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LINKING SELECTED VARIABLES WITH DIRECT AND INDIRECT EFFECT ON YOUNG SWIMMER'S PERFORMANCE

INTRODUCTION

One of the main goals of swimming research is to identify the scientific domains and/or variables that predict swimming performance in children (i.e., young athletes) in the perspective of detecting future talents (1). Nevertheless, research in young athletes should be less invasive, expensive and time-consuming than in adult/elite counterparts (2). In this sense, several authors (2-4) on regular basis estimate and/or measure variables in different scientific domains (i.e., anthropometric, hydrodynamic, kinematical and energetic) that are easy to collect and might predict performance and/or detect talented swimmers.

Based on this rational, it seems that the kinematical variables are the ones that better explained young swimmers' performance (4). During growth and maturation processes, anthropometric variables are related with swimming performance in young athletes as well (1). The arm span (AS), seems to be a major swimming performance determinant since it is correlated with stroking mechanics, namely the stroke length (SL) and the stroke index (SI) (5). Moreover, hydrodynamic variables also play an important role on swimming performance (3).

The understanding of the relationships between human morphology and hydrodynamic resistance allows coaches to modify stroke mechanics in order to enhance performance (6).

A confirmatory model of such relationships, based on the existing exploratory research reported in the main literature, can be useful not only to prescribe appropriate periodization programs and training sets for young swimmers, but also to promote feasible and effective programs to detect and to select talents in competitive swimming.

The aim of this study was to develop a structural equation model for performance in young swimmers based on some selected kinematical, anthropometric and hydrodynamic variables. It was hypothesized that swimming performance in young swimmers might be related with these variables. The swimming performance is mainly related to swimming efficiency and this one to several kinematical, anthropometric and hydrodynamic variables.

METHODS

A total of 114 (73 boys and 41 girls) young swimmers with a chronological age of 12.31 ± 1.09 years old (47.91 ± 10.81 kg of body mass; 156.57 ± 10.90 cm of height and Tanner stages 1-2 assessed by self evaluation) participating on regular basis in regional and national level competitions volunteered as subjects.

METHODS

Figure 1 presents the theoretical model adopted for swimming performance based on selected kinematical, anthropometric and hydrodynamic variables in young swimmers.

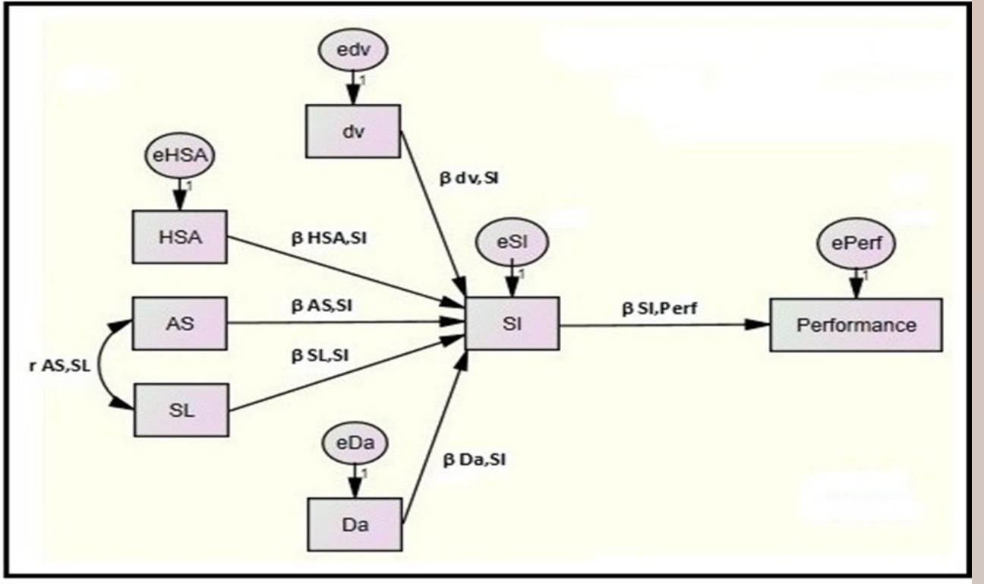

Figure 1 Theoretical model.

Performance data collection
Swimming performance was assessed by time lists of the 100 [m] freestyle event in short course competitions (i.e., 25 [m] swimming pool) at local, regional or national level competitions.

