Preliminary Attempt to Develop a Path-Flow Analysis Model for Swimming Performance in Children

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Abstract: The aim of this research was to develop a path-flow analysis model from age-group swimmer's performance based on biomechanical and energetic parameters. Twenty two young male age-group swimmers with several competitive levels volunteered to serve as subjects. It was assessed swim velocity, stroke length, stroke frequency, stroke index, propulsive efficiency, critical velocity and 200 m freestyle event performance. To verify the quality of the model, root mean square residuals (RMSR) was computed. The confirmatory model explained 54% of swimming performance. RMSR was 0.064. As a conclusion, the model based in biomechanical and energetic variables, according to the relationships suggested is appropriated to explain performance in age-group swimmers.

Keywords: Swimming, young swimmers, performance, biomechanics, energetics.

INTRODUCTION

The goal of competitive swimming is to travel the event distance as fast as possible. The identification of the parameters that predict swimming performances is one of the main aims of the swimming "science" community. Indeed, it is consensual that biomechanical and energetic variables are determinant for performance in this sport. Several research groups dedicate their attention to the relationships establish between biomechanical and energetic variables on adult swimmers, with special emphasis on elite adult swimmers. However, several parameters often assessed in adult swimmers are not able to be used in age-groups due to several reasons. Even so, on regular basis, age-group coaches also do biomechanical and energetic assessments but that are less expensive, evasive or complex. Nevertheless, the understanding of the relationships establish between these domains in age-group swimming is not fully understood (e.g. [1]).

The aim of this research was to develop a path-flow analysis model from age-group swimmer's performance based on biomechanical and energetic parameters. The theoretical model was developed according to main review papers about these relationships (e.g. [2]) and the age-group coach's assessments, being presented in Fig. (**1**).

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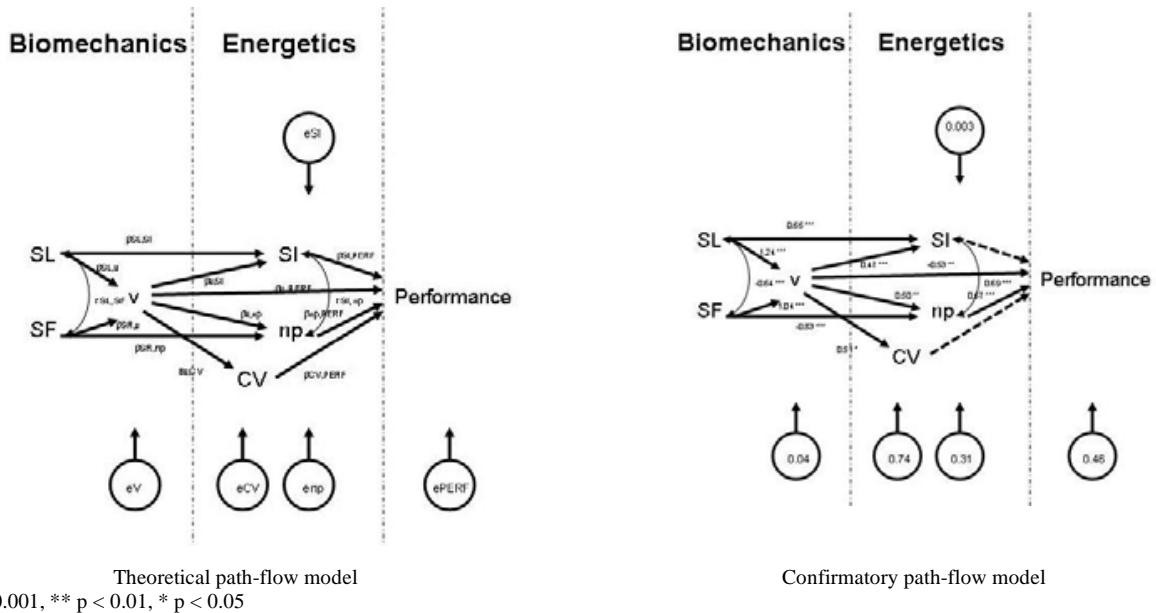
METHODS

Subjects

Twenty two male age-group swimmers with several competitive levels volunteered to serve as subjects (12.67 ± 0.49 years old; 1.56 ± 0.08 m of height; 46.08 ± 7.14 kg of body mass; 16.38 ± 5.77 % fat mass; Tanner stages 1-2). Parents and coaches gave their consent for the swimmers participate in this study. All procedures were in accordance to the Declaration of Helsinki in respect to Human research.

Data Collection

Each swimmer made a maximal 25-m swim with an underwater start. The swimmers were advised to reduce gliding during the start. Swimming velocity was measured in the middle 15-m as:

$$\bar{v} = \frac{d}{t} \tag{1}$$

Where v is the mean swimming velocity, d the distance covered by the swimmer, t the time spent to cover such distance and measured with a chronometer by an expert evaluator. The stroke frequency (SF) was measured with a crono-frequency meter from 3 consecutive stroke cycles, in the middle of the 15-m distance by an expert evaluator as well. Stroke length was estimated as [3]:

$$SL = \frac{\bar{v}}{SF} \tag{2}$$

Theoretical path-flow model

*** p < 0.001, ** p < 0.01, * p < 0.05

Confirmatory path-flow model

Fig. (1). Theoretical and confirmatory path-flow models.

