Australian Journal of Basic and Applied Sciences, 5(10): 1195-1201, 2011
ISSN 1991-8178

The Effect of the Sequence of Concurrent Strength and Endurance Training on Aerobic Capacity, Anaerobic Capacity and Maximum Strength of Male Adolescents

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Abstract: The objective of the present research was to compare the effect of the sequence of concurrent strength and endurance exercises on aerobic capacity, anaerobic capacity and maximum strength of male adolescents. 50 high school students with the average age of 17.22±0.94 years, 175.62±7.11 centimeters of height, and 62.82±7.78 kilograms of body mass were randomly chosen and divided into five groups of ten subjects – i.e. strength training (ST), endurance training (ET), strength-endurance training (SE), endurance-strength training (ES) and control (CO). Maximal aerobic capacity (VO_2max) was assessed by a 1600-meter run, lactic anaerobic capacity and fatigue index by RAST test, alactic anaerobic capacity by vertical jump test, strength by one-repetition maximum test (1RM), agility by Illinois Agility Run test and muscle endurance by sit-ups test. Based on the findings of the research, a significant increase was observed in VO_2max of the endurance and concurrent training groups. Alactic anaerobic capacity of the five groups did not have a significant increase. A significant increase was observed in the lactic anaerobic capacity and fatigue index in the strength training group. According to the findings of the research, relative maximum strength increased significantly in the strength and endurance-strength training groups. Moreover, the increase in agility and muscle endurance was significant in the four experimental groups. Combining strength and endurance exercises improves strength and endurance and adding strength training to the endurance training program does not risk the improvement of VO_2max. Also the endurance-strength sequence of training has the greatest effect on maximum strength and agility.

Key words: strength training, endurance training, concurrent training, training sequence.

INTRODUCTION

Training is a process in which sports activities and exercises are performed regularly, gradually and progressively and it increases the ability of individuals in achieving a better performance (Bishop, D and Jenkins, DG,1999 and Edwards, AM, 2008). Training adjustment depends on the type of the chosen training program, that is, strength training program has the greatest effect on strength and endurance training program has the greatest effect on cardiovascular system. Therefore each of the strength and endurance training programs results in its own specific adjustment (Edwards. AM, 2008 and Glowacki, SP, 2004). Endurance exercises increase VO_2max (Kraemer, WJ, 1995 and. Leveritt, 2003 and Shaw, BS. Shaw, 2009) and increase the number of mitochondria and their specific enzymes (Kraemer, WJ,1995 and Shaw, BS. Shaw, 2009). Endurance exercises lead to a significant increase in type I muscle fibers, since these fibers have a large amount of mitochondria (Jeffery Mador, 2004). As a result of endurance exercises, muscle mass does not increase and the actual size of muscle fibers decreases (Maiorana, 2002 and Izquierdo, 2004). Strength exercises lead to muscle hypertrophy due to the increase in the number of fibril proteins (McCarthy, 1995 and Mikkola, *et al*, 2007). Muscle hypertrophy usually occurs in slow-twitch and fast-twitch fibers and this type of training results in a special neuromuscular adjustment (Peterson, MD. and Rhea and, Alvar, BA, 2005). Unlike endurance exercises, mass density of mitochondria decreases in contrast to the increase in muscle mass (Mikkola, J *et al*, 2007). These contradictory results of endurance and strength exercises has led to uncertainties among some endurance and strength athletes in applying different training methods, fearing it might risk the desired training adjustments (Edwards, AM. and,Wells, C. and,Butterly, 2008). In any case, certain levels of strength and endurance are of interest for any athlete. Some sports are mainly strength-oriented and some others are mainly endurance-oriented, while most sports need a combination of both. Research studies have shown that performing strength and endurance exercises simultaneously and concurrently has a greater effect on athletes' performance in comparison with performing each of these exercises alone (Glowacki, SP, 2003 and Hakkinen K, 2003).

