The influence of direct supervision of resistance training on strength performance

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ABSTRACT

MAZZETTI, S. A., W. J. KRAEMER, J. S. VOLEK, N. D. DUNCAN, N. A. RATAMESS, A. L. GÓMEZ, R. U. NEWTON, K. HÄKKINEN, and S. J. FLECK. The influence of direct supervision of resistance training on strength performance. *Med. Sci. Sports Exerc.*, Vol. 32, No. 6, pp. 1175–1184, 2000. **Purpose:** The purpose of this study was to compare changes in maximal strength, power, and muscular endurance after 12 wk of periodized heavy-resistance training directly supervised by a personal trainer (SUP) versus unsupervised training (UNSUP). **Methods:** Twenty moderately trained men aged 24.6 ± 1.0 yr (mean ± SE) were randomly assigned to either the SUP group ($N = 10$) or the UNSUP group ($N = 8$). Both groups performed identical linear periodized resistance training programs consisting of preparatory (10–12 repetitions maximum (RM)), hypertrophy (8 to 10-RM), strength (5 to 8-RM), and peaking phases (3 to 6-RM) using free-weight and variable-resistance machine exercises. Subjects were tested for maximal squat and bench press strength (1-RM), squat jump power output, bench press muscular endurance, and body composition at week 0 and after 12 wk of training. **Results:** Mean training loads (kg per set) per week were significantly ($P < 0.05$) greater in the SUP group than the UNSUP group at weeks 7 through 11 for the squat, and weeks 3 and 7 through 12 for the bench press exercises. The rates of increase (slope) of squat and bench press kg per set were significantly greater in the SUP group. Maximal squat and bench press strength were significantly greater at week 12 in the SUP group. Squat and bench press 1-RM, and mean and peak power output increased significantly after training in both groups. Relative local muscular endurance (80% of 1-RM) was not compromised in either group despite significantly greater loads utilized in bench press muscular endurance testing after training. Body mass, fat mass, and fat-free mass increased significantly after training in the SUP group. **Conclusion:** Directly supervised, heavy-resistance training in moderately trained men resulted in a greater rate of training load increase and magnitude which resulted in greater maximal strength gains compared with unsupervised training. **Key Words:** PERSONAL TRAINING, TRAINING INTENSITY, PERIODIZATION

Different resistance training protocols have been shown to present a variety of exercise demands resulting in adaptations which are specific to the exercise program utilized (1,3,19,21–23,46,47). For example, multiple-set protocols that incorporate periodization and progressive overload have been shown to optimize improvements in maximal strength performance (4,26,38,39,44).

To date, the effects of direct supervision (i.e., one-on-one personal training) on resistance training adaptations have not been examined. Because many training studies have incorporated some level of supervision to ensure standardized training of all subjects (5,10,13,17,21,28–30), we hypothesized that in highly motivated moderately trained men, direct supervision of training sessions is important for maximal strength performance adaptations to periodized, heavy-resistance training.

Previous studies that have utilized individually supervised training in moderately trained subjects have shown improvements in leg press strength performance of 26 and 30% after 19 and 12 wk of resistance training, respectively (5,21). Strength performance adaptations resulting from other relevant studies, where the level of supervision was either less direct or not specified were as follows: 28% and 12% improvements in 1-repetition maximum (RM) squat and bench press strength, respectively, after 12 wk of linear periodized training; 22% improvement in 1-RM squat after 14 wk of multiple-set varied resistance training; and ~30 and ~25% improvements in relative (i.e., 1-RM/body weight) squat and bench press strength, respectively, after 16 wk of linear periodized training (2,17,44). Due to variations in the strength testing protocols, experimental

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periods, training protocols, and pretraining status of the subjects in these studies, it is difficult to formulate any concrete conclusions describing the influence of supervision of resistance training on strength performance adaptations. The primary purpose of this investigation, therefore, was to compare the changes in maximal strength after directly supervised versus unsupervised, periodized heavy-resistance training.

TABLE 1. Subject characteristics by group.

Variable	SUP ($N = 10$)	UNSUP ($N = 8$)
Age (yr)	25.2 ± 1.5	23.8 ± 1.3
Height (cm)	176.4 ± 2.2	177.7 ± 2.5
Body mass (kg)	85.9 ± 4.9	84.5 ± 3.4
Body fat (%)	19.7 ± 2.3	18.6 ± 3.0
1-RM squat (kg)	108.8 ± 9.8	100.2 ± 5.2
1-RM BP (kg)	93.9 ± 4.6#	83.7 ± 5.3

SUP, supervised; UNSUP, unsupervised; BP, Bench Press; 1-RM, One Repetition Maximum.
# $P < 0.05$ vs corresponding unsupervised value; values are means ± SE.

METHODS

Experimental design. This study utilized a pre- and post-test experimental design. Both week 0 (wk 0) and week 12 (wk 12) testing sessions were identical for the assessment of muscular strength, power, muscular endurance, and body composition. Both training groups performed the same periodized, heavy-resistance training program for 12 wk. The directly supervised group (SUP) was trained one on one by a personal trainer for all training sessions. Strength improvements in this group during training were observed and subsequent training loads (i.e., kilograms per set = kg/set) were increased by the personal trainer. The unsupervised group (UNSUP) attended only one private fitness consultation (i.e., one-on-one familiarization) at the beginning of the study with a personal trainer and subsequently performed all training sessions without direct supervision. Progression of the training loads in the UNSUP group was accomplished in the same manner as the SUP group but was the responsibility of each individual UNSUP subject.

