Journal of Strength and Conditioning Research, 2001, 15(1), 86–91

The Effectiveness of 0.5-lb Increments in Progressive Resistance Exercise

DAVID HOSTLER, MATTHEW T. CRILL, FREDRICK C. HAGERMAN, AND ROBERT S. STARON

Department of Biomedical Sciences, College of Osteopathic Medicine, Ohio University, Athens, Ohio 45701.

ABSTRACT

A traditional progressive resistance exercise program consists of increasing the number of repetitions at a constant load until exceeding an established repetition range. Subsequently, the load is increased by 1.1 kg (2.5 lb) or more, and the lifter works at the new load until again exceeding the repetition range. This investigation examines the use of small incremental loads for 2 upper-body exercises (bench press and triceps press). Subjects were randomly assigned to traditional (TRAD) progressive resistance exercise (5 women, 5 men) and small increment (SI) progressive resistance exercise (5 women, 4 men) groups. Initially, both groups trained for 8 weeks using TRAD progressive resistance exercise. Subjects who achieved 7 repetitions on the final set of an exercise increased the load for the next session by 2.2 (bench press) or 1.1 kg (triceps press). Following the initial 8-week training period, the TRAD group continued for another 8 weeks following the same protocol, whereas the SI group trained for an additional 8 weeks, increasing the load by 0.22 kg (0.5 lb) when completing 7 or 8 repetitions and 0.44 kg (1 lb) when achieving 9 or more repetitions. All groups, except TRAD women, made significant increases in 1 repetition maximum (1RM) for the bench press. Both TRAD men and SI men significantly increased 1RM triceps press. Groups that did not significantly increase 1RM, in either the bench press or triceps press, demonstrated similar trends. For TRAD men and SI men, the number of repetitions to failure for the bench press at 60% 1RM decreased after training. Both regimens proved effective for increasing strength throughout 8 weeks. In conclusion, SI progressive resistance exercise appears to be as effective as TRAD progressive resistance exercise for increasing strength during 8 weeks in short-term pretrained college-aged men and women. However, preliminary data suggest that the TRAD progressive resistance exercise program might be a more effective method of increasing resistance during an extended period.

Key Words: muscular strength, program design, bench press, triceps press

Reference Data: Hostler, D., M.T. Crill, F.C. Hagerman, and R.S. Staron. The effectiveness of 0.5-lb increments in progressive resistance exercise. *J. Strength Cond. Res. 15(1):86–91. 2001.*

Introduction

Progressive resistance exercise has proven effective for rehabilitation, training athletes, and general fitness. Based on the long-term overloading of skeletal muscle, traditional (TRAD) progressive resistance exercise requires adding repetitions at a constant load until achieving a target number of repetitions and progressively increasing the resistance. As the target number of repetitions is again reached, the load is again increased. Long-term overload assumes that skeletal muscle maintains a reserve strength margin above the level of strength required for normal activity. Working within this strength margin will elicit neural, metabolic, and muscular adaptations to raise the reserve strength margin that, in turn, can be overloaded again (6, 7).

The size of this reserve strength margin is unknown, and increasing resistance is limited by the increments available to the lifter, typically 1.1 or 2.2 kg. If this strength margin is very small, these increments may affect how rapidly strength can be improved at lighter loads. For instance, increasing a 90.7-kg (200-lb) bench press by 2.2 kg represents a 2.5% increase in resistance, whereas increasing a 45.3-kg (100-lb) bench press by the same 2.2 kg would be a 5% increase. For exercises that use even lighter loads (e.g., dumbbells), an increase of 2.2 kg represents a rather large percent change in resistance. These considerations become important in situations where less resistance is used, such as during exercises that require a smaller muscle mass, people new to resistance training, and rehabilitation.

