Journal of Strength and Conditioning Research, 1994, 8(4), 231-234

Strength/Endurance Effects From Three Resistance Training Protocols With Women

William J. Stone[1] and Scott P. Coulter[2]

[1]Department of Exercise Science/Physical Education, Arizona State University, Tempe, Arizona 85287; [2]Sports Training Institute, Livingston, New Jersey 07039.

Reference Data
Stone, W.J., and S.P. Coulter. Strength/endurance effects from three resistance training protocols with women. *J. Strength and Cond. Res. 8(4):231-234. 1994.*

ABSTRACT

Fifty college women were randomly assigned to one of three resistance training protocols that employed progressive resistance with high resistance/low repetitions (HRLR), medium resistance/medium repetitions (MRMR), and low resistance/high repetitions (LRHR). The three groups trained on the same resistance exercises for 9 weeks at 3 sets of 6 to 8 RM, 2 sets of 15 to 20 RM, and 1 set of 30 to 40 RM, respectively. Training included free weights and multistation equipment. The 1-RM technique was used for strength testing, and muscular endurance tests consisted of maximum repetitions either at a designated resistance or at a percentage of 1-RM. There were significant pre/post strength increases in both upper and lower body tests, but no significant posttreatment difference in muscular strength among the three protocols. Absolute muscular endurance increased significantly on 4 of 6 pre/post comparisons, while relative endurance increased significantly on only 4 of 12 comparisons. HRLR training yielded greater strength gains. LRHR training generally produced greater muscular endurance gains, and the percentage increase in absolute endurance was approximately twice the increase in strength for all groups. Lower body gains in both strength and endurance were greater than upper body gains.

Key Words: muscular strength, muscular endurance, training programs

Introduction

For nearly half a century the assumption has held that a continuum exists in terms of the primary training effect resulting from high resistance/low repetition (HRLR) training versus low resistance/high repetition (LRHR) training. Increased muscular strength is the anticipated effect of HRLR training, while increased muscular endurance is the expected result of LRHR training. The concept is rooted in the pioneering work of Delorme, whose earliest work was aimed at restoring muscular strength in injured veterans (7). Delorme and Watkins later proposed that strength could best be enhanced by gradually increasing levels of high resistance at 10 reps (8). Most training researchers and practitioners continue to support the strength/ endurance continuum theory (10, 11, 15, 19).

The search to establish an optimal training regimen for maximal strength has continued for decades. Most of the literature on combinations of sets and repetitions in the 1960s and 1970s reported that strength was maximized with few sets (1 to 3), and few repetitions (2 to 10 RM) at high resistance (2, 3, 14). Berger conducted a series of studies, initially concluding the superiority of 3 sets of 6 RM (2). Berger subsequently concluded that a number of combinations could maximize strength (3). Several investigations have directly compared various regimens considered to be the most effective for developing strength. The results of those studies yielded no differences in effectiveness among the various training protocols (17, 18, 20).

A decade has passed since Anderson and Kearney tested the strength/endurance continuum theory with a three-protocol training design (1). They trained their subjects at three points along the strength/endurance continuum: HRLR, medium resistance/medium repetitions (MRMR), and LRHR. The descriptive trend of their data tended to support the continuum concept—that the greatest increases in strength were attained by the high resistance group (+20%) while the greatest absolute (+41%) and relative (+28%) endurance was attained by the high repetition group. Although all three groups increased pre/post strength significantly, there were no statistically significant posttreatment differences in strength among the three training protocols, which did not unequivocally support the continuum theory.

The work of Anderson and Kearney (1) also addressed the specificity effect of resistance training on muscular strength versus muscular endurance. Delorme assumed that the factors of muscular strength and muscular endurance were mutually exclusive, hence the continuum (7). Previous studies using HRLR and LRHR training regimens have reported that they were equally effective in developing strength and endurance (6), and that strength was the primary effect (5, 16). Anderson and Kearney reported a higher degree of specificity in training effect, and a loss (–7%) in relative muscular endurance as a result of HRLR training (1).

The literature continues to support the concept of a strength/endurance training continuum, although no unequivocal support based on statistical analysis can be found. It is evident that the continuum concept of training warrants additional study. The purpose of this study was to examine the effects of three resistance training protocols on muscular strength, absolute muscular endurance, and relative muscular endurance.

