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Investigation of the Relationship between Maximal Strength and Swimming Performance in Adolescent Swimmers

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ABSTRACT

The aim of this study is to investigate the relationship between maximal strength and swimming performance in adolescent swimmers. 7 female and 8 male swimmers between the ages of 13-16 participated in the study voluntarily. 1 repetition maximal strength test (1RM) in butterfly, lat pull down, leg press and maximum push up test with self-body weights were applied to determine the maximal strength. Swimmers were asked to swim 50 m and 100 m freestyle to evaluate their swimming performances. Swimming performance data were measured in the form of swimming performances separately for 50 m and 100 m, 50 m freestyle kicking time (KT), stroke count (SC), stroke time (ST), distance per stroke (DPS), stroke length (SL), stroke rate (SR), heart rate (HR). Spearman correlation test was applied in order to determine the relationship between maximal strength and swimming performance ($p<0.05$). Significant and positive relationship was determined between butterfly & lat pull down maximal strength and HR of the female swimmers after the 100 m freestyle swimming (100 m HR & butterfly $r= 0.818$, $p= 0.015$; 100 m HR & lat pull down $r= 0.754$, $p= 0.038$); and between 100 m swimming time and maximal push-ups of the male swimmers ($r= -0.707$, $p= 0.037$). However a significant negative relationship was found between 1RM lat pull down and 50 m SC ($r= -.710$, $p= .037$), and a significant positive relationship was found between 1RM lat pull down and 50 m SL ($r= .710$, $p= .037$). No significant relationship was found between any other swimming performance and maximal strength in male and female swimmers. As a result, it is possible to suggest that lat pull down is a determining element for swimming performance. However, in dryland strength workouts (ground workout), it may be suggested that action plans may be transferred into the water.

1. Introduction

In swimming, performance depends on many factors wherein some technical and physiological factors play a predominant role. For distances ranging from 50 to 200 m, the propulsive efficiency has a major impact on performance [1]. This efficiency is mainly because of the involvement of muscle contractile qualities and muscle strength of the upper limbs [2,3]. The lower limbs only participated very slightly in the propulsion of the swimmer

[4,5].

Swimming performance is highly dependent on muscular strength and power [6–8]. Especially in short distance events, swimming performance depends on the power developed by both the upper and the lower limbs [9]. Using a variety of testing equipment, upper-body muscular strength and swimming power have demonstrated to be well correlated with swimming velocity [10–12]. Therefore, improvements in arm strength may result in higher maximum force per stroke, subsequently in higher swimming velocities, specifically in sprint distances [13,14]. In addition, greater leg power and jumping ability could lead to improved start performance and hence overall race time [15].

Dry-land strength training aims to increase maximal power outputs through an overload of the muscles used in swimming [8] and it may enhance swimming technique [5]. If these two points of view are correct, then the increase of muscular strength would improve swimming performance. However, results from the available experiments remain inconclusive [7,8,16]. Moreover, dry-land strength training is a common practice in swimming training, though the scientific evidence is still scarce [10,17]. In summary, the incongruous results of experiments developed so far, point out that the associations of dryland strength and swimming performance remains uncertain.

There are frequent studies in the literature investigating the effect of strength or strength training on swimming performance [18–20]. However, there are very few studies investigating the relationship between swimming performance and strength [9,15,21]. Nevertheless, as in all other sports disciplines, a challenging training process is necessary for the athlete for many years with specific training program until the level of elite athlete is reached (e.g. category of adults). Besides, monitoring and evaluation of the athlete in each and every age category is of great importance in this training process. Most of the researches conducted so far have been on senior athletes. Attention should be paid to the relationship between swimming performance of swimmers who are in the development stage and the strength applied to improve this performance. Consequently the purpose of present study was to investigate the relationship between maximal strength and swimming performance in adolescent swimmers.

2. Method

2.1. Participants

7 female and 8 male swimmers aged 13-16 were voluntarily participated in this study. Before starting the study, the subjects were informed about the study protocol and voluntary participation certificates and parental permission certificates were obtained. The procedures were approved by the Institutional Ethics Review Committee. All procedures were in accordance to the Declaration of Helsinki in respect to Human research. Descriptive information of the subjects such as age, body weight, body height, body mass index (BMI), fat percentage, years of experience were obtained before the study (Table 1).