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In recent years, researchers have become very interested in adjustability of strength and endurance exercises together and the effect of concurrent training on increasing aerobic capacity, anaerobic capacity, and maximal strength. Kraemer *et al*. (1995) showed that strength significantly increased in the combined group and maximal oxygen uptake significantly increased in the endurance and the combined groups (Kraemer, WJ. and,Patton, JF *et al*. 1995). McCarthy *et al*. (1995) showed that concurrent strength and endurance training increases both muscle strength and maximal oxygen uptake (McCarthy and, Agre, 1995). It has been suggested that neuromuscular characteristics which improve in strength training can improve endurance performance. On the other hand, some researchers have studied the effect of the sequence of concurrent training on improvement of strength and endurance and have concluded that the sequence of training has had no effect on the improvement of strength or endurance. The number of studies carried out on the effect of training sequence on physical fitness performance are limited and considering the fact that there has not yet been any general consensus regarding the effect of concurrent training and its sequence on the development of aerobic capacity, anaerobic capacity, and maximal strength, the present research aims to study the effect of the sequence of concurrent strength and endurance training on aerobic capacity, anaerobic capacity, and maximum strength among male adolescents and to answer the question whether the sequence of concurrent strength and endurance training leads to any changes in aerobic capacity, anaerobic capacity, and maximum strength in comparison with strength or endurance training alone.

Methodology:

After the statistical population of the research – i.e. second and third grade students of the sports high school of Zanjan Province who were studying in the period of 2005-2006 – filled out the qualification questionnaires for participating in the study, 50 qualified students with the average age of 17.22±0.94 years, 175.62±7.11 centimeters of height, and 62.82±7.78 kilograms of body mass were randomly chosen and divided into five groups of ten subjects – i.e. strength training (ST), endurance training (ET), strength-endurance training (SE), endurance-strength training (ES) and control (CO). After a briefing session and becoming familiar with the equipment, subjects took the preliminary pretest. Maximal aerobic capacity (VO_2max) was assessed by a 1600-meter run, relative maximum strength by one-repetition maximum test (1RM), lactic anaerobic capacity and fatigue index by RAST test, alactic anaerobic capacity by vertical jump test, agility by Illinois Agility Run test and muscle endurance by sit-ups test. Then the designed training program of each group was conducted for eight weeks. Each session involved three levels:

1. Warming up (10 minutes)
2. Main training
3. Cooling down (10 minutes)

The first and the third stages (warming up and cooling down) was the same in the strength, endurance, endurance-strength and strength-endurance training groups and the difference of exercises was in the main training stage. The main training stage was designed in a way as to be similar in all the four groups as much as possible with respect to intensity and duration.

Strength Training Program:

The strength training program was of circular strength training type and in each session the subjects of this group performed exercises including foot press with foot press machine, chest press with halter, half squats, and sit-ups. In this exercise program, a 60-90 second rest was considered between each station and a 2-3 minute rest between each round. The training program of the strength training group was conducted with the following conditions: it started with 2 rounds, 10 repetitions and 50% of 1RM and finished at the end of eighth week with 2 rounds, 6 repetitions and 80% of 1RM.

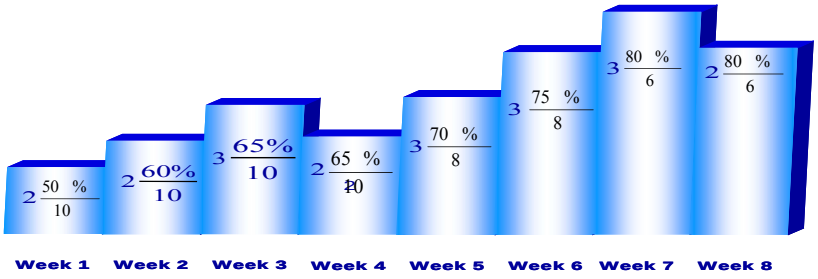

Fig. 1: Training program of the strength training group.