Early research has examined the optimal number of repetitions (4, 13), interaction of sets and repetitions (3, 5, 19), and optimal loading (2) for a progressive resistance training program. To our knowledge, there have been no studies that have investigated the optimal incremental increase for progressive resistance exercise. Therefore, the purpose of the present study was to examine the use of 0.22-kg magnets for use during the bench press and triceps press exercises and to

Table 1. Anthropometric data.*

	TRAD men		SI men		TRAD women		SI women	
	Pretraining	Posttraining	Pretraining	Posttraining	Pretraining	Posttraining	Pretraining	Posttraining
Mass (kg)	68.7 ± 10.4	69.7 ± 11.5	79.0 ± 7.9	79.5 ± 8.6	59.8 ± 6.7	59.8 ± 6.6	58.0 ± 4.0	58.9 ± 3.4
Body fat (%)	14.1 ± 5.3	11.4 ± 5.6	17.6 ± 4.2	14.6 ± 4.2	25.7 ± 3.3	24.3 ± 3.8	24.5 ± 2.2	24.3 ± 1.3
Lean body mass (kg)	58.7 ± 6.8	61.2 ± 6.3	65.0 ± 5.6	67.8 ± 6.2	44.3 ± 4.8	45.1 ± 3.7	45.8 ± 5.9	44.5 ± 2.4

* Values are mean ± *SD.* TRAD = traditional, SI = small increment.

quantify changes in strength and relative muscular endurance in college-aged women and men.

Methods

Ten college-aged women (age, 20.9 ± 1.1 years; height, 163.6 ± 7.6 cm; weight, 58.9 ± 5.3 kg) and 9 college-aged men (age, 20.8 ± 1.2 years; height, 173.0 ± 7.3 cm; weight, 73.3 ± 10.4 kg) completed the study and provided written informed consent. Subjects had not been performing resistance training at least 6 months before beginning the study. Approval was obtained from the Ohio University Institutional Review Board, and subjects were screened for normal neuromuscular function by a physician before beginning the study.

Subjects were randomly assigned to TRAD progressive resistance exercise (5 women, 5 men) and small increment (SI) progressive resistance exercise (5 women, 4 men) groups. To assist in discerning potential differences between the 2 training programs, both groups trained for 8 weeks using TRAD progressive resistance exercise. Training sessions were preceded by a brief warm-up period that consisted of light aerobic activity. The first 4 weeks consisted of 2 training sessions per week, 3 sets to failure of each exercise (bench press and triceps press). For the last 4 weeks, the subjects trained 3 times per week. Subjects achieving 7 or more repetitions on the final set of an exercise increased the load for that exercise at the next session by 2.2 kg (1.1 kg per side; bench press) or 1.1 kg (triceps press). Because of academic constraints, this initial 8 weeks of training (phase I) was followed by a 10-day break before continuing to the next phase (phase II). The posttraining values for phase I served as the pretraining values for phase II. Previous studies in our laboratory have demonstrated minimal loss of cross-sectional area after 30–32 weeks of detraining (17). Therefore, we felt a detraining stimulus of 10 days would not significantly impair the training status of the subjects after phase I. During phase II, the TRAD group continued for another 8 weeks following the same protocol, whereas the SI group increased the load by 0.22 kg when finishing an exercise with 7 or 8 repetitions and 0.44 kg when achieving 9 or more repetitions.

Subjects were tested for 1 repetition maximum (1RM) and the number of repetitions to failure at 60% of 1RM (60% 1RM) at the beginning and after each phase of the training. Exercises were supervised for safety and program compliance. Subjects were given approximately 3 minutes to rest between sets. Results for men and women were considered separately, and statistical treatment of data was conducted using paired samples *t*-tests with significance set at $p \leq 0.05$.

Results

Anthropometric Data

Table 1 presents the mean values (±*SD*) for body mass, body composition, and lean body mass. No significant

