Effect of Concurrent Training (Strength + Endurance) On Maximal Oxygen Uptake and Record Level of 1500m Swimming For Youth Swimmers

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The purpose of this study was to investigate the effects of concurrent training on cardiopulmonary response, power and record level of 1500m swimming among youth swimmers. Twenty-two youth swimmers were divided into three experimental groups: concurrent (n = 7), resistance (n = 8), and endurance (n = 7) training groups. Each group trained three times a week for eight weeks, with all types of training occurring in the same session. Parameters assessed were height, weight, and power, strength, training age, maximal oxygen uptake, and training experience. All participants were fully informed about the aims of the study and gave their voluntary consent before participation. The measurement procedures were in agreement with ethical human experimentation. Subjects in the concurrent group participated for eight weeks, three days per week. First, the subjects completed 8-10 resistance-training exercises and then completed the hour of training by walking /jogging /running for up to 30 minutes on a treadmill at a prescribed target heart rate. A strand Treadmill Test was used to determine the maximal oxygen uptake, and dynamometer instruments were used to measure the strength of the leg and back. The results revealed significant increases in Grip strength for the strength group versus the endurance group and for the concurrent group versus both the strength and endurance groups. Maximal oxygen uptake for the endurance group versus both the strength and concurrent groups and for the concurrent group versus the strength group. Leg strength for the strength group versus the endurance group and for the concurrent group versus the endurance group. Back strength for the strength group versus the endurance group and the concurrent group versus the endurance group. In conclusion, the present study shows that eight weeks of concurrent strength and endurance training has beneficial effects on musculoskeletal power, maximal oxygen uptake and record level of 1500m swimming.

***Key words**: Maximal oxygen uptake, strength, power*

Introduction

Improving swimming performance is the goal of every swimming scientists, coach, and athlete. Age, sex, style of play, physical components, technical components, tactical components, and psychological components, all determine the success of the Swimming athlete. The practicality of this information should be applied when designing training programs for higher level swimming players. Effective planning and training programs help in designing a safe, effective, and productive program to optimize performance. Performance depends on optimum muscle function to generate the forces required in Swimming and to protect against the loads applied to the body as a result of swimming play. Strength is the ability to generate a force or protect against a load; power is the ability to do that quickly; endurance is the ability to do that over extended periods. Muscle balance allows maximum joint protection and smooth motion of joints. Muscles may develop alterations due to lack of conditioning, wrong emphasis in training, fatigue or injury.

Swimming also puts demands on the anaerobic and aerobic abilities, which necessitates the simultaneous incorporation of training strategies designed to develop both systems. Many Swimming players train with little or no emphasis on power development or in a manner secondary to aerobic development. Such practices are illogical, as indicated by the physiological demands of Swimming (Kraemer, et al. 1995). Additionally, even if Swimming were a predominantly aerobic activity, anaerobic training is far less effective when employed secondary to aerobic development, while aerobic systems do not seem to suffer interference from anaerobic development processes. Contrary to popular belief, varying resistance exercise programs have been shown to enhance performance in highly aerobic activities, such as marathon running (Jung, 2003).

In the last two decades, physical training and competitive opportunities have increased dramatically in junior, collegiate, and professional Swimming. This arose due to a multitude of factors, but much of it has stemmed from an increase in knowledge and understanding of scientifically based training programs focused on improving performance.

In 1980, Hickson *et al*. first provided evidence for the existence of an "interference phenomenon" between resistance and endurance training by demonstrating that strength gains were hindered when the two types of training were performed concurrently. Since that time, the combination of resistance training and endurance training has been frequently used in athletics.

The term concurrent training is used to characterize the method whereby aerobic and strength training exercises are performed in the same training session (Bell, et al. 2000; Dantas, et al. 2008). That strategy was chosen because energy expenditure could be maximized both during and after the training through increased oxygen consumption after exercise. Some authors mention concurrent training in their publications (McCarthy, et al. 2002; Izquierdo, et al. 2005; Davis, et al. 2008).

The specificity of the training principle states that the nature of tissue adaptation after training is dependent on the specific type of training practiced (Baechle, 1994; Brooks, 2000; Nieman, 2003). As a corollary to this principle, combining two types of training (e.g., resistance and endurance training) may interfere with the training response induced by either type of training alone. Reasonable physiologic and metabolic evidence exists to support this principle.

