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A MECHANICAL SPEEDO-METER TO ASSESS SWIMMER'S HORIZONTAL INTRA-CYCLIC VELOCITY: VALIDATION FOR BREASTSTROKE AND BUTTERFLY STROKE

Wellington G Feitosa[1,5], Mário J Costa[5], Jorge E Morais[5], Nuno D Garrido[2,5], António J Silva[2,5], António B Lima[3], Tiago M Barbosa[4,5]

[1]University of Ceará, Fortaleza, Brazil
[2]University of Trás-os-Montes and Alto Douro, Vila Real, Portugal
[3]Ceará Federal University, Fortaleza, Brazil
[4]National Institute of Education, Nanyang Technological University, Singapore
[5]Research Centre in Sports, Health and human Development, Vila Real, Portugal

The aim was to validate a system to assess speed-fluctuation at breaststroke and butterfly stroke. 12 boys and 11 undertook a set of maximal 2x25 m swims (Breaststroke and Butterfly stroke). The speedo-meter cable was attached to the subject's hip and data was acquired on-line. At the same time, subjects were recorded in the sagital plane with an underwater video camera enabling the hip to be digitized. The following were analysed: (i) maximal velocity; (ii) minimal velocity; (iii) difference between maximal and minimal velocity; (iv) coefficient of variation. There were no significant differences for the mean values between methods, except for the coefficient of variation. Linear regression models were highly related. More than 80% of the Bland-Altman plots were within the 1.96 standard-deviation criteria used as a rule of thumb for technique validation.

KEY WORDS: validate, evaluation, instrument, speed fluctuation, swimming

INTRODUCTION: The horizontal intra-cyclic velocity of the subject's body for competitive swimmers is assessed on a regular basis. The intra-cyclic velocity is also known by practitioners as "speed fluctuation". This data can be acquired with several techniques: (i) videometric system (Barbosa et al., 2010); (ii) Doppler effect procedures, i.e., radar gun (Garrido et al., 2010) or; (iii) mechanical apparatus, i.e., speedo-meter (Vilas-Boas et al., 2010). The videometric technique presents high validity and accuracy when procedures are properly followed. On the other hand, it is very complex, time consuming and expensive. On one hand, the speedo-meter is friendly, less expensive, less time consuming and the data is obtained on-line. It is questionable if the radar gun is a valid way to assess speed while swimming. For this reason the speedo-meter is a quick, affordable and an easy way to assess the intra-cyclic velocity of the subject's body.
In previous papers the concept, development and validation of an integrated speedo-meter system (software plus hardware) for land-based locomotion was reported. (Barbosa et al., 2011a; 2011b). The system was shown to be appropriate in assessing horizontal intra-cyclic velocity and maximal velocity during land-based locomotion techniques, from walking to jogging/running (Barbosa et al., 2011a; 2011b). Notably this apparatus is mainly used in aquatic locomotion techniques such as swimming (Capitão et al., 2006; Morouço et al., 2006; Leblanc et al., 2007; Vilas-Boas et al., 2010). In these papers it was suggested that, in the near future, an apparatus validation for aquatic locomotion techniques be performed.
The aim of this paper was to validate the system for the assessment of horizontal intra-cyclic velocity while swimming the breaststroke and butterfly stroke.

METHODS: Subjects included 12 boys (14.42 ± 1.24 years-old, 166.29 ± 9.53 m of height, 56.45 ± 10.80 kg of body mass) and 11 girls (12.73 ± 0.79 years-old, 160.40 ± 5.60 m of height, 47.54 ± 5.60 kg of body mass) with at least 4-y of experience in competitive swimming, who were participating on a regular basis in regional and national level competitions at the time of data collection.

