World Applied Sciences Journal 10 (7): 797-802, 2010
ISSN 1818-4952

The Effect of Sequence Order in Combined Trainings on Maximal Strength and Aerobic Capacity

Aidin Valizadeh, Hamid Azmoon and Abbas Meamarbashi

Department of Physical Education and Sports Sciences,
University of Mohaghegh Ardabili, Ardabil, Iran

Abstract: The purpose of this study was to investigate the effect of sequence order of combined trainings on the maximal strength and aerobic capacity. Methods: Twenty eight physically active male university students were randomly assigned to participate for 8 weeks (3 days per week) in one of following training groups: 1) group C (n=8) as control, 2) ES (n=10) and 3) SE (n=10) combined the two programs in different orders during the same training sessions. The following measurements were taken before and after 8 weeks of training: weight, percent body fat, maximal oxygen consumption (ml/kg/min) and one repetition maximum (1RM) leg press (LP) and 1RM bench press (BP). Results: VO2max was significantly improved in both groups ES (11.7%) and SE (11.1%). No significant difference was observed regarding VO2max between ES and SE groups. Muscular strength significantly improved by 11.2% (BP), 46.1% (LP) for SE group and 17.7% (BP) and 52.2% (LP) for ES group. There was no significant difference between the two experimental groups for BP and LP. Conclusions: Although order of combined training had no significant differences between ES and SE groups but it appears strength training after endurance training in same session (ES) produces greater improvement in VO2max (ml/kg/min), LP and BP than opposite order.

Key words: Combined training · Strength training · Endurance training · Capacity Aerobic · Maximal Strength · Sequence Order

INTRODUCTION

From physiological point of view, the purpose of training on improvement of different systems of body functions is to optimize the athletic performances. Training causes increase in work capacities and skill abilities of the athletes. Each training program has a main and prevailing ability. In training or sport, rarely only one main and prevail ability can be considered, because one prevailing movement often needs a combination of two or more abilities. In general, every sport has different physical requirements that each of these physical requirements in special athletic fields combine to each other in different manners. In most sports, combination of three living movement abilities i.e. strength, resistance and speed, lead to different results that two factors of them determine cooperation of living movement abilities to reach high movement functional level. Their ratio indicates type of sport and development of each of the abilities considering rate of their cooperation, causes improvement of their performance in that sport or athletic field's. Therefore, it is proper to select an appropriate tool for removing requirements of every sport. This includes selection of tools and type of trainings related to combination of living movement abilities in training process [1].

There are many sports which are specified through need to combination of some physical readiness components in order to access to optimized performances. These sports include football, hockey, netball, basketball, etc [2]. Theoretically, those trainings that cause muscular adaptations are different and even can be opposite to each other in improvement of strength and resistance. Strength and endurance trainings create different adaptations despite little common features that exist between them. Strength training causes hypertrophy of muscles that this is related to increase in contractile proteins and increase of maximal contractile force of

Corresponding Author: Abbas Meamarbashi, Department of Physical Education and Sports Sciences,
University of Mohaghegh Ardabili, Ardabil, Iran.
Tel/Fax: +98 451 5516815, E-mail: a_meamarbashi@yahoo.com.

the muscle. Also, strength training decreases capillary density and activities of oxidative enzymes and because of this can be an obstacle for endurance capacity but has a little effect on substitution of fast and slow twitch muscle fibers. Contrarily, endurance training causes a little muscular hypotrophy or causes no hypertrophy, but amount of mitochondria, citric acid enzymes, oxidative capacity and increases possibility for conversion of fast-twitch fiber into slow- twitch fiber [3, 4].

Strength and endurance trainings are used as the base of athletic trainings and basic readiness trainings. Unlimited range of methods, styles and techniques are used frequently to access better performance and readiness and are placed in front of these training, combined training methods. Combined training, generally points to performance of both types of aerobic and anaerobic physical activity in one athletic training program or physical readiness training program. Strength and endurance trainings are performed in different sequences within a training session, a daily or weekly program. Combined training is essentially a complicated training and its training results are related to type of its components [5].

In many sports, combination of strength and endurance trainings is required to improve performance, but in some situations when strength and endurance trainings are done in form of combined, a potential interference is done in development of strength and causes a contradictory combination. Combined training phenomenon was explained for the first time by Robert C Hickson (1980) and after that published some research in agreement or rejection of Hickson remarks [6]. The specificity of training principle predict that combining strength and endurance training (concurrent trainings) could interfere with the maximum development of strength and endurance capacity that results from either type of training alone [7].