Designing and implementing training for Swimming requires a solid understanding of the many physiological variables critical to optimal performance. Swimming requires short explosive bursts of energy repeated dozens, if not hundreds, of times per match or practice session. Swimming, unlike many other sports, does not have time limits on matches. This can result in matches lasting less than one hour or as long as five hours (in five-set matches). This variability requires successful Swimming athletes to be highly trained both anaerobically for performance, and aerobically to aid in recovery during and after play.

Oxygen uptake (VO_2) at maximal exercise is considered the best index of aerobic capacity and cardiorespiratory function. VO_2 Maximal is defined as the point at which no further increase in measured VO_2 occurs and a plateau is reached, despite an increase in work rate during graded exercise testing.

Strength and endurance training regimes represent and induce distinctly different adaptive responses when performed individually. Typically, strength-training programs involve large muscle group activation of high-resistance, low-repetition exercises to increase the force output ability of skeletal muscle (Sale et al 1990). In contrast, endurance-training programs utilize low-resistance, high-repetition exercises, such as running or cycling, to increase maximum O_2 uptake (VO_2 max). Accordingly, the adaptive responses in skeletal muscle to strength and endurance training are different and sometimes opposite (Tanaka and Swensen, 1998). Therefore, the purpose of this investigation was to examine the effects of concurrent training on the cardiopulmonary response, power, and endurance among youth swimmers.

Materials and methods

Experimental approach

Three experimental groups performed a pre- and post-training intervention in which VO_2 max, heart rate during the effort (HR), and the physical variables, including grip strength (GS), leg strength (LS), back strength (BS), standing long jump (SLJ), and strength endurance for legs and arms (SEL; SEA), were measured.

Experimental group one included seven youth swimmers who performed resistance training for one hour per day, three times a week, for eight weeks. Experimental group two included eight youth swimmers who performed endurance training on the treadmill for one hour per day, three times a week, for eight weeks. Experimental group 3 included seven youth swimmers who performed concurrent training for one hour per day, three times a week, for eight weeks. The experimental groups completed the training programs to see whether this type of training modality would have a positive, negative, or neutral effect on VO_2 max, HR, GS, LS, BS, SLJ, SEL, and SEA.

Participants

Twenty-two male youth swimmers were divided into three experimental groups: Concurrent group (n = 7, mean age 14.14 ± 1.13 yrs., mean height 168.29 ± 6.6 cm , mean weight 63.04 ± 5.2 kg , training experience 5.03 ± 0.9 yrs. and record level of 1500 m 20.32.54 ± 0.23.54 minute). Resistance group (n = 8, mean age 14.89 ± 1.34 yrs., mean height 171.16 ± 5.06 cm, mean weight 62.47 ± 4.3 kg, training experience 5.00 ± 1.2 yrs. and record level of 1500 m 20.44.76 ± 0.46.18 minute.). and Endurance group (n = 7, mean age 14.00 ± 1.01 yrs., mean height 169.29 ± 5.2 cm , weight 60.35 ± 4.4 kg , training experience 4.94 ± 1.6 yrs. and record level of 1500 m 20.28.64 ± 0.30.54 minute). Each group trained three times a week for eight weeks, with all types of training being performed in the same session. Parameters assessed the height, weight, power, strength, training age, VO_2 max (determined by using the Astrand Treadmill Test), and training experience. All subjects were free of any disorders known to affect performance, such as bone fractures, osteoporosis, diabetes, and cardiovascular disease, and had not undergone recent surgery. The participants did not report use of any anti-seizure drugs, and cigarette smoking. All participants were fully informed about the aims of the study and gave their voluntary consent before participation. The measurement procedures were in agreement with ethical human experimentation.

Training Protocol

The eight-week, in-season training program consisted of resistance training and endurance training.

Testing Procedures

Subjects were assessed before and after the eight-week training program. All measurements were taken one week before and after training at the same time of day. Tests followed a general warm-up that consisted of running, calisthenics, and stretching.

A strand treadmill test (att)

To perform this test you will require:

- Treadmill
- Stopwatch
- Assistant

This test requires the athlete to run as long as possible on a treadmill whose slope increases at timed intervals.