Table 2. Muscle strength and relative muscular endurance data.†

	TRAD men			SI men		
	Phase I pretraining	Phase I posttraining	Phase II posttraining	Phase I pretraining	Phase I posttraining	Phase II posttraining
Bench press 1RM	83.9 ± 14.1	88.0 ± 13.1	100.6 ± 14.9**	78.8 ± 12.2	83.9 ± 19.7*	102.0 ± 12.7**
Triceps press 1RM	30.8 ± 6.1	46.0 ± 6.8*	57.6 ± 11.1**	27.8 ± 5.7	42.8 ± 7.8*	59.6 ± 8.8**
Bench press RF	19.8 ± 2.9	20.8 ± 2.7	14.6 ± 2.9**	19.0 ± 2.3	19.0 ± 3.8	14.0 ± 2.2**
Triceps press RF	19.8 ± 4.1	25.0 ± 3.7*	15.0 ± 5.4	18.0 ± 2.2	20.0 ± 5.0	17.8 ± 10.1

† TRAD = traditional; SI = small increment; 1RM = 1 repetition maximum; RF = repetitions to failure at 60% 1RM. All loads in kilograms. Phase I posttraining values were used as phase II pretraining values.

* Significantly different from phase I pretraining values ($p < 0.05$).

** Significantly different from phase I posttraining values ($p < 0.05$).

differences were found between groups or after training.

Strength Data

During phase I training, all groups except TRAD women made significant gains in 1RM for triceps press exercise. The bench press exercise increased significantly for all groups except TRAD men. Both male and female TRAD groups increased repetitions to failure at 60% 1RM for the triceps press exercise (Table 2).

During phase II training, all groups except TRAD women made significant increases in 1RM for the bench press. Both TRAD men and SI men significantly increased 1RM triceps press. Both TRAD men and SI men decreased the number of repetitions to failure for the bench press at 60% 1RM. There were similar trends in 1RM seen in all groups for both exercises.

During phase II, the SI groups increased resistance used at subsequent workouts approximately 4 times as often as the TRAD groups for the bench press exercise ($p < 0.05$) and nearly twice as often for the triceps press exercise (Table 3).

Table 3. Mean number of times resistance increased during phase II.†

	TRAD men	SI men	TRAD women	SI women
Bench press	2.8	12.3*	3.0	12.0*
Triceps press	8.8	15.3	8.8	13.0

† TRAD = traditional; SI = small increment.
* Significantly different from TRAD group ($p < 0.05$).

Discussion

There are discrepancies in the literature regarding the most appropriate methods for strength training. These differences, in part, may result from different program goals. There is support for exercise programs consisting of one set of 8–12 repetitions of an exercise to develop and maintain general fitness (1, 15). Although this format may be appropriate for maintaining general fitness, it may not be optimal for increasing strength. Berger (3) reported 3 sets of 10 repetitions optimal for improving strength, whereas Anderson and Kearney (2) reported 3 sets of 6–8 repetitions to be superior to greater numbers of repetitions for improving strength. Our training protocol in this study was within this range, performing 3 sets to failure and increasing the load if the final set was completed with 7 or more repetitions. Under this protocol, increasing resistance with SIs and TRAD increments proved effective throughout 8 weeks for increasing strength in college-aged men and women.

A TRAD progressive resistance exercise program requires adding repetitions as the major goal, and the resistance is increased only when the lifter achieves the target number of repetitions. The smallest increment normally available for resistance exercise is 1.1 kg (2.5 lb) or 2.2 kg (5.0 lb). The SI progressive resistance exercise protocol followed by the SI group in this study is a variation of TRAD strength training designed to add resistance while maintaining repetitions at a nearly constant level by using increments of 0.22 or 0.44 kg. Since both groups made significant strength gains, it is difficult to determine if one form of progressive resistance exercise was more effective than the other. Although the SI weights proved effective throughout 8 weeks, it is possible that our study did not extend over enough time to show long-term differences. Plotting the average resistance used within each group and exercise over time (Figure 1) suggests that TRAD progressive resistance exercise might be a more effective method of increasing resistance during extended training periods. This potential long-term difference could be related to a greater stimulus placed on the muscle by increasing resistance in larger increments even though the number of repetitions decreases. Prior studies have manipulated exercise intensity by varying the number of sets, repetitions, and the length of rest between sets (8–11, 14). These studies have reported

Table 2. Extended.

