International Journal of Science Culture and Sport
June 2017 : 5(2)
ISSN : 2148-1148
Doi : 10.14486/IntJSCS648

***Field** : Coaching*
***Type** : Research Article*
***Recieved:** 21.03.2017 – **Accepted:** 27.04.2017*

Relation of 25-meter Swimming Performance with Physical Properties and Isokinetic Knee Strength in Amateur Young Swimmers

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Abstract

The purpose of this study was to investigate the relationship between physical properties, isokinetic knee strength and swimming performance in young amateur athletes. Seventeen 18-24 year old amateur swimmers (n=13 males, mean age=20.0 ± 2.1 years; n=4 females, mean age=21.5 ± 1.7 years) volunteered to participate in this study. All athletes were member of the same team who were engaged to the swim training at least for 4 years. Following the 5-min warm up session, each participant performed three submaximal trials for familiarization and warm-up purposes, and then five maximal trials at three angular velocities: 60, 120, and 180°/s. A 30-s time interval was provided between familiarization and test session, whereas a 2-min rest period was given between each test velocity. A 25-m swimming performance was recorded in semi-olympic swimming pool, under race conditions. The results demonstrated that there was a statistically significant inverse relationship between height, body mass, BMI, and swimming performance ($p<0.05$ and 0.01), also, there was a significant inverse relationship between isokinetic knee strength and swimming performance ($p<0.01$). However, there is no significant differences between H/Q ratio and 25-m swimming performance ($p>0.05$). In conclusion, the lower limb muscle strength is as important as upper limb muscle strength and a combination of lower limb muscle strength and anthropometric variables are important for sprint swimming performance.

Keywords: Swimming, amateur athletes, isokinetic strength, performance

Introduction

Swimming requires high muscle strength and technical ability in order to achieve a good performance. This sport involves four different swimming style including freestyle stroke, butterfly stroke, breaststroke and backstroke. In the swimming, performance depends on a number of factors including development of relevant muscle groups and anthropometry. Several researchers have indicated that development of relevant muscle strength is important to achieve a success (Gola et al., 2014). There is a strong relationship between muscle strength and swimming performance (Bober and Pietraszewski, 1996; Bassa et al., 2002). Additionally, this relationship was statistically significant for shorter distance, with decreasing as the distance increased (Gola et al., 2014).

Isokinetic dynamometer is used to measure muscle strength and power in dynamic movement in several joints. Although isokinetic dynamometers are generally used to diagnose injury, isokinetic strength values is critical for the assessment of training induced changes in muscle function. Swimming performance is thought to be related with upper body extremities, but the movements performed by the extremities vary depending on swimming style (Gola et al., 2014). Mameletzi et al. (2003) suggested that swimming sport requires high muscle power in lower limb. Similarly, a study conducted with synchronized swimmers, found that there is a strong correlation between performance and isokinetic muscle strength of the lower limb muscle (Yamamura et al., 1999). On the other hand, Gola et al. (2014) reported that there is no relationship between isometric strength of the lower limb muscles and 25-m or 50-m swimming performance. Besides, isokinetic strength values are used to assess hamstring to quadriceps ratio (H/Q) and this ratio has been used to examine the similarity between hamstring and quadriceps moment-velocity patterns and to assess knee functional ability and muscle balance (Rosene et al., 2001). To our knowledge there is only one study that examined the H/Q strength ratio in swimmers and this study evaluated the sex differences in 10-12 year old swimmers (Mameletzi and Siatras, 2003).

Apart from muscle strength, anthropometry is the most important factor for swimmers to achieve success. There is a strong correlation between age and height variables and swimming performance (Zampagni et al., 2008). On the other hand, Mameletzi et al. (2003) reported that there is a relationship between lean body mass (LBM) and knee muscles strength. Although in freestyle, stroke speed is little influenced by some anthropometric variables, the combination of stroke length and stroke frequency is very much a function of swimmers anthropometric characteristics (Grimston and Hay, 1986). Duche et al. (1993) reported that there is a strong correlation between anthropometry (height, upper limb length, bi-iliac diameter) and 50-m, 100-m and 400-m in young male swimmers. Knechtle et al. (2010) indicated that swimming race performance was inverse related with anthropometry in elite ultra-endurance swimmers. The above-mentioned studies generally were conducted with adolescents, pre-pubescents and elite swimmers. There is limited information about amateurs and adult competitive swimmers. Having information about amateur Turkish swimmers will provide re-organization of the training program and find out the missing point of our training system and maybe it will form the basis for the elimination of lack of training. Hence, this study aim to investigate 25-m swimming performance relationship with anthropometry and isokinetic knee muscle strength in amateur Turkish sprint swimmers. The velocities were chosen based on similar velocities used in previous investigations (Rosene et al., 2001).

Materials and Methods

Participants

Seventeen 18-24 year old amateur swimmers (n = 13 males, mean age = 20.0 ± 2.1 years; n = 4 females, mean age = 21.5 ± 1.7 years) volunteered to participate in this study. All athletes were member of the same team who were engaged to the swim training at least for 4 years. None of the athletes had medical history, leg or arm injury, cardiovascular and pulmonary diseases. At the beginning of the study all participants were informed about possible risks and benefits of the study and written consents were obtained. The study was approved by the local ethical committee and was conducted in accordance with the Helsinki Declaration for experiments involving humans.

