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REPORT NO 30/87

THE EFFECTS OF VARIOUS PHYSICAL TRAINING PROGRAMS ON SHORT DURATION, HIGH INTENSITY LOAD BEARING PERFORMANCE AND THE ARMY PHYSICAL FITNESS TEST

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

AUGUST 1987

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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The purpose of this study was to contrast the effects of different physical training programs on short duration, high intensity load bearing performance and Army Physical Fitness Test (APFT) scores. Thirty-five soldiers were randomly assigned to one of four training groups: Group A, upper and lower body resistance training and high intensity endurance training (HIET) which included interval training; Group B, upper body resistance training and HIET; Group C, upper and lower body resistance training only; Group D, HIET only. Training took place four times per week (M,T,Th,F) for 12 weeks. Pre- and post-training measures were obtained for a two mile load bearing task with a total load of 44.67 kgs. APFT was administered at the pre-, mid-, and post-training time points. The results demonstrate that only Group A and Group B made significant ($p<0.05$) improvements in the load bearing performance task. Groups A, B, and D improved all components of their APFT scores while Group C improved in push ups and sit ups only. The results of this study suggest that a combination of running and resistance training is necessary to improve short duration, high intensity load bearing performance.

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APFT scores were responsive to training with resistance training impacting push ups and sit ups, and endurance training improving the two mile run time. Thus, training combinations and specificity of training are important concepts when trying to improve short duration, high intensity load bearing performance and APFT scores.

Technical Report

No.

The Effects of Various Physical Training Programs on Short Duration, High Intensity Load Bearing Performance and the Army Physical Fitness Test

By

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FOREWARD

This study represents one aspect of a large comprehensive study examining performance and physiological responses and adaptations to different combinations of training programs. It is our hope that the information included in this report may give commanders and soldiers insights into the type of training stimulus necessary to improve short, high intensity load bearing performance and APFT scores.

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ABSTRACT

The purpose of this study was to contrast the effects of different physical training programs on short duration, high intensity load bearing performance and Army Physical Fitness Test (APFT) scores. Thirty-five soldiers were randomly assigned to one of four training groups: Group A, upper and lower body resistance training and high intensity endurance training (HIET) which included interval training; Group B, upper body resistance training and HIET; Group C, upper and lower body resistance training only; Group D, HIET only. Training took place four times per week(M,T,Th,F) for 12 weeks. Pre- and post-training measures were obtained for a two mile load bearing task with a total load of 44.67 kgs. APFT was administered at the pre-, mid-, and post-training time points. The results demonstrate that only Group A and Group B made significant ($p<0.05$) improvements in the load bearing performance task. Groups A,B and D improved all components of their APFT scores while Group C improved in push ups and sit ups only. The results of this study suggest that a combination of running and resistance training is necessary to improve short duration, high intensity load bearing performance. APFT scores were responsive to training with resistance training impacting push ups and sit ups, and endurance training improving the two mile run time. Thus, training combinations and specificity of training are important concepts when trying to improve short duration, high intensity load bearing performance and APFT scores.

INTRODUCTION

Recently, a great deal of interest has been focused on the soldier's ability to bear loads over various distances. This has included ways to "lighten the soldier's load" and enhance his load bearing capacity (4,12).

To date, the majority of load bearing research has focused on energy cost as a function of load, distance and speed (2,3,6,9,11). Recently, Dziados et al. (5) examined various physiological variables in an attempt to determine their relative contributions to a field load bearing task [i.e. 10 mile road march]. His study suggested that in addition to aerobic capacity, leg hamstring strength may play an important role in load bearing performance.

It might be hypothesized that both aerobic and strength training would enhance load bearing performance. Yet, no longitudinal training data are available. Furthermore, no studies have examined various types and combinations of training programs. In order to obtain some initial data regarding the effects of different training programs on a short duration, high intensity load bearing task, this study was conducted as part of a larger project concerned with training program compatability. The purposes of this study were to examine the effects of four different three month training programs on: 1. a two mile maximal effort load bearing task, 2. vertical jump performance, and 3. the Army Physical Fitness Test (APFT).