TRAD women			SI women		
Phase I pretraining	Phase I posttraining	Phase II posttraining	Phase I pretraining	Phase I posttraining	Phase II posttraining
35.8 ± 6.5	43.5 ± 5.9*	58.5 ± 10.9	37.6 ± 9.4	44.9 ± 7.8*	54.0 ± 6.9**
12.9 ± 4.4	25.6 ± 6.0	37.6 ± 6.9	12.2 ± 2.8	23.1 ± 3.4*	36.7 ± 7.7
18.2 ± 3.5	20.8 ± 1.9	15.0 ± 4.8	19.0 ± 6.0	22.0 ± 3.9	18.0 ± 4.7
18.6 ± 6.0	23.2 ± 5.4*	22.0 ± 5.5	21.4 ± 3.8	20.2 ± 2.8	21.2 ± 4.1

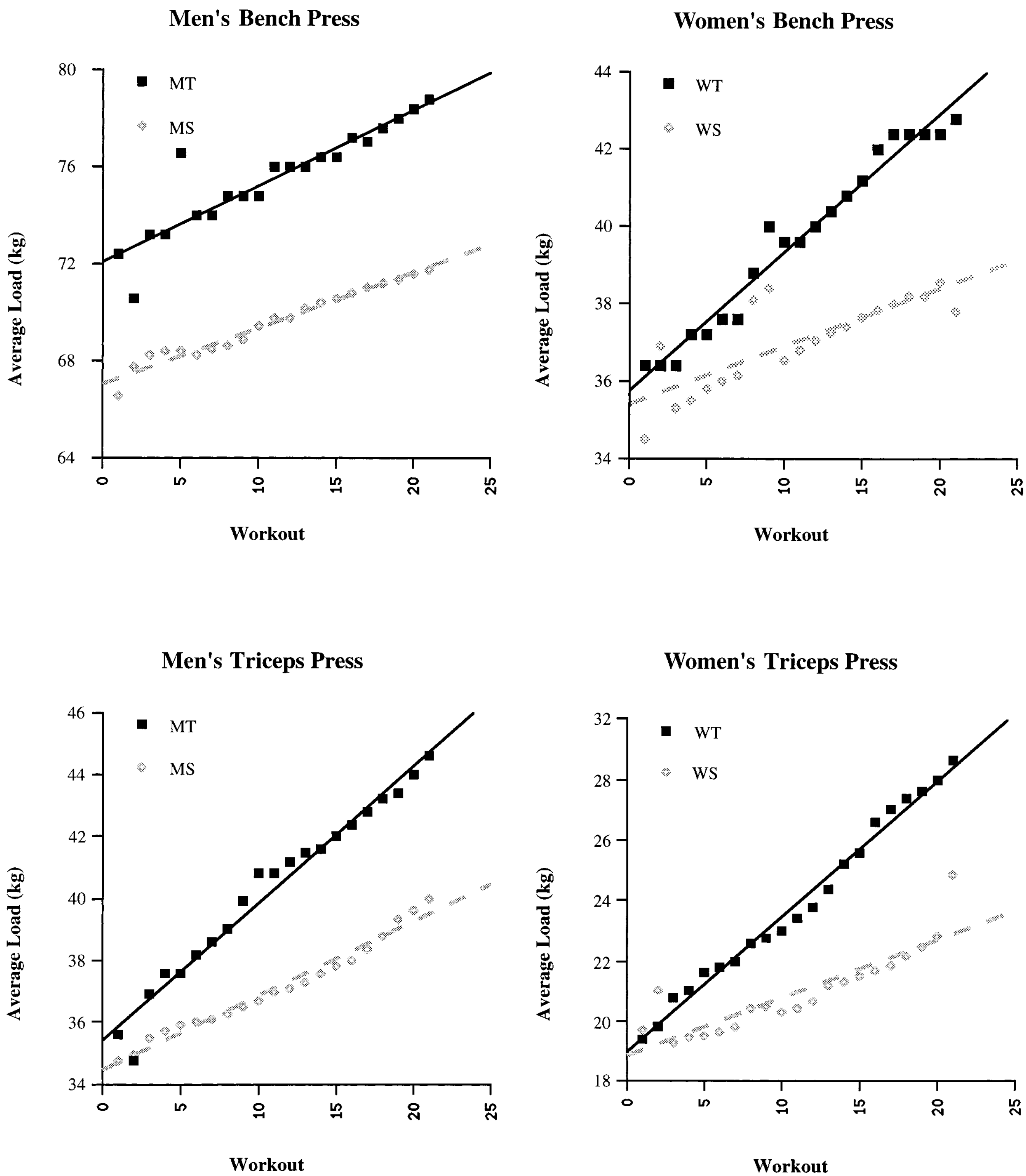

Figure 1. Average resistance (kg) for each workout during phase II. MT = traditional progressive resistance exercise program for men; MS = small increment progressive resistance exercise for men; WT = traditional progressive resistance exercise program for women; WS = small increment progressive resistance exercise for women.

higher exercise volume and intensity as important aspects for both muscular and hormonal responses to resistance exercise. Although our study did not address these issues directly, it is possible that increasing resistance by 0.22 or 0.44 kg may not be enough stimulus to induce optimal muscle changes.

Small increment resistance is likely to be effective at lighter loads, where it would represent a more manageable increase in resistance compared with increases of 1.1 or 2.2 kg. For this reason, we chose to examine exercises involving the upper body. Both bench press and triceps press involve less muscle mass compared with most lower-extremity exercises. As such, minimal increases of 2.2 kg (in the bench press) and 1.1 kg (in the triceps press) usually cause significant decreases in the number of repetitions.

Strength gains in response to resistance training are a combination of neurological and muscular adaptations. Initial, rapid improvements in strength appear to result primarily from neurological adaptation, whereas subsequent gains are primarily the result of muscular adaptations (12). Therefore, to discern potential differences in muscle adaptation between the 2 programs in the present study, it was necessary to pretrain both groups. Previous studies in our laboratory have shown 8 weeks of resistance training to be sufficient to induce fiber type transitions and increases in cross-sectional area (16–18).