Anthropometric data collection

Participants' heights were measured using a stadiometer (Holtain, Britain) to the nearest 0.1 cm, additionally participants' body mass, body mass index (BMI), and body fat percentage (%) were estimated by bioelectrical impedance analyzer (Tanita MC-180-MA, Japan).

Isokinetic measurements

Bilateral concentric isokinetic strength of the knee extensors and flexors was measured using the CSMI-Humac/NormTM-770 model (Humac Norm Testing and Rehabilitation System, USA). Before each testing session, the dynamometer was calibrated in accordance with the manufacturer's recommendations. Before the test, the participants warmed-up for 5 min by pedaling on a bicycles ergometer (Monark). Knee extension and flexion were performed with the subjects in an upright seated position, with their hands gripping the sides of the dynamometer chair. Stabilizing straps were placed around the thorax, pelvis and the thigh. The resistance shin pad was placed at a level just above the medial malleolus. Peak isokinetic concentric knee extension and flexion torque of both legs were evaluated at three angular velocities: 60, 120, and 180°/s. Contractions were performed through a range of zero - 90 (full extension defined as 0^0). Subjects were instructed to complete three submaximal trials for familiarization and warm-up purposes at each angular velocity, and then to perform five maximal repetitions of knee extension and flexion at 60, 120, and 180°/s angular velocities. A 30-s time interval was provided between familiarization and test session (Tsiokanos et al., 2002; Çakır-Atabek et al., 2009) whereas a 2-min rest period was given between each test velocity (Malliou et al., 2003; Çakır-Atabek et al., 2009). In addition, a break of at least 2-min was given when the machine setting was changed for the opposite leg. The order of testing was randomized for the dominant and non-dominant legs. Verbal encouragements and visual feedback were given by investigator to all participants to help them concentrate on the quality of their movements. The greatest peak torque (N·m) for knee extension and flexion (out of the 5 trials in each velocity) were measured automatically by the Humac®/2004 and served as the outcome measure. The body mass was used to determine relative strength expressed in N·m/kg (Mameletzi and Siatras, 2003). In addition, hamstring / quadriceps (H/Q) strength ratios were computed for each angular velocity (60, 120, and 180°/s).

25-m Swimming performance

The participants underwent a 25-meter swimming performance trial in semi-olympic swimming pool, under race conditions.

Statistical analysis

All values were presented as mean ± standard deviation (SD). The correlations between anthropometric variables (*age, height, body mass, body mass index, and body fat percentage*), isokinetic strength (*absolute and relative strength*), H/Q ratios and 25-m swimming performance was evaluated using the Pearson Product Moment Correlation analysis. All analyses were executed using the SPSS for windows version 18.0 and statistical significance was set at $p < 0.05$.

Results

General physical characteristics of the participants and correlation analysis of these values with best swimming performance time are presented in Table 1. There was a statistically significant inverse relationship between height, body mass, BMI, and swimming performance ($p < 0.05$ and 0.01).

Table 1. General physical characteristics and best swimming performance of participants.

Variables	Mean ± SD	Best swimming performance (r)
Age (years)	20.35 ± 2.08	0.413
Height (cm)	174.82 ± 7.03	-0.812**
Body mass (kg)	70.42 ± 10.98	-0.749**
Body Mass Index (kg/m^2)	22.91 ± 2.53	-0.505*
Body Fat Percentage (%)	18.22 ± 6.17	0.386
Best swimming performance 25 m (sec)	15.08 ± 3.16	

*p < 0.05; **p < 0.001; r = Pearson Correlation

The isokinetic strength values of knee extensor and flexors (peak torque expressed in N·m and N·m/kg) and correlation analysis of these values with best swimming performance time are presented in Table 2. The results demonstrated that there was a significant inverse relationship between isokinetic knee strength and swimming performance ($p < 0.01$). The mean ± (SD) values of knee H/Q strength ratios at the angular velocities of 60, 120, and 180°/s and correlation analysis of these values with best swimming performance time are presented in Table 3. There was not a significant relationship between H/Q ratios and swimming performance ($p > 0.05$), except right knee H/Q ratio at 60°/s ($p < 0.05$).

Table 2. Isokinetic knee extensors and flexors absolute and relative strength values of the participants (in Nm)