Training loads were determined using repetition maximum zones (e.g., 8- to 10- RM) and were progressively increased as subjects were able to perform the required number of repetitions using a given weight with proper exercise technique. In transition from one phase of the training program to the next, heavier loads were predicted from the previous lighter training loads. Specifically, training loads were increased in increments of 2.2, 4.5, 6.8, 9.1, 11.4, or 13.6 kg depending on the absolute load being used (i.e., the greater the absolute training load, the larger the increment of increase). The magnitude of the increments of training loads in both groups were determined based on the strength levels, quality of the exercise technique (i.e., exercise performed without deviation from safe and correct movements), and the potential for strength improvement of the subject (i.e., how easily did the subject perform the previous workload). In the SUP group, the increments were selected by the personal trainer based on previous personal training experience and feedback concerning feelings of fatigue and ability from the subject. In the UNSUP group, the increments were self-selected based on there own resistance training experience and personal feelings of fatigue and ability. The primary intent for both groups was to increase the training loads in a manner sufficient to optimize the exercise intensity and technique. This study design enabled us to compare one-on-one personal fitness training with unsupervised training where a fitness trainer, via a one-time fitness consultation, provided instruction and a descriptive periodized, resistance training program for the individual to perform on his own.

The qualified personal trainer (same trainer for all subjects) of the study had 3 yr of professional experience in training both the general public and collegiate athletes, and was professionally certified (i.e., ACSM-Certified Health and Fitness Instructor and NSCA-Certified Strength and Conditioning Specialist). The personal trainer was present at all training sessions for the UNSUP group, and questions concerning the construct and parameters of the training program were encouraged throughout the study. Spotting, verbal encouragement, and advice concerning the progression of training loads were not provided by the trainer for the UNSUP group at any time other than during familiarization. Subject training logs were maintained by the personal trainer for the SUP group throughout the 12-wk experimental period detailing the exercises, sets, and repetitions performed. For the UNSUP group, the training logs were provided by the personal trainer (Table 2) and the individual subject filled in the number of repetitions performed for each set during training sessions. The training logs of the UNSUP group were stored at the training facility and were visually inspected weekly by the personal trainer to insure that the subjects were completing them correctly. From the training logs, the number of repetitions, sets, and kg per set for the squat and bench press exercises were analyzed to quantify the progression of the training loads.

Subjects. Twenty men aged 18–35 yr volunteered to participate in this training study and were matched according to their physical characteristics and squat performance measures and randomly assigned to either the SUP or UNSUP training groups (Table 1). Two subjects in the UNSUP group did not complete the training due to reasons not related to the investigation yielding complete data from 18 men (SUP, $N = 10$ and UNSUP, $N = 8$). Each subject was informed of the potential risks associated with the investigation and signed an informed consent document approved by the Institutional Review Board at The Pennsylvania State University and in accordance with the policies outlined by the American College of Sports Medicine. All subjects had 1–2 yr of resistance training experience; however, none had trained with a personal trainer before the study. No significant differences were observed between groups in pretraining physical characteristics or 1-RM squat; however, 1-RM bench press was significantly greater in the SUP group due to subject attrition in the UNSUP group.

Experimental procedures. Body mass was measured using a Toledo electronic scale (Reliance Electronic Co., Worthington, OH) to the nearest 100 g, and skinfold measurements were obtained from seven sites (triceps, subscapular, mid-axillary, chest, supra-iliac, abdomen, and thigh). Skinfolds were taken with a Lange caliper on the right side in serial fashion by the same investigator using standard methods (24). Skinfold thickness from a site was based on the average of two trials except in the case where the measurements differed by greater than 2.0 mm. In this case, a third measurement was obtained and the mean value used. The equation described by Jackson and Pollock (15) was used to estimate body density. Percent body fat was subsequently estimated using the value obtained for body density and the Siri equation (36). All exercise testing protocols were performed using a Plyometric Power System (Lismore, NSW, Australia) previously described (46). The Plyometric Power System consisted of a Smith machine and barbell interfaced to an on-line computer system. Resistance is provided by the barbell, which can only move in the vertical direction. Linear bearings attached to either end of the bar allow it to slide up and down two steel shafts so that movements such as the squat may be performed in a dynamic, ballistic manner with minimal risk to the subject. The machine was connected to a rotary encoder that recorded the position and direction of the bar within an accuracy of 0.2 mm.

Performance testing. Performance testing included a warm-up followed by assessments for 1-RM squat and bench press, jump squat power, and bench press muscular endurance. The 1-RM squat and bench press testing procedures included two to three warm-up sets of two to five repetitions per set using light to moderate resistance as determined by recent training loads. Subjects were permitted three to five attempts until a 1-RM was attained (18,20). A successful lift in the squat required descending to a thigh parallel position defined by the trochanter head of the femur reaching the same horizontal plane as the superior border of the patella. A successful lift in the bench press required lowering the bar under control until it lightly touched the chest (i.e., subjects were not permitted to bounce the bar off of the chest). The subjects then lifted the bar back to a straight-arm position with the hips and feet remaining in contact with the bench and floor, respectively, throughout the lift. Subjects rested for 10 min and subsequently performed a single set of 10 continuous repetitions of jump squats with a resistance equal to 30% of their 1-RM squat. Thirty percent of the 1-RM was chosen as the resistance because mechanical power is maximized near this value (46). Starting in an upright position, subjects were instructed to squat down and then jump repeatedly as high as possible without pausing between repetitions within a set. Power output for each repetition was recorded via The Plyometric Power Systems' on-line data acquisition system. Subjects rested for 10 min and subsequently performed a single set of bench press to fatigue using a load equal to 80% of their pretraining 1-RM bench press, which corresponds to approximately an 8 to 10-RM training intensity (7). After training, subjects performed the bench press endurance test using 80% of the wk-12 1-RM bench press. Eighty percent of the 1-RM was chosen because 8 to 10-RM was the most frequently used RM zone throughout the training program (i.e., specificity of testing). Fatigue was defined as the time point when the bar ceased to move or if the subject paused for greater than one second when the arms were in the extended position. Two spotters immediately racked the bar when the investigator (same for all subjects) determined that fatigue had occurred. Repetitions were recorded to the nearest 1/4 of a full repetition. Resistance, total repetitions, and the percentage of wk-zero 1-RM resistance used during wk-12 bench press endurance testing were determined for comparison between groups. No exercise was permitted for a period of 48 h before the testing sessions.