An interesting variation would have been to detrain the subjects and subsequently have them retrain using the opposite protocol. However, we chose not to cross over the groups to the opposite protocol because of a number of potential confounding factors. The magnitude and frequency of strength gains become smaller as the training program continues. Therefore, changing protocols at the end of phase II and training for another 8 weeks would have been an unfair comparison. To perform an accurate crossover study, subjects would have to detrain to the initial fitness level. The amount of time required to detrain the subjects and repeat the study would have proven excessive in an academic setting.

A limitation of the study was the number of subjects available for analysis. Four men and 2 women did not complete phase I of the study. The calculated power to identify significant changes in the subjects who completed the study was approximately 75% for 1RM and 40% for repetitions to failure. Although we are confident of the conclusions regarding the strength data, the repetitions to failure data are difficult to generalize.

Previous studies from our laboratory have shown individual responses in repetitions to failure after strength training varies (Staron 1996). This assessment of local muscular endurance could vary in individuals according to fiber type profile, muscle glycogen stores, and capillarity, which was beyond the scope of this study.

In conclusion, SI progressive resistance exercise appears to be as effective as TRAD progressive resistance exercise for increasing strength after 8 weeks in pretrained college-aged men and women. However, it is not known if SI progressive resistance exercise is as effective as TRAD progressive resistance exercise for long-term training. More work needs to be done to confirm this.

Practical Applications

Progressive resistance exercise that uses small increments of resistance can be an effective adjunct to a resistance training program. Increasing the load by smaller increments more often may improve the level of satisfaction in novice lifters and increase the likelihood of continuing a program by providing the positive feedback of increasing resistance at a rapid rate. Additionally, it may be of use to experienced lifters currently experiencing a plateau in training. However, it is not known if SI progressive resistance exercise is as effective as TRAD progressive resistance exercise for long-term training.

