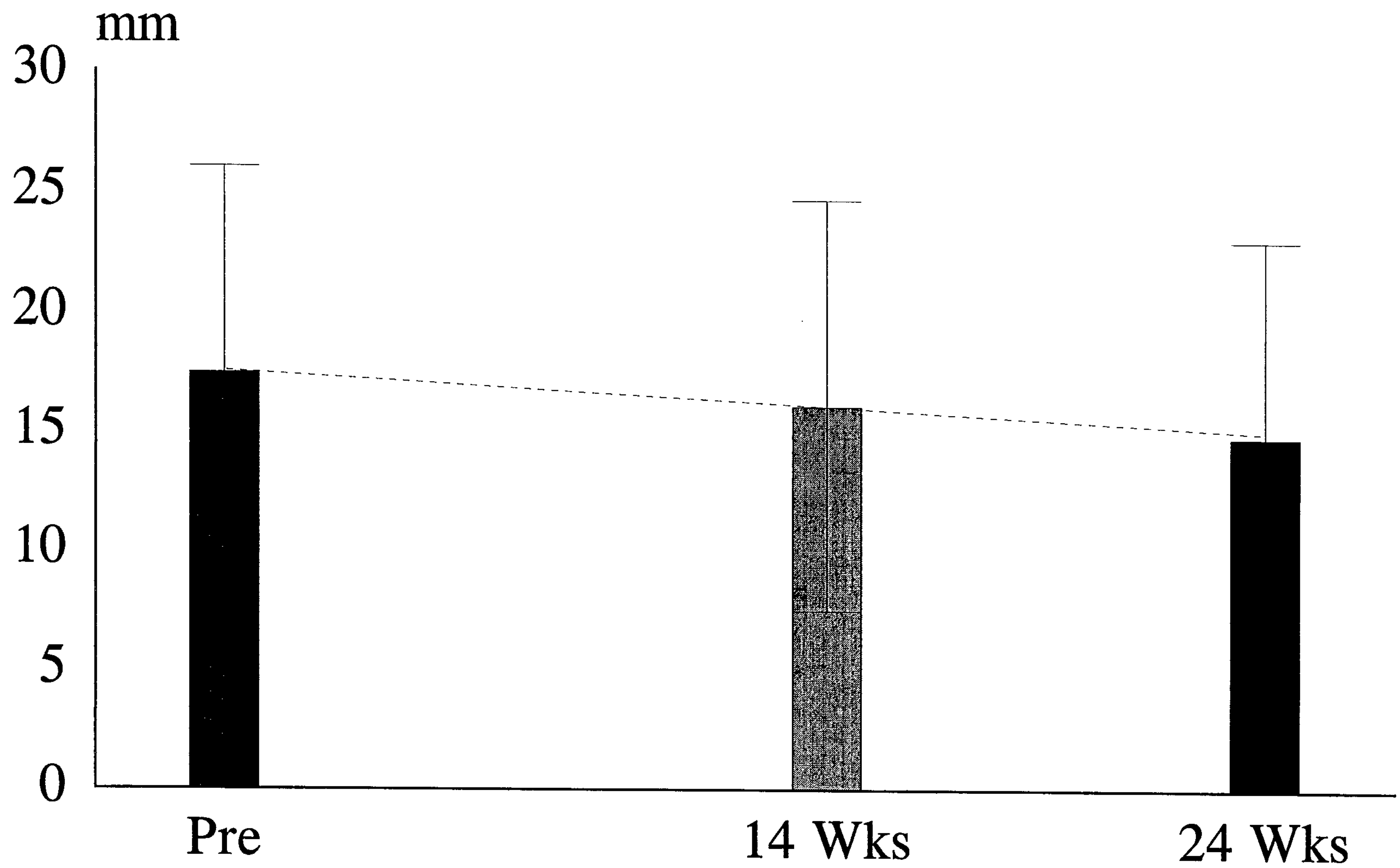

Figure 21. Suprailiac skinfold (mean±SD). Probability that pre-post difference occurred by chance <0.001

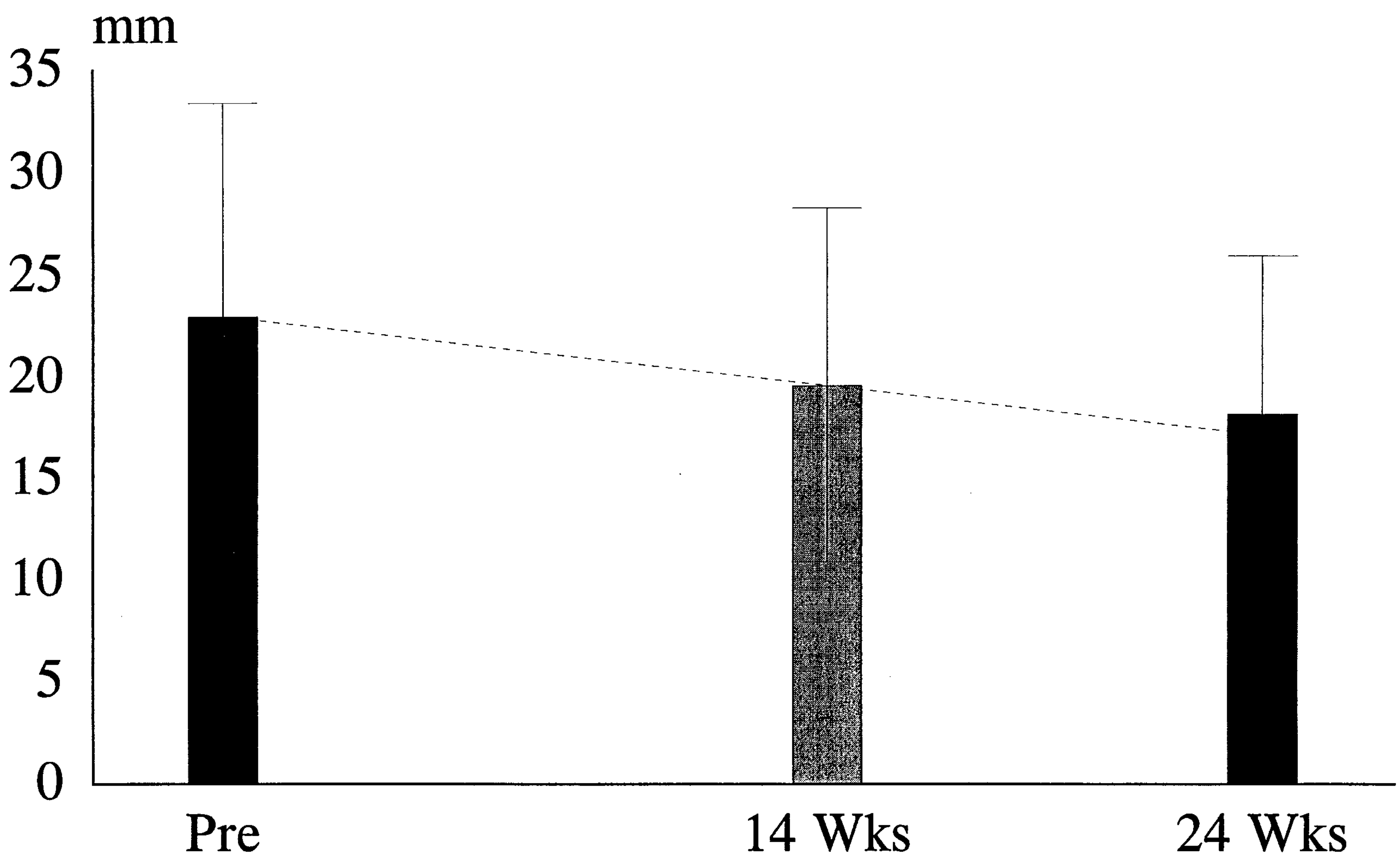

Figure 22. Subscapular skinfold (mean±SD). Probability that pre-post difference occurred by chance <0.0005