Table 1. Characteristics of the subjects

	Female (n=7)	Male (n=8)
Age (year)	14.6 ± 1.3	14.4 ± 1.1
Years of experience (year)	7.0 ± 1.7	5.4 ± 1.3
Body weight (kg)	56.1 ± 7.2	59.3 ± 10.8
Body height (cm)	161.7 ± 3.1	173.1 ± 8.6
BMI (kg.m $^{-2}$)	21.5 ± 5.0	19.9 ± 2.4
Fat percentage (%)	24.8 ± 3.3	15.7 ± 3.1

24 hours before all the tests, the participants were informed about not to use caffeine, drug and substances included in the scope of ergogenic aid and avoiding high intensity exercises. The criterion for participating in the study is to be training at least 6 times a week for the last 2 years. The swimmers who had suffered a disability or surgery in the last six months were excluded from the study.

2.2. Study protocol

The study protocol was performed on 4 separate days. After each measurement day, one day break was applied and complete rest was performed. On the first day, body weight, BMI and fat percentages of the subjects were determined with bioimpedance device (Tanita BC 418 (Japan) body composition analyzer measuring with 0.1 kg sensitivity).

In swimming performance, the swimmers completed free style swimming at 50 m and 100 m respectively on the 3rd and 5th day of the measurement. Swimming performance data were measured separately for 50 m & 100 m, 50 m freestyle KT, SC, ST, DPS, SL, SR, HR. Ambient temperature was maintained 24°C. Verbal encouragement was given to maximize performance. Subjects completed race-specific warm-up for 30 minutes before swimming measurements were taken. 50 m & 100 m freestyle swimming scores were measured (F-1.30.040 Finis Stopwatch 3x300M was used) and then the SC, SL and SR of the athletes were calculated. All measurements were performed at the morning hours on the predetermined days. In all performance tests, the athletes were allowed to try 2 times and the best score was taken into account. After each swim, the heart rates of the subjects were taken through palpation from the carotid artery for 15 seconds and the heart rates in a minute were calculated.

1RM test in butterfly, lat pull down, leg press for maximal strength and maximum push-up test with their body weight were applied. Before the 1RM test, the subjects performed standardized warm-up and stretching (20 min in total). Based on the previous 1RM data of all subjects, subjects performed 3 warm-up sets of 8 repetitions at 50% 1RM, 4 repetitions at 70% 1RM, and finally 2 repetitions at 80% of their 1RM, which was approximately from their training log [15]. After the final warm-up set, subjects attempted 1 repetition of a set load (1RM), and if successful, the weight lifted was increased until the subject could not lift the weight through the full range of motion. All subjects had been previously exposed to 1RM testing for each movement. The particular weight that subjects were able to lift 1 time and could not lift for the second time were determined as their 1RM value. In the maximum push up test, the subjects were asked for maximum push ups with the appropriate range of motion. If the subject did not perform the action correctly or could not continue voluntarily, the test was terminated.

2.3. Statistical analysis

Descriptive statistics (mean ± SD) for the outcome measures were calculated. Spearman correlation test was used to determine the relationship between maximum strength and swimming performance. Statistical significance was accepted at an alpha level of $p<0.05$.

3. Results

The 1RM test values of male swimmers of the same age group were found to be quantitatively higher than female swimmers (Table 2).

Table 2. 1RM strength test results of the subjects (kg). All data are presented as mean (standard deviation).

	Female n=7	Male n=8
Butterfly (kg)	53.6±15.5	66.3±17.3
Lat pull down (kg)	47.1±9.5	55.0±10.0
Leg press (kg)	117.9±16.0	123.1±20.9
Push up (count)	22.9±6.1	27.3±8.4

50 m swimming times were found in female and male respectively 32.02±1.30 sec, 30.5±0.9 sec and 100 m swimming time was 69.01±1.89 sec, 67.4±2.5 sec (Table 3).