Methods

Subjects

The subjects ($N = 50$) were college age women (23.1 ± 3.5 yrs, 167 ± 6.8 cm, and 58.9 ± 8.6 kg) without formal or extensive resistance training experience. In exchange for a personal training program, the subjects agreed to restrict training to the assigned protocol and maintain their standard diet. They gave informed consent in writing.

Procedures

Orientation and Practice. After an orientation session designed to familiarize the women with the exercises and equipment, they were given three practice sessions with the exercises. This was to give the inexperienced subjects an opportunity to learn the motor skill portion of the exercises and thus reduce the impact of low initial skill on overall improvement from pre- to posttests. The women trained on five basic exercises: bench press, squat, triceps push-down, arm curl, and the lat pull. At the end of the orientation and practice sessions they were pretested and randomly assigned to one of three resistance training protocols.

Testing. Pre- and posttesting for muscular strength and muscular endurance was conducted over two sessions, with random order 2 days apart. Strength and relative endurance were tested in one session and absolute endurance in the other, with alternating of upper and lower body tests. Strength testing was conducted with free weights on the bench press (upper body) and squat (lower body) using the 1-RM method.

Absolute endurance for the bench press was tested with 15.9 kg at 40 reps a minute (rpm). A cadence was specified to prevent ballistic movement or "cheating" on repetitions. As many repetitions as possible were allowed, but only at the correct form and pace. The squat test was administered similarly with 25 kg at 30 rpm. The test weights were selected on the basis of the 50th percentile of standards provided for women by Hatfield and Krotee (12), and adjusted for the average weight of the subjects.

Relative endurance was tested with two loads: Load 1 was on the basis of pretest 1-RM, and Load 2 was on the basis of the posttest 1-RM. The bench press was tested at 45% of 1-RM at 40 rpm, and the squat at 55% of 1-RM at 30 rpm. The slightly higher percentage for lower body testing has been used successfully by other investigators (4).

Training Procedures. The subjects trained on both free weights and multistation equipment. Supervised training was conducted three times a week for 9 weeks on each on the three training protocols. All subjects completed the entire training program. The HRLR training ($n = 17$) consisted of 3 sets of 6 to 8 RM, with 2 to 3 min rest between sets. When 8 RM could be performed correctly for 3 sets, additional weight was added. In each of the three protocols, 2.3 kg was the minimum weight addition. The MRMR group ($n = 16$) training involved 2 sets of 15 to 20 RM with 2 to 3 min rest. When 20 RM could be performed correctly for 2 sets, weight was added. The LRHR group ($n = 17$) trained for 1 set of 30 to 40 RM. When 40 RM were achieved correctly, weight was added.

The training techniques were adapted from several other sources (1, 4, 12) to equalize the training volume. The training volumes were compared but not statistically analyzed for difference. The subjects were posttested at the end of the training period using the same procedures as in the pretest.

Data Analyses

Pre/post mean comparisons were made on the dependent variables, using t tests. The level of significance was set at $p < 0.001$ in order to deal with the probability of Type I error associated with multiple comparisons; the procedure is consistent with Keppel (13). ANCOVA was used for comparison among the three protocols on posttreatment strength, absolute endurance, and relative endurance in Loads 1 and 2 for upper and lower body. ANCOVA was selected in order to reduce the potential that any pretest differences among the groups would influence the posttest comparisons. Descriptive data were analyzed to compare percentage changes among protocols, and between strength and endurance as well as upper and lower body.

Results

Pre/post means comparisons indicated that all three protocols produced statistically significant increases in maximum strength for upper and lower body ($p < 0.001$). Absolute endurance was also improved significantly on four of six comparisons ($p < 0.001$) (see Table 1). ANCOVA results indicated there were no statistically significant posttreatment differences among the three protocols in strength, absolute endurance, or relative endurance in Loads 1 or 2 (see Table 2).

HRLR and LRHR training protocols yielded significant pre/post increases ($p < 0.001$) in relative endurance Load 1, using a percentage of the pretest 1-RM. None of the protocols yielded significant increases in relative endurance Load 2, using a percentage of the posttest 1-RM (see Table 1).