Familiarization. Each subject was familiarized with all testing and training equipment and procedures to minimize possible learning effects (5). During familiarization, all essential parameters of the training program were explained including training session sequence, exercise selection, number of sets and repetitions, rest periods between sets, and progression principles. Each subject was provided a training log on which to record all workouts. Attendance for the UNSUP group was monitored via daily sign-in sheets for each training session. A 100% attendance for all workouts was observed, indicating the high level of motivation in both training groups. In addition, all subjects were given the opportunity to ask questions after familiarization, thus reducing any impact of misunderstanding on the resultant data.

Resistance exercise training. The training log showing the basic training paradigm including exercises, number of sets and repetitions, and rest periods between sets for each phase of the resistance training program are provided in Table 2. All resistance training in both groups was performed in the same facility utilizing identical equipment which consisted of a combination of free weights and Cybex (Cybex International, Medway, MA) and Nautilus (Nautilus International, Independence, VA) exercise machines. Because the primary goal of the resistance training program was to increase maximal strength, a classical linear periodized resistance training program emphasizing strength and hypertrophy phases was used (28,38,39,44). Heavy-resistance workouts were partitioned into four consecutive phases including general preparatory (2 and 3 sessions/wk during weeks 1 and 2, respectively), hypertrophy (4 sessions/wk during weeks 3, 4, 5, and 6), strength (3 sessions/wk during weeks 7, 8, 9, and 10) and peaking (3 sessions/wk during weeks 11 and 12).

The general preparatory phase was a low-intensity protocol that trained all major muscle groups during each session (Table 2). This phase was designed to prepare the subjects to tolerate the following heavy-load training phases. The hypertrophy phase utilized a split protocol similar to a bodybuilding program where the primary goal was to increase muscle size. In this phase, each muscle group was trained once per week with multiple exercises and sets, higher repetitions, and short rest periods between

TABLE 2. Resistance training program.

General Preparatory Phase (Weeks 1–2) 3 Sets 12 Repetition Maximum Intensity 60–120 s Rest between Sets		
Monday	Wednesday	Friday
Abdominal Crunch	Abdominal Crunch	Abdominal Crunch
Barbell Squats	Leg Press	Deadlifts
Hyperextension	Heel Raise	Leg Extension
Seated Heel Raise	Dumbbell Incline Press	Leg Curl
Bench Press	Dumbbell Reverse Fly's	Behind Neck Press
Seated Cable Row	Pull Ups (machine assisted)	Row (machine)
Lateral Raise (machine)	Triceps Extension (machine)	Pec Deck
Narrow Grip Pulldown	EZ Bar Curls	Wide Grip Pulldown

Hypertrophy Phase (Weeks 3–6) 3 Sets 8–10 Repetition Maximum Intensity 45–90 Seconds Rest between Sets			
Monday	Tuesday	Thursday	Friday
Abdominal Crunch	Abdominal Crunch	Pull Ups (machine)	Abdominal Crunch
Barbell Squats	Dumbbell Incline Press	Seated Cable Row	Bench Press
Leg Press	Lateral Raise (machine)	Hyperextension	Behind Neck Press
Leg Extension	Heel Raise	Deadlifts	Chest Press Machine
Leg Curl	EZ Curls	Row (machine)	Dumbbell Fly's
Dumbbell Row	Triceps Extension (bar)	Narrow Grip Pulldown	Dumbbell Shoulder Press
Wide Grip Pulldown	Dumbbell Curls	Single Leg Extension	Dumbbell Lateral Raise
Dumbbell Reverse Fly's	Dips	Seated Leg Curl	Seated Heel Raise

Strength Phase (Weeks 7–10) 3–4 Sets 6–8 Repetition Maximum Intensity 1–2 Minutes Rest between Sets		
Monday	Wednesday	Friday
Smith Machine Squats	Leg Press	Barbell Squats
Abdominal Crunch	Abdominal Crunch	Abdominal Crunch
Unilateral Leg Curl	Stiff Legged Deadlift	Leg Extension
Bench Press	Heel Raise	Seated Leg Curl
Row (machine)	Behind Neck Press	Bench Press
Dumbbell Shoulder Press	Dumbbell Row	Seated Cable Row
Wide Grip Pulldown	Triceps Extension (machine)	Shoulder Press (machine)
	Alternating Dumbbell Curls	Body Weight Pull Ups

Peaking Phase (Weeks 11–12) 2–3 Sets 3–6 Repetition Maximum Intensity 1–2.5 Minutes Rest between Sets		
Monday	Wednesday	Friday
Smith Machine Squats	Leg Press	Barbell Squats
Abdominal Crunch	Abdominal Crunch	Abdominal Crunch
Leg Curls	Stiff Legged Deadlift	Seated Leg Curl
Bench Press	Dumbbell Incline Press	Bench Press
Row (machine)	Dumbbell Row	Seated Cable Row
Dumbbell Shoulder Press	Upright Row	Shoulder Press (machine)
Narrow Grip Pulldown	EZ Bar Curls	Body Weight Pull Ups
	Triceps Extension (bar)	

sets in order to activate each muscle group as highly as possible and allow for adequate recovery time between training sessions for each muscle group (42). Free-weight squat and bench press exercises were utilized during the general preparatory and hypertrophy phases, each performed once per week. The strength phase was a high-intensity protocol that trained all major muscle groups during each session. This phase was designed to increase strength performance by utilizing heavy loads, longer rest periods, and exercise sequencing (i.e., exercises which train opposing muscle groups were alternated) in order to activate and load the high recruitment threshold-Type II muscle fibers as much as possible and allow for adequate recovery between sets and exercises during training (9,34,35,48). In addition, the squat and bench press exercises were performed twice per week during the strength and peaking phases, once using free weights and once on a Smith machine. The Smith machine was incorporated into the training protocol to optimize the specificity of training related to the testing exercises (9). The peaking phase of training was similar to the strength phase, but with fewer sets and repetitions, and was designed to taper training for peaking physical strength and power.