Table 3. 50 & 100 m freestyle swimming performance of the subjects. All data are presented as mean (standard deviation).

50 m	**Female** n=7	**Male** n=8	**100 m**	**Female** n=7	**Male** n=8
KT (sec)	47.9±2.3	44.8±3.1			
Swimming time (sec)	32.02±1.30	30.5±0.9	Swimming time (sec)	69.0±1.89	67.4±2.5
SC	47.9±3.2	47.6±3.4	SC	95.3±9.6	96.3±7.3
ST (sec)	0.67±0.04	0.64±0.05	ST (sec)	0.73±0.08	0.71±0.07
DPS (m)	1.05±0.07	1.06±0.08	DPS (m)	1.06±0.11	1.04±0.08
SR (min/stroke)	54.3±3.3	57.5±6.8	SR (min/stroke)	47.1±3.8	52.5±5.9
HR	169.4±11.1	175.5±28.1	HR	188.9±13.8	191.8±11.8

KT: Kicking time, SC: Stroke count, ST: Stroke time, DPS: Distance per stroke, SR: Stroke rate, HR: Heart rate

There was a significant positive relationship between 100 m HR and butterfly & lat pull down maximal strength in female swimmers (Table 4, r=.818 p=.015, r=.754 p=0.38, respectively). There was no significant relationship between 1RM and swimming performance in female swimmers in this age group.

Table 4. The relationship between 1RM and swimming performance of the female subjects

Female	**Butterfly**		**Lat Pull Down**		**Leg Press**		**Push Up**	
n=8	r	p	r	p	r	p	r	p
50 m								
KT (sec)	.262	.545	.397	.341	-.037	.905	.126	.720
Swimming Time (sec)	.334	.438	.225	.602	.148	.720	-.107	.781
SC	.001	.968	-.019	.905	.093	.781	-.360	.338

ST (sec)	-.222	.602	-.374	.388	-.482	.255	-.214	.602
SL (m)	.001	.968	.018	.905	-.094	.781	.360	.388
SR (min/stroke)	.299	.491	.623	.121	.636	.096	.703	.054
HR (beat/min)	-.482	.255	-.337	.438	-.556	.150	-.250	.545
100 m								
Swimming Time (sec)	-.148	.720	-.262	.545	.185	.660	-.143	.720
SC	.224	.602	.264	.545	.206	.602	-.126	.720
ST (sec)	-.408	.341	-.505	.217	-.408	.341	-.143	.720
SL (m)	-.224	.602	-.264	.545	-.206	.602	.126	.720
SR (min/stroke)	.057	.843	.333	.438	.019	.805	.182	.660
HR (beat/min)	.818	.015*	.754	.038*	.613	.121	.591	.121

*: Significant difference, p<0.05. *KT: Kicking time, SC: Stroke count, ST: Stroke time, DPS: Distance per stroke, SL: Stroke length, SR: Stroke rate, HR: Heart rate*

There was a significant negative relationship between 100 m swimming time and maximal push-up count in male swimmers (Table 5, r= -.707 p=.037). However a significant negative relationship was found between 1RM lat pull down and 50 m SC (r= -.710, p=.037), and a significant positive relationship was found between 1RM lat pull down and 50 m SL (r= .710, p=.037).

Table 5. The relationship between 1RM and swimming performance of the male subjects

Male	**Butterfly**		**Lat Pull Down**		**Leg Press**		**Push Up**	
n=8	r	p	r	p	r	p	r	p
50 m								
KT (sec)	.172	.662	-.323	.387	.356	.353	-.095	.794
Swimming time (sec)	-.135	.705	-.383	.321	-.454	.233	-.405	.290
SC	-.222	.578	-.710	.037*	.139	.705	.012	.931
ST (sec)	.037	.885	.527	.160	-.233	.537	-.119	.749
SL (m)	.222	.578	.710	.037*	-.139	.705	-.012	.931
SR (min/stroke)	.373	.321	-.383	.321	.222	.578	.558	.139
HR (beat/min)	.352	.353	-.283	.460	.019	.931	.120	.749
100 m								
Swimming time (sec)	-.562	.120	-.067	.839	-.605	.102	-.707	.0.37*
SC	.393	.321	-.515	.160	.098	.794	.238	.537
ST (sec)	.528	.160	.299	.423	-.356	.353	-.429	.290
SL (m)	-.393	.321	.515	.160	-.098	.794	-.238	.537
SR (min/stroke)	.139	.705	-.383	.321	.063	.839	.430	.260
HR (beat/min)	.566	.120	-.331	.387	-.025	.931	.073	.839