Table 1
Pre/Post Mean (*SD*) Comparisons (*t* ratio) and % Differences Among 3 Training Protocols for Strength and Endurance

Training protocol	Upper body (bench press) Pre	Post	Δ%	*p*	Lower body (squat) Pre	Post	Δ%	*p*
Maximum strength (kg)								
HRLR	29.4 (5.6)	35.0 (6.4)	18.9	<.001	52.1 (8.1)	69.4 (11.2)	33.0	<.001
MRMR	31.3 (4.6)	36.5 (5.1)	16.7	<.001	49.1 (5.7)	63.8 (7.1)	30.9	<.001
LRHR	33.4 (5.8)	37.2 (6.8)	11.6	<.001	59.0 (15.2)	73.7 (15.4)	25.1	<.001
Absolute endurance (reps)								
HRLR	32.6 (11.4)	42.7 (13.4)	31.0	<.001	33.2 (10.6)	61.2 (23.1)	84.3	<.001
MRLR	39.8 (15.2)	56.2 (19.0)	41.2	<.001	38.2 (24.2)	68.8 (29.9)	80.1	.002
LRHR	38.9 (14.7)	46.8 (10.5)	20.3	.023*	34.8 (19.6)	82.6 (55.9)	137.4	<.001
Relative endurance 1 (reps)								
HRLR	46.7 (8.5)	58.3 (9.4)	24.8	<.001	35.2 (10.4)	58.4 (20.5)	65.9	<.001
MRMR	46.6 (11.8)	67.1 (28.7)	44.0	.002*	48.9 (31.0)	78.9 (29.1)	61.3	.003
LRHR	41.1 (9.0)	53.6 (17.2)	30.4	<.001	33.1 (12.8)	60.5 (31.5)	82.6	<.001
Relative endurance 2 (reps)								
HRLR	46.7 (8.5)	43.7 (10.5)	−6.4	.310*	35.2 (10.4)	46.0 (10.8)	30.7	.010
MRMR	46.6 (11.8)	51.5 (11.3)	10.5	.098*	48.9 (31.0)	55.9 (16.1)	12.9	.333
LRHR	41.1 (9.0)	44.8 (12.4)	9.0	.161*	33.1 (12.8)	43.9 (17.4)	32.6	.004

Table 2
Posttreatment Comparisons (ANCOVA) Among 3 Training Protocols for Strength and Endurance

	Upper body (bench press) *F*	*p*	Lower body (squat) *F*	*p*
Maximum strength	2.15	0.13	0.66	0.52
Absolute endurance	2.85	0.07	1.57	0.22
Relative endurance 1	1.80	0.18	0.76	0.47
Relative endurance 2	2.49	0.09	0.45	0.64

The descriptive data indicated that HRLR training yielded larger strength gains than LRHR training. Comparisons indicate an 18.9 versus 11.6% increase for the upper body, and a 33 versus 25.1% increase for the lower body. LRHR training generally produced larger muscular endurance increases, and the average endurance increase was double the average strength gain (44 vs. 23%). Lower body strength increases were double the upper body gains on average (29.4 vs. 15.7%), and lower body muscular endurance gains were about three times greater (65.3 vs. 22.8%).

Discussion

The failure of the HRLR training protocol to produce statistically more strength than MRMR or LRHR protocols is consistent with the results reported by Anderson and Kearney (1). The LRHR protocol did not produce statistically greater muscular endurance, also failing to unequivocally support the continuum. The research design and overall results of the two studies are similar except for the sex of the subjects. The descriptive data in both studies suggest larger strength increases for HRLR training and larger muscular endurance for LRHR training. However, others have also reported results that did not support the strength/continuum theory (5, 16).

In studies in which the strength/continuum is not statistically supported, a number of confounding factors might be responsible: initial level of training, intensity of training, volume of work done, or statistical problems associated with small samples or large standard deviations. We attempted to design the study to reduce the effect of such confounds. Those volunteers with extensive resistance training experience were intentionally excluded from the present study to eliminate the potential "ceiling effect" confound, or lower percentage gains for highly trained subjects.

The intensity of training was maintained at a very high level throughout the study. The dropout rate of 42% in 9 weeks was higher than normal in supervised exercise programs; usually it is 30% at 3 months and 50% after 6 months (9). The attrition rate was probably related to the rigorous training programs. An effort was made to equalize the total amount of weight lifted per group by varying the number of sets in the three protocols. The number of subjects who completed the study is a limitation, but it was larger than that in the Anderson and Kearney study (1).