Anthropometric data collection

The anthropometric variables selected for the path-flow model were the arm span (AS) and the hand surface area (HSA). For AS assessment, subjects were in an orthostatic position, with both arms in lateral abduction at a 90º angle with the trunk. Both arms and fingers were fully extended. It was measured the distance between the tip of each third finger with a flexible anthropometric tape (RossCraft, Canada).

For HSA measurement, swimmers put their dominant hand on the scan surface of a copy machine with fingers in the position they usually adopt while swimming. In the scan surface there was also a 2D calibration frame. Thereafter, the perimeter of the HSA was digitalized in the Xerox machine (Xerox 4110, Norwalk, Connecticut, USA) and files were converted in *.pdf format. Hand surface area was afterward computed with a specific software (Universal Desktop Ruler, v3.3.3268, AVPSoft, USA). The measurement procedures were: (i) scale calibration; (ii) digitalization of hand surface perimeter and; (iii) compute and record of HSA value (7).

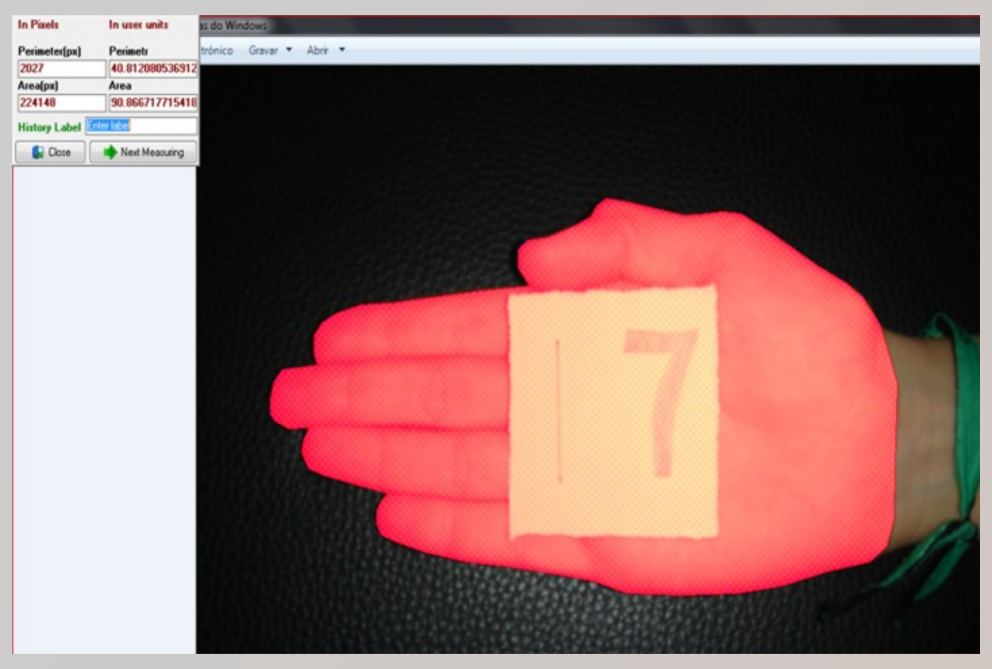

Figure 2 Hand surface area measurement.

Biomechanical data collection
Speed fluctuation (*dv*), SL and SI were selected as kinematical variables. Each swimmer performed three bouts of 25 [m] at freestyle with underwater start. For further analysis it was computed the mean value of the three repetitions

METHODS

To assess *dv* a speedo-meter cable (Swim speedo-meter, Swimsportec, Hildesheim, Germany) was attached to the swimmers' hip (Figure 3) and the bio-signal was acquired on-line at a sampling rate of 50 [Hz]. Software's interface in LabVIEW® (v. 2009) was used to acquire, to display and to process pair wises velocity-time data on-line during the swim bout. To transfer data from the speedo-meter to the software application it was used a 12-bit resolution acquisition card (USB-6008, National Instruments, Austin, Texas, USA) (8).

Figure 3 Speedo-meter apparatus.

Speed fluctuation was computed as (9):

$$dv = \frac{\sqrt{\sum_i (v_i - \bar{v})^2 F_i / n}}{\sum_i v_i F_i / n}$$

Where *dv* represents speed fluctuation [dimensionless], *v* represents the mean swimming velocity in [m·s^{-1}], v_i represents the instant swimming velocity in [m·s^{-1}], F_i represents the absolute frequency and *n* represents the number of observations.

