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# PATH-FLOW ANALYSIS MODEL FOR ANTHROPOMETRIC, HYDRODYNAMIC AND BIOMECHANICAL VARIABLES IN AGE-GROUP SWIMMERS

## 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 enhance performance (Barbosa et al, in press). Added to this, there are also anthropometrical and hydrodynamic variables that are often reported as being related to swimming performance. Indeed, several research groups dedicate their attention to the relationships establish between all these domain and performance but, 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 biomechanics, anthropometric and hydrodynamic assessments but with less expensive, evasive or complex procedures. Moreover, the understanding of the relationships establish between these domains in age-group swimming is not fully understood (e.g. Jurimae et al., 2007). Namely, how these variables interplay among themselves.

The aim of this research was to develop a path-flow analysis model of age-group swimmer's performance based on anthropometric, hydrodynamic and biomechanical parameters. The theoretical model was developed according to main review papers about these relationships (e.g. Lavoie and Montpetit, 1986; Barbosa et al., in press) and the age-group coach's assessments. The theoretical model designed is presented in figure 1.

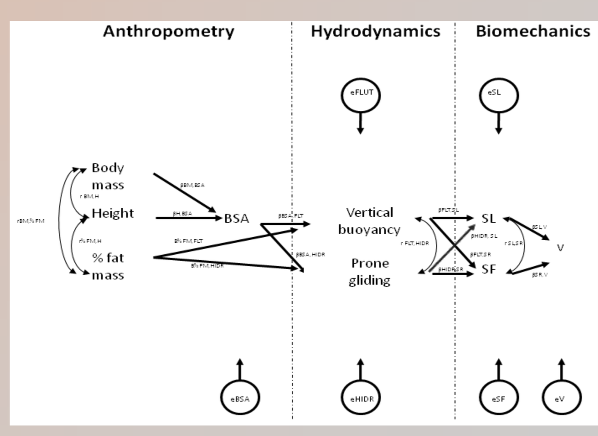



Figure 1. Theoretical path-flow model.

## METHODS

**Subjects.** Thirty eight male swimmers (12.97 ± 1.05 years-old; Tanner stages 1-2) with several competitive levels were evaluated. Parents and coaches gave their consent for the swimmers participation in this study. All procedures were in accordance to the Declaration of Helsinki in respect to Human research.

**Data collection.** For anthropometrical assessment it was recorded the body mass (SECA, 884, Hamburg, Germany), height (SECA, 242, Hamburg, Germany), fat mass (Tanita, BC-545, Middlesex, UK) and body surface area, this last one as (Haycock et al., 1978):

$$BSA = BM0.5378 \times H0.3964 \times 0.024265 \qquad (1)$$

Where *BM* is the body mass in [kg] and *H* is the height in [cm].

The hydrodynamic variables assessed were the vertical buoyancy and the prone gliding after wall push-off (Costa et al., 2009). For vertical buoyancy it was asked for the swimmer be in the vertical position on a 2.20-m deep pool, arms close to the trunk, without any movement. It was given a discrete value if the water surface was at the neck (5 arbitrary units), mouth (4 arbitrary units), nose (3 arbitrary units), eyes (2 arbitrary units) and vertex (1 arbitrary units). Prone gliding was measured by the maximum horizontal distance achieved by the swimmer in ventral gliding, after a wall push-off.

For biomechanical assessment it was measured the swimming velocity, stroke frequency and stroke length. 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:

$$\bar{v} = \frac{d}{t} \qquad (2)$$

Where *v* is the mean swimming velocity in [$m.s^{-1}$], *d* the distance covered by the swimmer in [m], *t* the time spent to cover such distance in [s] measured with a chronometer by an expert evaluator. The stroke frequency (SF) was measured with a chronofrequency meter from 3 consecutive stroke cycles, in the middle of the 15-m distance by an expert evaluator as well. Stroke length in [m] was estimated as (Craig and Pendergast, 1979):

$$SL = \frac{\bar{v}}{SF} \qquad (3)$$

## METHODS

**Statistical procedures.** The normality of the distributions were evaluated with the Shapiro-Wilk test. Descriptive statistics (mean, one standard deviation, minimum, maximum) from all variables were calculated.

Path-flow analysis was performed with the estimation of 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:

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

Where *r* is the Pearson correlation coefficients and *p* the correlation predicted by the model (based on 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. Grecco et al., 2005; Jurimae et al., 2007; Schidt and Ungerechts, 2008). Data dispersion, expressed as 1*SD,* was moderate-high for almost every variable. This same idea can be supported analyzing the range values.