METHODS

Thirty-five active duty soldiers volunteered to participate in this study. None were specifically trained or experienced in military load bearing. All subjects were fully briefed, gave informed consent and were medically screened prior to participation.

The soldiers were then randomly assigned to one of four training groups. There were no statistically significant differences among the groups for the subject characteristics presented in Table 1 prior to training.

Table 1. Selected subject characteristics.

	Height (cm)	Weight (kg)	Age (years)
GROUP A (N=9)	174.10(±6.4)	74.2(±6.7)	23.3(±3.6)
GROUP B (N=9)	176.7(±4.0)	75.6(±8.5)	22.9(±5.0)
GROUP C (N=9)	175.3(±6.1)	76.6(±14.0)	24.3(±5.1)
GROUP D (N=8)	177.6(±7.8)	75.3(±6.7)	21.4(1.41)

Mean values ± 1 SD

The training programs for each group were as follows:

GROUP A Combination of upper and lower body resistance training workouts plus high intensity endurance workouts (HIET).

GROUP B Upper body only resistance training workouts plus HIET workouts.

GROUP C Combination of upper and lower body resistance training workouts only (no HIET).

GROUP D HIET workouts only (no resistance training).

This design allowed for a comparison of HIET and resistance training along with different combinations of resistance workouts.

Table 2. Training schedule

	Mon	Tue	Wed	Thur	Fri
HIET	Dis	Int	Rest	Dis	Int
Resistance	H	S	Rest	H	S

Sat and Sun were used as rest days. Dis=continuous distance run workout. Int=interval workouts. S=strength training workout and H=hypertrophy workout

Training was conducted for 12 weeks with running and resistance exercise sessions performed on a four day per week schedule (Table 2). All training sessions were supervised and exercise data recorded to monitor progress, provide motivation and change the exercise prescription. The basic principles of progressive overload, variation, specificity and individualization were adhered to in the development of each exercise program (7). HIET training, if performed, always was the first workout completed in the morning. It was followed by a recovery period of 4 hours prior to resistance training.

A. Resistance Training Programs

The resistance training program was divided into two different workout styles (labeled S and H) each with an upper and lower body exercise routine (labeled S-U, S-L and H-U, H-L). The differences in workout styles related to the choice of exercise, rest period lengths, exercise orders, number of sets and training loads (i.e. repetition maximum used) which were chosen to provide variation and progressive overload during the weekly training over the twelve week period. The purposes of the resistance training programs were to improve maximal force capabilities of the skeletal muscle exercised and provide better toleration of high intensity exercise (i.e. tolerate higher lactate levels). This was accomplished with the "S" workout which was

developed to produce maximal strength gains and the "H" workout which was designed to stress glycolytic (i.e.lactic acid) energy sources and improve high intensity (>70% 1 RM) muscular endurance and thus enhance performance capabilities under heavy anaerobic stress (See Table 3).

Table 3. Individual exercises for the four resistance workout styles.

"S" Resistance Training Workout

Upper Body (S-U) workout:	1. Bench Press	5 sets X 5 RM
	2. Military Press	5 sets X 5 RM
	3. Arm Curls	5 sets X 5 RM
	4. Lat Pull Down	5 sets X 5 RM
	5. Obliques	5 sets X 10 RM
	6. Bent Leg Sit Ups	5 sets X 10 RM
Lower Body (S-L) workout:	1. Calf Raisers	3 sets X 10 RM
		2. Double Leg Exten5 sets X 5 RM
		3. Leg Press 5 sets X 5 RM
	4. Dead Lift	4 sets X 6 RM

RM=repetition maximum loads were utilized (a weight that would only allow the listed number of repetitions), 2-3 minutes rest was allowed between sets and exercises, the soldier was allowed to start with any exercise the wanted.