Chatra *et al* (2005) expressed that interfere between endurance and strength trainings are explained by the following factors: Lack of ability of the muscle for optimized adaptation in two different stimulation because of simultaneous demands for energy from different metabolism ways during one training session; muscular fatigue as a result of previous training; type and characteristics of strength and aerobic training; physical readiness; athlete's age; gender (due to hormonal differences); amount, frequency and intensity of training; recovery after physical activity and finally sequence of combined training secants (which include a combination of strength and endurance training in one training program) [3].

A few studies reported that when both forms of strength and endurance trainings should perform in one session, which training should be done in first session and which one should perform after that [3, 8, 9]. The previous researches in the field of impacts of combined trainings have used different secants:

- A few weeks' periods of strength training before endurance training or endurance training before strength training [10, 2, 11].
- Alternative training days in training period [12, 13]
- Alternation of the secants during the training sessions [3, 8, 9]

Base on literature reviews surveys done in this particular area, only two studies published on the effects of sequence of combined training secants (in one training session) on aerobic strength and capacity parallel [8, 9]. Another study has done on effects of combined training sequence only on endurance and aerobic capacity performance [3]. Considering that in one of these studies, gender of all examinees were female [9] and in another study among 34 subjects who participated in the research, a number of 23 persons were female [8], it is obvious that female gender has played a main role in final result of these studies and it is clear that gender makes a principal difference in hormone responses (specially testosterone and estrogen) in the training. In one of these studies, endurance training has been done in the form of rowing and the below organs have not involved in endurance training and influenced results of the research [9]. On the other hand, these three researches, have reported contradictory results and on the basis of them no definite result about effect of sequence of combination training secants (strength and endurance) on training adaptations, can be explained. Therefore, the present research is done in order to response whether change in sequence of combined training secants within 8 weeks would make a significant difference in obtaining aerobic strength and capacity in active men?

Method

Subjects: Statistical population of this research were consists of all male students in B.Sc level in the field of Physical Education at the University of Mohaghegh Ardabili. Among 62 students of physical education, 28 students were selected and placed randomly in 3 groups of: strength-endurance (SE) training, endurance-strength (ES) training and control (C). Some of individual particulars of the subjects are presented in Table 1.

Table 1: Subjects characteristics in group1.

Group	N	Age (yr)	Height (cm)	Weight (kg)	Body Fat %
SE	10	23.41 ±1.17	1.78 ±5.32	67.4 ±9.39	11.19 ±4.23
ES	10	24.36 ±1.07	1.72 ±5.12	60.96 ±4.80	9.44 ±2.7
C	8	23.31 ±1.26	1.76 ±4.24	65.58 ±9.23	10.37 ±1.22

Data presented as mean ± SD

SE = Strength-endurance training ES = Endurance-Strength training

C = Control Group N = number of subjects.

Data Collection Method: Before starting the training program and after completion of 8 weeks of training, the following measurements done.

Maximal Oxygen Consumption: Maximal oxygen consumption was calculated through Astrand Treadmill Test. In Astrand Treadmill Test, the subjects ran with a speed of 8.05 km/h (5 mile/hour) and with gradient of 0% on treadmill; after 3 minutes gradient of the treadmill increased 2.5%, then every 2 minutes, gradient of the treadmill increased 2.5%. The test continued until exhaustion. Testing time was measured and recorded up to two decimals in minute and was used considering the following assessment equation in functional form to evaluate maximal oxygen consumption.

Maximal Consumed Oxygen
(milliliter/kilogram/minute) = (1.444×min) + 14.99

Maximal Strength: Maximal Strength in two moves of bench press and leg press was calculated by using Berezicki equation.

One Max Repeat = Moved Weight (Kg) ÷ 1.278 - 0.0278 Number of Repeats: In order to using this equation and evaluation of maximal strength, replacement of a weight was repeated under maximal in chest press and leg press until getting fatigued and then, it was evaluated through placing of amount of weight and number of repeats in Berezicki equation. It must be mentioned that Berezicki equation is used for repeats under maximal amount that would be less than 10 [14].

Fat Percentage: Fat percentage was calculated by using Lange Skinfold Caliper and through 3-points equation of Jackson-Pollock (for men) after measurement of skinfold thickness in three areas of abdominal, thigh and pectoral folds and by using the following formula and in the form of percentage from total body mass.

$$\text{Density} = 1.1093800 - S \times 0.000826 + (S)^3 \times 0.0000016\text{-Age} \times 0.0002574$$

Fat Percentage = 495 ÷ Density - 450
S = Total Skinfold Thicknesses

The studied variables in this scheme included maximal strength in two movements of chest press and leg press, maximal aerobic capacity which were measured before starting of training program and after 8 weeks of training.