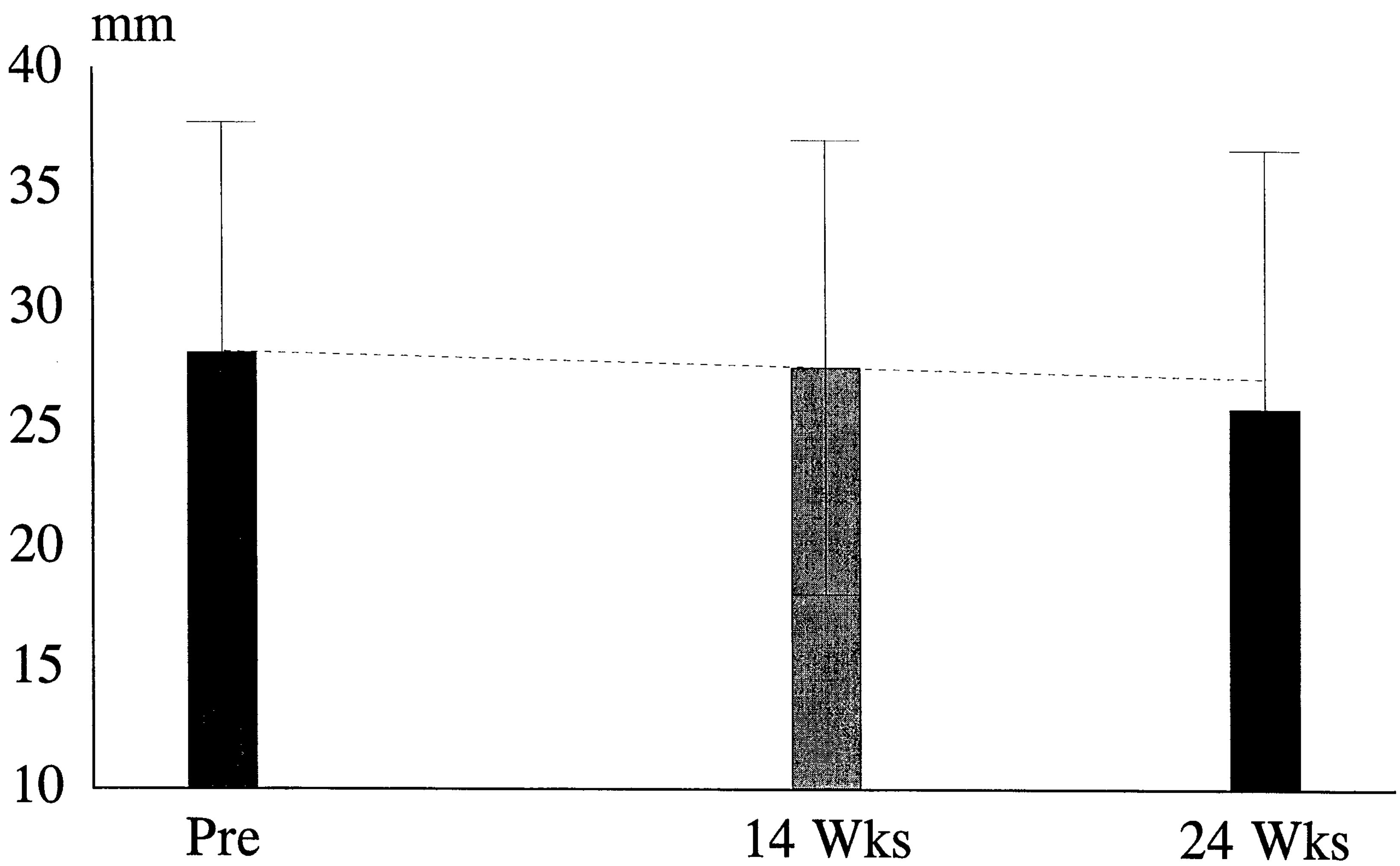

Figure 23. Abdominal skinfold (mean±SD). Probability that pre-post difference occurred by chance <0.05

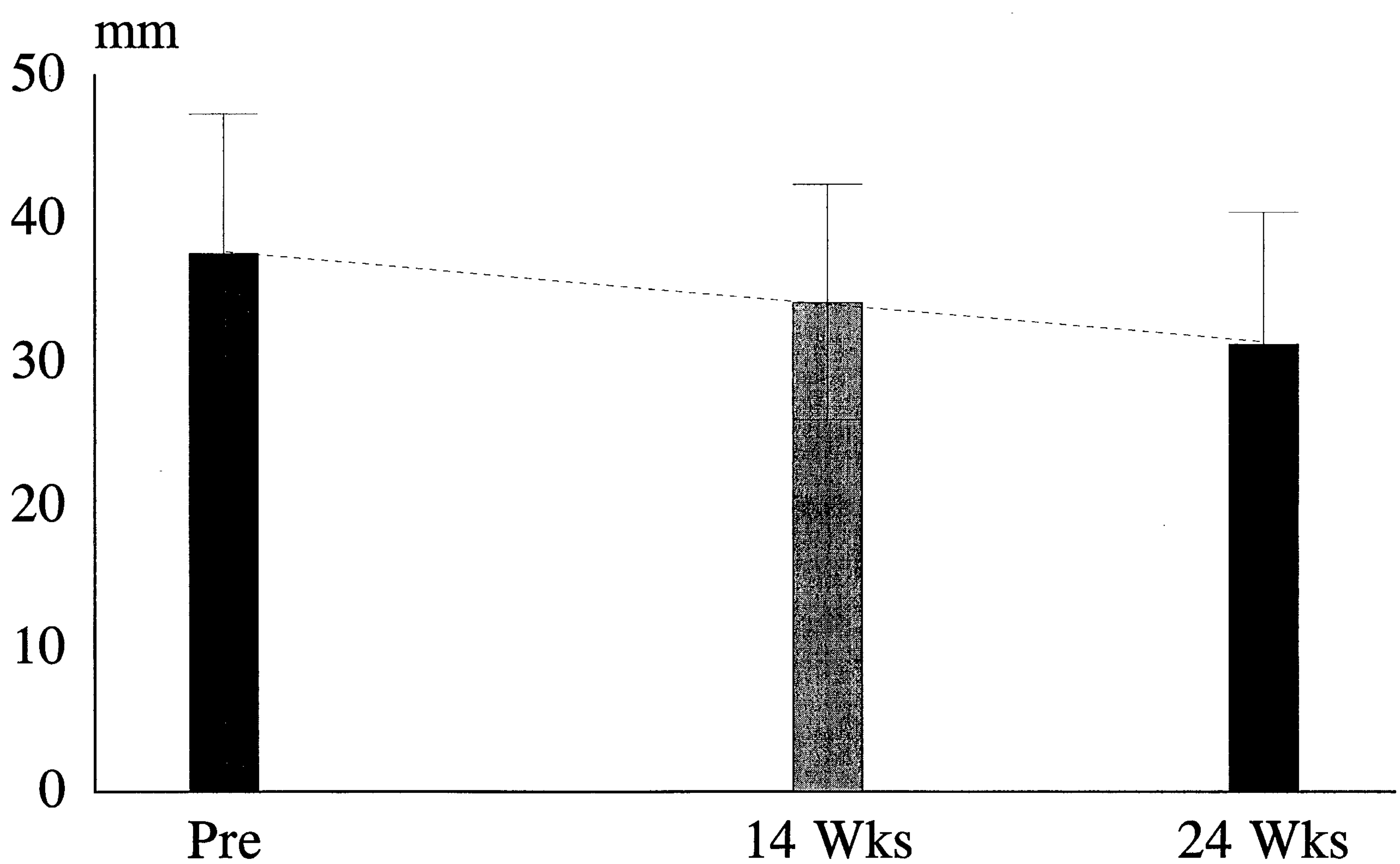

Figure 24. Thigh skinfold (mean±SD). Probability that pre-post difference occurred by chance <0.0005