"H" Resistance Training Workout

Upper Body (H-U) workout: Superset: 1.Bench Press and Flys
3 sets of 10RM

Superset: 2. Military Press and Upright Rows
2 sets of 10 RM

Superset: 3. Lat Pull and Seated Rows
3 sets of 10 RM

4. Arm Curls
3 sets of 10 RM

5. Bent Leg Sit Ups
2 sets of 25 RM

Lower Body (H-L) workout: Superset: 1. Single leg ext.& single leg curl
3 sets of 10 RM

2. Calf Raisers
3 sets of 15 RM

3. Split Squats
3 sets of 10 RM

Rest period duration between supersets, sets and exercises was one minute. Superset= a two exercise pair performed in succession without rest (e.g. 10 repetitions of the bench press then 10 repetitions performing flys then take a rest of 1 min before performing another superset). This workout produces blood lactate levels $>9 mmol \cdot L^{-1}$

B. HIET Training

The high intensity endurance training was devided into interval run and distance run exercise sessions. The purpose of this training program was to improve aerobic capacity and endurance performance times (8).

1. Distance Run Training: The distance run exercise session consisted of running the maximum distance possible for 40 minutes. The intensity of the exercise ranged from 70-80% of the VO_2 max and was monitored by heart rate after each mile was completed during the run.

The exercise prescription for the distance run training was based on treadmill determination of maximal oxygen uptake and related to the required heart rate necessary to elicit a training zone of 70 to 80% of the individual's maximal oxygen consumption value. This was done every four weeks. These training sessions contributed to about 80% of the total volume of running exercise perfromed each

week. All training was performed on a measured one mile course with varying terrain. As training progressed the distance covered for each session increased over the 12 week training period.

2. Interval Run Training: Interval run training took place on a measured 440 yard track. The distances used during each training period ranged from 440 to 880 yards and the exercise to rest ratios ranged from 1/4 to 1/0.5. The distance covered and the rest allowed between interval runs were functions of the individual's fitness level and training progression over the 12 weeks. As training progressed the total distance covered increased and the rest utilized between the intervals decreased. The intensity of the intervals ranged from 90-100% of maximal oxygen uptake (distance and time dependent) and was computed from heart rate determinations following each interval. The two mile run time trials were used to give an individual an approximate time to "shoot" for in the intervals and heart rates were taken to verify the intensity of the exercise. Appendix A contains the basic guidelines used in this study for determination of interval and distance run target times as they relate to the required maximal oxygen uptake target percentages. The interval run sessions accounted for about 20% of the total volume of running exercise performed each week. A one mile warm up and cool down was not included in this calculation.

Injury Checks

Following each exercise session soldiers were told to check in with the medical monitor and report any possible injury developments. Special care was taken to eliminate any acute injuries secondary to overtraining by appropriate exercise prescriptions based on individual fitness levels. The subjects were instructed not to deviate from their exercise intensities prescribed and not to "overshoot" their fitness

levels. Also, adequate stretching, warm up and cool down procedures were utilized at every training session. Acute medical problems (e.g. strains) were initially treated at the exercise site and a first aid kit consisting of ice, Ace wraps etc. was available to treat the minor injuries that took place during the course of training. The assigned medical monitor provided the follow up care for any of the test subjects that required further medical attention. No training related injuries leading to the removal of a test subject occurred. This was attributed to the above conservative measures.

Testing

Prior to training, a two week orientation, teaching, familiarization and practice period was utilized to eliminate any learning effects and gain the most out of the training time available. Tests were performed at the beginning (pre-training), mid-training (APFT only) and immediately following (post-training) the three month training program. The tests evaluated for the part of the project reported here were the APFT, no-step vertical jump, and a two mile load bearing task.

The load bearing task consisted of a maximal effort two mile carry with a total load of 44.67 kilograms which included Alice pack, BDU's, boots and pack load. Each soldier was instructed to cover the two mile distance in the shortest possible time. The test was conducted over a flat, measured one half mile asphalt course and repeated four times. In pilot testing the test/re-test reliability of this performance task was r=0.92.(N=11). The time for each half mile split was called out to each subject and verbal encouragement was given. Immediately upon completion of the load bearing task, heart rate and Borg scale overall ratings of perceived exertion (1) were obtained. The unloaded run (APFT 2 mile) and loaded two mile performance tests were conducted on the same course.

