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A Comparison of the Effects of Two Resistance Training Programs on Upper and Lower Body Muscle Strength and Endurance in Untrained Women

Ramin Amirsasan[1], Javad Vakili[2], Shabnam Akbarzadeh[3*]

1- Associate Professor, College of Physical Education and Sport Sciences, University of Tabriz, Tabriz, Iran
2- Assistant Professor, College of Physical Education and Sport Sciences, University of Tabriz, Tabriz, Iran
3- MSc Physical Education and Sport Sciences, University of Tabriz, Tabriz, Iran

***Corresponding Author, Email:** shabnam.akbarzade@yahoo.com

Abstract

The purpose of this research was to compare the effects of an 8-week 1-set and 3-set resistance training program on upper and lower body muscle strength and endurance in untrained women. 19 untrained women with no history of strength training were selected as the sample using accidental sampling and were divided into homogenous 1-set (N = 10; 26.7 ± 1.88 yrs.; 160.3 ± 6.53 cm; 56.82 ± 6.9 kg) and 3-set groups (N = 9; 27.6 ± 2.06 yrs.; 162.8 ± 4.98 cm; 59.56 ± 6.7 kg) based on their personal characteristics (age, BMI, and fat percentage) and pretest scores (upper and lower body muscle strength and endurance). The subjects performed their exercises for eight weeks and three sessions per week. Exercise intensity was the same for both groups (80% of one-repetition maximum). At the beginning and end of the training period muscle strength was measured by 1RM bench press and squat and muscle endurance was measured by 75% of pretest 1RM performance. Data were analyzed in SPSS 21 using t-tests for dependent and independent samples at the 0.05 significance level. The results showed significantly increase in upper and lower body muscle strength and endurance after 8 weeks of resistance training in both 1-set and 3-set groups ($P < 0.05$). Moreover, no significant difference between training groups was observed in the maximum muscle strength and muscular endurance. The results demonstrate that there was no significant difference between the performance of 1-set and 3-set resistance training in untrained women.

Keywords: Resistance training, muscle strength, muscle endurance, untrained women

Introduction

Resistance training is an effective method for increasing muscle strength, endurance, and size and is often used for general preparation, athletic training, rehabilitation, and prevention of muscular and orthopedic disorders (Izadmanesh et al., 2012). Exercise volume, intensity, and frequency are the main variables that must be taken into account when designing resistance training programs (Bird et al., 2005). Exercise volume is an important factor in improving strength. It is calculated by multiplying the number of repetitions per set by the number of sets in each session (Hass et al., 2001). Due to its special importance, exercise volume has always been an interesting topic for researchers and trainers. Most studies on exercise volume have examined the effect of the number of sets for each movement on muscle strength and endurance (Bottaro et al., 2009; Marshall et al., 2011; Thomas et al., 2013). However, some studies have focused on the total number of repetitions (Gonzalez et al., 2006; Izquierdo et al., 2006). It is still unknown whether performing single or multiple sets for each movement leads to more desirable results. There is much research on the principles of overload, progressive resistance, exercise specificity, and exercise volume in weight training. Despite the large body of research on

resistance training volume (Humburg et al., 2007; Huang et al., 2011; Thomas et al., 2013), researchers have not yet found conclusive evidence about an optimal volume for weight training. Some studies have shown that 3-set resistance training produces better results (Wolfe et al., 2004; Kelly et al., 2007), while others have reported no significant difference between 1-set and 3-set training programs (Wolfe et al., 2001; Huang et al., 2011).

Each muscle is unique in terms of fiber composition, fiber diameter, and performance. Thus, different resistance training programs can have different effects on the strength and endurance of different muscles (Fleck et al., 2004). Moreover, lower body muscles are used more frequently in daily activities (e.g. walking, standing, etc.) and may need a different training volume for adaptation than upper body muscles. Paulsen et al (2003) compared the effects of 1-set and 3-set strength training in the upper and lower body. Strength increased in both groups, but lower-body strength was higher in the group that performed 3 sets in leg exercises. Upper body strength was similar in both groups. Ronnestad et al (2007) and Bottaro et al (2009) reported that 3-set strength training is superior to 1-set strength training in terms of strength and muscle mass gains in the leg muscles, while no difference was observed between 1- and 3-set training in upper-body muscles. On the other hand, Humburg et al (2007) and Thomas et al (2013) showed that a 3-set strength training program creates more strength in upper body muscles than a 1-set program, but no significant differences were observed in the effects of these programs on lower body muscles. In another study, Huang et al (2011) examined and compared the changes in maximal strength with different weight training workouts (1-set, 3-set, and 6-set) in 22 untrained men. Maximal strength increased in all these groups, but no significant differences were observed in 1 repetition maximum between the three groups after ten weeks of training.