During training, all subjects were required to perform the squat exercise inside a power rack in which the pins were positioned 1 inch below the barbell when the lifter was in the lowest squat position. The lowest squat position during training was defined (same as for strength testing) by the trochanter head of the femur reaching the same horizontal plane as the superior border of the patella. Subjects in the UNSUP group were required to have a spotter (i.e., another unsupervised subject) during squat and bench press exercises. All sets for all exercises performed by both groups were terminated once assistance was provided. Subjects were not permitted to participate in any additional formal exercise training, including endurance training, which would have compromised the resultant adaptations and confounded the interpretation of these data (21).

Statistical analyses. Statistical analyses of the data were accomplished with two-way analysis of variance

(ANOVA) with repeated-measures design. When a significant F-ratio was achieved, a Tukey HSD (Spjotvoll and Stoline test) for unequal sample sizes was used. The linear slope of the relation between weeks and the training loads for the squat and bench press exercises were determined for each subject using linear regression as previously described (5). Week 0 values and delta changes between groups were analyzed using independent t-tests with alpha level corrections as needed. No significant differences were observed between groups for any variables at week 0 except for 1-RM bench press performance. Thus, 1-RM bench press values were analyzed via ANCOVA using week-zero 1-RM values as the covariate. Test-retest reliability correlation (intraclass Rs) for all performance tests were ≥ 0.95. Statistical power ranged from 0.78 to 0.80 at a P-value equal to 0.05. Significance in this study was defined as $P \leq 0.05$.

RESULTS

Training loads. No differences were observed between groups for the number of training sessions, sets, or repetitions performed per week during training for squat and bench press exercises. Significant interaction occurred between groups in the squat and bench press kilograms per set (kg/set) during training (Fig. 1). Significantly greater kg/set were observed in the supervised subjects at weeks 7 through 11 for the squat and weeks 3 and 7 through 12 for the bench press. When analyzed by phase (i.e., general preparatory, hypertrophy, strength, and peaking), squat and bench press kg/set were significantly greater in the SUP group during the strength and peaking phases. The rates of increase (slopes) in squat and bench press kg/set per week (mean ± SE) were significantly greater in the SUP group (7.2 ± 0.48, and 3.9 ± 0.34, respectively) than the UNSUP group (5.6 ± 0.52, and 2.8 ± 0.25, respectively).

1-RM strength. At wk-0, no significant differences were observed between groups for 1-RM squat, but in the supervised subjects, the 1-RM bench press was significantly greater than the UNSUP group (Fig. 2). Significant increases in 1-RM squat and bench press were observed in both groups from wk-0 to wk-12. A significant interaction occurred between groups for the 1-RM squat and bench press, and *post hoc* analyses revealed significantly greater strength improvements in the SUP group for both exercises. Percent improvements (mean ± SE) for the squat and bench press were 33 ± 4.2 and 22 ± 2.2% versus 25 ± 3.4 and 15 ± 3.6% for the SUP and UNSUP groups, respectively.

Jump squat testing. Both groups improved significantly in mean and peak jump squat power output from wk-0 to wk-12 (Fig. 3). No significant differences were observed between groups in mean or peak power at wk-0 or wk-12.

Relative local muscular endurance. Total bench press repetitions did not change in either group after training, and no significant differences were observed between groups at wk-0 or wk-12 (Fig. 4). Week 0 bench press endurance resistance (BPER) (kg) was 80% of the respective 1-RM values for both groups as per the relative local muscular endurance protocol employed. The wk-12 BPER (mean ± SE) increased significantly to 97.6 ± 1.8 and 92.0 ± 2.7% of previous week-zero 1-RM values for the SUP and UNSUP groups, respectively. Interaction between groups for the increase in wk-12 BPER percent of week zero 1-RM resistance was not significant ($P = 0.09$).