Vertical jump tests were used to evaluate leg power changes over the training period. Subjects utilized a no step jump protocol previously described (8).

The APFT was administred according to FM 21-20. All soldiers were familiar with this test and had experience with its performance requirements.

Statistical Analysis

The data were analyzed using dependent "t" tests pre- to post-training or an analysis of variance with Tukey post-hoc analysis where appropriate. A significance of $p<0.05$ was chosen for this study.

RESULTS

Only Groups A and B, who performed a combination of both run and resistance training, made significant improvements in their two mile load bearing performance times. These data are presented in Table 4. In Figure 1 a comparison of the percentage improvements in the load bearing task and the unloaded two mile run are presented. The unloaded two mile run times improved for Groups A,B and D while performance times for the load carry improved only for Groups A and B. These results were the same even when corrected for body weight or fat free mass.

The effects of the different training programs on the APFT performances can be seen in Table 5 with percentage improvements compared in Figure 2. Table 5 shows the changes made over 6 weeks(mid) and 12 weeks(post) for push ups, sit ups and the 2 mile run time.

Group A, who performed all of the running and resistance training exercise programs, demonstrated significant increases from pre-test values for push ups (mid

and post), sit ups (post) and two mile run time (mid and post). Group B who performed the running and the upper body (H-U,S-L) resistance training programs only, showed significant improvements in push ups (mid and post), sit ups (mid and post) and two mile run time (post). Group C, who performed the entire resistance training program only, made significant increases in push ups(mid and post), and sit ups(mid and post) but did not improve the two mile run time. Group D, who performed the running program only, significantly improved their push ups (post), sit ups(post) and two mile run time(mid and post). The percentage improvement over the twelve week training program (i.e. pre to post) for each of the tests can be seen in Figure 2. The magnitude of improvement for sit ups and push ups was greater for Groups A, B and C who participated in resistance training than for Group D who participated just in the run training.

Table 4. Pre- to post-training responses for the loaded two mile load bearing task.

Group		Heart Rate Rest / IP-run	RPE IP-run	Time (min:sec)
A	Pre-Training	72.2(9.8)/205.2(6.6)	18.0(1.4)	25:18(4:13)
	Post-Training	82.8(10.7)/199.2(8.8)	19.0(0.7)	21:45(2:44)*
B	Pre-Training	78.0(20.8)/201.0(14.3)	18.0(1.9)	28:37(2:51)
	Post-Training	79.5(7.5)/196.1(12.9)	17.5(1.9)	25:32(3:06)*
C	Pre-Training	80.2(11.1)/186.0(17.9)	16.5(2.5)	29:27(3:22)
	Post-Training	85.1(8.1)/178.0(15.3)	17.9(1.8)	28:12(3:35)
D	Pre-Training	86.4(15.1)/192.0(11.2)	16.6(1.6)	30:32(5:19)
	Post-Training	91.5(19.2)/183.6(10.3)	17.4(1.7)	30:31(6:23)

IP= immediate post-exercise. *=$p<0.05$

Means ($\pm$1 SD) are presented

Table 5. The effects of the different training programs on APFT results.

		Push Ups	Sit ups	2 Mile Run
Group A	Pre	62.8(13.6)	68.9(11.7)	13.4(1.6)
	Mid	73.7(12.4)*	73.3(15.4)	12.3(1.2)*
	Post	87.2(11.2)*&	84.7(7.8)	12.2(1.1)*
Group B	Pre	50.6(13.0)	58.4(12.6)	15.1(0.7)
	Mid	60.4(17.7)*	71.8(14.8)*	14.4(1.1)
	Post	68.3(17.9)*&	72.8(17.2)*	13.3(1.0)*&
Group C	Pre	51.2(9.8)	52.9(7.8)	14.8(1.3)
	Mid	60.0(8.9)*	66.8(6.7)*	15.6(1.5)
	Post	73.4(11.7)*&	72.8(4.2)*&	14.8(1.4)
Group D	Pre	44.5(10.2)	47.6(7.0)	15.4(2.8)
	Mid	47.8(4.9)	48.0(4.1)	14.2(2.1)*
	Post	52.4(9.1)*	55.0(8.5)*&	13.4(1.9)*&

*=$p<0.05$ within group difference from pre-test values.
&=$p<0.05$ within group difference mid to post test values

Figure 3 shows the percentage improvement pre- to post-training for the vertical jump. Increases were observed in vertical jump performance over the twelve weeks of training for those groups (A and C) which utilized a lower body leg resistance training program (i.e. H-L,S-I). Groups B and D, despite the use of an interval training program demonstrated no improvements in vertical jump ability.