The magnitude of the muscular endurance gains over strength is also consistent with Anderson and Kearney. The sole loss in muscular endurance occurred in the HRLR group for upper body relative endurance Load 2 (−6.4%) and is nearly identical to the Anderson and Kearney results (−6.9%). These results suggest that greater muscular endurance is the predominate effect of both strength and endurance training.

The training results for the female subjects in this study were similar to those in other studies. Although there were absolute differences, the gains were much like those Anderson and Kearney (1) reported for men. We had hypothesized that female subjects would experience greater upper than lower body strength increases. The expectation was based on the relatively smaller upper body strength for women compared to men, and the assumption that women recruited from aerobics classes were less likely to have trained the upper body. The results did not support that prediction, and others have attributed larger muscle mass for greater lower body strength increases with training.

Practical Applications

Practical experience and descriptive data have traditionally supported HRLR training for maximizing strength gains. Although the statistical results of this study do not unequivocally support the strength/endurance continuum theory of training, the descriptive data suggest that the strength training professional must rely on HRLR training for maximizing strength.

References

1. Anderson, T., and J.T. Kearney. Effect of three resistance training programs on muscular strength and absolute and relative endurance. *Res. Q. Exerc. Sport* 53(1):1-7. 1982.
2. Berger, R.A. Effect of varied weight training programs on strength. *Res. Q.* 33:168-181. 1962.
3. Berger, R.A. Comparative effects of three weight training programs. *Res. Q.* 34:396-398. 1963.
4. Clarke, D.H., and R. Irving. Objective determination of resistance load for ten repetitions maximum for knee flexion exercise. *Res. Q.* 31:131-135. 1960.
5. Clarke, D.H., and G.A. Stull. Endurance training as a determinant of strength and fatigue ability. *Res. Q.* 41:19-26. 1970.
6. Delateur, B.J., J.F. Lehmann, and W.E. Fordyce. A test of the Delorme axiom. *Arch. Phys. Med. Rehab.* 49:245-248. 1968.
7. Delorme, T.L. Restoration of muscle power by heavy resistance exercise. *J. Bone Jt. Surg.* 27:645-667. 1945.
8. Delorme, T.L., and A.L. Watkins. Techniques of progressive resistance exercise. *Arch. Phys. Med.* 29:263-273. 1948.
9. Dishman, R.K. *Exercise Adherence: Its Impact on Public Health.* Champaign, IL: Human Kinetics, 1988.
10. Fischer, A.G., and C.R. Jensen. *Scientific Basis of Athletic Conditioning* (3rd ed.). Philadelphia: Lea & Febiger, 1990.
11. Fleck, S.J., and W.J. Kraemer. *Designing Resistance Training Programs.* Champaign, IL: Human Kinetics, 1987.
12. Hatfield, F.C., and M.L. Krotee. *Personalized Weight Training for Fitness and Athletics* (2nd ed.). Dubuque, IA: Kendall Hunt, 1984.
13. Keppel, G. *Design and Analysis: A Researcher's Handbook.* Englewood Cliffs, NJ: Prentice Hall, 1982.
14. O'Shea, P. Effect of selected weight training programs on the development of strength and muscular hypertrophy. *Res. Q.* 37:95-102. 1966.
15. Stone, W.J., and W.A. Kroll. *Sports Conditioning and Weight Training* (3rd ed.). Dubuque, IA: Wm. C. Brown, 1991.
16. Stull, G.A., and D.H. Clarke. High-resistance, low-repetition training as a determiner of strength and fatigability. *Res. Q.* 41:189-193. 1970.
17. Unsworth, J.A. A comparison of two weight training programs used to develop strength. Master's thesis, Arizona State University. 1972.
18. Westcott, W.L. Female response to weight training. *J. Phys. Educ.* 77:31-33. 1979.
19. Westcott, W.L. *Strength Fitness: Physiological Principles and Training Techniques* (3rd ed.). Dubuque, IA: Wm. C. Brown, 1991.
20. Westcott, W.L., K. Greenberger, and D. Milius. Strength training research: Sets and repetitions. *Schol. Coach* 58:98-100. 1989.