	Variables	Mean ± SD	Best swimming performance (r)
600/s	Right knee extension (N·m)	118.29 ± 30.36	- 0.901 **
	(N·m / kg)	1.67 ± 0.32	-0.646 **
	Right knee flexion (N·m)	98.35 ± 22.22	-0.845 **
	(N·m / kg)	1.39 ± 0.23	-0.508 *
	Left knee extension (N·m)	123.63 ± 22.98	-0.808 **
	(N·m / kg)	1.76 ± 0.25	NS
	Left knee flexion (N·m)	99.90 ± 17.70	-0.746 **
	(N·m / kg)	1.42 ± 0.20	NS
1200/s	Right knee extension (N·m)	111.82 ± 31.69	-0.886 **
	(N·m / kg)	1.57 ± 0.33	-0.679 **
	Right knee flexion (N·m)	91.52 ± 22.81	-0.853 **
	(N·m / kg)	1.29 ± 0.26	-0.550 *
	Left knee extension (N·m)	111.47 ± 27.60	-0.835 **
	(N·m / kg)	1.57 ± 0.27	-0.551 *
	Left knee flexion (N·m)	94.23 ± 26.30	-0.885 **
	(N·m / kg)	1.32 ± 0.25	-0.778 **
1800/s	Right knee extension (N·m)	99.88 ± 32.36	-0.894**
	(N·m / kg)	1.40 ± 0.35	-0.732 **
	Right knee flexion (N·m)	81.58 ± 23.04	-0.806**
	(N·m / kg)	1.14 ± 0.26	-0.584 *
	Left knee extension (N·m)	95.17 ± 28.11	-0.903**
	(N·m / kg)	1.33 ± 0.29	-0.744 **
	Left knee flexion (N·m)	81.64 ± 27.58	-0.892**
	(N·m / kg)	1.14 ± 0.27	-0.831 **

*p < 0.05; **p < 0.001; r = Pearson Correlation

Table 3. H/Q strength ratios in swimmers.

	Variables	Mean ± SD	Best swimming performance (r)
600/s	Right knee	0.84 ± 0.08	0.532 *
	Left knee	0.81 ± 0.06	NS
1200/s	Right knee	0.82 ± 0.09	NS
	Left knee	0.84 ± 0.11	NS
1800/s	Right knee	0.83 ± 0.14	NS
	Left knee	0.86 ± 0.17	NS

*p < 0.05; r = Pearson Correlation

Discussion and Conclusion

The purpose of this study was to investigate the relationship between anthropometric variables, isokinetic knee strength and 25-m sprint swimming performance in amateur Turkish swimmers. Our results show that lower limb muscle strength is very important for sprint swimmers in order to achieve good performance. Also, body weight and BMI were inverse related with sprint performance. General hypotheses were that swimmers with a higher percentage of body fat would have a better performance than swimmers with lower percentage (Knechtle et al., 2010). In constrast to the general hypotheses, present study results show that there is a strong inverse relationship between height, body mass, BMI and 25-m swimming performance and there is no relationship between body fat percentage and 25-m swimming performance. Knechtle et al. (2010) indicated that there is no significant correlation between anthropometric variables (body height, body mass index, length of arm and length of leg) and swimming race time in endurance male and female swimmers. In addition, Zampagni et al. (2008) cocluded that there was an inverse significant relationship between body weight, height and from 50-m to 800-m free style swimming performance. The inverse relationship between 25-m performance and anthropometric variables that were found in the present study is expected, because the participants' of the present study were sprint swimmers. As in every sport, incerased body weight and BMI have a negative effect on sprint swimming performance in our study group.

Although it is difficult to generalize, the normal H/Q ratio is considered to be 50% to 80% as averaged through the full range of knee motion, with a higher ratio at faster speeds. As the ratio approaches 100% indicating that significant functional capacity of the hamstring muscles for providing muscular stability at the knee joint in such situations. In the current study, the H/Q ratios were not significant related with 25-m swimming performance, however, the H/Q strength ratios of the participants were higher than the other study which conducted with different sports (Holm et al., 1994; Aagaard et al., 1995; Rosene et al., 2001). In the present study the H/Q ratios are in range of 0.81 – 0.86 at velocities of 60,120, and 180^0/s. To our knowledge, in literatuer there is only one study that investigating the H/Q ratio in swimmers. This study is conducted with 10-12 years old boys and girls swimmers. Maletzi et al. (2003) reported that H/Q values changed between 0.66-0.69 for boys and 0.62-0.67 for girls. These values also are higher than the other studies (Holm et al., 1994; Rosene et al., 2001). The swimming sports require a continiously propulsive force against greater water resistance (Mameletzi and Siatras, 2003). Therefore, almost all muscles group in the lower and upper limb are active, depending also on the swimming style during training in water. Actually, lower limb muscle always work against resistance even the swimmers don't do dry-land resistance training. This may be one of the reasons why the H/Q ratio is higher in swimmers than the other. Also, no reduction was observed in quadriceps strength when the results of the current study were analyzed individually.

Generally, swimmers' upper limb muscles strength were measured in isokinetic dynamometer (Sharp et al., 1981; Juárez Santos-García et al., 2013). According to a few studies, lower limb muscle strength is quielty important especially in sprint swimming performance (Yamamura et al., 1999). In the present study, there was a strong relationship between 25-m swimming performance and lower limb musle strength and these findings are in line with literature (Yamamura et al., 1999; Mameletzi and Siatras, 2003).

In conclusion, the lower limb muscle strength is as important as upper limb muscle strength and a combination of lower limb muscle strength and anthropometric variables are important for sprint swimming performance.

Acknowledgements

The authors would like to thanks to swimmers for their willingness to participate in this study and to Murat Özkan for his support during data collection process.

Conflict of Interest

The authors have not declared any conflicts of interest.

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