A SWIMMER’S CLASSIFICATION SYSTEM BASED IN KINEMATICS, ANTHROPOMETRICS AND HYDRODYNAMICS

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SUMMARY
The aim of this paper was to identify active drag determinants and classify swimmers based on such features. 67 young swimmers made a maximal 25m Front-Crawl to measure with a speedo-meter the swimming velocity (v), speed-fluctuation (dv) and dv normalized to v (dv/v). Another two 25m bouts with and without a perturbation device were made to estimate active drag coefficient (C_{Da}). Trunk transverse surface area (S) was measured with photogrammetric technique on-land and in the hydrodynamic position. Cluster 1 was related to swimmers with a high speed fluctuation (i.e., dv and dv/v). Cluster 2 was characterized by the anthropometrics (i.e., S). Cluster 3 was associated with the high hydrodynamic profile (i.e., C_{Da}). The variable that seems to discriminate better the clusters was the dv/v (F=53.680; P<0.001), followed by the dv (F=28.506; P<0.001), C_{Da} (F=21.025; P<0.001), S (F=6.297; P<0.01) and v (F=5.375; P=0.01). Stepwise discriminant analysis extracted 2 functions. Function 1 was mainly defined by dv/v and S (74.3% of variance), while Function 2 was mainly defined by C_{Da} (25.7% of variance). So, it can be concluded that kinematics, anthropometrics and hydrodynamic features are determinant domains to classify and characterize swimmers’ profiles.

INTRODUCTION
Swimming is characterized as being an accelerated motion, where the changes in the acceleration within the stroke cycle can be assessed through the body’s intra-cyclic variations of the horizontal velocity (dv). So, Newtonian law:

\[ a = \frac{F}{m} \]

Where F is the resultant force, m is the body mass and a is the acceleration; can be changed to change:

\[ dv = \frac{Pr+D}{m} \]

Where dv is the speed-fluctuation, Pr is the total propulsive forces, D is the drag force, m is the swimmer’s body mass. It is the resultant vector sum of Pr by D that play a main part in the dv throughout the swim, as m is fairly constant (neglecting the added mass that a swimmer carries out; to be strict: m=body mass+added water mass). While actively swimming, D is also a Newtonian force computed as:

\[ D_a = \frac{1}{2} \rho \cdot v^2 \cdot S \cdot C_{Da} \]

Where \( D_a \) is the swimmer’s active drag, \( \rho \) is the density of the water, \( v \) is the swimmer’s velocity and \( S \) is his/her projected frontal surface area. From equation 2 and 3 becomes a theoretical relationship between kinematics (e.g. dv and v) with hydrodynamics (e.g. C_{Da}) and anthropometrics (e.g., S). However, human beings while performing a motor task (in this case swimming) can select different approaches to reach a same outcome, as they might be considered “over-determinate” systems. For the case of the \( D_a \), probably different swimmers also adopt different approaches, changing its determinant variables to reach a given force intensity as well.

The aim of this paper was to identify active drag determinants and classify young swimmers based on such features.

METHODS
67 young swimmers (34 girls, 33 boys, 12.83 ± 1.26 years-old) with at least 4-v of experience in competitive swimming, participating on regular basis in regional and national level competitions at the moment of data collection volunteered as subjects. Each swimmer made a maximal 25m Front-Crawl swim with an underwater start. A speedo-meter cable (Swim speedo-meter, Swimpportec, Hildesheim, Germany) was used to measure the mean swimming velocity within the stroke cycle (v). Intra-cyclic variation of the horizontal velocity of the hip (dv) was analyzed as well [1]. Thereafter, dv was also normalized to the swimming velocity (dv/v). Active drag and Active Drag coefficient (C_{Da}) were calculated from the difference between the swimming velocities with and without towing the perturbation buoy [2].

For the trunk transverse surface area (S) measurement, swimmers were photographed with a digital camera (DSC-T7, Sony, Tokyo, Japan) in the transverse plane from above [3]. Subjects were on land, in the upright and hydrodynamic position. The S was measured with a photogrammetric technique from the subject’s digital photo with specific area measuring software (Udruler, AVPSoft, USA).

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Swimming performance was taken from the time lists of the 100-m freestyle event of official short course (i.e., 25 m swimming pool) competition of regional or national level. The time gap between data collection and swimming performance was made in less than two weeks.

Two clustering approaches were used: (i) a hierarchical cluster analysis using Ward’s linkage method with the squared Euclidian distance measure; (ii) a k-Means (non-hierarchical) cluster analysis. It was used standardized z scores of the selected variables in the clustering analysis. To identify the variables with highest influence in each cluster, cluster’s ANOVA and discriminant analysis (stepwise method) tests were computed (p<0.05). MANOVA using cluster group as the independent variable and swimmers’ characteristics (i.e., gender, swim performance) were also computed.

RESULTS AND DISCUSSION
Table 1 presents descriptive statistics for non-standardized data (i.e. SI units) of the selected variables for overall sample. Classifications of the swimmers was conducted with k-Means method (k=3). ANOVA statistics revealed significant variations in all tested variables (table 2). Cluster 1 was related to swimmers with a high speed fluctuation (i.e., dv and dv/v). Cluster 2 was characterized by the anthropometrics (i.e., S). Cluster 3 was associated with the high hydrodynamic profile (i.e., Cda). The variable that seems to discriminate better the clusters is the dv/v (F=53.680; P<0.001), followed by the dv (F=28.506; P<0.001), Cda (F=21.025; P<0.001), S (F=6.297; P<0.01) and v (F=5.375; P<0.01). MANOVA showed non-significant multivariate effect of age and swimming performance on cluster groups (Λ<0.05). Stepwise discriminant analysis extracted 2 functions including on it the dv/v, S, dv and dv/v/v. Function 1 is mainly defined by dv/v and S explaining 74.3% of variance (Λ=0.179; Λ2=104.976; P<0.001). Function 2 is mainly defined by Cda explaining 25.7% of variance (Λ=0.569; Λ2=34.359; P<0.001). Classification functions (89.2% of original grouped correctly classified) were:

Cluster 1 (n=16)

- dv/v: -12.58 ± 1.20
- dv: +2.24 ± 1.20
- S: -0.67 ± 0.09
- Cda: +0.25 ± 0.32

Cluster 2 (n=33)

- dv/v: -10.99 ± 1.40
- dv: +2.38 ± 1.36
- S: 0.75 ± 0.16
- Cda: -0.12 ± 0.07

Cluster 3 (n=17)

- dv/v: 1.32 ± 0.24
- dv: 1.30 ± 0.19
- S: 1.31 ± 0.16
- Cda: 0.24 ± 0.07

CONCLUSIONS
Cluster and discriminant analysis revealed that swimmers can be classified according to their dv and dv/v (cluster 1, “kinematics’ cluster”), to their S (cluster 2, “anthropometrics’ cluster”) and their Cda (cluster 3, “hydrodynamics cluster”). It can be concluded that kinematics, anthropometrics and hydrodynamic features are determinant to classify and characterize swimmers’ profiles.

REFERENCES