Given the contradictory results of previous studies and the fact that studies in this area have been limited in untrained individuals, especially women, there is clearly a need for further investigation. Moreover, according to statistics, women are more susceptible than men to longevity and age-related diseases. Thus, incorporating strength exercises into women's training programs has been recommended (Wernbom et al., 2008). As mentioned earlier, exercise volume is an important factor in designing resistance training programs. It can influence neural, hypertrophic, metabolic, and hormonal responses as well as post-exercise adaptations (Bird et al., 2005). While high exercise volume may lead to overtraining and cause injuries, low exercise volume may fail to produce the desired adaptations; therefore, it is critical to determine the optimal exercise volume (Wolf et al., 2004). On the other hand, if a low-volume training program can produce the same results as a high-volume program, the former is recommended. The purpose of the present research was to compare the effects of 1-set and 3-set resistance training programs on upper and lower body muscle strength and endurance in untrained women.

Materials and Methods

The present research is quasi-experimental. The population consisted of 20-30-year-old untrained women with a BMI of 20-25 kg/m^2 and with no history of resistance training and musculoskeletal and cardiovascular diseases. 19 women were selected as the sample using accidental sampling and were divided into homogenous 1-set (N = 10; 26.7 ± 1.88 yrs.; 160.3 ± 6.53 cm; 56.82 ± 6.9 kg) and 3-set groups (N = 9; 27.6 ± 2.06 yrs.; 162.8 ± 4.98 cm; 59.56 ± 6.7 kg) based on their personal characteristics (age, BMI, and fat percentage) and pretest scores (upper and lower body muscle strength and endurance). After completing an informed consent form and a medical questionnaire, the subjects were made familiar with the correct way of performing the movements and with the test procedures. At the beginning of the training program, the height and weight of the subjects were recorded and their skinfold thickness was measured using the Jackson-Pollock 3-site method (triceps, suprailiac, and abdominal) on the right side of the body. In a separate session, 1-repetition maximum (1RM) bench press and squat was determined indirectly using submaximal estimation. After general warm-up, each subject selected a weight and performed one set with 10 repetitions as specific warm-up. Then, by increasing and decreasing the weights, the test ended when the subject performed 4-6 repetitions maximum for each movement. Brzycki Formula was used to determine the 1RM (Brzycki et al., 1993):

$$1RM = \frac{w}{1.0278 - (r \times 0.0278)}$$

where w is the amount of weight used in kg and r is the number of repetitions until fatigue. In another session, muscle endurance of the subjects was evaluated by having the subjects perform maximum possible repetitions of bench press and squat at 75% of pretest 1RM and with the same speed (using a metronome) (Hass et al., 2000; Marx et al., 2001).

After these measurements, the subjects in both groups participated in an 8-week resistance training program (3 sessions per week) consisting of bench press and squat. Exercise intensity was similar in both groups (70% of 1RM in the first week and 80% of 1RM in weeks 2 to 4). At the end of the fourth week, 80% of 1RM was calculated again and the weight was adjusted accordingly (Huang et al., 2011; Marshall et al., 2011; Thomas et

al., 2013). Exercises continued at the same intensity up to the eighth week. The subjects of the first and second groups performed one set and three sets of each movement respectively. Each set included 8 repetitions, with 2-minute rests between sets and movements for both groups (Paulsen et al., 2003; Ronnestad et al., 2007). All the stages of the research took place under similar standard conditions (24-26°C) at a specific time, by taking the subjects' menstrual cycle into account, and in a gym with similar lighting and ventilation for both groups. 24-hour diet recall questionnaire and 3-day food intake record were distributed among the subjects. The subjects' diet was analyzed and in a session before the training period the participants were advised about their nutrition in order to correct eating habits and ensure similar diets. Also the subjects were asked to avoid regular exercise and to not consume any supplements during the period of the research. All the exercise sessions started with general (slow running and stretching) and specific warm-up (performing one set of movement with 12-14 repetitions at 30-40% of 1RM) and ended with a 5-minute cool-down (stretching and slow running). At the end of the training period, maximal strength and muscular endurance of the subjects were assessed again.