Stroke index (SI) considered as a swim stroke efficiency index was computed [4]:

$$SI = SL \cdot \bar{v} \tag{3}$$

Propulsive efficiency (ηp) was also estimated [5]:

$$\eta_p = \left(\frac{v \cdot 0.9}{2\pi \cdot SF \cdot l} \right) \cdot \frac{2}{\pi} \tag{4}$$

Where *v* is the swim velocity, *SF is* the stroke frequency and *l* is the arm's length.

Critical velocity (CV) was computed based on the swimmers curriculum [6] on the 200 m and 800 m freestyle short course events. The *CV* was calculated using the slope of the simple linear regression model, plotting the swimming performances over the time and determined by:

$$d = a.t + b \tag{5}$$

Where *d* is the distance of the swim event, *a* is the slope of the fit line, *t* is the time spent to cover the distance and *b* the y- interception in the origin of the *xx* axis.

Swimming performance was assessed by the 200 m freestyle event in official short course competition. Time gap between biomechanical plus energetic assessments and swim performance were made in no more than two weeks.

Statistical Procedures

The normality of the distributions was evaluated with the Shapiro-Wilk test. Descriptive statistics (mean±1SD) from all variables were calculated.

Path-flow analysis was performed with the estimation of linear regression standardized coefficients between the exogenous and endogenous variables. All assumptions to per-

form the path-flow analysis were taken into account. When appropriate, according to the theoretical model, simple or multiple linear regression models were computed. Standardized regression coefficients (β) were considered. Significance of each β was assessed with the t-Student test (p < 0.05). The effect size of the disturbance term, reflecting unmeasured variables, for a given endogenous variable, was $1-R^2$.

To verify the quality of the model, root mean square residuals (RMSR) was computed:

$$RMSR = \sqrt{ \frac{\sum\limits_{i=1}^{p} \sum\limits_{i=1}^{q} (rij - pij)^2}{p + q} } \tag{6}$$

Where *r* is the Pearson correlation coefficients and *p* the correlation predicted by the model (based in total effect, i.e., the addiction of the direct and indirect effects plus spurious effects). Qualitatively, it is considered that if: (i) RMSR < 0.1 the model adjust to the theory; (ii) RMSR < 0.05 the model adjusts very well to the theory and; (iii) RMSR ~ 0 the model is perfect.

RESULTS AND DISCUSSION

Table **1** presents descriptive statistics from all variables studied. Mean data values are somewhat within the range of values reported in the literature for swimmers with similar chronological age and gender (e.g. [7-9]). Data dispersion, expressed as 1*SD,* was moderate-high for almost every variable. This same idea can be supported analyzing the range values.

Fig. (**1**) presents the theoretical and confirmatory path-flows for age-group swimmer's performance. Almost every partial relationship confirmed the hypothesis. The only ex-

Table 1.   Descriptive Statistics of Biomechanical Variables, Energetic Variables and Swim Performance

	Mean	Standard Deviation	Min	Max
SL (m)	1.62	0.19	1.25	2.14
SF (Hz)	0.90	0.08	0.69	1.03
v (m.s^{-1})	1.45	0.11	1.20	1.69
SI (m^2.c^{-1}.s^{-1})	2.37	0.40	1.60	3.16
ηp (%)	24.07	5.25	17.27	34.93
CV (m.s^{-1})	1.08	0.11	0.87	1.26
200 m freestyle (s)	157.20	17.41	136.12	206.27

ception was the relationship between ηp and performance (β=0.67), as it is considered in the literature that best performances are achieved in most efficient subjects [5]. *CV* and *SI* did not include the final model as t-Student test was not-significant. New studies should focus in these phenomenons to clear out data reported here. The confirmatory model explained 54% of swimming performance. So, the correlation coefficient was 0.73, meaning qualitatively a high prediction. RMSR was 0.064. In this sense, the confirmatory path-flow model can be considered suitable of the theory presented. Although the model is appropriate, it do not explains 46% of the swim performance. Swimming performance is a multifactorial phenomenon, where e.g. psychological, anthropometrical, genetic, motor control or environmental aspects also play a significant role (e.g. [10]) and were not included in this model. Moreover, there are as well biomechanical and energetic variables that were not inserted, such as speed fluctuation, segmental velocities', energy cost or energy expenditure [2] since they are less suitable to be used with age-group swimmers.

As a conclusion, the model based in biomechanical and energetic variables, according to the relationships suggested is appropriated to explain performance in age-group swimmers. Nevertheless, the model should be expanded, including other variables in order to increase the prediction level of the swimming performance.

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