Training Protocols: All the groups did three sessions of training in a week and during 8 weeks in 24 sessions. These 24 sessions were divided into three 8-session sections that in every of these sections specific training program were done. ES and SE combined training groups in Sundays, Tuesdays and Thursdays did their training programs. Strength-Endurance (SE) group at the beginning of each training session and after general warming up the body that lasts 15 minutes performed strength training and after 10 minutes of taking rest, performed endurance training. Endurance-strength (ES) group performed conversely to strength-endurance (SE).

Endurance Training Program: Endurance training was performed in form of running and during 8-week period of training, time and activity intensity was increased. In the first 8 sessions [15, 12, 18, 19, 14, 3] the subjects trained for 25 minutes with 65% of maximal heart beats and in the second 8 sessions [8, 1, 7, 9, 16, 19] for 35 minutes with 65%-75% of their maximal and in the last 8 sessions [17, 10, 2, 11, 8], the subjects trained for 40 minutes with 75% to 85% of their maximal heart beats. All the subjects at the time of performing of endurance program used Polar heart rate monitor chest strap (Polar Electro, Finland) for determination of intensity of their training. Also, the subjects were trained to get their pulse from radial artery so that in case of appearance of any problem in polar, the subjects could assess the accurate intensity of their training [19].

Table 2: The comparison of maximal strength and VO_2max before and after 8 weeks of training.

Variable	Group	Pretest	Posttest	T-value	Significance
VO2max (ml.kg.min)	ES	48.21 ±4.45	53.87 ±5.63	-3.625	0.006
	SE	47.34 ±6.58	52.62 ±7.28	-5.948	0
	C	46.90 ±4.66	42.36 ±4.55	10.185	0
Bench press	ES	0.914 ±0.124	1.076 ±0.120	-4.56	0.001
(kg/body weight)	SE	0.865 ±0.100	0.962 ±.085	-3.599	0.006
	C	0.843 ±0.096	0.796 ±0.091	8.252	0
Leg press	ES	2.715 ±0.333	4.134 ±0.502	-11.591	0
(kg/body weight)	SE	2.664 ±0.353	3.894 ±0.413	-20.172	0
	C	2.278 ±0.360	2.136 ±0.338	6.079	0.001

Values are given as mean ± SD

The mean difference is significant at the 0.05 level

Table 3: Statistical results related to intra-group differences in the studied variables

variable	intra-group differences		F	Sig.
	ES	SE	28.785	0.968
VO2max	ES	C		0
(ml/kg/min)	SE	C		0
Bench press	ES	SE	13.88	0.238
(kg/body weight)	ES	C		0
	SE	C		0.006
Leg press	ES	SE	90.954	0.289
(kg/body weight)	ES	C		0
	SE	C		0

The mean difference is significant at the 0.05 level

Strength Training Program: Strength trainings were done 3 times in a week and included bench press, leg press, shoulder press, flexion and extension knee, push up, Scott and forearm by halter. During the first 8 sessions [15, 20, 21, 22, 12, 23, 7] of training, the subjects trained with a load of 50-60% of a maximal repeat. 10-15 repeats in every set and 3-4 sets in every training session were done. During the second 8 sessions [8, 7, 9, 19, 1, 16] of training, the subjects trained with a load of 60-70% of a maximal repeat in 3-5 sets and 10-12 repeats. During the last 8 sessions [17, 10, 2, 11, 8] of training, the subjects performed strength training with a load of 70-80% of a maximal repeat in 3-5 sets with 8-12 repeats in every session [16].

Statistical Analysis: In this paper, we used paired t test to assess inter-group difference and One Way ANOVA test for assessment of intra-group changes, using ANOVA test. Scheffe test was used for determination of differences between the groups. It must be mentioned that study on intra-group changes were done on the basis of differences of average of each group in pretest and after-test. A significant level was set at p=0.05.

Findings: In table 2 presented measurements related to the studied variables. There was no significant difference between SE, ES and control groups in pretest that would show random distribution and homogeneity in the research sample. After 8 weeks performance of training programs, measurements were repeated. Table 2 shows statistical results related to changes of variables from pretest until after test in three research groups.

Table 3 shows statistical results related to intra-group differences in the studied variables according to differences of average of each group in pretest and after-test.

DISCUSSION

Maximal Strength: As a result of 8 weeks of training, both combined training groups (ES and SE groups) showed a significant increase in strength. In this relation, Collins (1993) and Gravelle (2000) reported the same results and expressed significant increase of strength in both combined training groups [9, 8]. On the other hand, almost all of the studies that were done regarding combined training have expressed significant development of strength in upper and lower body muscles without consideration of sequences order [7, 20-23].