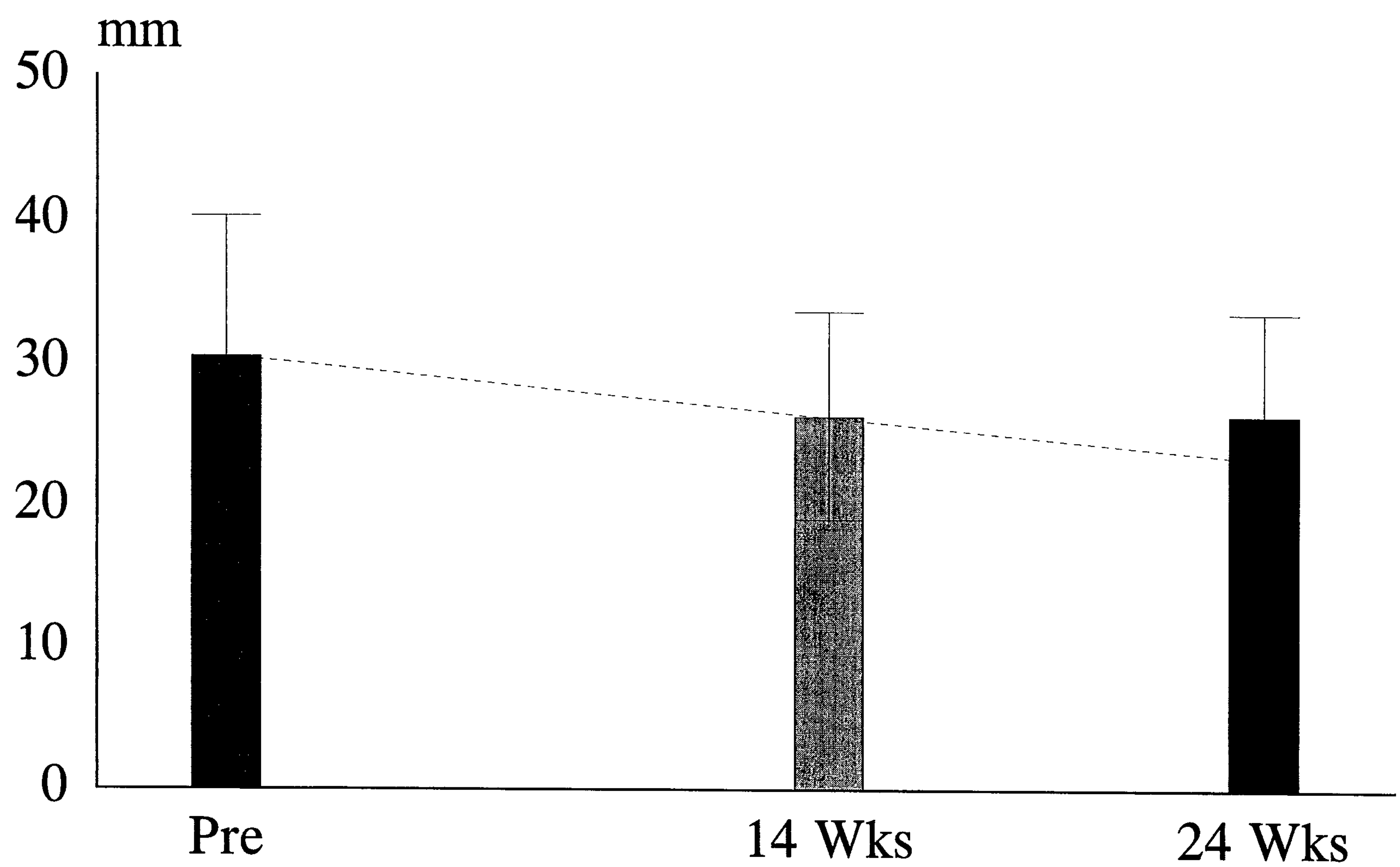

Figure 25. Calf skinfold (mean±SD). Probability that pre-post difference occurred by chance <0.0005

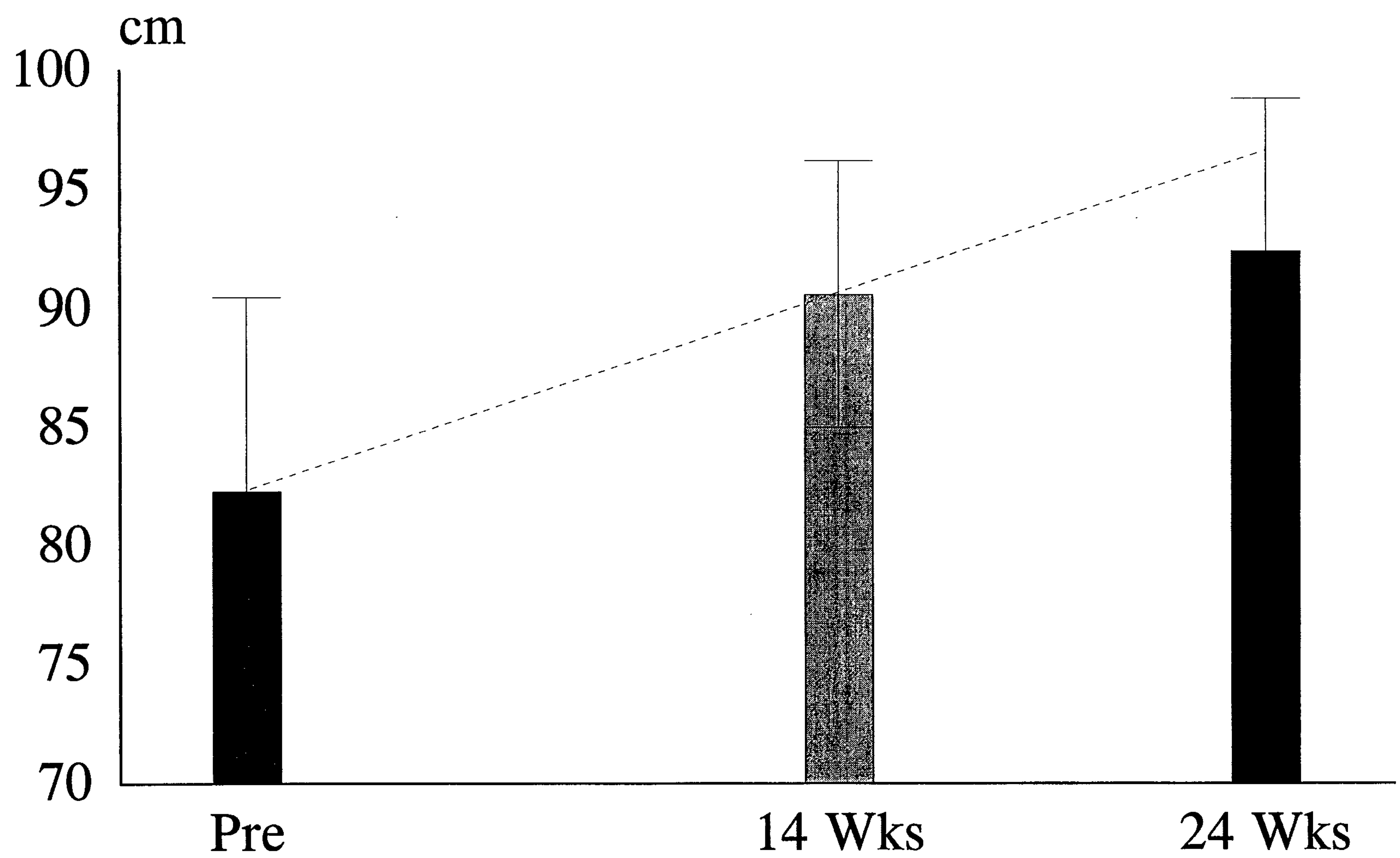

Figure 26. Chest circumference (mean±SD). Probability that pre-post difference occurred by chance <0.0005