Data from this project which are being prepared for publication elsewhere showed that significant strength (1RM) changes occurred in the legs and the arms when resistance training was performed. If no resistance training was performed on the lower body musculature (B and D), no increases in the muscle's ability to apply force was observed. High intensity endurance training which included the interval training described did not result in leg strength changes for groups B and D. Still, B did improve in upper body strength. Maximal oxygen uptake also improved if the

program included run training. Thus, group C, who participated in no run training, demonstrated no improvements in maximal oxygen uptake nor in their two mile run performance time.

DISCUSSION

The data from this study suggest that a combination of resistance training and running is necessary to improve performance on a load bearing task of a short duration, high intensity nature. This was demonstrated by the improvements in load bearing by Group A who performed upper and lower body resistance training programs and the running program, and by Group B who performed the upper body resistance training program and the running program. This, combined with the lack of any significant improvements by either the all run or all lift groups, suggests that the load bearing task in this study demanded more than just improvements in aerobic capacity or muscle strength/power alone.

While resistance training appears to be an essential portion of a program to improve load bearing, the distinction between the contribution of upper body and lower body training is less clear. Upper body resistance training in combination with aerobic run training produced an eleven percent improvement in performance time. Adding lower body (leg) resistance training to upper body training (Group B) showed a fifteen percent improvement which was not statistically different from upper body only. Thus leg resistance training did not appear to add significantly to load bearing performance. However, since leg strength training without upper body training was not examined, it is possible that load bearing was improved by the "H" portion of the workouts (i.e. the glycolytic or lactic acid stimulus), irrespective of the muscle group.

Thus "H" type workouts of either major muscle group may enhance the muscular endurance (muscular power) which in turn improves load bearing ability.

Dziados, et al. (5) previously demonstrated, through a correlational analysis approach, that leg hamstring strength was significantly related to load bearing performance using a lighter load (18 kg) and a longer distance (10 miles). The role of a leg strength component to the type of load carriage used in the present study is questioned by the vertical jump results. Again, only Groups A and C demonstrated significant increases in leg strength as measured by vertical. Groups B and D demonstrated no significant changes but still Group B improved load bearing performance. Thus, increases in leg strength may not enhance shorter, load bearing tasks. It might be speculated that as the weight of the load and the speed of movement are increased, different combinations of aerobic capacity and strength of different muscle groups are required.

The load bearing task utilized in this study was physically very demanding. The intensity of the task as computed from heart rate demonstrated that it was greater than 95 % of maximal oxygen consumption. It is possible that certain combat operations may require such an effort. The use of high lactate producing exercise sessions (i.e. H workout and Interval run resulted in blood lactate levels of > 9.0 $mmol \cdot L^{-1}$.) would be predicted to improve the blood and tissue buffering capacity of the individuals in the training groups (8). The total number of exercise training exposures which produced high lactate responses was less in the single training groups. Thus, the volume of exercise and adaptive time course of tissue and blood buffering capacities and their impact on high intensity load bearing performance remains to be more definitively studied, but cannot be ruled out in this study.

The APFT was selectively responsive to the various training programs. The magnitude of increase for the APFT scores for push ups and sit ups improved more for those groups who participated in the resistance training (See Table 5). The small but significant increases noted in the all running group (D) may have been due to the non-specific increases in blood buffering capacity or local muscular endurance from the shorter and faster intervals used in the study. The all resistance training group(C) observed no improvements in two mile run performance time. Even with the greater anaerobic stress utilized in the H workout, it did not provide an effective stimulus to improve two mile run performance. The absolute percentage increases observed are consistent with other circuit type weight training protocols which have demonstrated small or nonsignificant changes in aerobic capacity or performance (7).

