A model for assessing the effectiveness of swimming technique in the training of young sprint swimmers

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Abstract

Objective of the study is to develop a model of swimming technique based on anthropometric factors, strength, power and the kinematic characteristics of young swimmers.

Methods and structure of the study. The study involved 24 young male swimmers aged 12.5±0.9 years, with 3.5 years' experience in competitive swimming, who regularly participate in regional competitions. A factor model of swimming technique effectiveness has been developed, taking into account current data on the factors determining the performance of young swimmers during the training phase of their preparation.

Results and conclusions. The factor model of swimming technique efficiency includes variables relating to total force, hydrodynamic power and the kinematic efficiency of the stroke, which account for 68.7% of the performance of young swimmers.

Keywords: *training phase, performance indicators, swimmers, anthropometry, kinematic characteristics.*

Introduction. Most studies on the athletic performance of swimmers are based on the development and validation of correlation and regression models of the training process. This provides insight only into the degree of association between training stimuli and training outcomes, without revealing the mechanisms by which training factors exert their effects. The method of proof in studying the phenomena of adaptation to training load involves calculating the coefficients of equations describing functional relationships.

Previous studies have identified a positive and significant correlation between elbow extension strength and push-off force in the final phase of the stroke. It has also been demonstrated that, compared to training conducted solely in the pool, an integrated programme of strength training on land and in water significantly improves the performance of young swimmers.

When developing specifically targeted training methods, it is assumed that swimming technique depends on the level of muscle strength development and, consequently, influences the improvement of competitive performance. Despite the apparent validity of this assumption, there is as yet no formalised evidence for this hypothesis in the literature. On the one hand, improvements in strength and power appear to be associated with increased performance; however, there is a lack of comprehensive knowledge regarding the interrelationships between the characteristics under investigation and their quantitative contribution to competitive results.

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The sporting result of the main competitive event, the 100 m freestyle, was selected as the criterion for the effectiveness of the training process and, consequently, as the dependent variable.

Hydrodynamic power in water, strength and power on land, as well as kinematic and anthropometric characteristics, were measured.

Hydrodynamic swimming power Ps was selected as the independent variable; to assess this, active resistance (Ra) was first calculated using the velocity perturbation method [3]. Each swimmer swam two 25-metre freestyle laps at maximum speed, both with and without an additional hydrodynamic body. Ra was calculated using the formula:

$Ra = R_b v_b v^2/v^3 - v_b^3$, where R_a (N) is the active drag on the swimmers at maximum speed, R_b (N) is the drag on the additional hydrodynamic body with a predetermined drag coefficient, and v_b and v (m/s) are the swimming speeds with and without the additional hydrodynamic body.

The value of Ps was calculated using the formula [5]:

$P_s = D_a \times v$, (2)

where P_s is the hydrodynamic power required to overcome drag (W); Da is the active drag (N); v is the speed (m/s).

Strength and power on land were measured during a medicine ball throw (weighing 1 kg and with a circumference of 0.72 m) over the head. A Doppler radar with an accuracy of ±0.04 m/s within a 12° field of view from the device was used to measure the throw velocity. The radar was positioned 1 m behind the athlete at the height of the protruding part.

Forearm flexion strength was measured using a seated barbell lift test, with the barbell raised to the point where the elbows were bent.

The kinematic parameters selected for measurement were 25 m swimming speed and stroke efficiency. Each swimmer performed three 25-metre freestyle heats at maximum speed. Between heats, the swimmers rested for 30 minutes to allow for full recovery. The average value of the three heats was used for analysis.

A speedometer cable was attached to the swimmer's belt. A 12-bit resolution data acquisition board was used to transmit data (f = 50 Hz) from the speedometer to the software interface. The data was exported to signal processing software and filtered using a low-pass filter with a cut-off frequency of 5 Hz. Swimming speed (v) was calculated over an average of 15 m (between 5 and 20 m) using the formula: v = d/t, where v is the average swimming speed (m/s), d is the distance covered (m), and t is the time taken (s).