References

1. American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults, *Med. Sci. Sports Exerc.* 22:265–274. 1990.
2. Anderson, T., and K.T. Kearney. Effects of three resistance training programs on muscular strength and absolute and relative endurance. *Res. Q.* 53:1–7. 1982.
3. Berger, R. Effect of varied weight training programs on strength. *Res. Q.* 33:168–181. 1962.
4. Berger, R. Optimum repetitions for the development of strength. *Res. Q.* 33:334–338. 1962.
5. Berger, R. Comparative effects of three weight training programs. *Res. Q.* 34:396–398. 1963.
6. Fleck, S.J., and W.J. Kraemer. Resistance training: Physiological responses and adaptations (2 of 4). *Phys. Sportsmed.* 16:108–124. 1988.
7. Fleck, S.J., and W.J. Kraemer. Resistance training: Physiological responses and adaptations (3 of 4). *Phys. Sportsmed.* 16:63–74. 1988.
8. Gotshalk, L.A., C.C. Loebel, B.C. Nindl, M. Putukian, W.J. Sebastianelli, R.U. Newton, K. Häkkinen, and W.J. Kraemer. Hormonal responses of multiset versus single-set heavy-resistance exercise protocols. *Can. J. Appl. Physiol.* 22:244–255. 1997.
9. Kraemer, W.J., L. Marchitelli, S.E. Gordon, E. Harman, J.E. Dziados, R. Mello, P. Frykman, D. McMurry, and S.J. Fleck. Hormonal and growth factor responses to heavy resistance exercise protocols. *J. Appl. Physiol.* 69:1442–1450. 1990.
10. Kraemer, W.J., B.J. Noble, M.J. Clark, and B.W. Culver. Physiologic responses to heavy-resistance exercise with very short rest periods. *Int. J. Sports Med.* 8:247–252. 1987.
11. Kramer, J.B., M.H. Stone, H.S. O'Bryant, M.S. Conley, R.L. Johnson, D.C. Nieman, D.R. Honeycutt, and T.P. Hoke. Effects of single vs. multiple sets of weight training: Impact of volume, intensity, and variation. *J. Strength Cond. Res.* 11:143–147. 1997.
12. Moritani, T., and H.A. deVries. Neural factors versus hypertrophy in the time course of muscle strength gain. *Am. J. Phys. Med.* 58:115–130. 1979.
13. O'Shea, P. Effects of selected weight training programs on the development of strength and muscle hypertrophy. *Res. Q.* 37: 95–102. 1963.

14. Ostrowski, K.J., G.J. Wilson, R. Weatherby, P.W. Murphy, and A.D. Little. The effect of weight training volume on hormonal output and muscular size and function. *J. Strength Cond. Res.* 11:148–154. 1997.
15. Starkey, D.B., M.L. Pollock, Y. Ishida, M.A. Welsch, W.F. Brechue, J.E. Graves, and M.S. Feigenbaum. Effect of resistance training volume on strength and muscle thickness. *Med. Sci. Sports Exerc.* 28:1311–1320. 1996.
16. Staron, R.S., D.L. Karapondo, W.J. Kraemer, A.C. Fry, S.E. Gordon, J.E. Falkel, F.C. Hagerman, and R.S. Hikida. Skeletal muscle adaptations during early phase of heavy resistance training in men and women. *J. Appl. Physiol.* 76:1247–1255. 1994.
17. Staron, R.S., M.J. Leonardi, D.L. Karapondo, E.S. Malicky, J.E. Falkel, F.C. Hagerman, and R.S. Hikida. Strength and skeletal muscle adaptations in heavy-resistance trained women after detraining and retraining. *J. Appl. Physiol.* 70:631–640. 1991.
18. Staron, R.S., E.S. Malicky, M.J. Leonardi, J.E. Falkel, F.C. Hagerman, and G.A. Dudley. Muscle hypertrophy and fast fiber type conversions in heavy resistance-trained women. *Eur. J. Appl. Physiol.* 60:71–79. 1990.
19. Withers, R.T. Effect of varied weight-training loads on the strength of university freshman. *Res. Q.* 41:110–114. 1970.

Acknowledgments

The authors would like to thank Louis A. Winans for bringing his theory of PACE weight training to our attention and for his generous donation of PACE weights for this study. We would also like to thank our subjects for their dedication and hard work.