SUMMARY

The results of this study suggest that resistance training combined with an aerobic running program produce improvement in short duration, high intensity load bearing capacity. Upper body muscle group strength, as opposed to leg strength, appears to play a more critical role in the heavier load, shorter duration load bearing task. Tests utilized in the APFT were sensitive and specific to the training programs utilized.

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APPENDIX A

General guidelines for initial pace speeds based on two mile run time and percentage of the maximal oxygen consumption for distance and interval run programs.

Two mile run time (min)	Interval Distance 90-100 $\dot{V}O_2max$ 880 yds. / 440 yds.	70% $\dot{V}O_2max$ mile
10	2:30 / 1:15	6:50
11	2:45 / 1:22.5	7:30
12	3:00 / 1:30	8:00
13	3:15 / 1:37.5	8:40
14	3:30 / 1:45	9:20
15	3:45 / 1:52.5	10:00
16	4:00 / 2:00	10:40
17	4:15 / 2:07.5	11:20
18	4:30 / 2:15	12:00
19	4:45 / 2:22.5	12:50
20	5:00 / 2:30	13:20
21	5:15 / 2:37.5	14:00
22	5:30 / 2:45	14:40

These pace guidelines provide an appropriate pace to be performed in training and allow for an initial pace to be given at the onset of the training program based on an all out two mile run

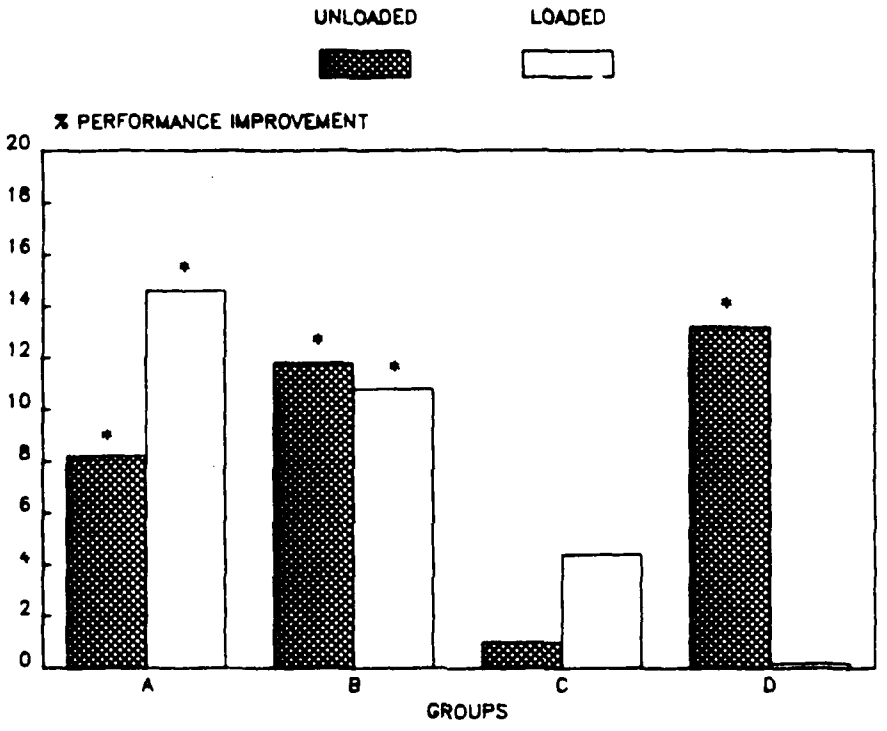

Figure 1. Percentage improvements in load bearing performance and unloaded running as a function of training program.