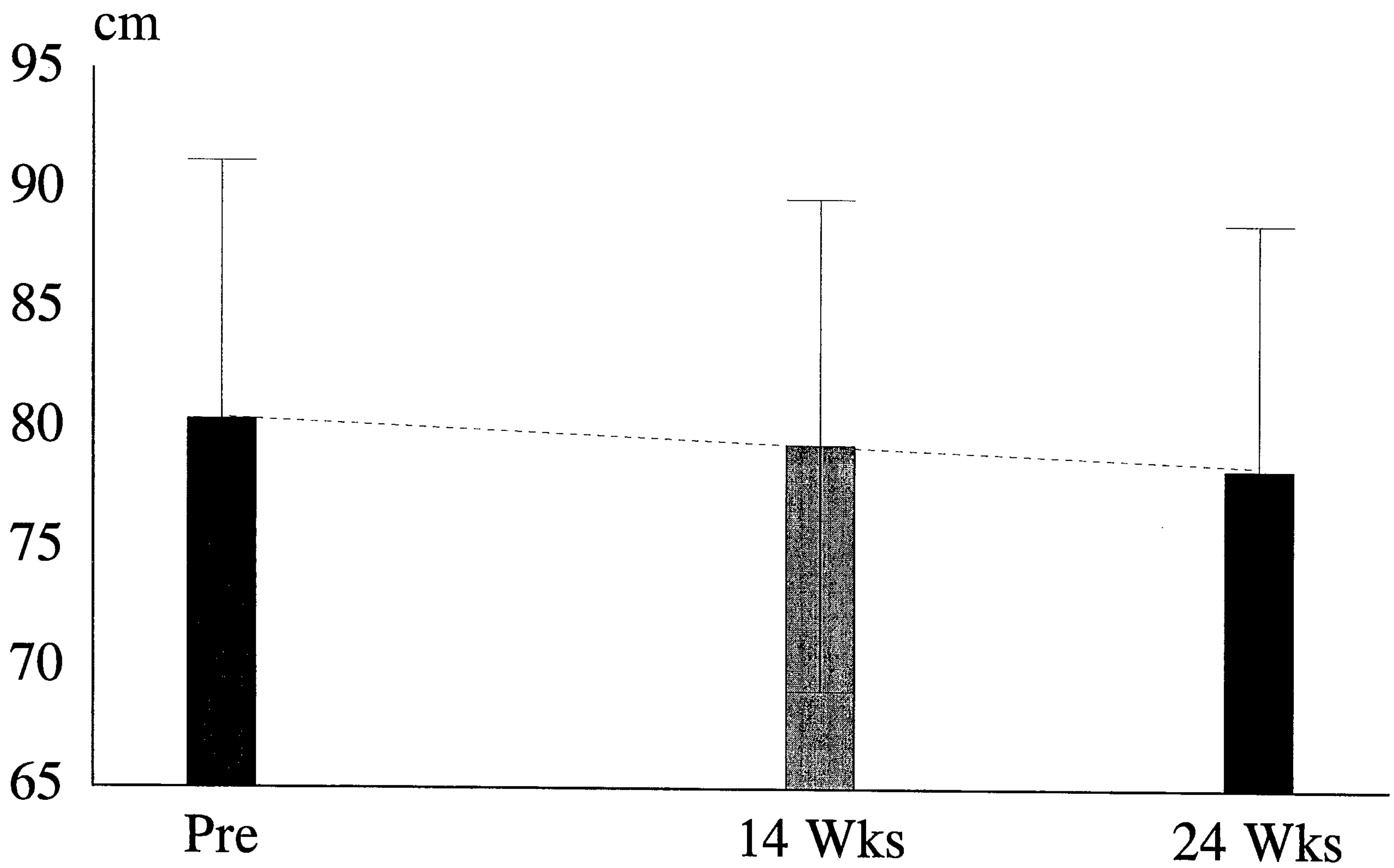

Figure 27. Waist circumference (mean±SD). Probability that pre-post difference occurred by chance <0.005

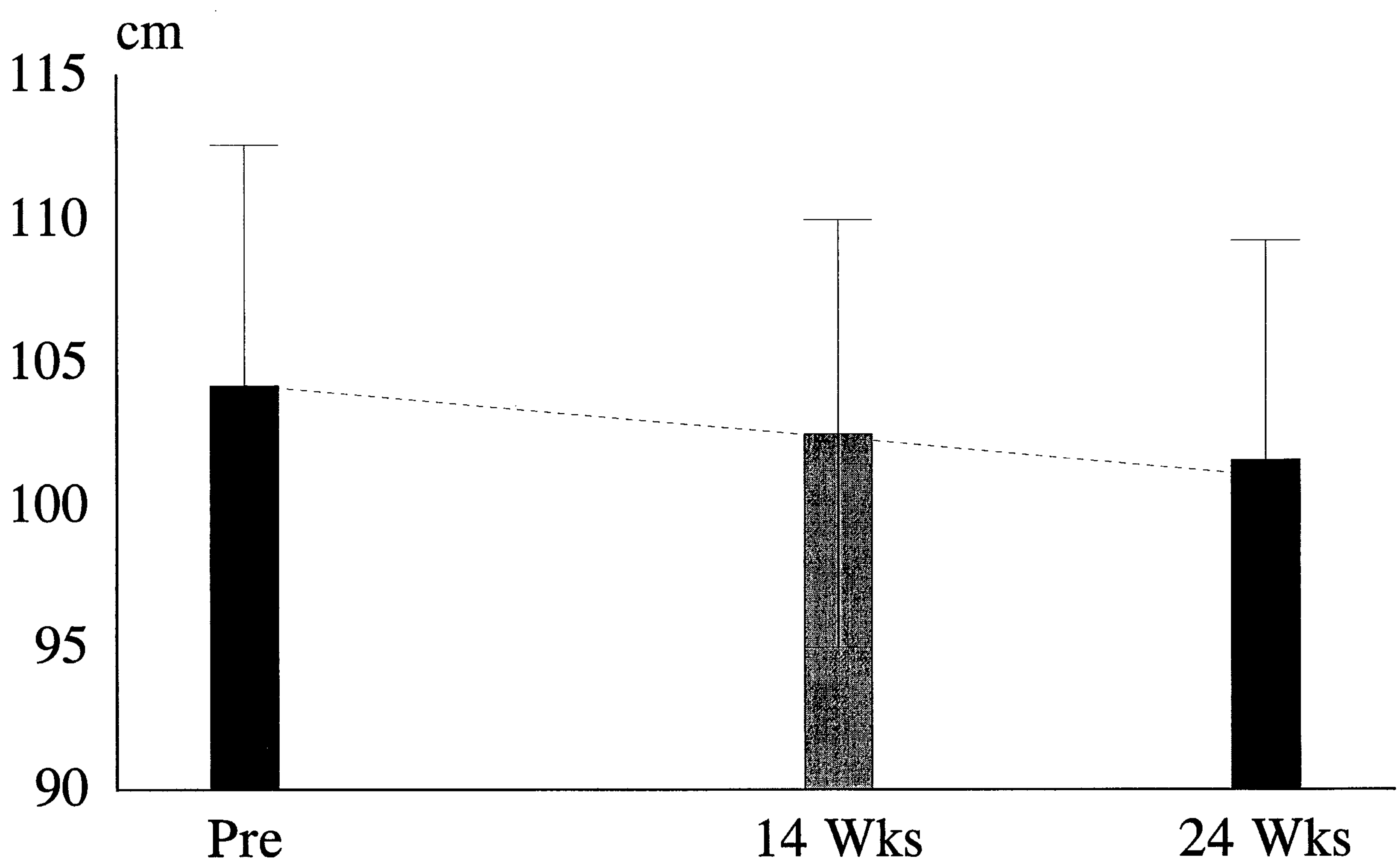

Figure 28. Hip circumference (mean±SD). Probability that pre-post difference occurred by chance <0.0005

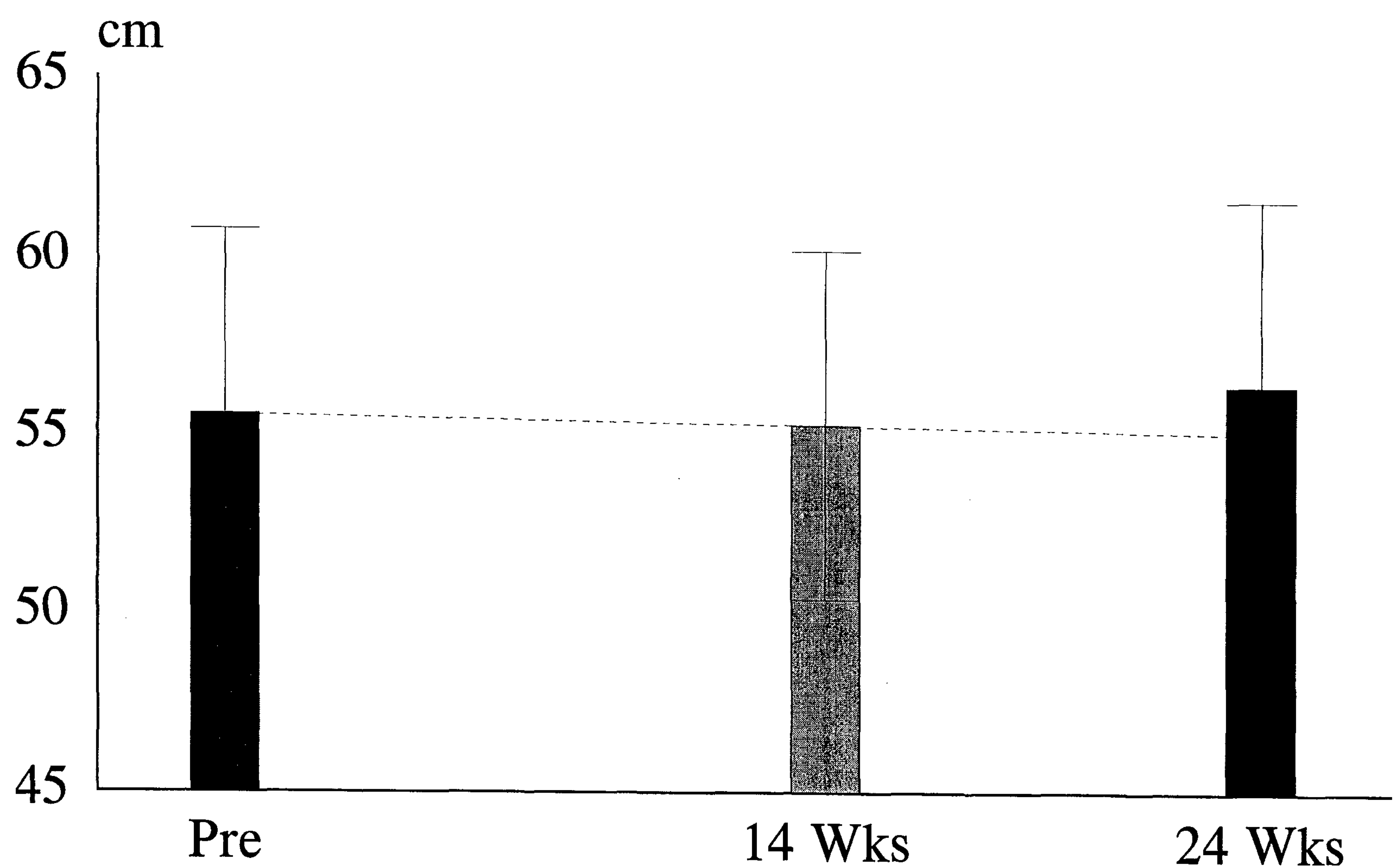

Figure 29. Thigh circumference (mean±SD). Probability that pre-post difference occurred by chance <0.05