Endurance Training Program:

The endurance training too included running, since we can control factors such as intensity, speed, distance and duration and the other reason for choosing runs as main exercise in the training program was its

being undemanding and involving less injuries. The intensity of training was controlled by a pulse rate watch; an individual whose aerobic capacity was close to the group-averaged aerobic capacity wore the watch and the transmitter was worn as a belt around the sternum area which started working after a few minutes of its attachment to the chest. The endurance training program was conducted with the following conditions: it began with running for 16 minutes with 65% of maximum heart rate which increased to 30 minutes with 80% of maximum heart rate at the end of the eighth week.

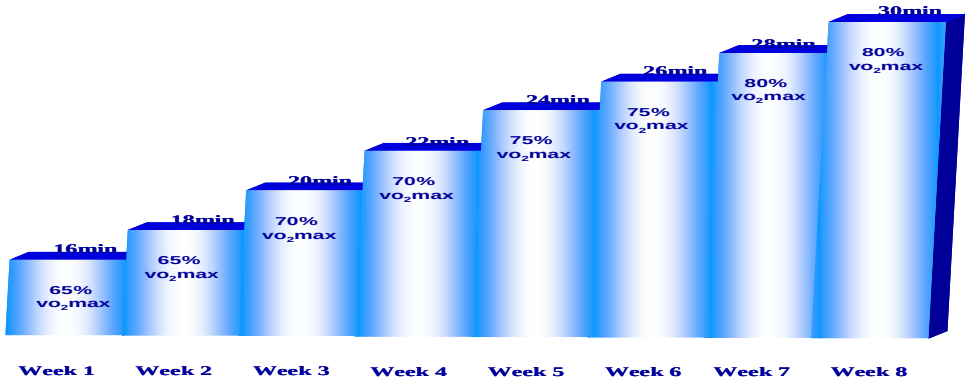

Fig. 2: Training program of the endurance training group.

Concurrent Training Program:

The training program for the strength-endurance and endurance-strength training groups was similar with a difference that the strength-endurance training group first performed the strength exercises in each session an then the endurance exercises, while the endurance-strength group performed the opposite. The strength and endurance training program considered for the strength-endurance and endurance-strength groups was the same as the program of strength and endurance groups. That is, the strength-endurance group first performed the exercises of the strength training group and at the end of these exercise performed exactly the exercise protocol of the endurance training group, while the endurance-strength group did the opposite.

After performing the exercises and at the end of the eighth week, subjects took the final test. The control group did not perform any specific exercise and only participated in physical education classes related to their high school physical education course. The information from the pretest and the posttest was calculated and recorded with the methods explained above to be statistically analyzed.

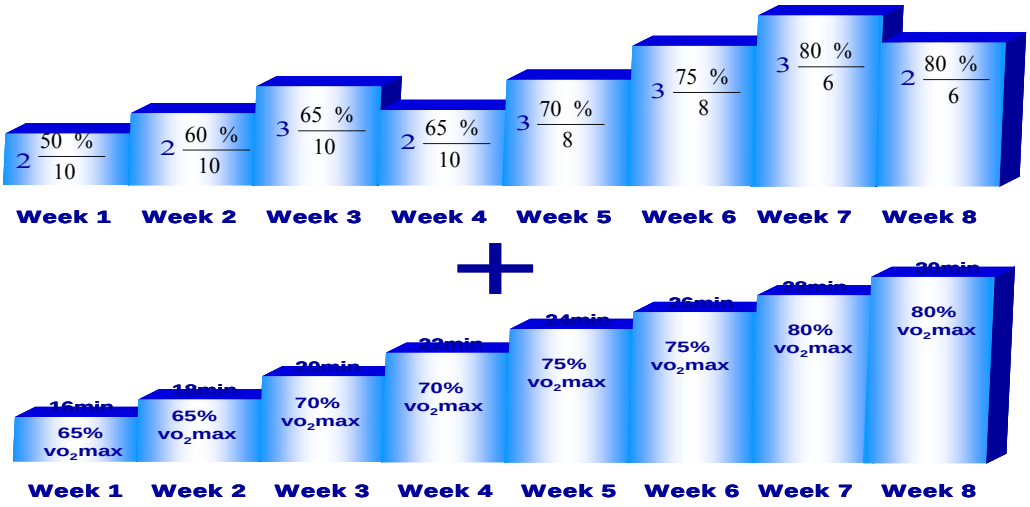

Fig. 3: Training program of the concurrent training groups.