- The athlete warms up for 10 minutes.
- The assistant sets up the treadmill at a speed of 8.05 km/hr. (5 mph) and an incline of 0%.
- The assistant gives the command “GO,” starts the stopwatch, and the athlete commences the test.
- Three minutes into the test, the assistant adjusts the treadmill incline to 2.5% and then every two minutes thereafter increases the incline by 2.5%.
- The assistant stops the stopwatch and records the time when the athlete is unable to continue.

From the total running time, an estimate of the athlete's VO_2 max can be calculated as follows:

- VO_2 max mLs/kg/min = (Time × 1.444) + 14.99

Where "Time" is the recorded test time expressed in minutes and fractions of a minute.

Push-Up Test

A standard push-up begins with the hands and toes touching the floor, the body and legs in a straight line, feet slightly apart, and arms shoulder width apart, extended, and at a right angle to the body. Keeping the back and knees straight, the subject lowers the body to a predetermined point, to touch some other object, or until there is a 90-degree angle at the elbows, then returns back to the starting position with the arms extended. This action is repeated, and the test continues until exhaustion, until they can do no more in rhythm, or until they have reached the target number of push-ups.

Dominate Grip Strength Test (GS)

The subject holds the dynamometer in the hand to be tested, with the arm at a right angle and the elbow by the side of the body. The handle of the dynamometer is adjusted if required - the base should rest on first metacarpal (heel of palm), while the handle should rest on the middle of the four fingers. When ready, the subject squeezes the dynamometer with maximum isometric effort, which is maintained for about five seconds. No other body movement is allowed. The subject should be strongly encouraged to give maximum effort.

Static Strength Test (LS) (BS)

A back dynamometer was used to measure static leg strength. The subject stands on the dynamometer platform and crouches to the desired leg bend position while strapped around the waist to the dynamometer. At a prescribed time they exert a maximum force straight upward by extending their legs. They keep their backs straight, head erect, and chest high. Three trials were performed, and the best score was taken. Subjects rested between the trials.

Standing Long Jump Test (SLJ)

The subject stands behind a line marked on the ground with feet slightly apart. A two-foot take-off and landing is used, with swinging of the arms and bending of the knees to provide forward drive. The subject attempts to jump as far as possible, landing on both feet without falling backwards. Three attempts are allowed.

Wall Sit Test (WST)

The subject stands comfortably with feet approximately shoulder width apart and back against a smooth vertical wall. The subject then slowly slides their back down the wall to assume a position with both their knees and hips at a 90° angle. The timing starts when one foot is lifted off the ground and is stopped when the subject cannot maintain the position and the foot is returned to the ground. After a period of rest, the other leg is tested. The total time in seconds that the position was held for each leg is recorded.

Record of 1500m swimming

The subject swim in the pool (1500m) and take the record time by stopwatch.

Statistical Analysis

All statistical analyses were calculated by the SPSS statistical package. The results are reported as means and standard deviations (SD). Differences between three groups are reported as mean difference ± 95% confidence intervals (mean diff ± 95% CI). one way ANOVA were used to determine the differences in parameters between the three groups. A P-value <0.05 was considered statistically significant.

Table 1. Age, anthropometric characteristics, and training experience of the groups (mean ± SD)

Group	N	Age [years]	Weight [kg]	Height [cm]	Training experience [years]	record level of 1500m swimming [minutes]
RG	7	14.89 ± 1.34	62.47 ± 4.3	171.16 ± 5.06	5.00 ± 1.2	20.44.76 ± 0.46.18
EG	8	14.00 ± 1.01	60.35 ± 4.4	169.29 ± 5.2	4.94 ± 1.6	20.28.64 ± 0.30.54
CG	7	14.14 ± 1.13	63.04 ± 5.2	168.29 ± 6.6	5.03 ± 0.9	20.32.54 ± 0.23.54

Results

Table 1 shows the age and anthropometric characteristics of the subjects. No significant differences were observed in the anthropometric characteristics and training experience for the subjects in the three groups.