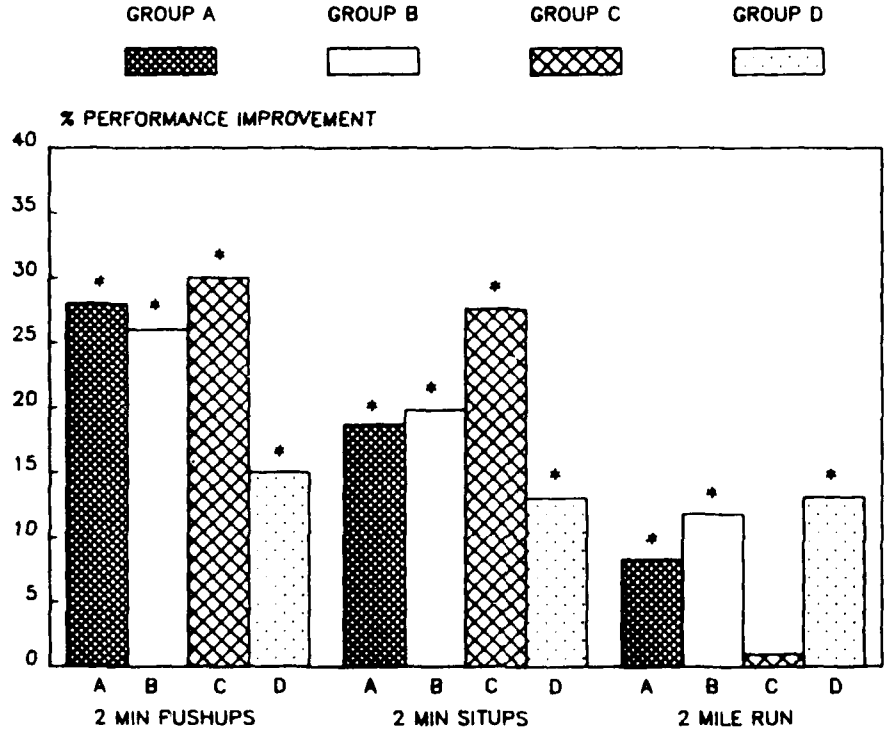

Figure 2. Percentage improvements in the APFT as a function of training program.

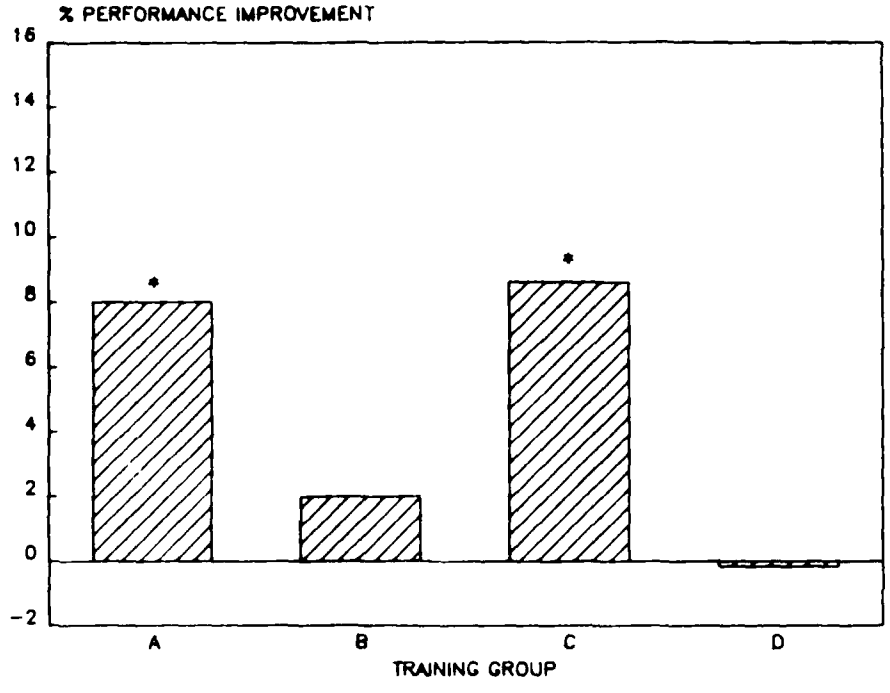

Figure 3. Percentage improvements in vertical jump performance as a function of training program.

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