Stroke efficiency was estimated using the formula [7]:

$\eta p = 0.9v \times SF \times k \times 100$,

where ηp is stroke efficiency (%), v is speed (m/s), SF is the stroke rate (Hz), k (cm) is the distance between the shoulder and the tip of the third finger during the forward stroke phase, measured using a tape measure whilst simulating the stroke cycle on land. Arm span was measured whilst the subject was in an upright standing position with arms fully extended and fingers abducted at a 90° angle to the torso. The distance between the tips of the third fingers was measured.

Standardised regression coefficients (b) were examined, and the significance of each was assessed using Student's t-test ($p<0.05$).

Results of the study and discussion. The highest variance was observed in the swimming power metrics, whilst the lowest was found in the arm stroke metrics. Overall, all determinants except one showed a moderate or high significant correlation with competitive performance ($p<0.05$) (Table 1).

The development of a factor model to enhance the performance of young swimmers, based on the improvement of specific kinematic and hydrodynamic characteristics, showed that all factors in the training model have a significant impact on sporting performance, collectively accounting for 69% of the contribution to competitive results.

The mean values fall within the confidence in-

Table 1. Statistical indicators and correlation coefficients (r) between the variables under study and sporting performance

Indicator	x ± SD	σ²	r	p
100 m swim, s	71,2±8,8	37,5	-	-
Arm stroke length, cm	162,8± 23,6	23,7	0,542	< 0,05
Forearm flexion strength, kg	7,3±0,6	0,9	0,645	< 0,05
Ball velocity, m/s	6,7±0,3	1,6	0,398	< 0,05
Power, W	72,7±4,6	221,8	0,563	< 0,05
25 m swim, m/s	1,4±0,2	0,62	0,817	< 0,05
Stroke efficiency, %	28,8±3,2	16,4	0,481	< 0,05

tervals reported in the scientific literature for swimmers of the corresponding age group and fitness level. Correlation coefficients revealed significant relationships between swimming performance and all selected independent variables, with correlation strengths ranging from moderate to high.

It was established that conducting combined training on land and in the water contributed to an improvement in the results of young swimmers.

In the constructed factor model, the characteristics of ball flight speed during a throw, swimming power, swimming speed and stroke efficiency are predictive factors of swimming performance. Ball flight speed had a positive influence on swimming power, which in turn influenced swimming speed and stroke efficiency.

Using telemetry methods, a high correlation was established between arm span and forearm flexion strength ($r=0.73$; $p \leq 0.05$). Consequently, it was hypothesised that arm span would have a positive and significant effect on the flight speed of the medicine ball during a throw. However, no data were found in the literature regarding the relationship between arm swing and upper limb strength in young swimmers. Therefore, removing the factor relating arm swing to forearm flexion strength improved the fit of the factor model of young swimmers' fitness.

It was hypothesised that the strength and power demonstrated on land are related to the strength and power demonstrated in water. Although the strength-power relationship is not significant ($=0.23$; $p>0.05$), the force developed during a medicine ball throw explains 91.6% of hydrodynamic power. It was also suggested that greater force is associated with higher generation of propulsive force and output power in water. Total force accounts for 59.3% and 85.1% of the medicine ball's flight speed during an overhead throw and the level of hydrodynamic power, respectively, and is a significant factor in relation to swimming speed ($\beta = 0.61$; $p < 0.05$). Overall, swimmers demonstrating the greatest strength are both efficient (achieving higher swimming speed) and economical (developing greater hydrodynamic power), which enables them to achieve better results in swimming.

Both factors – power and strength on land and in water – had a significant influence on swimming technique. Therefore, the combined development of specific physical qualities and work on swimming technique will enable young swimmers to develop strength and refine the kinematic component of their stroke, and consequently improve their performance.

Conclusions. A factor model of swimming technique efficiency includes variables relating to total force, hydrodynamic power and stroke kinematic efficiency, which account for 68.7% of young swimmers' performance. The level of general strength development has a positive and significant influence on hydrodynamic power in the water and stroke kinematics, which ultimately improves sporting performance. Although anthropometric data were not included in the factor model, they demonstrated a significant contribution to the kinematic determinants that underpin the competitive success of young swimmers.

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