RELATIONSHIP BETWEEN FORCE PARAMETERS AND PERFORMANCE IN 100M FRONT CRAWL SWIMMING

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Original scientific paper

Abstract
Strength in water has been evaluated in several ways. The most common method is tethered swimming, a valid and reliable source of information for freestyle sprint swimmers. Yeater et al., (1981) concluded that tethered swimming method can provide prediction of performance as well as diagnose of technical problems. The aim of the research is to investigate the relationship between the 100 m freestyle swimming and the variables that determine force application during freestyle sprint swimming. In this study 23 active swimmers of national level participated (age = 15,04±1,6 years, body height =169,7±8,7 cm and body mass=62,4±9,7kg).Firstly, force of the right handgrip was recorded with a portable dynamometer. After a warm up, participants was asked to swim with maximum intensity fully tethered with freestyle their best time of 100m freestyle swimming. For the determination of the relationship between the independent and the dependent variable, stepwise multivariate regression analysis will be applied. Two prediction models occurred from the analysis. The variables that best describe the criterion variable are circumference of biceps in contraction and mean force. The finding of this research confirms that tethered swimming is a useful tool for the coaches and swimmers in order to reach best results.

Key words: *tethered swimming, performance, prediction.*

Introduction

Maximal swimming velocity depends on pulling force characteristics. Propulsion in swimming depends on a series of cyclic movements performed by the alternation of leg and arm strokes. Each stroke results in a characteristic force which pulls the swimmer forward. The most commonly used test to measure pulling force is tethered swimming (Keskinen, Tilli, & Komi, 1989; Maglischo, 2003; Sidney et al., 1996; Yeater et al., 1981). Furthermore, tethered swimming is one of the most famous types of training for swimmers and aims in strength improvement and coordination (Maglishco, 2003). Many researchers suggested the use of tethered swimming that improves strength and allows the monitoring and evaluation of essential parameters of swimming performance (Avlonitou, 2000, Colwin; 1993; Counsilman, 1979; Hannula, 1995; Maglischo, 2003; Smith, 2002). Some other reviewers found positive correlation between swimming performance and muscular strength that can be measured with several training ways (Costil et al., 1980; Costill et al., 1983; Crowe et al., 1999; Hawley & Williams, 1991; Hopper et al., 1980; Sharp et al., 1982). Previous research has focused on the relationship between the maximal pulling force or the average of maximal pulling forces (Fmax or avgFmax) of a single stroke and swimming velocity achieved mainly at sprint distances (Keskinen et al., 1989; Sidney et al., 1996). The methodology of establishing the relationship and quality between swimming velocity at a given distance and the characteristics of pulling force realized by tethered swimming requires that the test lasts at least approximately as long as the distance covered. Recent studies have focused on the determination of important force parameters that better describe performance in swimming (Barbosa et al., 2010; Dopsaj et al., 1999; Dopsaj, Matkovic, Zdravkvovic, 2000; Loturco et al., 2015; Morouco et al., 2014; Moura dos Santos et al., 2012). Apart from force characteristics derived from tethered swimming, handgrip strength has been studied in relation to swimmers performance. Wind et al., (2009) found strong relationship between handgrip strength and total muscle strength. Furthermore, Mitsionis et al., (2009) concluded that handgrip strength is highly correlated to height. Garrido et al., (2012) studied the relationship between dominant handgrip strength and performance time in 100 and 200m of all four swimming strokes and found high correlations for male and female for freestyle swimming. The aim of the present research is to determine performance in 100m front crawl swimming through a tethered swimming test of equal duration. It was hypothesized that pulling forces will be highly correlated with 100m front crawl swimming.

Methods

In this study 23 active swimmers of national level participated (age = 15,04±1,6 years, Body height =169,7±8,7 cm and Body mass=62,4±9,7kg) in freestyle swimming. Before the conduction of the measurements, all participants were informed for the purpose of the research and along with their parents, they gave their written consent. This study has the approval of Athens University Ethics committee.

All measurements were conducted during main competition of summer. In the first session, they swam 100 meters front crawl swimming with maximum intensity. Time performance and heart rate were recorded and velocity was afterwards calculated to be used as criterion. In the next session, participants were tested in tethered swimming, in equal time to that they achieved in 100 meters and the characteristics of force were recorded according to the following procedure (Dopsaj, 2000).

Before the test, circumference of left arm biceps bracket in contraction and in relaxation with a tape measure and hand grip strength was tested with a portable dynamometer (Takei 5401 handgrip dynamometer). Afterwards, swimmers warmed up independently with up to 1000 m swimming. After a 10-minute rest, each swimmer put on a belted harness adjusting it to his body dimensions.