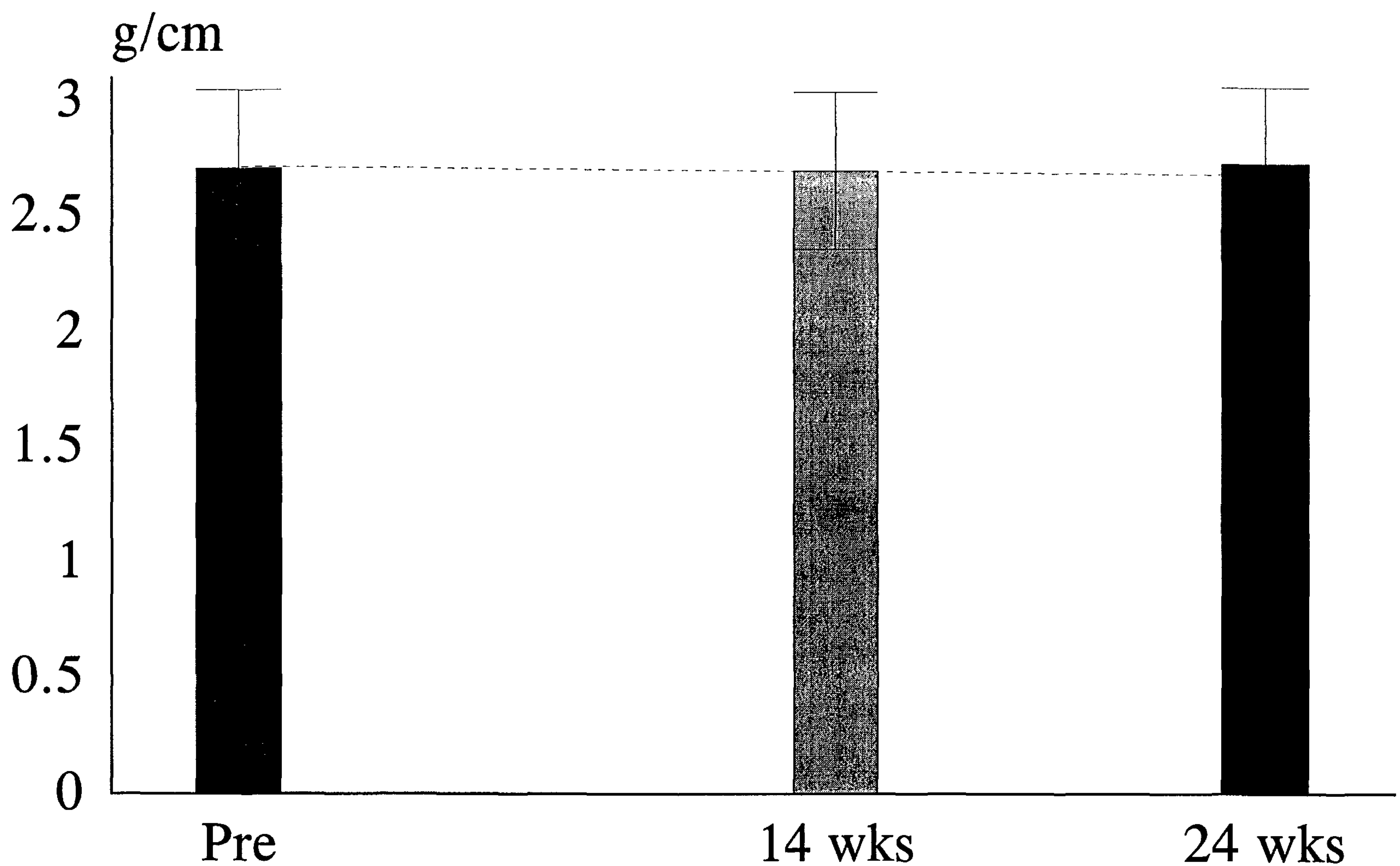

Figure 30. Bone mineral content determined by DEXA (mean±SD).
Probability that pre-post difference occurred by chance <0.08

TRAINING-INDUCED CHANGES IN FEMALE PSYCHOLOGICAL STATUS

After the training program was completed, questionnaires were distributed to all of the 40 female research volunteers who completed at least the initial 14 weeks of training and took the mid-experiment test battery. Thirty-four of the subjects filled out and returned the questionnaires. The following is an analysis of 11 questions that relate to the psychological effects of the program.

Please indicate how the study has affected you. Rate any changes using a scale from -5 to +5 where 0 = no change. (write -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, or 5)

---

your physical strength — -5 = you became much weaker; +5 = you became much stronger

mean±SD score = +3.94±1.43
94.1% had positive scores, indicating they felt they became stronger.
52.9% scored +5, the highest possible score.
5.9% indicated no change in strength.
There were no negative scores.

---

your physical appearance — -5 = you look a lot worse; +5 = you look a lot better

mean±SD score = +2.50±1.71
85.3% had positive scores, indicating they felt their appearance improved.
11.8% scored zero, indicating no change in their feelings about their physical appearance.
2.9% (one person) had a negative score (-1), indicating a slight decline in her feelings about her appearance.

---

your self confidence — -5 = you became much less confident; +5 = you became much more confident

mean±SD score = +3.03±2.17
85.3% had positive scores, indicating they felt their confidence improved.
11.8% scored zero, indicating no change in self-confidence.
Only one person indicated a decline in self-confidence (probably because she had sustained a muscle injury during training and couldn't finish the study; the injury subsequently healed).

---

your peace of mind — -5 = you became much less at ease; +5 = you became much more at ease

mean±SD score = +2.29±2.44
73.5% had positive scores, indicating their peace of mind improved.
17.6% scored zero, indicating no change in peace of mind.
8.8% had negative scores, indicating reduced peace of mind.

---

your self affection (liking yourself) — -5= you like yourself much less; +5= you like yourself much more

mean±SD score = +2.41±1.64
82.4% had positive scores, indicating their self affection improved.
17.6% scored zero, indicating no change self affection.
There were no negative scores.

---

your feelings towards other women — -5 = you like other women much less; +5 = you like other women much more

mean±SD score = +1.85±2.03
58.8% had positive scores, indicating their liking for other women improved.
41.2% scored zero, indicating no change in their liking for other women.
There were no negative scores.

---

your social skills — -5 = your social skills have greatly deteriorated; +5 = your social skills have greatly improved

mean±SD score = +1.71±1.88
55.9% had positive scores, indicating their social skills improved.
44.1% scored zero, indicating no change in social skills.
There were no negative scores.

---

your feelings about the physical capabilities of women — -5 = you think women have a lot less capability than you thought before; +5 = you think women have a lot more physical capability than you thought before

mean±SD score = +3.09±1.93
82.4% had positive scores, indicating they developed a more positive opinion of the physical capabilities of women.
17.6% scored zero, indicating no change in their opinion about the physical capabilities of women.
There were no negative scores.

---

your feelings about the general capabilities of women (may include emotional strength, ability to achieve goals, etc)

-5 = you think women have a lot less general capability than you thought before
+5 = you think women have a lot more general capability than you thought before

mean±SD score = +3.03±1.87
85.3% had positive scores, indicating they developed a more positive opinion of the general capabilities of women.
14.7% scored zero, indicating no change in their opinion about the general capabilities of women.
There were no negative scores.

How much do you feel you've learned about planning an exercise program?

-5 = your knowledge about exercise has greatly deteriorated
+5 = your knowledge about exercise has greatly improved

mean±SD score = +3.38±1.58
94.1% had positive scores, indicating their ability to plan an exercise program improved.
5.9% scored zero, indicating no change in their ability to plan an exercise program.
There were no negative scores.