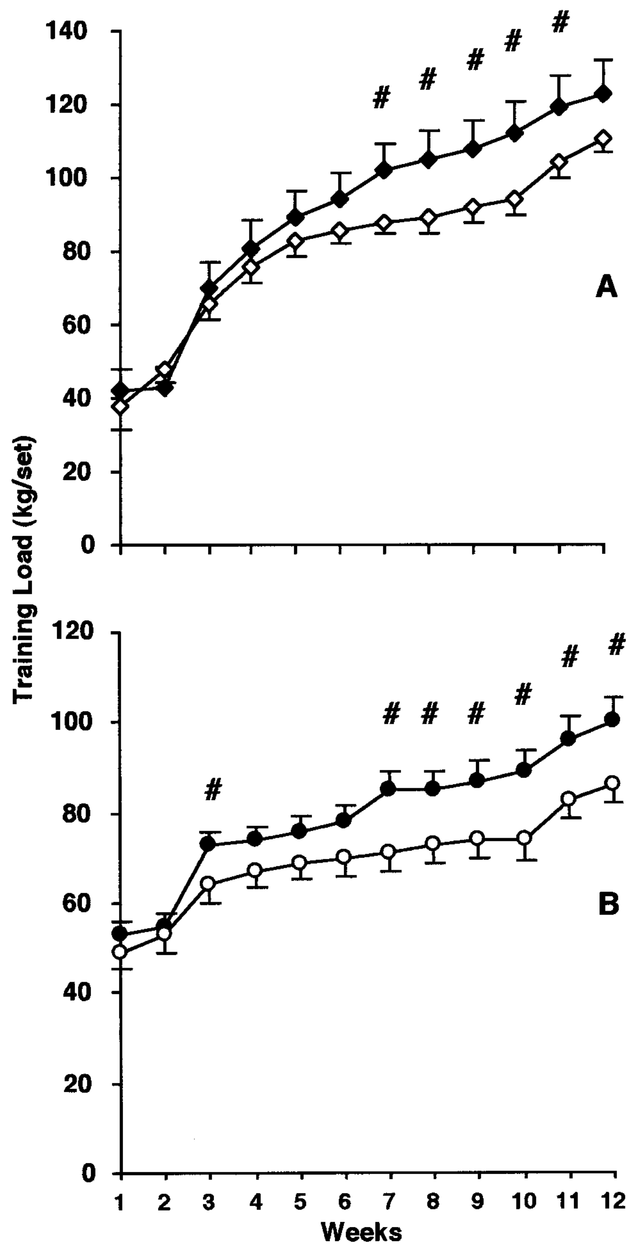

Figure 1—Comparison of the training loads (kg/set) for the squat (A) and bench press exercises (B) during a 12-wk periodized heavy-resistance training program. Darkened symbols = supervised; open symbols = unsupervised. # $P < 0.05$ vs corresponding unsupervised value. Values are means ± SE.

Body composition. Body mass, fat mass, and fat-free mass (FFM) each increased significantly from wk-0 to wk-12 in the SUP group (Table 3). No significant changes were observed in the body composition variables from wk-0 to wk-12 in the UNSUP group, although % body fat increased nonsignificantly in the UNSUP group (delta change = 2.03%) similar to the SUP group (delta change =

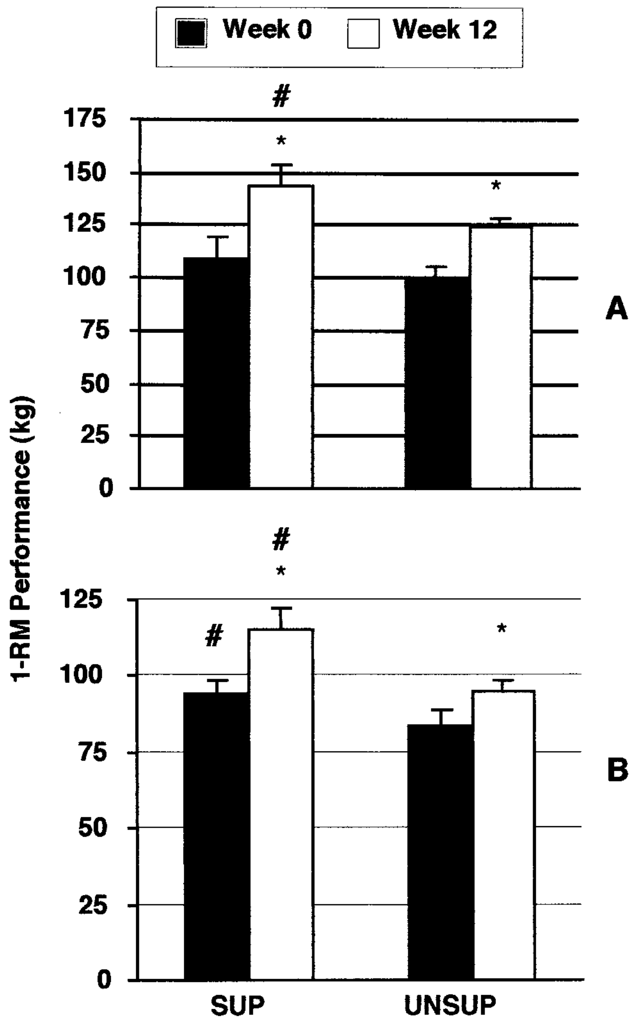

Figure 2—Comparison of 1-RM squat (A) and bench press (B) performance (kg) at week 0 and after 12 wk of periodized heavy-resistance training. SUP = supervised; UNSUP = unsupervised. * $P < 0.05$ vs corresponding week 0 value. # $P < 0.05$ vs corresponding UNSUP value. Values are means ± SE.

2.10%). No significant group interactions in body mass, fat mass, FFM, or % body fat were observed between groups.

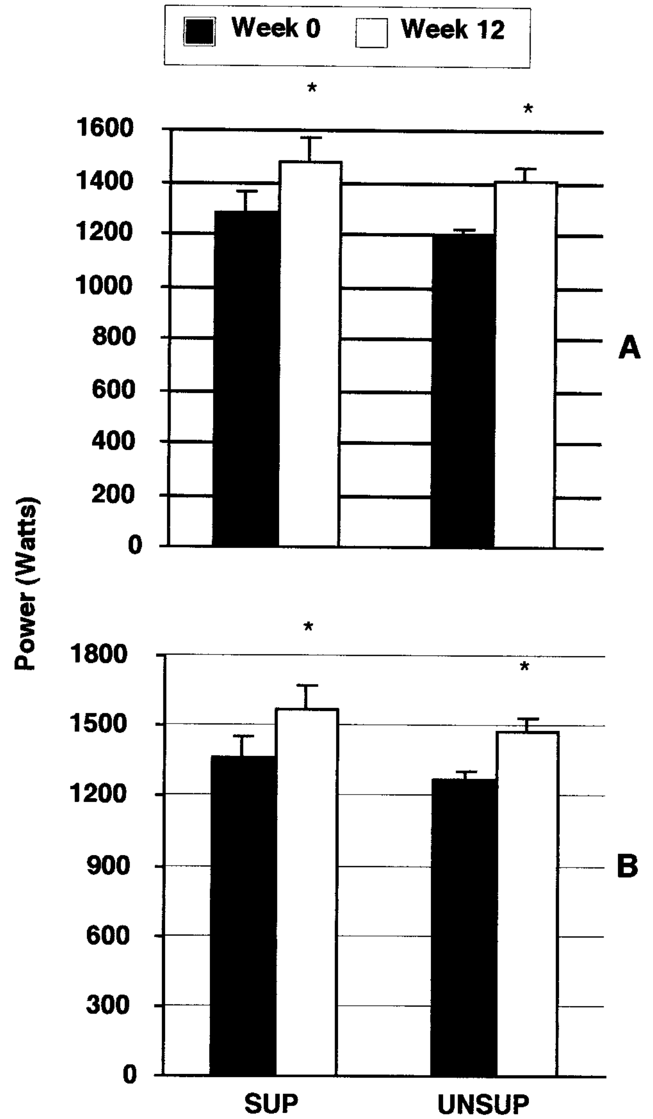

Figure 3—Comparison of the mean (A) and peak (B) power output (W) for one set of 10-repetition jump squats at week 0 and after 12 wk of periodized heavy-resistance training. SUP = supervised; UNSUP = unsupervised. * $P < 0.05$ vs corresponding week 0 value. Values are means ± SE.

