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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:

$$a = \frac{F}{m} \quad (1)$$

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

$$dv = \frac{\mathrm{Pr} + D}{m} \quad (2)$$

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:

$$D_a = \frac{1}{2} \cdot \rho \cdot v^2 \cdot S \cdot C_{Da} \quad (3)$$

Where D_a is the swimmer's active drag, ρ 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 *Da*, 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-y 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, Swimsportec, 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).

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., C_{Da}). The variable that seems to discriminate better the clusters is the *dv/v* ($F=53.680$; $P<0.001$), followed by the *dv* ($F=28.506$; $P<0.001$), C_{Da} ($F=21.025$; $P<0.001$), *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 ($\Lambda_{Wilk's}=0.808$; $\Lambda_{Pillai's}=0.194$; $P=0.08$). Stepwise discriminant analysis extracted 2 functions including on it the *dv/v*, C_{Da} and *S* (fig. 2). Function 1 is mainly defined by *dv/v* and *S* explaining 74.3% of variance ($\Lambda=0.179$; $X^2(6)=104.976$; $P<0.001$). Function 2 is mainly defined by C_{Da} explaining 25.7% of variance ($\Lambda=0.569$; $X^2(2)=34.359$; $P<0.001$). Classification functions (89.2% of original grouped correctly classified) were:

$Cluster1_{kinematics}=44.198\cdot S-2.852\cdot C_{Da}+4.604\cdot dv/v-41.280$;

$Cluster2_{anthropometrics}=49.082\cdot S-0.305\cdot C_{Da}+2.752\cdot dv/v-28.175$

$Cluster3_{hydrodynamics}=37.788\cdot S-+17.963\cdot C_{Da}+2.195\cdot dv/v-24.175$

Considering both the clustering and discriminative analysis swimmers can be classified according to their kinematics, their anthropometrics and/or hydrodynamic features. In this sense, research, as well as, control and evaluation protocols with young swimmers should consider selected a few variables from each one of these domains. Added to that, it should also be considering the interaction that might exist among all of them to determine other outcomes (notably the performance) but using other data analysis procedures. On top of that, based in the discriminative analysis it is possible to classify new swimmers in a given cluster according to discriminant equations. The solution with highest value refers to the cluster where the swimmer should be allocated and classified.

Table 1: Descriptive statistics of the selected variables.

	v [m/s]	dv [%]	dv/v [a.u.]	S [m^2]	C_{Da}	100m free [s]
Mean	1.27	9.32	7.45	0.70	0.31	71.30
1SD	0.19	2.73	2.47	0.13	0.15	6.12
Min	0.81	4.57	3.63	0.51	0.14	58.44
Perc 25	1.15	8.00	5.85	0.62	0.20	67.02
Perc 50	1.30	9.00	6.96	0.69	0.27	71.07
Perc 75	1.38	10.05	8.66	0.75	0.39	76.40
Max	1.71	21.20	15.04	1.24	1.05	81.12

Table 2: Descriptive and summary ANOVA statistics by clustering.

	Cluster 1 (n=16)		Cluster 2 (n=33)		Cluster 3 (n=17)		
	M ± SD	z	M ± SD	z	M ± SD	z	P
v	1.14 ± 0.16	-0.66	1.32 ± 0.19	0.24	1.31 ±0.16	0.18	0.01
dv	12.58 ± 3.38	1.20	8.58 ± 1.36	-0.27	7.75 ± 1.52	-0.57	<0.001
dv/v	10.99 ± 2.24	1.40	6.60 ± 1.32	-0.34	5.94 ± 1.21	-0.60	<0.001
S	0.67 ± 0.12	-0.28	0.75 ± 0.14	0.39	0.63 ± 0.07	-0.50	<0.01
C_{Da}	0.25 ± 0.09	-0.32	0.24 ± 0.07	-0.41	0.47 ± 0.20	1.04	<0.001

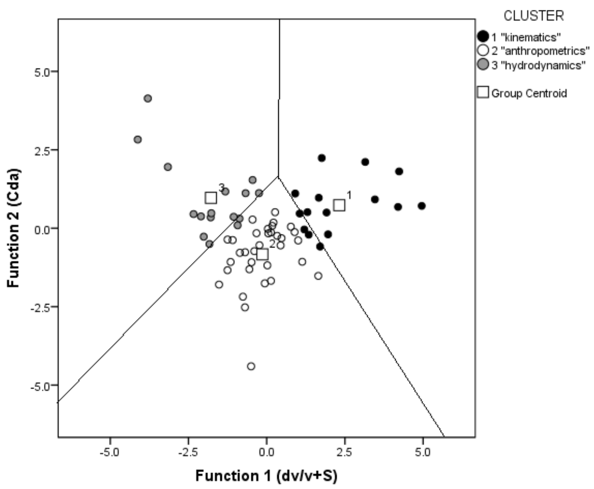

Figure 2: Territorial map of the two canonical discriminant functions.

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 C_{Da} (cluster 3, "hydrodynamics cluster"). It can be concluded that kinematics, anthropometrics and hydrodynamic features are determinant to classify and characterize swimmers' profiles.

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