Table 2. ANOVA for VO_2 max and physical variables

Grip strength	**Sum of Squares**	**Df.**	**Mean Square**	**F**	**Sig.**
Between Groups	17.607	2	8.804	40.884	.000
Within Groups	4.737	22	.215		
Total	22.345	24			
VO_2 max					
Between Groups	14.184	2	7.092	29.343	.000
Within Groups	5.317	22	.242		
Total	19.502	24			
LS					
Between Groups	512.651	2	256.326	23.168	.000
Within Groups	243.402	22	11.064		
Total	756.053	24			

Table 2. ANOVA for VO_2 max and physical variables

Grip strength	Sum of Squares	Df.	Mean Square	F	Sig.
BS					
Between Groups	777.760	2	388.880	23.504	.000
Within Groups	364.000	22	16.545		
Total	1141.760	24			
SLJ					
Between Groups	1133.569	2	566.785	27.561	.000
Within Groups	452.431	22	20.565		
Total	1586.000	24			
PUT					
Between Groups	110.463	2	55.231	11.901	.000
Within Groups	102.097	22	4.641		
Total	212.560	24			
WST					
Between Groups	743.403	2	371.701	22.932	.000
Within Groups	356.597	22	16.209		
Total	1100.000	24			
Record level of 1500m swimming					
Between Groups	777.760	2	388.880	1.23	0.218
Within Groups	364.000	22	16.545		
Total	1141.760	24			

Table 2 shows significant differences between the three groups in all variables (physical and VO_2 max.) except the record level of 1500m swimming.

Table 3. LCD for VO_2 max and physical variables

Dependent Variable			Mean Difference	Sig.
Grip strength	**Strength group**	**endurance group**	**1.43917***	**.000**
		concurrent group	**-.51250***	**.038**
	endurance group	**concurrent group**	**-1.95167***	**.000**
VO_2 max	**Strength group**	**endurance group**	**-1.817069***	**.000**
		concurrent group	**-1.154000***	**.000**
	endurance group	**concurrent group**	**.663069***	**.011**
LS	**Strength group**	**endurance group**	**9.051528***	**.000**
		concurrent group	**-.726250-**	**.667**
	endurance group	**concurrent group**	**-9.777778***	**.000**
BS	**Strength group**	**endurance group**	**12.500000***	**.000**
		concurrent group	**2.000000**	**.336**
	endurance group	**concurrent group**	**-10.500000***	**.000**
SLJ	**Strength group**	**endurance group**	**15.347222***	**.000**
		concurrent group	**3.125000**	**.182**
	endurance group	**concurrent group**	**-12.222222***	**.000**
PUT	**Strength group**	**endurance group**	**4.55556***	**.000**
		concurrent group	**.37500**	**.731**
	endurance group	**concurrent group**	**-4.18056***	**.001**
WST	**Strength group**	**endurance group**	**1.80556**	**.366**
		concurrent group	**-10.62500***	**.000**
	endurance group	**concurrent group**	**-12.43056***	**.000**

***. The mean difference is significant at the 0.05 level.** Table 3 shows

- A significant increase in grip strength for the strength group over the endurance group and for the concurrent group over the strength and endurance groups.
- Significantly higher VO_2 max for the endurance group than the

strength and concurrent groups and for the concurrent group than the strength group.

- Significantly higher LS for the strength group than the endurance group. No significant difference in LS between the strength group and the concurrent group. Significantly higher LS for the concurrent group than the endurance group.
- Significantly higher BS for the strength group than the endurance group. No significant difference in BS between the strength group and the concurrent group. Significantly higher BS for the concurrent group than the endurance group.
- Significantly higher SLJ for the strength group than the endurance group. No significant difference in SLJ between the strength group and the concurrent group. Significantly higher SLJ for the concurrent group than the endurance group.
- Significantly, higher PUT for the strength group than the endurance group. No significant difference in PUT between the strength group and the concurrent group. Significantly, higher PUT for then concurrent group than the endurance group.
- No significant difference in WST between the strength group and the endurance group. Significantly higher WST for the concurrent group than the strength and endurance groups.

Discussion

The purpose of this study was to determine if concurrent training could enhance VO_2 max, LS, BS, SLJ, WST, and PUT among youth swimmers. The main findings were significant improvements in physical variables, VO_2 max and record level of 1500m swimming, which proved three training program efficacy.