Each swimmer undertook a set in random order of maximal 2x25 m (Breaststroke and Butterfly) swims with a push-off start. Participants performed the trial alone with no other swimmer in the lane or in nearby lanes to reduce any effect of drafting and pacing, or being affected by extra drag force due to exogenous factors.
Subject's velocity was acquired from both speedo-meter system and a videometric system in each trial (fig 1). The speedo-meter cable was attached to the subject's hip and data was acquired on-line with an integrated system at a sampling rate of 50 Hz (Barbosa et al., 2011a; 2011b). Data was exported to signal processing software (AcqKnowledge v.3.5, Biopac Systems, Santa Barbara, USA) using a 5 Hz low pass cut-off 4th order Butterworth filter.
At the same time, subjects were recorded in the sagital plane with an underwater video camera (Samsung, Sdc-415, Japan) at a sampling rate of 50 Hz, positioned at 11.60m from the head wall. The camera was connected to a mixing table (Samsung, SSC-1000N, Japan and a DVD recorder (*DIGA DMR-EH55, Japan*). The subject's hip was manually digitized (Ariel Performance Analysis System, Ariel Dynamics Inc., USA) for one single stroke cycle in each trial. Thereafter data was transformed (Abdel-Aziz and Karara, 1971) and smoothed with a digital filter with a cut-off frequency of 5 Hz. The following was analysed: (i) maximal velocity within the stroke cycle; (ii) minimal velocity within the stroke cycle; (iii) difference between maximal and minimal velocity within the stroke cycle; (iv) coefficient of variation of the subject's velocity within the stroke cycle.
Validation of the integrated system *versus* videometric system was computed with (Barbosa et al., 2011a; 2011b): (i) paired Student's t-test (validation criterion: $\alpha \geq 0.05$); (ii) linear regression models (validation criterion: $R^2 \geq 0.49$) and; (iii) Bland-Altman plots (validation criterion: at least 80 % of the plots within the ± 1.96 standard deviation).

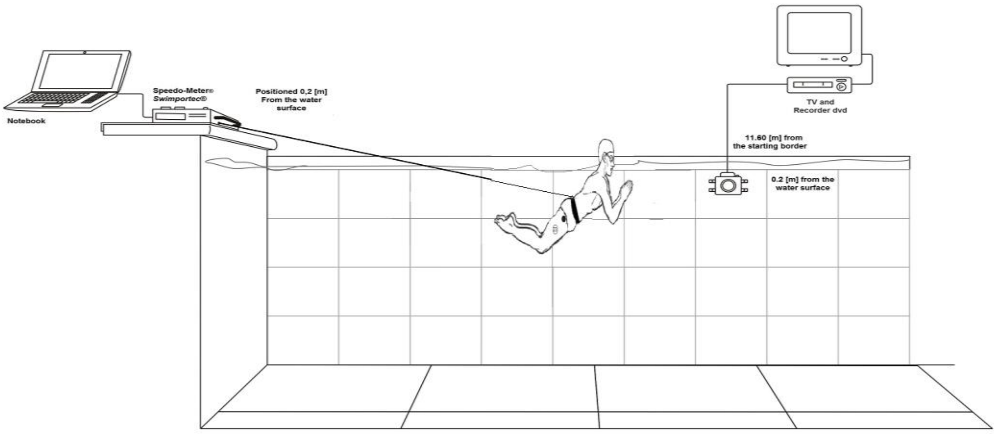

Figure 1: Apparatus set-up.

RESULTS: There were not statistically significant differences for pair-wise data between the speedo-meter system and the videometric system,(see table 1): (i) maximal velocity ($p > 0.05$); (ii) minimal velocity ($p > 0.05$); (iii) difference between maximal and; (iv) minimal velocity ($p > 0.05$). There were significant differences for the coefficient of variation ($p < 0.05$). Linear regression models between speedo-meter system and videometric system presented very high associations for all variables, for example: (i) maximal velocity ($R^2 = 0.984$; $p < 0.001$); (ii) minimal velocity ($R^2 = 0.989$; $p < 0.001$); (iii) difference between maximal and minimal velocity ($R^2 = 0.988$; $p < 0.001$) and; (iv) coefficient of variation ($R^2 = 0.951$; $p < 0.001$) (figure 2). A close inspection of the 95 % interval of confidence level revealed that the agreed limits were very close. More than 80 % of the Bland-Altman plots were within the 1.96 standard-deviation criterion (figure 2). The differences between APAS® and Speedo-meter® were, respectively: (i) maximal velocity (-0.004); (ii) minimal velocity (0.004); (iii) difference between maximal and minimal velocity (-0.008) and; (iv) coefficient of variation (0.008).

Therefore, the integrated speedo-meter system accomplished all three selected validation criteria

Table 1: Means comparison between speedo-meter system and videometric system.