What is the likelihood that you will continue exercising on a regular basis?

-5 = you will definitely stop exercising regularly
+5 = you will definitely continue exercising regularly

mean±SD score = +4.53±0.86
100% had positive scores, indicating they would continue exercising regularly.
67.6% scored +5, the highest possible score.
There were no neutral or negative scores.

TRAINING AND TESTING RELATED INJURIES

Pre-tests

Forty-six women began the pre-test battery to establish their baseline capabilities before the training program. During the test for maximal weight lifted in a box to a 52" height, one woman tore the anterior cruciate ligament (ACL) in her knee, and was withdrawn from the experiment. She had previously torn the ACL in her other knee, and it was never surgically corrected. During the box lift she turned her body to favor the previously injured knee, despite the instruction to all volunteers to lift symmetrically, and apparently put increased strain on the other knee, resulting in the ACL tear. The remaining 45 women began the experimental physical training program.

Data obtained from physician records revealed that during the initial testing period there was a total of four injuries, resulting in a total of 28 visits to a study physician, orthopedic physician or physical therapist. The total injury incidence during pre-testing was 8.7% (4 out of 46 women sustained one or more injuries). The total number of woman-days of injury-associated lost testing time was 25. All of the injuries were of the soft tissue overuse variety, and resulted in at least one woman-day of lost testing time. In addition to the torn ACL, injuries included low back strain, hip strain, groin tendinitis.

Maximal lift tests accounted for two injuries. The load carriage test and trailer pull each resulted in one injury. The average number of testing days lost per injury (excluding the knee injury) was 8.3. Hip strain resulted in the majority of the lost testing days (14).

The average number of clinic visits per injury was seven. Hip strain and low back pain resulted in the majority of clinic visits. Twenty-one physical therapy or orthopedic consults were generated during the testing period with hip strain and groin tendinitis accounting for a majority of the consults.

Training

Of the 45 women that began the physical training program, five women dropped out before the mid-test. Of the five dropouts, one woman was removed because of an illness and four women left due to non-medical problems. The balance of the dropouts shown in Table 4 left the study after the mid-test.

Of the 40 women that continued to train beyond the mid-test period, there was a total of 24 training-related injuries recorded resulting in 89 visits to a study physician, orthopedic physician or physical therapist. The total training-related injury incidence (women with one or more injuries) was 57.5% (23/40). The total number of injury-associated lost training days was 29. Seventy-five percent of the injuries resulted in at least one day of lost training time. More than ninety-five percent of the injuries were soft tissue overuse injuries. The three most common overuse injuries reported were low back strain, foot blisters, and knee tendinitis. Other types of overuse injuries included hip tendinitis, knee pain, hip bursitis, knee ligament sprain, neck strain, calf strain, knee cartilage tear, lumbar strain with sciatica, knee bursitis, ankle sprain, and foot strain. The only traumatic injury reported was a head contusion.

Strength training accounted for eight injuries, followed by running (7 injuries), and backpack hiking (7 injuries). The remaining two training injuries could not be associated with specific training activities. The average number of training days lost per injury was 1.2. The average number of training days lost was highest for injuries affecting the knee (4.9 days) and low back (4.3 days). The average number of clinic visits per injury was 3.7. The average number of clinic visits per injury was highest for injuries affecting the hip (6.7 visits), the calf (6.5 visits), and the knee (4.7 visits). Thirty-four physical therapy or orthopedic consults were generated during the training period. The number of consults was the highest for injuries involving the knee (21 consults) and hip (14 consults).

COMPARISON OF FEMALES TO MALES

An effort was made to recruit male volunteers to provide a standard for the performance tests against which the females could be compared. Unfortunately, it proved difficult to recruit a sample of representative Army males, apparently due to the physically demanding nature of the tests. The female volunteers were rewarded for their participation by being physically conditioned for six months by professional physical trainers. The male comparison volunteers did not have that incentive because they were only tested and not trained. For the most part, males who volunteered for the study were those who enjoyed testing their physical capabilities and who had the confidence that their performance would be good. They therefore were in large part individuals somewhat bigger, stronger, and more athletic than average males. Half were civilians and half were military personnel. Their physical dimensions are shown in Table 11 along with those of some sample U.S. Army male populations of similar age. The group's test performances are shown in Table 12, along with those of the trained female volunteers and some of those demonstrated by groups of Army male volunteers.

After training, the female volunteers were able to lift to a height of 52" a box weighing 81% of what sample groups of Army males could lift to that height; our control males lifted 16% more than the Army male sample. In the squat test, the trained females performed 97% as many repetitions with 100 pounds as did an Army male sample, while our male control group could do 33% more repetitions than the Army male sample. As to aerobic power, the trained females had 84% of the maximal oxygen uptake of the Army male sample, while our male control group was 2% lower than the Army male sample. Larger men, even if athletic, typically have lower maximal oxygen uptake relative to body mass than smaller men (Astrand and Rodahl, 1977). This is due to the fact that, as body size increases, active tissue that must be fed by the blood increases in volume at a faster rate than the cross-sectional area of the blood vessels. As to the two-mile 75-pound backpack run, the women were 84% as fast as the Army male sample while our control males were 93% as fast as the Army male Army sample.

For several of the tests depicted in Table 12, there is no data from typical Army males. However, based on the tests that both our male control group and Army male samples took, our male control group is shown to be somewhat stronger but not more aerobically fit than the sample Army males. Therefore, it would be expected that the trained females would be somewhat closer to typical Army males in the strength tests than they were to our male control group. In the 30" high box lift, the trained females lifted 77% as much as the control males. In lifting a box from a 30" high table to a 60" high shelf, the trained females lifted 69% as much as the control males. The trained females compared more favorably in repetitive lifting, performing 93% as many 40-pound box lifts to a 52" height in 10 minutes as the male controls, and 87% as many of the lifts with 25-foot carries. The trained women jumped 75% as high as the control males and 79% as far. They towed the 110-pound trailer 82% as fast as the males did over the two-mile mixed-terrain course.

Table 11. Vital statistics on male control volunteers and U.S. Army males

Variable	Male Controls n=18		U.S. Army Males	
	mean	SD	mean	SD
Age (years)	26.9	5.8	22.9*	5.7*
Body Mass (kg)	81.8	13.8	74.5*	11.2*
Height (cm)	179.1	7.8	174.7*	6.8*
Percent fat (%)	17.9	5.1	17.7*	6.2*
Lean Body mass (kg)	62.1	8.8	60.9*	7.3*
Knee diameter (cm)	-	-	31.0#	3.1#
Elbow diameter (cm)	-	-	6.6#	0.6#
Neck circumference (cm)	38.3	3.9	36.4#	2.2#
Chest circumference (cm)	101.6	9.1	88.7#	6.6#
Upper arm circumf. (cm)*	32.1	3.6	28.1#	2.5#
Waist circumference (cm)	87.1	9.3	80.8#	8.5#
Hip circumference (cm)	99.8	9.8	95.9#	6.5#
Thigh circumference (cm)	56.2	5.4	53.3#	5.0#
Calf circumference (cm)	37.9	3.7	36.8#	2.9#
Suprailiac skin fold (mm)	11.6	7.1	20.1#	9.9#
Subscapular skin fold (mm)	13.9	4.1	14.6#	5.5#
Biceps skin fold (mm)	5.0	1.7	5.2#	2.2#
Triceps skin fold (mm)	9.5	3.1	10.5#	4.4#
Abdominal skin fold (mm)	23.5	12.2	21.0#	10.1#
Thigh skin fold (mm)	13.9	5.8	13.0#	6.1#
Calf skin fold (mm)	12.6	3.6	9.1#	4.3#

* = Combined results from three studies described in Teves et al. 1985, and Patton et al. 1987; combined n = 388.

= Results from Fitzgerald et al., 1986

Table 12. Comparison of pre- and post-training female physical performance scores (mean±SD) with those of the male control group and, when possible, the performance scores of more typical male soldiers.