Statistical Method:

Descriptive and inferential statistics have been used in the present research to analyze data. In descriptive statistics, we described data using indices such as mean, standard deviation, and maximum and minimum number. In inferential statistics, t-test for correlated samples was used to compare differences within group and one-way ANOVA and Scheffe post-hoc test were used to compare differences between groups.

Table 1: Personal characteristics of subjects.

	Age (Years)				Height (Centimeters)				Weight (Kilograms)			
Groups	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Strength	17	1.24	16	19	178.80	5.67	170	185	57.80	7.08	49	72
Endurance	17.40	1.17	16	19	179	7.3	170	190	67.600	7.89	55	80
Strength- Endurance	17.70	0.48	17	18	177.60	9.90	160	190	65.5	8.05	57	85
Endurance- Strength	16.70	0.67	16	18	174.50	7.04	159	180	60.5	7.69	48	76
Control	17.30	1.15	16	19	168.20	5.67	160	180	62.700	8.20	51	75

Findings:

The findings of the research showed a significant increase of VO_2max in the endurance and concurrent exercise groups (Table 2). The difference of increase of VO_2max between the endurance group and the strength and control groups was significant (Tables 3 and 4). The results of the present research indicate that the strength and concurrent training groups demonstrated a significant increase in relative maximum strength (Table 5) and analysis between the groups revealed that the difference between the strength and endurance-strength groups and the control group was significant (Tables 6 and 7). No significant different in alactic anaerobic capacity was observed between or within the groups (Table 10). Moreover, a significant increase of lactic anaerobic capacity and fatigue index was observed in the strength training group (Tables 8 and 9). The increase in agility and muscle endurance in all the four groups was significant (Tables 11 and 12) and the endurance-strength sequence of training had the greatest effect on agility.

Table 2: Comparison of maximal oxygen uptake (VO_2max) in all groups (t-test).

Groups	Mean		Difference of Means	P Value	Statistical Result
	Pretest	Posttest			
Strength (S)	54.48	54.21	-0.27	0.7	-
Endurance (E)	51.24	53.85	2.60	0.00	Significant
Strength- Endurance (SE)	52.53	54.50	1.96	0.001	Significant
Endurance- Strength (ES)	51.80	53.71	1.90	0.02	Significant
Control (C)	51.08	51.09	0.01	0.97	-

* Significant at 0.05 level

Table 3: Statistical results of the comparison between the effect of 8 weeks of strength (S), endurance (E), Strength- Endurance (SE) and Endurance- Strength (ES) training on maximal oxygen uptake (ANOVA test).

		Sum of Squares	Degree of Freedom	Mean Squares	F	P<0.05
Difference between Pretest and Posttest	Between Groups	66.29	4	16.57	5.30	0.001
	Within Groups	140.54	45	3.12		
	Total	206.83	49			

* Significant at 0.05 level

Table 4: The results of Scheffe post-hoc test for determining the point of difference in maximal oxygen intake variations of the 5 groups.

	Group	Group	Differences in the Value of D	P≤0.05
Difference between the Means of Pretest and Posttest	Strength	Endurance*	-2.87	0.018
		Strength-Endurance	-2.23	0.11
		Endurance-Strength	-2.17	0.12
		Control	-2.28	0.99
	Endurance	Strength-Endurance	0.639	0.95
		Endurance-Strength	0.7	0.93
		Control*	2.59	0.043
	Strength-Endurance	Endurance-Strength	0.065	1.00
		Control	1.95	0.20
	Endurance-Strength	Control	1.95	0.23

* Significant at 0.05 level

Table 5: The comparison of relative maximum strength in all the groups (t-test).