Stroke length was computed as (10):

$$SL = \frac{\bar{v}}{SF}$$

Where *SL* represents stroke length in [m], *v* represents the mean swimming velocity in [m·s^{-1}] and *SF* represents the stroke frequency in [Hz].

Stroke index was also computed as a swim efficiency estimator (11):

$$SI = SL \cdot \bar{v}$$

Where *SI* represents stroke index in [m^2·c^{-1}·s^{-1}], *SL* represents stroke length in [m] and *v* is the mean swimming velocity in [m·s^{-1}].

Hydrodynamic data collection
Each swimmer performed two maximal 25 [m] bouts. One without the perturbation device and other with the perturbation device. Swimming velocity was assessed during 13 [m] (between 11th [m] and 24th [m] from the starting wall).

Active drag was calculated as (12):

$$D_a = \frac{D_b v_b v^2}{v^3 - v_b^3}$$

Where D_a represents the swimmer's active drag at maximal velocity in [N], D_b is the resistance of the perturbation buoy in [N] and, v_b and *v* are the swimming velocities with and without the perturbation device in [m·s^{-1}], respectively.

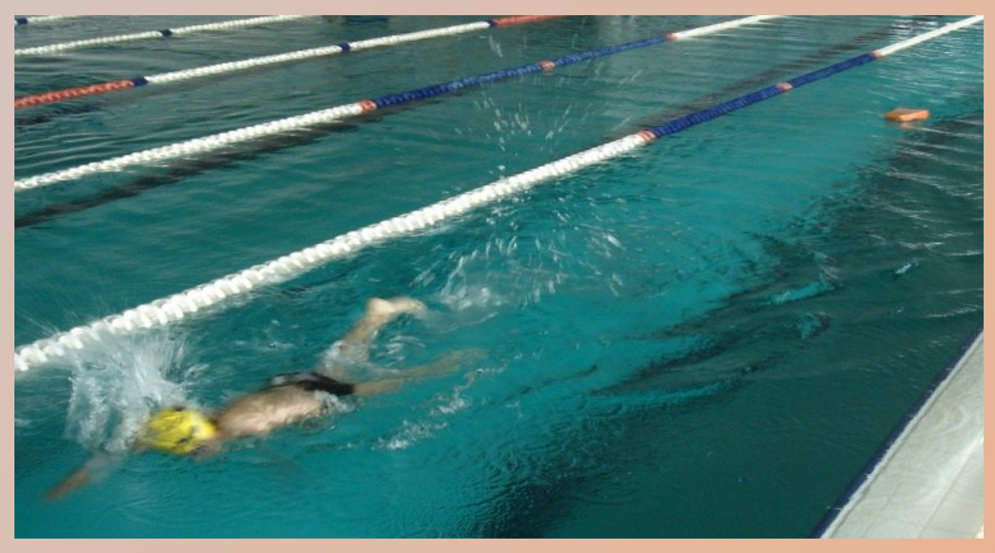

Figure 4 Active drag measurement.