	Females		Males	
Variables	Pre	Post	Controls	Army samples
52" box lift (lbs)	90.1±16.9	117.5±21.2	168.4±23.2	144.8±4.2*
30" box lift (lbs)	132.0±25.3	175.4±25.0	227.3±36.9	-
30-60" box lift (lbs)	59.4±12.7	87.3±17.1	126.4±23.8	-
40-lb 52" box lift (reps)	105.8±19.3	139.6±18.3	149.7±21.3	-
40-lb 52" lift, 25' carry (reps)	52.5±6.5	61.7±5.9	71.1±7.3	-
vertical jump (in)	12.3±2.8	14.8±3.0	19.7±2.8	-
standing long jump (ft)	4.97±.76	5.73±.88	7.29±.49	-
100 lb barbell squat (reps)	15.8±13.6	62.1±29.4	85.6±66.7	64.3±31#
VO2 (ml/kg)	40.8±5.0	46.5±5.5	54.0±4.9	55.3±6.0♦
2-mile 110-lb trailer tow (mph)	4.35±.54	5.01±.56	6.11±1.10	-
2-mile 75-lb pack hike (mph)	3.35±.35	4.44±.69	4.95±.87	5.30±1.0#

Pre = before the physical training program
Post = after 24 weeks of training
* = Combined results from three studies described in Teves et al. 1985, and Patton et al. 1987; combined n = 388.
♦ = Harman et al., 1988.
= Military test subjects from Harman and Frykman, 1995.

DISCUSSION

BASIC TRAINING VS. THE EXPERIMENTAL PROGRAM

The experimental training program was clearly successful in increasing the percentage of women capable of performing "very heavy" work, and was decidedly more successful than Army Basic Training. It must be noted that the latter is only 8 weeks, compared to our training duration of 24 weeks. The difference in effectiveness is not surprising considering that the exercises performed in normal Army physical training do not involve lifting. In contrast, our program placed a major emphasis on weightlifting, which along with interval training, has found widespread use among athletes at all levels, from high school to professional. These programs have proven their effectiveness over many years (Wathen and Roll, 1993). However, such training techniques have not been used much within the Army because of a concern that any training requiring equipment beyond running shoes is too expensive and difficult to manage. An Army physical training program modeled after our experimental program would require more equipment and more knowledgeable instructors than does the standard Army physical training program. Cost-to-benefit ratio must no doubt be considered. One possibility for minimizing cost is to set up such training programs at Advanced Individual Training (AIT) schools that prepare soldiers for "very heavy" MOS's. Recruits would be physically conditioned to a base level in Basic Training and thus should be physically prepared for the more physically demanding program in AIT. A means of further minimizing expense might be to provide such training only as remedial programs for soldiers, both male and female, not strong enough to perform lifts required by the job.

INDIVIDUAL DIFFERENCES IN RESPONSIVENESS TO TRAINING

The differences among the women in responsiveness to training was quite remarkable. Despite the fact that the women all performed the same exercise program, and there were few absences, some of the women responded to training much more than others in regard to both physical performance and body composition changes. While there was no doubt some variation as to the amount of effort with which the exercises were performed, the differences in responsiveness to training can largely be ascribed to individual differences in physical potential. Those women with greater natural ability were able to train hard for the full 24 weeks without becoming injured and reached a very high level of physical capability (e.g. running for an extended distance while carrying a 75 pound backpack).

INJURY RISK IN HIGH-LEVEL PHYSICAL TRAINING PROGRAMS

It has been shown (Jones et al., 1988) that, among basic trainees, females are injured at twice the rate (51%) of males (25%). Some of the difference between males and females in susceptibility to injury may be accounted for by a generally lower physical activity level among females than males before their military service (Jones at al., 1988), leaving them less prepared for the rigors of training. It takes years for bone density and the strength of tendons, ligaments, and their points of attachment to develop to high levels. Therefore, while training for six months to a year can be effective for increasing muscle strength, it cannot make up for 18 years of a relatively sedentary lifestyle, especially in regard to the non-contractile elements of the musculo-skeletal system.

Our program was much more physically demanding than Army Basic Training, and even though care was taken to start at a low level of intensity and increase gradually, several of the women required medical attention for injuries resulting from the training. Most of these were minor and resulted in only temporary and/or only partial cutback in exercise participation. However, twelve percent of the volunteers could not complete post-testing because of study-related injuries. All of the volunteers appeared to recover fully after the study, except for a volunteer who suffered an anterior cruciate ligament tear during early testing (not training), and who declined to have it treated surgically because exercise rehabilitation can restore most non-athletic function, and she was apprehensive about scarring.

It is apparent that the higher the intensity at which people exercise, the more likely they are to become injured, most likely because of the higher musculo-skeletal forces involved. Therefore, a woman strengthened to 95% of her physical potential, who works continually at that level, is more likely to be injured than a larger male who is trained to only 70% of his potential and can adequately perform his job at that level. Thus, even when women are brought up to high levels of physical capability, they can be expected to suffer more injuries on average than males when performing physically demanding military tasks, even if they can perform such work at the required level. This greater mean injury risk for females may be considered a reasonable price to pay for the greater talent pool made available by inclusion of women in the military, and fulfilling the goal of equal opportunity for all citizens.

APPLICABILITY OF SIMILAR TRAINING PROGRAMS TO MALE SOLDIERS

The experimental physical training program could be very usefully applied to male soldiers, most obviously as a tool for improving the functional capability of male soldiers who lack the strength to adequately perform their jobs. In addition, the program would be effective in raising the performance level of combat units. Higher levels of physical capability should translate to faster cross-country march times, ability to transport more equipment and ammunition, faster loading of trucks and artillery, and faster breakdown and setup of artillery pieces, shelters, radar and communications units, and field kitchens. All these can contribute to improved mobility and greater fighting effectiveness.

STRENGTHENING THE SOLDIER VS. LIGHTENING THE SOLDIER'S LOAD

Some concern has been expressed within the Army that the availability of good physical strengthening programs might remove the incentive to lighten the soldier's load. That should not be the case. Strengthening and lightening programs can readily coexist as two different aspects of an effort to improve the soldier's ability to do his/her job. It would clearly take a massive effort to lighten all existing equipment that must be lifted or carried by soldiers. Even with a major allocation of resources, it is unlikely that the equipment lightening program will reduce the strength required to adequately perform most Army jobs in the foreseeable future.

CONCLUSIONS

- A specially designed and implemented physical training program, administered within normal Army time constraints, can be very effective in improving the ability of women to perform physically demanding military jobs, and much more effective than the physical component of standard Army Basic Training.

- A great majority of women undergoing specialized physical training could qualify for military jobs categorized as "very heavy" under the present classification system.

- A well designed physical training program brings about desirable body composition and psychological changes.

- Implementation of specialized physical training for both female and male soldiers who cannot otherwise adequately perform physically demanding military jobs does not conflict with efforts to lighten the soldier's load; rather the two approaches complement each other.

- Specialized training programs could be designed for various military units, using the exercise-prescription principles applied in this study, to improve the physical performance and fighting effectiveness of various kinds of soldiers.

RECOMMENDATIONS

- That Army should implement a trial physical training program, modeled after the experimental program used in this study, during AIT for "very heavy" MOS's. Any soldier, either male or female, not meeting the required strength standard should participate in the program. The trial should be conducted as a scientific study, so that the training can be carefully controlled, injuries monitored, and soldier's tested to determine their ability to perform the tasks demanded by their MOS's.

- If the proposed trial physical training program proves effective in bringing strength-deficient soldiers up to the strength level required by their MOS's, the program should be expanded to a larger number of AIT schools and, if successful again, to all AIT courses for "very heavy" MOS's.

- Specialized training programs should be designed and implemented for various military units, using the exercise-prescription principles applied in this study, to improve the physical performance and fighting effectiveness of various kinds of soldiers. Initial programs should be carefully monitored to assess their effectiveness.

DISCLAIMER

The conclusions, recommendations, and any other opinions expressed in this report are those of the author alone and do not reflect the opinion, policy, or position of the Department of the Army or the United States Government.

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APPENDIX

1. List of exercises used for training

2. Sample workout week for the training group research volunteers

DESCRIPTION OF EXERCISES USED FOR TRAINING

Definition: elbow-to-elbow width - The distance between the elbows when the arms are stretched out horizontally to either side.