ES group in strength improvement in bench press and leg press are in higher level toward SE group and showed a higher increase after 8 weeks. However, in taking of strength no significant difference was observed statistically.

Results of the present research are similar to the results that Collins (1991) had investigated by fulfillment of 7-week study on effects sequences order of combined training on 34 subjects (23 female and 11 male). In this research which 30 persons of the subjects were placed in combined group (ES and SE) and 4 subjects were placed

in control group, ES group experienced more maximal strength in bench press, leg press, shoulder press and forearm in compare with SE group and except in shoulder press no significant difference was observed statistically between 2 groups [8]. Results of the present research are contrary to the results of Gravelle (2000) obtained from physiological responses during 11-week study on 19 active female students. In that study, endurance training was done in form of rowing and a significant increase in strength of both combined groups and both ES and SE groups placed in the same level from maximal improvement of strength and no difference was seen between two groups [19].

Increase of strength in both groups can be a result of adaptations that are gained due to fulfillment of combined training parts (strength and endurance trainings). Mechanisms of strength increment due to training might be a result of increment in number of neural impulses of motor units, increase in size of muscular fibers type I and type II and increase in anabolic hormones [24]. Probable mechanisms of increase in strength due to endurance training can be related to neuro-muscular adaptations and improvement in muscle blood perfusion which occurs in result of endurance trainings performance.

ES group had a better strength improvement compare to SE group. A clear reason cannot be expressed for this difference. It might be because of this fact that endurance training was performed with average intensity continuously and with average duration (maximal 40 minutes) somehow associated with the effects of body warm-up. Raise in body temperature, stimulation of CNS, coordination of physical systems, increase of blood circulation and delivery of oxygen to the muscle can cause strength improvement in ES group toward SE group.

Another point which can be expressed from our results is that strength of lower body in ES group has a little difference in compare with SE group, while difference in upper body between two groups was a little more than lower body. These results are similar to those reports which express lower body strength improvement will be diminished while lower body is involved in combined training (strength and endurance) [15, 24]. In other words, maybe a fewer difference in strength improvement in leg press between two groups would be because of less strength improvement in ES group.

All studies which have used running as the endurance training program in combined training, have expressed interference in strength improvement. Since running has physically much dependent to the lower body muscles, therefore strength training of lower body is influenced and muscular power output and strength do not increase that much [18].

Vo_2max: Both combined training groups in the present research showed a significant increase in VO_2max after 8 weeks and no significant difference was observed statistically ($p \leq 0.05$). Improvement of VO_2max in ES group was a little more than SE group (11.7% toward 11.1%).

Previous studies which investigated effects of sequences order of endurance and strength combined training on VO_2max, obtained different results. Chatra (2005) expressed 13.6% increase for ES group and 10.7% increase for SE group and declared that the best secant for aerobic adaptations included endurance training without the previous fatigue which is followed by strength training [3]. Collins showed 6.7% increase for SE group and 6.2% for ES group and expressed that sequence of combined training does not have any influence on aerobic adaptations [9]. Gravelle (2000) explained that combined training when the session starts with endurance training and in follow strength training would be done, will restrict increment of VO_2max in compare with the time that strength training is at the beginning of the session and in follow endurance training would be done and in fact, they explained priority of SE training over ES in improvement of VO_2max [9].

Increment of VO_2max in the present research can be related to both parts of combined training. Endurance training can play a role through increase of activities of oxidation enzymes, increase of size, quantity and volume of mitochondria, increase of number of muscular fibers, increase of muscle cross sectional, increase of myoglobins supply of muscle in VO_2max improvement [4]. Also, strength training can cause increase of VO_2max through increase in muscle capillary density, increase of blood volume and hemoglobin. Less improvement of VO_2max in SE group toward ES group can be somehow due to fatigue resulted from strength training which might have a little influence on physiological adaptations which are gained from endurance training [20, 4].

Considering results of the research, we can explain that, although sequences order of combined training does not statistically make a significant difference in improvement of maximal strength and aerobic capacity, but it seems that the combined training that endurance training is done at the beginning of it and strength training is done in follow of it, have more influence in improvement of maximal strength and aerobic capacity in compare with other sequences.

ACKNOWLEDGEMENTS

Hereby, authors would like to appreciate financial support received from the University of Mohaghegh Ardabili and also all the participants for their enthusiasm and support.