	M ± Std		Paired differences							
						95% Confidence Interval of the Difference				
	Speedo-Meter®	APAS®	M	Std	Std. Error Mean	Lower	Upper	t	df	*p*
Maximal velocity	1.458 ± .209	1.462 ± .211	-.004	.026	.003	-.012	.003	-1.015	45	.316*
Minimal velocity	.617 ± .306	.613 ± .301	.004	.032	.004	-.005	.013	.837	45	.407*
Difference between maximal and minimal	.840 ± .324	.849 ± .331	-.008	.036	.005	-.018	.002	-1.499	45	.141*
Coefficient of variation	.239 ± .094	.231 ± .092	.008	.020	.003	.001	.014	2.650	45	.011

M = Mean; Std = Standard Deviation; t – t value; df = degree of freedom; *p* – *p* value t test paired. *$p > 0.05$.

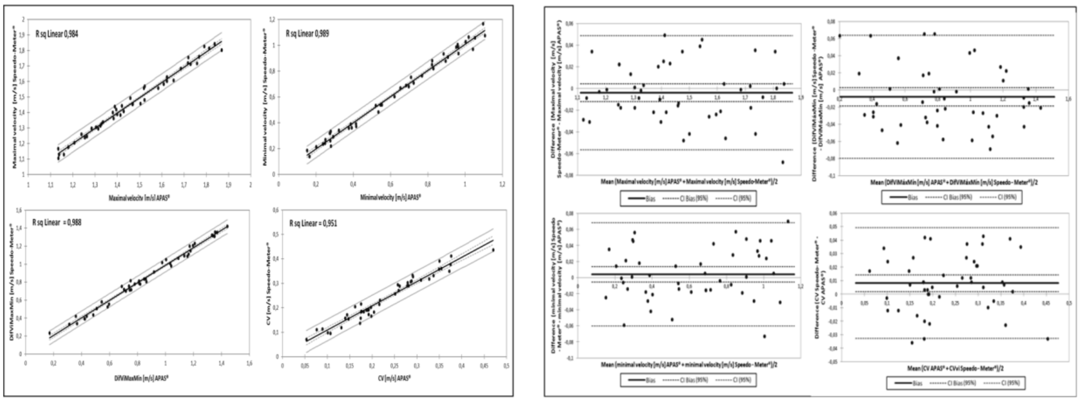

Figure 2: Linear regression models and Bland Altman plots between speedo-meter system and videometric system.

DISCUSSION: The aim of this paper was to validate an integrated system to assess a human's horizontal intra-cyclic velocity with a mechanical speedo-meter swimming both breaststroke and butterfly. The speedo-meter system met all the validation criteria tested.

At least one research group tested the validation of another speedo-meter system for breaststroke (Capitão et al., 2006) and butterfly (Morouço et al., 2006). Although the use of a radar gun is a possible alternative, both authors used as gold-standard the videometric technique. There are some serious concerns that the Doppler effect apparatus may not guarantee valid and accurate data of traveling bodies when the bodies are partially immersed in water.

There were not significant differences between pair-wise data ($p > 0.05$), except for coefficient of variation ($p < 0.05$). There were very high relationships between data collected with both techniques ($0.95 \leq R^2 \leq 0.98$). More than 80 % of the Bland-Altman plots were within the 1.96 standard-deviation criterion. Therefore, all the validation criteria were accomplished. This same trend was verified for this system in land-based locomotion (Barbosa et al., 2011a; 2011b), as well as front crawl and backstroke swimming (Feitosa et al., 2012).

There bias are differences between the gold-standard apparatus and the speedo-meter method ($- 0.008 < \Delta < 0.008$). This slight difference may be explained due to some random errors that are related to manual digitizing (Allard, Stokes & Blanchi, 1995). It must be stressed that to reduce the difference as much as possible, a dot-target was painted on the subjects' hip and the digitalization was done by a person with vaste experience in such a technique. Even so, situations, such as: (i) the wake, turbulent flow and bubbles around the swimmer and; (ii) in the butterfly stroke, the hand passing by in front of the hip during the upsweep increases the challenge of an accurate digitizing the hip in some specific frames.

CONCLUSION: The integrated speedo-meter system accomplished all three validation criteria selected. Therefore the researchers believe the system to be an appropriate apparatus to assess human horizontal intra-cyclic velocity performing the breaststroke and butterfly stroke. In the near future similar validation procedures could be performed with other aquatic locomotion techniques related to fitness and rehabilitation (e.g., shallow- and deep-water walking/running).

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