Groups	Mean		Difference of Means	P Value	Statistical Result
	Pretest	Posttest			
Strength (S)	0.81	0.91	0.095	0.000	Significant
Endurance (E)	0.76	0.79	0.025	0.24	-
Strength- Endurance (SE)	0.96	0.99	0.027	0.23	-
Endurance- Strength (ES)	0.71	0.82	0.103	0.001	Significant
Control (C)	0.73	0.72	-0.004	0.30	-

* Significant at 0.05 level

Table 6: Statistical results of the comparison between the effect of 8 weeks of strength (S), endurance (E), Strength- Endurance (SE) and Endurance- Strength (ES) training on relative maximum strength (ANOVA test).

		Sum of Squares	Degree of Freedom	Mean Squares	F	P<0.05
Difference between Pretest and Posttest	Between Groups	0.089	4	0.022	7.354	0.000
	Within Groups	0.136	45	0.003		
	Total	0.225	49			

* Significant at 0.05 level

Table 7: The results of Scheffe post-hoc test for determining the point of difference in relative maximum strength variations of the 5 groups.

	Group	Group	Differences in the Value of D	P≤0.05
Difference between the Means of Pretest and Posttest	Strength	Endurance	0.070	0.10
		Strength-Endurance	0.068	0.12
		Endurance-Strength	-0.008	0.99
		Control*	0.099	0.007
	Endurance	Strength-Endurance	0.639	1.00
		Endurance-Strength	-0.002	0.055
		Control	-0.078	0.844
	Strength-Endurance	Endurance-Strength	0.029	0.065
		Control	0.03	0.81
	Endurance-Strength	Control*	0.10	0.03

* Significant at 0.05 level

Table 8: Comparison of lactic anaerobic capacity in all the groups (t-test).

Groups	Mean		Difference of Means	P Value	Statistical Result
	Pretest	Posttest			
Strength (S)	855.75	971.60	115.84	0.01	Significant
Endurance (E)	967.55	913.35	-54.19	0.27	-
Strength- Endurance (SE)	1074.83	1057.19	-17.63	0.26	-
Endurance- Strength (ES)	927.18	824.61	-84.57	0.13	-
Control (C)	905.37	905.04	-0.33	0.63	-

* Significant at 0.05 level

Table 9: Comparison of fatigue index in all the groups (t-test).

Groups	Mean		Difference of Means	P Value	Statistical Result
	Pretest	Posttest			
Strength (S)	0.017	0.019	0.0017	0.003	Significant
Endurance (E)	0.020	0.018	-0.0020	0.54	-
Strength- Endurance (SE)	0.017	0.016	-0.0006	0.58	-
Endurance- Strength (ES)	0.018	0.019	0.0003	0.62	-
Control (C)	0.017	0.017	0.000	0.93	-

* Significant at 0.05 level

Table 10: Comparison of alactic anaerobic capacity in all the groups (t-test).

Groups	Mean		Difference of Means	P Value	Statistical Result
	Pretest	Posttest			
Strength (S)	385.95	367.97	-14.98	0.14	-
Endurance (E)	433.62	380.61	-53.01	0.13	-
Strength- Endurance (SE)	374.38	403.11	28.72	0.53	-
Endurance- Strength (ES)	374.38	29.04	-22.34	0.41	-
Control (C)	376.90	379.15	2.25	0.14	-

* Significant at 0.05 level

Table 11: Comparison of agility in all the groups (t-test).

Groups	Mean		Difference of Means	P Value	Statistical Result
	Pretest	Posttest			
Strength (S)	17.77	15.64	-2.13	0.00	Significant
Endurance (E)	17.92	15.57	-2.34	0.00	Significant
Strength- Endurance (SE)	16.61	15.31	-1.29	0.00	Significant
Endurance- Strength (ES)	18.29	15.20	-3.09	0.00	Significant
Control (C)	17.31	17.01	-0.30	0.56	-

* Significant at 0.05 level

Table 11: Comparison of muscle endurance in all the groups (t-test).