DISCUSSION

The primary findings of this investigation were that the magnitude and rate of training load increases were greater for directly supervised than for unsupervised periodized, heavy-resistance exercise. The greater magnitude of squat and bench press training loads during directly supervised training may explain the greater 1-RM strength performance and FFM increases in the SUP group after the 12 wk training program. Mean and peak jump squat power did not respond differently to directly supervised and unsupervised training, but did improve in both groups after heavy-resistance training. Bench press muscular endurance performance (80% of 1-RM) was not compromised in either training group despite significantly greater testing loads utilized after training.

The rate of increase of the squat and bench press training loads were greater in the directly supervised than the unsupervised subjects indicating that the progression of training loads may be influenced by direct supervision. Differences between groups in the training loads in both the squat and bench press exercises were demonstrated during the 4-wk strength and 2-wk peaking phases of the training program. These differences between groups may not have been evident earlier in training because the goals of the first two phases were primarily for hypertrophy and not for strength improvement. Specifically, the kg/set were greater during weeks 7 through 11, and 3 and 7 through 12 for the squat and bench press, respectively. Heavier training loads have been shown to insure the activation of the higher recruitment threshold fast twitch motor units, which are essential for inducing optimal gains in strength (4,9,12,35). These data indicate that direct supervision of resistance training enhances the magnitude and rate of increase in training loads

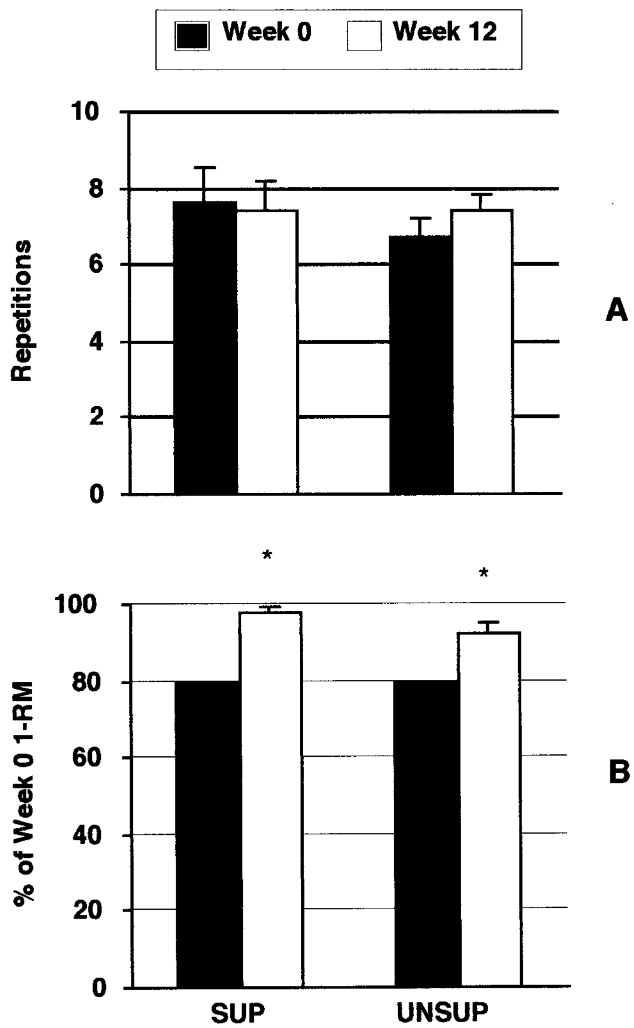

Figure 4—Comparison of bench press muscular endurance repetitions (A) and percentage of week zero 1-RM (B) at week 0 and after 12 wk of periodized heavy-resistance training. SUP = supervised; UNSUP = unsupervised. * *P* < 0.05 vs corresponding week 0 value. Values are means ± SE.

of multiple joint and upper and lower body free-weight exercises.

A probable explanation for the greater training intensity in the SUP group relates to the accelerated progression of training loads demonstrated by the directly supervised subjects. As shown in Figure 5, this trend was evident during the transitions of the training program (i.e., from one phase of training to the next) where a higher intensity was predicted from a lower intensity. In fact, further analysis revealed significantly greater increases (mean ± SE) from weeks 2 to 3 and 6 to 7 in the squat (26.6 ± 2.9 and 7.3 ± 1.6 kg, respectively) and bench press (18.0 ± 1.9 and 7.1 ± 1.0 kg, respectively) for the SUP group as compared with the increases in the squat (18.0 ± 2.6 and 2.6 ± 1.5 kg, respectively) and bench press (11.4 ± 1.8 and 1.3 ± 0.9 kg, respectively) for the UNSUP group. Direct supervision, therefore, promoted the use and toleration of greater training loads in the squat and bench press exercises during heavy, 3 to 8-RM training, which may have optimized the stimulation of higher recruitment threshold motor units and muscle tissue mass with each session (12,31,35). Thus, the primary factor mediating the differential response in strength performance between directly supervised and unsupervised training was related to the progression of the training loads by the personal trainer.