Kraemer, *et al*. (1995) reported that concurrent training interfered with leg press and double leg extension strength development. This study also showed that only the resistance-trained group improved in peak and mean power during the Wingate anaerobic test. Bell, *et al*. (1997) reported interference in strength gains in the subjects of the concurrent group who were female, but not in the male subjects. Another study by Bell, *et al*. (1991) found that the resistance training group made larger gains in knee extension one repetition maximum (1 RM), but not leg press 1 RM when compared to the concurrent group. A very recent study conducted by Balabinis, *et al*. (2003) showed that the resistance-training group made greater gains in leg press and bench press 1 RM compared to the concurrent group.

Interestingly, the concurrent group in this study showed greater improvements in many other performance tests conducted. It should also be noted that in all but one of the above studies, changes in VO_2 max were the same for the concurrent and endurance only groups.

Based on the findings of these studies, it seems rather convincing that endurance training interferes with strength development. However, several studies have been conducted showing no interference in strength development by concurrent training (Hickson, 1980 ;Dudley and Djamil, 1985 ;Craig, et al. 1991 ;Hennessy and Watson. 1994 ;Bell, et al. 1997). Sale, *et al*. (1990) found no interference in strength or endurance development with concurrent training. Actually, the concurrent group improved the most in the number of repetitions performed at 80% of leg press 1 RM. These results may have been due to the hybrid nature of the training program (endurance training = 3 minute bouts at 90%-100% VO_2 max and resistance training = sets of 15-20 repetitions) used.

Abernethy and Quigley (1993) performed a study solely examining concurrent training in elbow extensor muscles. Their study also showed no interference in strength development. Four other studies have also reported no difference in the strength gains of the concurrent and resistance training only groups.

Balbinis, *et al*. (2003) actually found the concurrent group to improve more than the resistance-training group in Wingate power. In this study, the resistance only group out-performed the concurrent group in 1 RM leg press and bench press, but the concurrent group showed greater improvements in 1 RM squat, vertical jump, and Wingate power. Hunter, *et al*. (1987) showed interference in vertical jump performance when comparing untrained subjects who concurrently trained to those who only resistance trained. However, they failed to show any interference when a group of trained runners who began resistance training was compared to the untrained group who only resistance trained. A recent study conducted by McCarthy, *et al*. (2002) also reported no strength impairments with concurrent training.

A small number of other studies have examined whether or not adding resistance training to the training regimen of endurance-trained athletes could improve their endurance performance. The results of these studies are also inconsistent. Bishop, *et al*. (1999) showed that resistance training of endurance-trained cyclists did not improve their performance. In this study, the resistance-trained subjects did improve in the strength test, but showed no difference from the control group in average power output during a 1 h cycle test, lactate threshold, or VO_2 max. Nelson, *et al*. (1990) reported that 11 weeks of concurrent training actually interfered with gains in VO_2 max as compared to endurance training alone. Here, the authors speculated that as a result of hypertrophy, a dilution in mitochondrial volume of the type IIa fibers might have occurred in the concurrent group.

Häkkinen, *et al*. (2005) performed a study showing just the opposite of Nelson’s findings. They found that subjects who had resistance trained showed greater improvements in short- and long-term endurance compared to those who only endurance trained. Short-term endurance was 5-8 min to exhaustion and long term was maximal cycling time to exhaustion at 80% VO_2 max. It was hypothesized that resistance training increased short-term endurance performance by increasing high-energy phosphate and glycogen stores. Short-term endurance may have also been improved by increases in the fast twitch to slow twitch fiber area ratio. Long-term endurance performance was believed to have increased due to a delay in the recruitment of fast twitch fibers as a result of resistance training increasing maximum strength (Nelson, et al. 1990). In addition, long-term endurance performance can benefit from resistance training not only by reducing large motor unit recruitment, but also by improving running or cycling economy. Similar to Hickson’s findings (1980), Balabinis *et al*. (2003) recently reported that those who concurrently trained made greater gains in VO_2 max than those who only endurance trained.

Practical implications

Two months of concurrent training, (endurance and resistance training) can improve physical variables , VO_2 max and record level of 1500m swimming among young youth swimmers.

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