RESULTS AND DISCUSSION

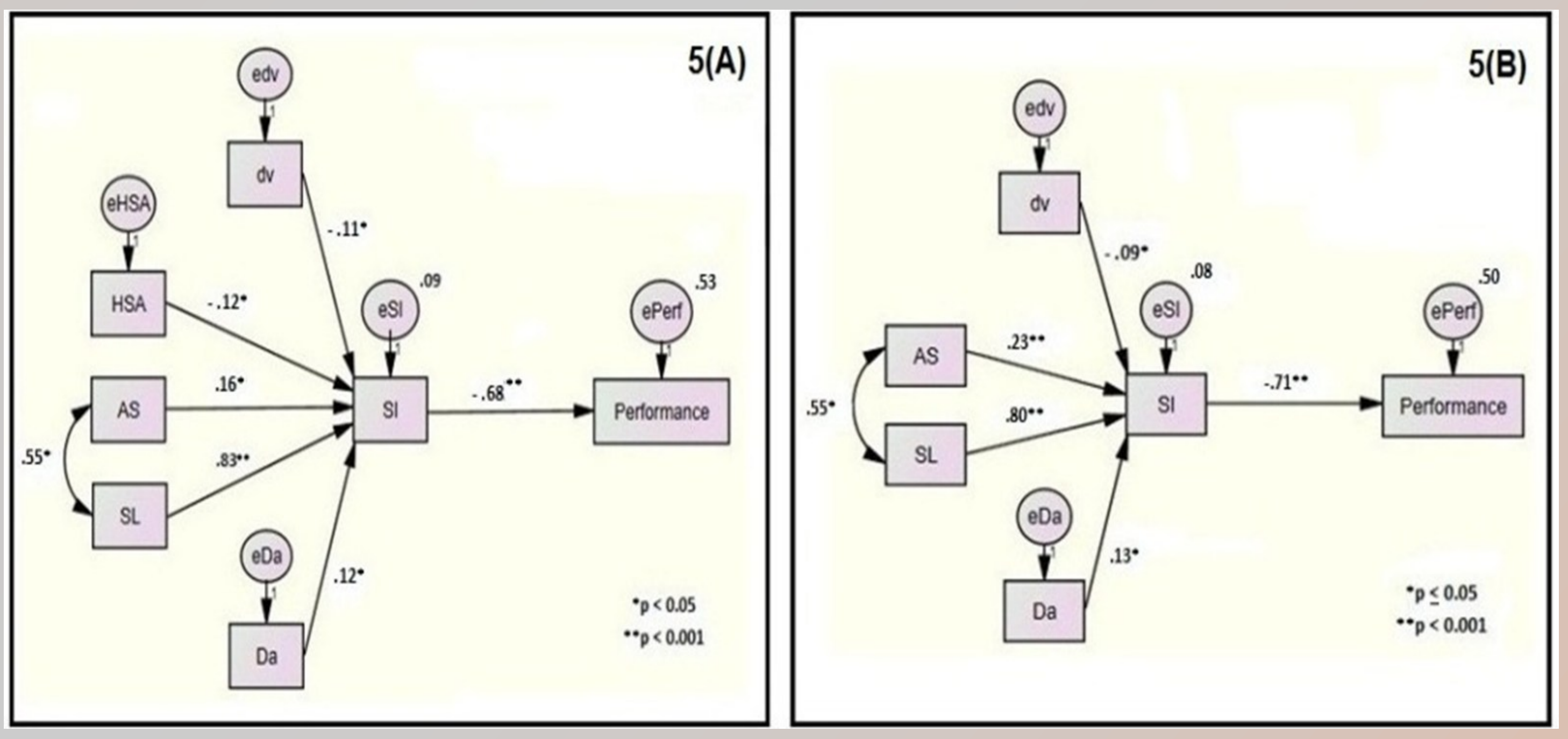

Figure 5 Confirmatory path-flow model including all variables computed (5A) and deleting variable that allowed to reduce the residual error (5B).

The first confirmatory model (Figure 5A), including the HSA linked to SI, had a bad adjustment. Some studies suggested a relationship between hand's shape (i.e., hand's length) with swimming efficiency or at least its thrust (13). The second confirmatory model (Figure 5B) removed the HSA-SI link presenting two hierarchical levels, and increased the model's good-of-fit (i.e., good adjustment).

The second level it is the relationship between the SI and remaining kinematical, anthropometric and hydrodynamic variables selected. The SI is considered a feasible variable to estimate the overall swimming efficiency (12). The capacity to cover a given distance (i.e., SL) with faster velocity represents an increased swimming efficiency. The variables maintained in the final confirmatory model (i.e., AS, SL, *dv* and D_a) had a very high capability to predict SI (r^2 = 92%). From those variables, the SL was the one with the higher standardized direct effect to SI ($\beta = 0.80$, $p < 0.001$).

The final confirmatory first level included the SI-performance relationship. The SI had a moderate-high standardized direct effect to performance ($\beta = -0.71$, $p < 0.001$). The biomechanical domain and its determinants had a good prediction of the performance (r^2 = 50%).

So, it can be speculated that remaining 30% might be explained by energetics, which was not considered now.

Therefore, for young swimmers, probably biomechanics have a higher performance prediction power than energetics. The technique should be the core of the training program at these ages. So, young swimmers coaches should design training programs focusing on the improvement of the swimming technique.

CONCLUSION

The final confirmatory model explained significantly young swimmers' performance with a good adjustment.

Arm span is associated with SL, and these ones plus D_a and *dv* determine SI. Increasing SI imposes an increase in swimming performance.

On the other hand, swimming efficiency improvement is related to a decrease in the *dv*, and an increase of the SL and AS. However, the increase of the D_a is the result of the increase of the swimming velocity.

Therefore, young swimmers coaches should put the focus of training sessions in the technical enhancement. Increase of the swimming efficiency (i.e., improving the swim technique) leads to a performance enhancement.

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