TABLE 3. Comparison of body composition variables between supervised (SUP) and unsupervised groups (UNSUP) at week 0 and after 12 wk of periodized heavy-resistance training.

Group	Week 0	Week 12	Δ (12–0)
Body mass (kg)			
SUP	85.92 ± 4.86	89.97 ± 5.12*	4.05 ± 1.06
UNSUP	84.53 ± 3.36	87.11 ± 3.69	2.59 ± 1.20
Fat mass (kg)			
SUP	17.69 ± 2.91	20.36 ± 2.89*	2.67 ± 0.81
UNSUP	16.36 ± 3.21	18.70 ± 3.39	2.34 ± 1.16
Fat-free mass (kg)			
SUP	68.22 ± 2.55	69.60 ± 2.62*	1.38 ± 0.52
UNSUP	68.16 ± 1.50	68.41 ± 1.46	0.25 ± 0.37
Body fat (%)			
SUP	19.65 ± 2.27	21.76 ± 1.97	2.10 ± 0.77
UNSUP	18.63 ± 3.04	20.66 ± 3.08	2.03 ± 0.93

Δ, delta change; * $P < 0.05$ vs corresponding week 0 value; values are means ± SE.

Another potential explanation for the greater training loads in the SUP group, although not examined in this investigation, may be related to differential psychological factors due to constant supervision in the SUP group. Specifically, the presence of a personal trainer during supervised training may have enhanced the competitiveness (i.e., performing for an audience) and external motivation (i.e., verbal support) for the SUP subjects. Regarding motivation, it is significant to note that both training groups utilized very similar training loads during weeks 1 and 2, and no statistically significant differences between groups were evident in the training loads until week 7 of the training program, except for the bench press at week 3 (Fig. 1). Also, there were no significant differences in the number of training sessions, sets, or repetitions performed per week during training. Based on the similarity in the training loads in both groups during the initial 6 weeks of the training program, it seems likely that the influence of motivation provided by the personal trainer was minor thus lending further support for the progression of training loads as a primary mediating factor for the subsequent differences in strength performance between groups.

Significant 1-RM strength improvements in the squat and bench press exercises were observed after training in both groups. These results are consistent with other studies that also used periodized training in previously trained men and similar experimental training periods (2,14,23,44). Improvements in strength are typically attributed to neurologic adaptations, muscle fiber transformations, and muscle fiber hypertrophy (27,32,35,37). Neurologic adaptations have been suggested to be the most prominent contributors to improvements in strength performance with short-term resistance training (12,16,32,35). During long-term training (i.e., usually greater than 6–8 weeks in previously trained subjects), increases in the cross-sectional area of individual muscle fibers due to fiber hypertrophy have been shown to contribute to increased force production capabilities of intact muscle (12,16,32,35,40). These underlying factors,

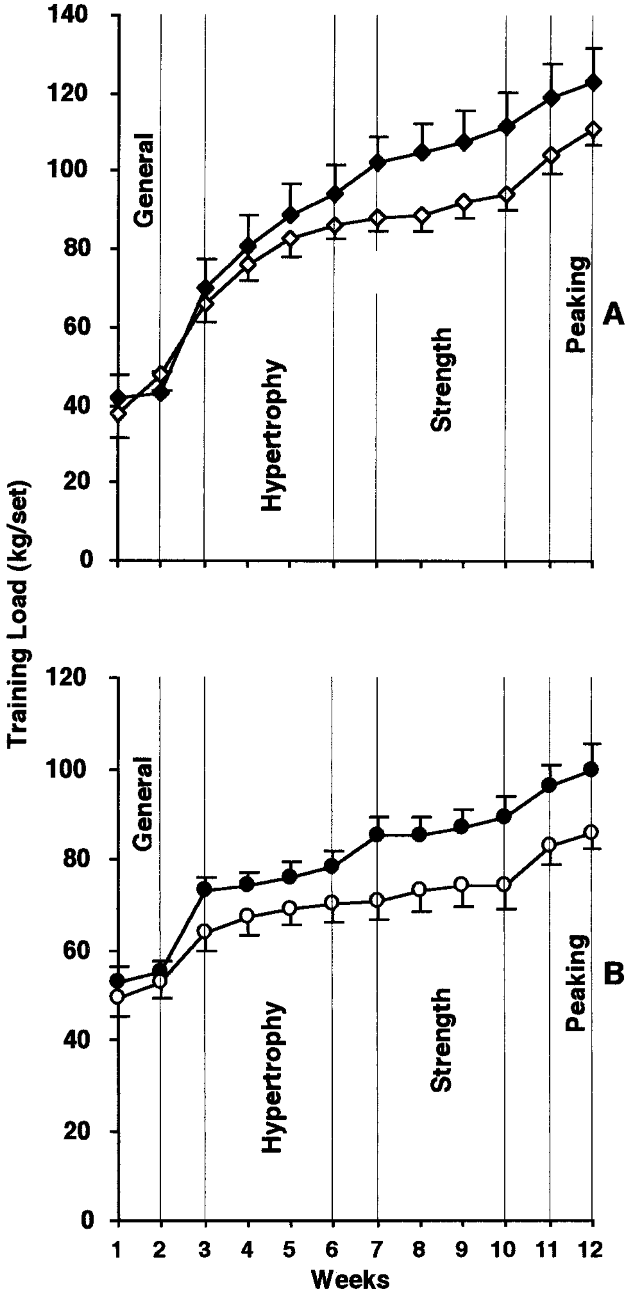

Figure 5—Comparison of training load (kg/set) progression for the squat (A) and bench press exercises (B) from one training phase to the next (i.e., general preparatory [general], hypertrophy, strength, and peaking phases) during a 12-wk periodized heavy-resistance training program. Darkened symbols = supervised; open symbols = unsupervised. Values are means ± SE.

although not studied here, are possible mechanisms for changes in strength performance.