Data were described using descriptive statistics and tables. The results of the Kolmogorov-Smirnov test showed that the data are normally distributed. T-test for dependent samples was used to compare changes in muscle strength and endurance within groups before and after the training period, and t-test for independent samples was used to compare differences between groups at the 0.05 significance level.

Results

Table 1 shows the anthropometric characteristics of the subjects (mean ± standard deviation). Table 2 provides the mean and standard deviation of muscle strength and endurance in the pretest and posttest. The results show that upper and lower body 1RM strength and muscle endurance significantly increased in 1-set and 3-set groups ($P < 0.05$). Moreover, the data indicate that there is no significant difference between the two groups in maximal strength and muscle endurance.

Table 1: Anthropometric characteristics of the subjects (mean ± standard deviation)

Group	Age (yrs.)	Height (cm)	Weight (kg)	BMI (kg/m^2)	%Fat
3-set (N = 9)	27.66 ± 2.06	162.8 ± 4.98	59.56 ± 6.7	22.43 ± 1.47	25.73 ± 2.08
1-set (N = 10)	26.7 ± 1.88	160.3 ± 6.53	56.82 ± 6.9	22.04 ± 1.72	25.05 ± 2.7

Table 2: Comparison of muscle strength and endurance in the pretest and the posttest

Variable		Group	Stage	Mean ± SD	Dependent t	p	Independent t	p
Muscle Strength	Bench press (kg)	3-set	Pretest	20.35 ± 3.7	-49.49	0.000	0.54	0.59
			Posttest	31.88 ± 3.64*				
		1-set	Pretest	21.5 ± 4.86	-20.58	0.000		
			Posttest	30.7 ± 5.43*				
	Squat (kg)	3-set	Pretest	74.32 ± 16.93	-17.92	0.000	0.22	0.82
			Posttest	115.12 ± 23.23*				
		1-set	Pretest	76.91 ± 19.75	-11.38	0.000		
			Posttest	112.66 ± 24.79*				
Muscle Endurance	Bench press (rep)	3-set	Pretest	11.88 ± 1.05	-11.7	0.000	0.83	0.41
			Posttest	16 ± 1.22*				
		1-set	Pretest	11.4 ± 0.96	-16.83	0.000		
			Posttest	15.6 ± 0.84*				
	Squat (rep)	3-set	Pretest	11.66 ± 0.86	-37.31	0.000	1.19	0.25
			Posttest	18.22 ± 1.09*				
		1-set	Pretest	11.8 ± 0.91	-13.93	0.000		
			Posttest	17.6 ± 1.17*				

Notes: * Significant difference compared to the pretest ($P < 0.05$).

Discussion and Conclusion

The purpose of this research was to compare the effects of 1-set and 3-set resistance training programs on upper and lower body muscle strength and endurance in untrained women. The results showed that after 8 weeks of training upper and lower body muscle strength significantly increased in both 1-set and 3-set groups (P = 0.000). Exercise intensity was 80% of 1-repetition maximum (1RM), which has been shown to produce necessary adaptations for strength gain (Hass et al., 2000; Bumpa et al., 2009). Adaptations to resistance training that lead to increased maximal strength are: (1) neural adaptations such as increased mobilization of motor units, recruitment of motor units in agonist muscles, stimulation of motor units at higher frequency, spontaneous inhibition, and increased neuromuscular coordination; (2) muscular adaptations such as increased muscle cross-sectional area and change in muscle structure; and (3) metabolic adaptations (Rajabi et al., 1995; Wilmore et al., 2007). In the early stages of resistance training (6-8 weeks), neural adaptations are the dominant mechanism for increased strength, but in later stages (12-26 weeks) strength gain is the results of increased myofibrillar area (hypertrophy) (Izadmanesh et al., 2012).