Table 1. Descriptive statistics of biomechanical variables, energetic variables and swim performance.

| | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|
| Body mass (kg) | 50.4 | 13.3 | 32.3 | 68,6 |
| Height (m) | 1.59 | 0.12 | 1.36 | 1.68 |
| Fat mass (%) | 14.9 | 4.95 | 7.7 | 28.2 |
| BSA ($m^2$) | 1.49 | 0.23 | 1.16 | 2.02 |
| Vertical buoyancy (a.u.) | 1.31 | 0.52 | 1.00 | 3.00 |
| Prone gliding (m) | 6.81 | 0.79 | 5.50 | 8.20 |
| SL (m) | 1.64 | 0.20 | 1.25 | 2.14 |
| SF (Hz) | 0.89 | 0.08 | 0.69 | 1.03 |
| v ($m.s^{-1}$) | 1.46 | 0.13 | 1.15 | 1.69 |

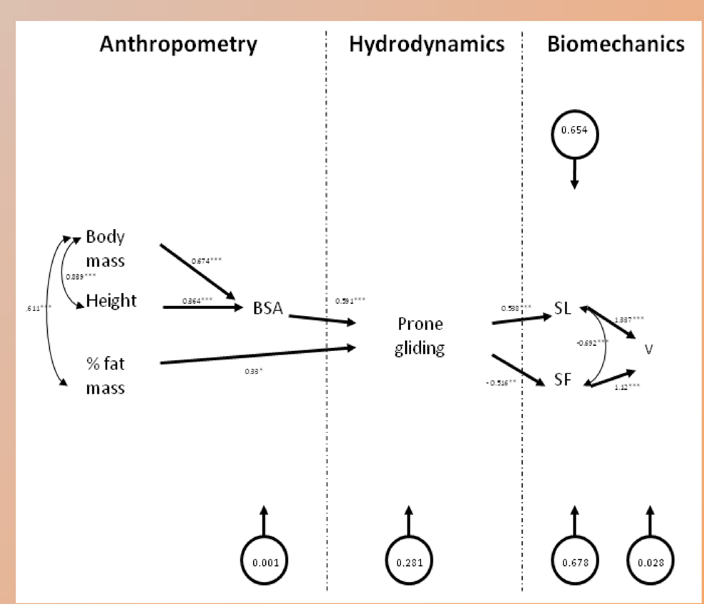
Figure 2 presents the confirmatory path-flows model.

A couple of partial relationship (i.e., theoretical (6)paths) did not confirmed the hypothesis. The confirmatory model excluded the vertical buoyancy and the relationship between height and fat mass.

The *v* had a 97.2 % capability to be predicted based on the *SF* and the *SL*. Such relationship it is consensual in the literature (e.g., Barbosa et al., in press). However, only 32.2% from the *SF* and 34.6 % of the *SL* were predicted based on the prone gliding. This means that some hydrodynamic latent variables that it were not included in the model might have a determinant influence in both biomechanical variables. It might be suggested to insert new hydrodynamic variables, such as frontal surface area, projected frontal area, active drag or passive drag. Although these last ones are less able to be used on regular basis by practitioners.

Moreover, it can be discussed if the prone gliding and the vertical buoyancy variables are actually the most valid ways to assess the swimmers hydrodynamic profile. E.g., prone gliding seems to be dependent not only from the hydrodynamic body position, but as well, from the power developed during the wall push-off. It was hypothesized that vertical buoyancy would be related to fat mass. However, lungs volume, vital capacity, residual volume, tidal volume, etc. might also have a significant influence.

Confirmatory path-flow model can be considered as being close to the RMSR milestone. Even so, the model is not suitable of the theory (RMSR = 0.11). Vertical buoyancy path deleting had a huge impact in the *RMSR*, increasing its value.




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

Figure 2. Confirmatory path-flow model.

## CONCLUSION

As a conclusion, the model based on anthropometric, hydrodynamic and biomechanical variables, according to the relationships suggested was not appropriated to explain performance in age-group swimmers. New studies should focus in these phenomenon to clear out data reported here. The model should include other variables (mainly hydrodynamic ones) in order to increase the prediction level.

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# EXERCITAÇÃO DA PAREDE ABDOMINAL EM SUPERFÍCIES INSTÁVEIS: ADAPTAÇÕES ELECTROMIOGRÁFICAS E CINEMÁTICAS



## RESULTS AND DISCUS-SION

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Agradecimentos

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