REFERENCES

1. Dudley, G.A. and R. Djamil, 1985. Incompatibility of endurance and strength tarining modes of exercise. J. Appl. Physiol., 59(5): 1446-51.
2. Hickson, R.C., M.A. Rosenkoetter and M.M. Brown, 1980. Strength training effects on aerobic power and short term endurance. Med. Sci. Sports. Exerc., 12(5): 336-9.
3. Chtara, M., K. Chamari, M. Chaouachi, A. Chaouachi, D. Koubaa, Y. Feki, G.P. Millet and M. Amri, 2005. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. British J. Sports Med., 39(8): 555-560.
4. Wilmore, J.H. and D.L. Costill, 1994. Physiology of sport and exercise. Champaign IL: Human Kinetics Publications.
5. Abernethy, P.J. and B.M. Quigley, 1993. Concurrent strength and endurance training of the elbow extensors. J. Strength Cond. Res., 7(2): 234-40.
6. Nader, G.A., 2006. Concurrent strength and endurance training: from molecules to man. Med. Sci. Sports. Exerc., 38(11): 1965-70.
7. Glowacki, S.P., S.E. Martin, A. Maurer, W. Baek, J.S. Green and S.F. Crouse, 2004. Effects of resistance, endurance and concurrent exercise on training outcomes in men. Med. Sci. Sports. Exerc., 36(12): 2119-27.
8. Collins, M.A. and T.K. Snow, 1993. Are adaptations to combined endurance and strength training affected by the seqennce of training?. J. Sports. Sci., 11(6): 485-91.
9. Gravelle, B.L. and D.L. Blessing, 2000. Physiological Adaptation in Women Concurrently Training For Strength and Endurance. 2000. J. Strength Cond. Res.,14(1): 5-13.
10. Hickson, R.C., 1980. Interference of strength development by simultaneously training for strength and endurance. Eur. J. Appl. Physiol., 45(2-3): 255-63.
11. Hunter, G., R. Demment and D. Miller, 1987. Development of strength and maximum oxygen uptake during simultaneous training for strength and endurance. J. Sports. Med. Phys. Fitness., 27(3): 269-75.
12. Bell, G.J., S.R. Petersen, H.A. Quinney and H.A. Wenger, 1988. Sequencing of endurance and high-velocity strength training. Can. J. Sport. Sci., 13(4): 214-9 .
13. Sale, D.G., I. Jacobs, J.D. MacDougall and S. Garner, 1990. Comparison of two regimens of concurrent strength and endurance training. Med. Sci. Sports. Exers., 22(3): 348-56.
14. Brzycki, M., 1993. Strength testing-predicting a one-rep max from reps-to-fatigue. J. Physical Education, Recreation and Dance., 68: 8-90
16. Hakkinen, K., M. Alen, W.J. Kraemer, E. Gorostiaga, M. Izquierdo, H. Rusko, J. Mikkola, A. Hakkinen, H. Valkinen, S. Kaarakainen. Romu, V. Erola, Ahtianen and L. Paavolainen, 2003. Neuromuscular adaptations during concurrent strength and endurance training versus strength training. Eur. J. Appl. Physiol., 89(1): 42-52.
17. Dudley, G.A. and S.J. Fleck, 1987. Strength and endurance training. Are they mutually exclusive? Sports Med., 4(2): 79-85.
18. Leveritt, M., P.J. Abernethy, B.K. Barry and P.A. Logan, 1999. Concurrent strength and endurance training: A review. Sports Med., 28(6): 413-427
19. Bompa. T.O., 1999. Periodization: Theory and Methodology of Training. Human Kinetics, 4 th Edition,
20. Bell, G.J., S.R. Petersen, J. Wessel, K. Bagnal and H.A. Quinney, 1991. physiological adaptations to concurrent endurance training and low velocity resista training. Int. J. Sports. Med., 12(4): 384-90.
21. Bell, G.J., D. Syrotuik, T.P. Martin, R. Burnham and H.A. Quinney, 2000. Effects of concurrent strength and endurance training on skeletal muscle properties and hormone concentrations in humans. Eur. J. Appl. Physiol., 81(5): 418-27.
22. Bell, G.J., S.R. Petersen, J. Wessel, K. Bagnall and H.A. Quinney, 1991. Adaptations to endurance and low velocity resistance training performed in a sequence. Can. J. Sport. Sci., 16(3): 186-92.
23. Ferketich, A.K., T.E. Kirby and S.E. Always, 1998. Cardiovascular and muscular adaptations to combined endurance and strength training in elderly women. Acta. Physiol. Scand., 164(3): 259-67.
24. Hennesy, L.C. and A.W.S. Watson, 1994. The interference effects of training for strength and endurance simultaneously. Can. J. Sport. Sci., 8(1): 12-19.