*: Significant difference, p<0.05. *KT: Kicking time, SC: Stroke count, ST: Stroke time, DPS: Distance per stroke, SL:*

Stroke length, SR: Stroke rate, HR: Heart rate

No significant relationship was found between all other swimming performance and maximal strength for female and male swimmers.

4. Discussion and Conclusion

The main purpose of the competitor swimmers is to range the maximum distance in minimum time. Accordingly, as the distance to swim decreases, the number of strokes decreases in parallel. Therefore, for shorter competition distances, strength is shown as one of the most important factors that can increase swimming speed [22]. Furthermore, with regard to power and technique, it is observed that the role of applied strength increases as the swimming distance decreases [21,23,24].

There are few studies evaluating the relationship between swimming performance and strength. Upper body strength is relatively more effective in swimming. Johnson et al. [25] investigated the relationship between 1RM bench press and swimming speed in male swimmers. According to researchers, dry-land strength training is not related to sprint speed. The broad age scale of the subjects (between the ages of 14 and 22) is also effective in this result. Crowe et al. [26] applied a more extensive strength parameter in their studies in which they examined the relationship between 1RM bench press, lat pull down and triceps press and swimming performance in female and male swimmers. They found a significant relationship between swimming performance and lat pull down only in females ($r= 0.64$, $p<0.05$).

Strength training using dry-land regimens may enhance the ability to produce propulsive forces in-water, especially in short distance events [9,19]. Another study supports the importance of lower body strength and power for start time in 50 m sprint swimmers [15]. However, in that study, the focus was only to 1RM test, start time, horizontal and vertical jump. The relationship between parameters with regard to total swimming performance and swimming mechanics and 1RM was not investigated.

In their studies examining the relationship between 50 m different swimming styles and some motor characteristics in 14-15 year old girl swimmers, Dimitric et al. [9] reported that the push-up as a measure of arm strength affected the 50 m backstroke performance. However, there was no significant relationship between push-ups and 50 m free-style swimming. In our study, no significant relationship was found between 50 & 100 m freestyle swimming performance and push-up of female swimmers in this age group. In addition, there was a negative correlation between push-up and 100 m swimming time of the male swimmers of the same age group ($r= -.707$, $p=.037$). Whether this relationship exists in both genders with age increase and strength gain should be investigated in future studies.

Morouço et al. [21] investigated the relationship between bench press, lat pull down and squat 1RM and tethered swimming performance in male adolescent swimmers. They found a significant relationship only between lat pull down and tethered swimming performance. In our study, a significant relationship was found between 1 RM lat pull down and SC & SL for the male swimmers of the same age group. These findings suggest that lat pull down plays a decisive role in swimming performance in adolescent swimmers.

Garrido et al. [17] stated that the strength development after six weeks of strength training in adolescent swimmers remained stable but there was an improvement in swimming performance. However, they added that the competition levels of the swimmers might be affected by the strength training. There are also some studies suggesting that perhaps technical training is more important than strength training at these ages [27,28].

In this study, no significant relationship was found between the maximal strength and swimming performance of female and male swimmers (except for three parameters). This finding supports the literature. However, when choosing females in this age group for most of swimming techniques, it was pointed out that it was important to have long longitudinal characteristics, especially big arm span. Also, it is important for female swimmers to have strong body, arms and legs [9]. As a result, lat pull down plays a decisive role in swimming performance in adolescent swimmers. However, it may be advisable to plan the transfer of movements into water in non-water strength studies.

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Conflicts of Interests

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