Then he hooked a 1cm-thick PVC rope to the belt at the back hip area. The other end of the 5m rope was attached to a water-resistant high-resolution (100 kHz) tensiometric dynamometer placed on a wooden support fixed on the side of the pool. The dynamometer was connected to a PC. fter a 15-seconds trial, at the whistle of the timekeeper, swimmers started tethered swimming (full technique – arms and legs stroke) at maximum intensity. The duration of the test was equal to 100m front crawl time. The raw data were processed by software specially designed by ProIng to analyze the parameters relevant to pulling force. There was the second whistle blow as the signal to stop the measuring. Swimmers were told to follow during the tethered swimming test the breathing pattern they would normally use during a race. All results are expressed as means and standard deviations. Regression analysis was applied for the determination of variables that better describe performance of 100m freestyle swimming, and the prediction of performance in swimming. In addition, Pearson's correlation coefficient was used to calculate the relationships between time in 100m freestyle swimming and force parameters. Statistical significance was set at $p<0.05$. All statistical analysis was conducted with the program SPSS 21.

Results

The descriptive statistics of variables are presented in table 1.

Table 1. Descriptive statistics for measured variables.

Variables	Mean	St.Deviation
Velocity 100m freestyle swimming (m/sec)	1,57	0,15
Maximum Force (Newton)	183,6	51,5
Mean Force (Newton)	72,1	24,7
Minimum Force (Newton)	7,7	5,6
Handgrip Force (Newton)	35,5	9,8
Biceps bracket circumference in contraction (cm)	27,7	2,3
Biceps bracket in relaxation (cm)	30,3	2,5

According to the analysis of results, 100m freestyle swimming velocity was highly correlated with all measured variables apart from minimum force (Table 2).

Table 2. Correlations between variables and 100 m freestyle velocity.

Variables	Pearson's r	Sig
Maximum Force	.734	.000
Mean Force	.679	.000
Minimum Force	.087	.346
Handgrip Force	.714	.000
Biceps bracket circumference in contraction	.613	.001
Biceps bracket in relaxation	.765	.000

Two models occurred from the Multivariate stepwise regression analysis. The first predictive variable that entered in the first step of regression analysis is circumference of biceps in contraction.

According to Table 3, the first prediction model has R^2 =.585, explains 58% of the variance of the criterion variable (velocity of 100m freestyle swimming), ($F_{1,21}$=29,58, Sig=.000). In the second model, two variables were included, circumference of biceps in contraction and mean force, with coefficient R^2 =.702, and explains 70% of the variance of freestyle swimming velocity ($F_{1,20}$=7,84, Sig=.011).

Table 3. Model summary of regression analysis.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig F Change
1	,765	,588	,565	4,2793	,585	29,583	1	21	,000
2	,838	,702	,672	3,7161	,117	7,848	1	20	,011

Predictors: (Constant), CircStr; Predictors: (Constant), CircStr, MeanF; Dependent Variable: time100m.

Discussion

From the regression analysis two prediction models occurred. The variables that better describe velocity of 100m freestyle swimming in this sample of youth swimmers of 15 years are circumference of biceps in contraction and mean force. Concerning force parameters, only Mean force entered the second prediction model. These finding are in accordance with previous studies. Loturco et al. (2015) found that 100m freestyle swimming is highly correlated with Maximum force and Mean force (coefficients of correlation: .74 and .67 respectively).

Another study of Morouco et al. (2015) concerning performance time of 50m, studied the force of hands, of legs and full stroke force and concluded that Maximum force of hands is highly correlated with velocity in 50m freestyle swimming for male, and that Mean force of full stroke is highly correlated with 50m velocity for female. In a study of Barbosa et al. (2010), 50m breastroke swimming velocity was highly correlated with Mean force. Morouco, Villas Boas and Fernandes (2012) found that velocity of 100m freestyle swimming is highly correlated with Max force and Mean force (coefficients of correlation .83 and .83 respectively). In another study of Morouco et al., (2011) the correlation between Mean force and 100m freestyle velocity was higher in relation to Max force (.91 and .77 respectively, p<0.01), as well as relative Mean force (.82, p<0.01). According to Gourgoulis et al (2010), the positive relationship of upper body strength and swimming performance has been confirmed by Hawley et al 2002; Sharp, Troup & Costill 1982; Smith, Norris & amp; Hogg 2000. Contrary to previous studies, handgrip strength did not enter any of the prediction models. However, it was highly correlated with velocity of 100m freestyle swimming (r: .714, p. .05). The first prediction model that occurred from the analysis included the variable circumference of biceps in contraction. A study of Moura dos Santos et al. (2012) found that arm muscle area (cm^2), is highly correlated with arm force in swimming.

Conclusion

The findings of this research confirm the importance of tethered swimming in swimming training process and the help researches and coaches clarify the most important factors that describe performance in sprint swimming. The significance of Mean force and Max force in swimming as well as Biceps bracket circumference corroborate the need of specific and oriented strength training during training season.

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Received: June 5, 2018
Accepted: June 15, 2018
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