In the present research, a significant increase in strength occurred in both training groups. Some researchers believe that early increase in maximal strength is associated with neural adaptations; thus, performing a bout of resistance training can produce necessary adaptations and exercise volume has no effect in this regard (Fleck et al., 2004). The results of this research showed no significant difference between the 1-set and 3-set training groups in maximal strength, both in the upper and lower body muscles. In terms of upper body movements, the present findings are consistent with the results of Abdulkadir et al (2014), Silva et al (2014), Baker et al (2013), Bottaro et al (2009, 2011), Ronnestad et al (2007), Paulsen et al (2003), and Hass et al (2000). However, our findings are inconsistent with Thomas et al (2013) who reported that 12 weeks of 3-set resistance training at 80% of 1RM leads to higher strength gain in bench press, Humburg et al (2007) who reported higher strength gain in bench press and biceps curl in the 3-set strength training program, Rhea et al (2002) who showed that a 3-set strength training for 12 weeks is superior to a 1-set program in eliciting maximal strength gains in bench press in recreationally trained men, and Marx et al (2001) who reported that after 24 weeks, the 3-set strength training program produces more strength gain in bench press in untrained women. This inconsistency may be due to differences in the fitness of the subjects (Rhea et al., 2002) or training period (Marx et al., 2001; Thomas et al., 2013). The subjects of Rhea et al (2002) were recreationally trained men who were more prepared to participate in the strength training program, which may have influenced their adaptations to strength training. However, the subjects of the present research were untrained women with no experience in resistance training. Moreover, the training period was 12 weeks in Thomas et al (2013) and Rhea et al (2002) and 24 weeks in Marx et al (2001), while the subjects of the present research participated in an 8-week training program.

In terms of lower body movements, the present findings are consistent with the results of Wilhelm et al (2014), Thomas et al (2013), Robbins et al (2012), Huang et al (2011), Humburg et al (2007), and Hass et al (2000). However, our findings are inconsistent with Marshall et al (2011) who showed higher strength gain in squat in the 4-set group compared to the 1-set group after 10 weeks of resistance training, Bottaro et al (2011) who reported that after 12 weeks of strength training the 3-set group had higher strength gain than the 1-set group in knee extension, Kelly et al (2007) who showed that after 8 weeks of strength training using isokinetic system maximal knee extension significantly increased in the 3-set group compared to the 1-set group, and Rhea et al (2002) who showed that after 12 weeks of strength training the 3-set program produced higher strength in leg press than the 1-set program. This inconsistency may be due to differences in the fitness of the subjects (Rhea et al., 2002; Kelly et al., 2007; Marshall et al., 2011) or the training and test protocols (Bottaro et al., 2011). The subjects in Marshall et al (2011) were 32 trained men who participated in a 10-week training program, the subjects in Kelly et al (2007) were 40 male and female physical education students who were relatively more prepared to participate in the strength training program. The subjects in Rhea et al (2002) were also trained men who had necessary training adaptations. However, the subjects of the present research were 19 untrained women with no experience in strength training. In addition, the subjects in Bottaro et al (2011) performed exercises on an isokinetic system and their strength was assessed using such a device, while in the present research the subjects' strength was assessed using indirect 1RM determination.

The results of the present research showed that after 8 weeks of resistance training upper and lower body muscle endurance significantly increased in both 1-set and 3-set groups (P = 0.000). Exercise intensity was 80% of 1RM. In fact, training at this intensity can increase muscle strength and endurance (Hass et al., 2000). It can be argued that given the link between increased muscle strength and endurance, strength training can, in and of itself, increase muscle endurance (Izadmanesh et al., 2012). The mechanisms for improvement in endurance are increase in the number of blood vessels (angiogenesis), increased recruitment of type II fibers (Wernbom et al., 2008), increased muscle glycogen storage, and improved glycolytic capacity of type II fibers (Takarada et al., 2002). In fact, improved muscle endurance occurs as a result of increased muscle strength and changes in metabolic characteristics and local circulation (Wilmore et al., 2007). The present findings indicated that upper

and lower body muscle endurance increased in both 1-set and 3-set groups. This is consistent with the results of Taaffe et al (2005), Marx et al (2001), Hass et al (2000), and De Hoyos et al (1998). Furthermore, the results of the present research showed no significant difference between 1-set and 3-set training groups in upper and lower body muscle endurance. This is in line with the results of Hass et al (2000) who found no significant difference in upper and lower body muscle endurance between 1-set and 3-set groups after 13 weeks of training at 75% of 1RM. However, our findings were inconsistent with Taaffe et al (2005) who showed higher upper and lower body muscle endurance in the 3-set group compared to the 1-set group after 20 weeks of training, Marx et al (2001) who reported higher upper and lower body muscle endurance in the 3-set group compared to the 1-set group after 24 weeks of training, and De Hoyos et al (1998) who showed higher upper and lower body muscle endurance in the 3-set group compared to the 1-set group after 25 weeks of training. It appears that differences in training period is the main reason for this inconsistency.

Based on the present findings, untrained individuals can use a lower volume in the early stages of resistance training. Hence, coaches are recommended to optimize exercise duration and volume when designing training programs for untrained individuals. Nonetheless, further research is required to arrive at conclusive results.

Conflict of interest

The authors declare no conflict of interest

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