Groups	Mean		Difference of Means	P Value	Statistical Result
	Pretest	Posttest			
Strength (S)	49.10	60.50	11.40	0.00	Significant
Endurance (E)	52.20	61.20	9.00	0.002	Significant
Strength- Endurance (SE)	59.50	63.80	4.30	0.012	Significant
Endurance- Strength (ES)	58.60	65.00	6.40	0.029	Significant
Control (C)	55.80	55.60	-0.20	0.65	-

* Significant at 0.05 level

Discussion and Conclusion:

Maximal aerobic capacity (VO_2max) significantly increased in the endurance training group and the two concurrent training groups and the difference of increase of VO_2max between the endurance training group and the strength training and control groups was significant. Our findings indicate the fact that adding strength training to an endurance training program does not inhibit the increase of aerobic capacity and considering the lack of significant difference between the endurance and concurrent training groups, we can assert that the sequence of concurrent exercise does not affect aerobic capacity and that to increase aerobic capacity, we can conduct concurrent exercises with any arbitrary sequence; this result is consistent with the studies of Hakkinen and Hannonen (2003) and Maiorana and Driscoll (2002) who reported that VO_2max only increased in the endurance and concurrent training groups. Glowacki *et al*. (2004) and Shaw *et al*. (2009) reported the increase of VO_2max only in the endurance training group.

In the present research, a significant increase of relative maximum strength was observed in the strength training group and the two concurrent training groups and the difference of increase in relative maximum strength between the strength and endurance-strength training groups and the control group was significant indicating that combining strength and endurance exercises into the endurance-strength sequence of exercise has the greatest effect on relative maximal strength. Thus, these concurrent and strength exercises significantly increase relative maximum strength of muscles which is consistent with Moritani and DeVries model regarding neural adjustment and muscle hypertrophy. The increase of strength in this research is consistent with the studies of Mikkola *et al*. (2007), Kraemer *et al*. (1995), Jeffery Mador (2004) and Leveritt *et al*. (2003) who reported the increase of strength in strength and concurrent training groups. In their research, Glowacki *et al*. (2004) reported a significant increase of strength in strength, concurrent and endurance training groups.

No significant increase of alactic anaerobic capacity was observed within and between the groups. The results indicate that depending on the type of training, the resulting adjustments have certain characteristics. Since none of the exercises involved anaerobic or explosive movements, no significant difference was observed in the alactic anaerobic capacity of the groups which is consistent with the results of the studies of Koch *et al*. (1991), Bishop *et al*. (1999) and Edward *et al*. (2008). Moreover, a significant increase was observed in the lactic anaerobic capacity and fatigue index in the strength training group which is contrary to the results of Leveritt *et al*. (2003) who reported that the concurrent training group had a better anaerobic capacity performance in comparison with the strength training group. The increase of agility and muscle endurance between the four training groups was significant and the endurance-strength sequence of training had the greatest effect on agility.

To sum, considering the findings of the present research, we can conclude that concurrent strength and endurance training as a new training method which has been very much noted by sports researchers and trainers is highly efficient and has been introduced as an effective and efficient training method for improving and developing aerobic capacity, anaerobic capacity, maximum muscle strength, agility and muscle endurance. The present research and many previous studies have proven the positive effect of combining strength and endurance exercises and we recommend conducting this method for healthy individuals as well as athletes who wish to achieve physical fitness. The results of the present research revealed that adding strength training to an endurance training program is not a deleterious and troublesome factor in improving and enhancing aerobic capacity and strength.

The increase in maximal aerobic capacity, anaerobic capacity and fatigue index was less in concurrent exercises in comparison with strength and endurance exercises. Improvement of relative maximum strength and agility was more in concurrent exercises in comparison with individual exercises. The noteworthy point of the present research is the sequence of concurrent training and considering the findings of this research we can say that if endurance exercises are performed before strength exercises, they will have the greatest effect on strength and agility; that is, the sequence of concurrent exercises affects some physical fitness indices. Thus, we recommend those who wish to improve and develop physical fitness factors to apply the training program of the present research. We also recommend athletes who are active in multiple sports to pay special attention to concurrent training and to include it in their training program.

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