Knee extension/ Hip extension/ Back extension

squat: Standing with barbell on shoulders behind neck, volunteer squats down until thighs are parallel to the floor then returns to a standing position. A safety rack is used upon which the volunteer can place the bar if she has trouble rising from the low position.

box lift: Volunteer lifts a metal box with handles from the floor to a 30" high surface (table height) or to a 52" high surface (truck bed height), or lifts the box from a 30" high surface to a 60" high surface.

step up: Standing with a barbell on the shoulders behind the neck, the volunteer places one foot on a platform up to 22" in height then steps up so that she is standing up on the platform. She then steps back down to the ground.

lunge: Standing with a barbell on the shoulders behind the neck, the volunteer steps forward with one foot then bends the forward knee while keeping the back knee straight, subsequently straightening the forward knee and returning to the standing position.

stair climb: Volunteer walks up and down stairs with or without a weighted vest or backpack.

uphill walk/run: The volunteer walks or runs up and down a hill with or without a weighted vest or backpack.

back extension machine: The volunteer sits on the machine and presses the back against a pad, extending the back and raising a stack of weight plates.

prone trunk raise on bench: With the legs braced by pads, the volunteer, while face-down, raises the trunk.

clean pull: With a slightly arched back, the volunteer bends at the knees and hips to grip a bar positioned on the floor. While letting the arms hang down, the volunteers rapidly straightens the knees and hips to accelerate the bar upwards. The bar reaches a high point at about abdomen level when the body is erect with the lifter up on her toes, and the shoulders shrugged.

clean high pull: The lift is begins the same way as the **clean pull** described just above. However, the weight is lighter, the pull is longer, and the arms assist by pulling

up until they are about parallel to the ground, so that the bar rises to just below shoulder height.
dead lift: With a slightly arched back (maintained throughout the exercise movement), the volunteer bends at the knees and hips to grip a bar positioned on the floor. While letting the arms hang down, the volunteers slowly straightens the knees and hips to raise the bar. The bar reaches a high point at about pelvic height when the body is erect.
straight-legged dead lift: While keeping the legs straight and arms down, the volunteer bends over, grips a weight bar, then raises the trunk while lifting the weight until the body is erect and the weight is about pelvis level.
twist lift: volunteer picks up a dumbbell or weight plate from the floor and swings it up to shoulder level at one side then returns it to near the floor beneath the body and swings it up to the other side at shoulder level.

Knee flexion
leg curl: While in a prone position on a machine, the volunteer flexes the knees by pressing the lower calves against a pad, thereby lifting a weight stack.

hip sagittal plane flexion/back flexion
leg raises: While lying supine or from a hanging position, the volunteer raises the legs, with the knees either bent or straight, until the thighs are parallel to the floor.
situps: While lying supine on either a flat or inclined padded board, the volunteer raises the trunk to a vertical position, then returns the trunk to the starting position. A weight of up to 25 lbs. may be held in the volunteer's hands during the movement.
crunch: While lying on the floor, the volunteer raises the elbows and knees until they touch.

shoulder frontal plane abduction/
shoulder transverse plane adduction/
elbow extension
flat bench press: While supine on a padded bench the volunteer lifts a barbell from a rack, lowers it to her chest, then pushes it up until the elbows are straight.
incline bench press: While seated on an inclined padded bench, the volunteer lifts a barbell from a rack, lowers it to her chest, then pushes it up until the elbows are straight.

decline bench press: While supine on a padded bench, inclined so that the head is lower than the knees, the volunteer lifts a barbell from a rack, lowers it to her chest, then pushes it up until the elbows are straight.
wide-grip military press: While seated on a seat or bench, with the trunk vertical, the volunteer grips a shoulder-level barbell at elbow-to-elbow width, then pushes the bar up until the elbows are straight.
upright row: Volunteer stands with arms down, holding bar with a narrow grip, then raises the bar while keeping it close to the trunk until the bar is near shoulder level.

<u>shoulder transverse plane abduction/</u>
wide-grip high row: While seated on a weight machine and keeping the upper arms parallel to the floor, the lifter grips two elbow-to-elbow width handles or a bar, then pulls them towards herself until the hands are close to the chest. A similar movement can be performed with free weights by pulling a weight bar towards the chest while the trunk is inclined forward, roughly parallel to the floor.

<u>shoulder frontal plane adduction</u>
wide-grip pulldown: With the legs under pads to keep the body from rising, the lifter reaches up, grips at elbow-to-elbow width a bar attached by pulley cable to a weight stack, and pulls the bar down to the shoulders.
wide-grip pullup: The volunteer grips an overhead bar at elbow-to-elbow width and bends the arms to raise the body until the chin reaches bar level. This exercise may be done with a machine that applies a selected force under the feet to assist in raising the body. For stronger research volunteers this also may be done with weight added to the body in a vest or by other means.

<u>shoulder sagittal plane flexion</u>
medium-grip military press: While seated on a seat or bench, with the trunk vertical, the volunteer grips a barbell at shoulder width, then pushes it up until the elbows are straight.
forward barbell raise: Standing with arms down and a barbell in the hands, the volunteer moves the arms forward and upward, keeping the elbows straight, until the barbell is overhead.

shoulder sagittal plane extension

pullover machine: While seated in a specially designed machine, starting with the upper arms raised forward and upward, the volunteer brings the elbows down to waist level by pressing against a bar and pads with the hands and upper arms.

medium grip pulldown: With the legs under pads to keep the body from rising, the lifter reaches up, grips at shoulder width a bar attached by pulley cable to a weight stack, and pulls the bar down to the shoulders.

medium grip pullup: The volunteer grips an overhead bar at shoulder width and bends the arms to raise the body until the chin reaches bar level. This exercise may be done with a machine that applies a selected force under the feet to assist in raising the body. For stronger research volunteers this also may be done with weight added to the body in a vest or by other means.

medium grip low row: While seated on a weight machine the lifter grips two shoulder width handles or a bar at waist level, then pulls them towards herself until the hands are close to the waist. A similar movement can be performed with free weights by pulling a weight bar towards the waist while the trunk is bent over roughly parallel to the floor.

shoulder shrug

shoulder shrugging movement: While standing with arms straight down, the volunteer raises a weight bar by shrugging the shoulders.

locomotion

running: volunteer performs various kinds of runs including distance runs of up to 5 miles and repeated interval runs of 1/8 mile, 1/4 mile, 1/2 mile, and 1 mile. Interval workouts do not exceed a total distance of 4 miles.

occupational load carriage

backpack hikes: The load and distance is selected according to each individual's capability, not to exceed a backpack load of 75 lbs, and a distance of 5 miles.

occupational lifting

box lift: The load and repeat rate is selected according to each individual's capability. Volunteers lift a box with handles, individually or in 2-person teams, onto a shelf up to 60" cm high, repeating the cycle as many as 20 times per minute for 10 minutes.

occupational lifting-carry-lifting

sandbag shuttle: The load and repeat rate are selected according to each individual's capability. Volunteers lift a 40-pound sandbag off the ground, carry it up to 40 feet, and lift it onto a 60" high shelf, repeating the cycle as many as 10 times per minute for 10 minutes.

SAMPLE WORKOUTS

Sample Monday and Thursday Weightlifting and Running Workout

#	Exercise	Repetitions	Weight	Comments
1	squat	15		
2	bench press	15		
3	squat	10		
4	bench press	10		
5	squat	10		
6	bench press	10		
7	squat	10		
8	bench press	10		
9	squat	10		
10	bench press	10		
11	squat	10		
12	bench press	10		
13	machine back extension	10		
14	medium grip military press	10		
15	machine wide grip high row	10		
16	machine back extension	10		
17	medium grip military press	10		
18	machine wide grip high row	10		
19	machine back extension	10		
20	medium grip military press	10		
21	machine wide grip high row	10		
22	running	2 miles		

Note: Each weightlifting set will take approximately 2 minutes. The resistance training should thus be completed within 45 minutes. There will be a 15 minute rest between the resistance training and the run. The run will take a maximum of 25 minutes. Thus the entire workout should be done within 90 minutes. With changing and showering the day's program should be completed within 2 hours.

Sample Tuesday and Friday Weightlifting and Running Workout

#	Exercise	Repetitions	Weight	Comments
1	clean high pull	8		
2	clean high pull	6		
3	clean high pull	6		
4	clean high pull	6		
5	clean high pull	6		
6	clean high pull	6		
7	incline bench press	10		
8	wide grip pulldown	10		
9	incline bench press	10		
10	wide grip pulldown	10		
11	incline bench press	10		
12	wide grip pulldown	10		
13	situp	10		
14	leg curl	10		
15	medium grip low row	10		
16	situp	10		
17	leg curl	10		
18	medium grip low row	10		
19	situp	10		
20	leg curl	10		
21	medium grip low row	10		
22	hill runs	15	≈30 sec hill, 1 min rest	

Note: Each weightlifting set will take approximately 2 minutes. The resistance training should thus be completed within 45 minutes. There will be a 15 minute rest between the resistance training and the hill runs. The hill runs will take a maximum of 25 minutes. Thus the entire workout should be done within 90 minutes. With changing and showering the day's program should be completed within 2 hours.

Sample Wednesday Backpack Hiking Workout

Hike five miles at a minimum speed of four miles per hour, with the load determined by the trainer. The first weekly hike was with no backpack and the second was with an empty backpack. For the subsequent hikes weight was added to the pack according to how easily the volunteer was able to maintain the required speed on the previous hike. Generally, no more than eight pounds would be added to the previous week's load. Some volunteers chose to travel much faster than the required four miles per hour. There were some who completed the five miles in as little as 50 minutes, carrying up to 75 lbs.

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