Significant increases in mean and peak jump squat power output were observed in both groups after training. These increases in power may be surprising as it is well documented that typical heavy-resistance strength-training programs lead to greater increases in maximal force, whereas changes in the higher velocity portions of the force-velocity curves and muscle power usually remain considerably minor (12,38,39,46). On the other hand, explosive training, which utilizes exercises performed with lighter loads but with much higher movement velocities, usually leads to improvements primarily in the higher velocity portions of the force-velocity curves and ultimately muscle power (12,46). This principle of specificity of training seemed to be true during the present heavy-resistance training; however, the data showed that muscle power could also be increased after "pure" heavy-resistance strength training.

A partial explanation for the improvements in power may be related to possible training adaptations in the fast twitch muscle fibers. Previous investigations have shown enhanced power output after resistance-training programs using heavy loads (i.e., 80–90% of maximum) (33,34,46). Heavier loads are required to ensure the recruitment of fast twitch motor units, which are important for dynamic performance (35). Furthermore, Type II fibers have been shown to contribute two and a half times more than Type I fiber types to total power in heterogeneous muscle (6). In the present investigation, the heavy squat loads used during the latter phases of training may have recruited more high threshold motor units primarily involved in high force production, thereby increasing the force production capabilities of the Type II muscle fibers sufficiently to increase power (i.e., power = force × velocity).

Power output was examined in the present investigation primarily to enable a complete analysis of performance changes after the resistance-training program. The fact that mean and peak jump squat power did not respond differently to directly supervised and unsupervised resistance training was not surprising because the primary goal of this training protocol was to increase strength performance. Therefore, an explanation for the absence of differences in mean and peak power output between groups may be explained by lack of specificity of the training program for motor unit recruitment and power performance as compared with the jump squat testing regimen (46). Despite the fact that heavy squat training and jump squats both involve high-threshold—fast-twitch motor units, jump squats differ in that they require force to be developed in a much shorter duration of time (i.e., rate of force development). Therefore, maximizing improvements in power output may require more specific power-related exercises where the rate of force development can be enhanced (11,46).

No differences were observed between groups at wk-0 or wk-12 in repetitions performed in bench press endurance testing, but the BPER increased significantly (mean ± SE) in both SUP (Δ change = 17.1 ± 2.2 kg) and UNSUP (Δ change = 9.3 ± 1.7 kg) groups. At wk-12, the SUP group used a BPER of 97.6% (SE = 1.8%) of the week zero 1-RM bench press as compared with 92.0% (SE = 2.7%) for the UNSUP group (*P* = 0.09) (Fig. 4). According to previous studies, increases in relative local muscular endurance result when a higher number of repetitions are performed during training (1,13,23). Thus, relative local muscular endurance is influenced to a greater extent by the duration of the repetitive physical work than the intensity. Our results, consistent with existing literature, show that relative local muscular endurance was not compromised by the significantly greater BPERs in both groups after training despite the emphasis of this training program on improving strength performance as opposed to muscular endurance. However, the maintenance of bench press endurance repetitions in the SUP group after significantly greater improvements in BPER than in the UNSUP group is worth noting.

Body mass, fat mass, and FFM increased significantly after training in the SUP group, but no significant changes in body composition variables occurred in the UNSUP group. The significant increase in body mass (Δ change = 4.05 kg) in the SUP group after training may have been due to significant increases in both fat mass (Δ change = 2.67 kg) and FFM (Δ change = 1.38 kg). On the other hand, the increase in body mass in the UNSUP group after training (Δ change = 2.59 kg) may have been due mostly to a change in fat mass (Δ change = 2.34 kg). A greater change in the SUP group FFM as compared with the UNSUP group seems possible based on fact that the squat and bench press training loads were significantly greater in the SUP group than the UNSUP group. Other resistance training investigations have shown that increases in muscle fiber size were greater in individuals subjected to heavier training loads (5,41). Furthermore, changes in FFM after resistance-training studies have been used to represent muscle fiber hypertrophy (2,45). Ultimately, these conclusions regarding body composition adaptations after the 12-wk resistance-training program are quite speculative because the changes in % body fat in both groups (~2%) were within the error range associated with the determination of body fat via skinfold methods (i.e., ± 3.5%) (25). Thus, it is possible that the changes in body composition in both training groups may have been associated with variation during skinfold data collection.

Other explanations for the potential increasing fatness observed in the SUP (Δ change = 2.10%) and UNSUP groups (Δ change = 2.03%) may be related to alterations in the subject's aerobic activity levels and dietary habits. Specifically, all subjects were required to refrain from all aerobic exercise during the 12-wk resistance training program to avoid the attenuating effects of combined high-intensity aerobic and resistance training (21). All subjects were also informed of the importance of the quantity and quality of nutrients required for sufficient recovery during heavy-resistance training designed primarily to increase strength performance (43). Because alterations in aerobic activity levels and dietary intake may have occurred, the changes in body composition in both groups after training may be due to factors unrelated to the resistance training protocol employed.

In summary, our data indicate that 12 wk of periodized, heavy-resistance training directly supervised by a personal trainer elicits significantly greater adaptations in strength performance compared with unsupervised training in moderately trained men. Although the physiological mechanisms responsible for the differences in the improvements in strength performance between the directly supervised and unsupervised groups cannot be surmised from the present data, it seems that the primary factor was related to the magnitude and rate of progression of the training loads by the supervised group. Specifically, direct supervision promoted the use and toleration of greater training loads in the squat and bench press exercises during the heavy-load strength and peaking phases of the linear periodized strength-training program. The greater training loads in the SUP group may have elicited a training stimulus sufficient to increase FFM in the SUP group after training. "Pure" heavy-resistance strength training elicited improvements in mean and peak jump squat muscle power, whereas relative local muscular endurance was not compromised. Based on the results of this study, we propose that direct supervision is an integral component to elicit optimal strength performance adaptations to periodized resistance training in highly motivated and moderately trained subjects.

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