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VALIDATION WITH VIDEOMETRY OF AN INTEGRATED SYSTEM TO ASSESS HORIZONTAL INTRA-CYCLIC VELOCITY WITH A MECHANICAL SPEEDO-METER

INTRODUCTION

A lot of research is done regarding human motion kinematics in several sets, such as for land- and aquatic-based environments. On regular basis it is assessed the horizontal intra-cyclic velocity of the subject's body, also known as "speed fluctuation". This data can be acquired with several techniques, e.g.: (i) computational digitizing of anatomical landmarks, i.e., videometric system (Barbosa et al., 2010); (ii) Doppler effect procedures, i.e., radar gun (Garrido et al., 2010; Barbosa et al., in press) or; (iii) mechanical apparatus, i.e., speedo-meter (Vilas-Boas et al. in press). The videometric technique presents a high validity and accuracy when procedures are properly followed. On the other hand, it is very complex, time consuming and expensive. The speedo-meter is an apparatus easy to be used, less expensive and data is obtained on-line.

Commercially, several speedo-meter systems (hardware plus software) or only the hardware component are available. One of the commercially available speedo-meter's hardware components (Swim speedo-meter, Swimsportec®, Hildesheim, Germany) (Fig 1) needs an acquisition card and a software aplication to process and display captured data when a subject is performing a land- or aquatic-based locomotion activity.

The aim of this paper was to validate an integrated system (software application and Swimsportec® hardware after its calibarion) to assess human's horizontal intra-cyclic velocity with a mechanical speedo-meter.

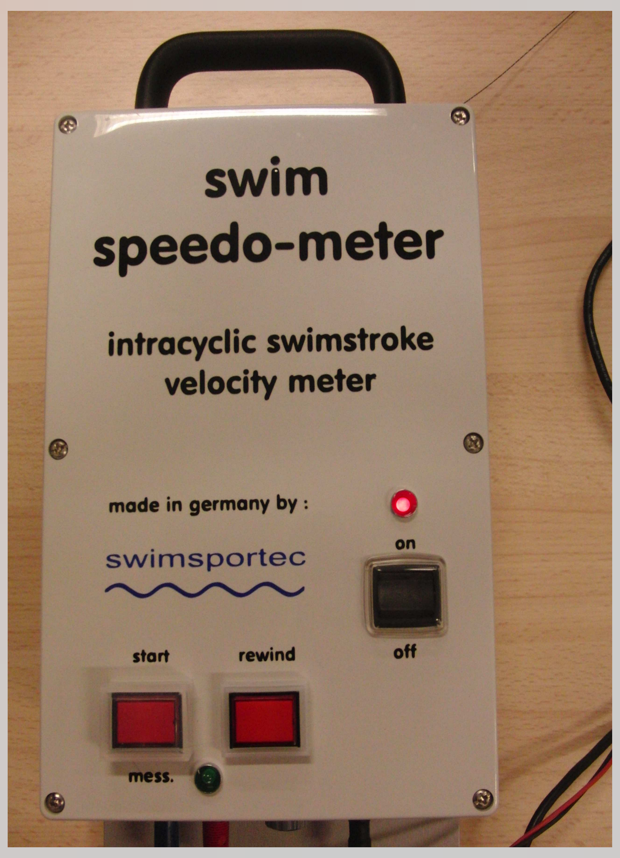


Figure 1. The speedo-meter hardware

METHODS

The speedo-meter calibration was done assessing the relationship between the DC tension and the linear velocity with an industrial robot (IRB 1400, ABB, Karlskrona, Sweden) as reported elsewhere (Barbosa et al., in press) (Fig 2).

Software's interface was developed in LabVIEW® (v. 2009) to acquire, display and process pair wises velocity-time data on-line during the subject's locomotion bout (Fig 3). To transfer data from the hardware (i.e., speedo-meter) to the software application a 12 bit resolution acquisition card (USB-6008, National Instruments, Austin, Texas, USA) is used. Further details about the software application can be read elsewhere (Barbosa et al., in press).

Four subjects performed seven bouts of proximally 5 meters at a wide range of self-paced speeds from very slow walking to maximal running intensities. Subject's velocity was acquired from both speedo-meter system and a videometric system in each bout. The speedo-meter cable was attached to the subject hip and data was acquired on-line with the integrated system at a sampling rate of 50 Hz. At the same time, subjects were recorded in the sagital plane with a video camera, with a sampling rate of 50 Hz. (GR-SXM 26, JVC, Yokoama, Japan) (Fig 4). The subject hip was manually digitized (Ariel Performance Analysis System, Ariel Dynamics Inc., USA) for one single gait cycle in each bout (Fig 5). Thereafter data was transformed (Abdel-Aziz & Karara, 1971) and smoothed with a digital filter with a cut-off frequency of 5 Hz. It was analyzed the: (i) coefficient of variation of the subject's velocity within the gait cycle and; (ii) the maximal velocity in the gait cycle.

Validation of the integrated system *versus* videometric system was computed with: (i) paired Student's t-test (validation criterion: a ≥ 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).

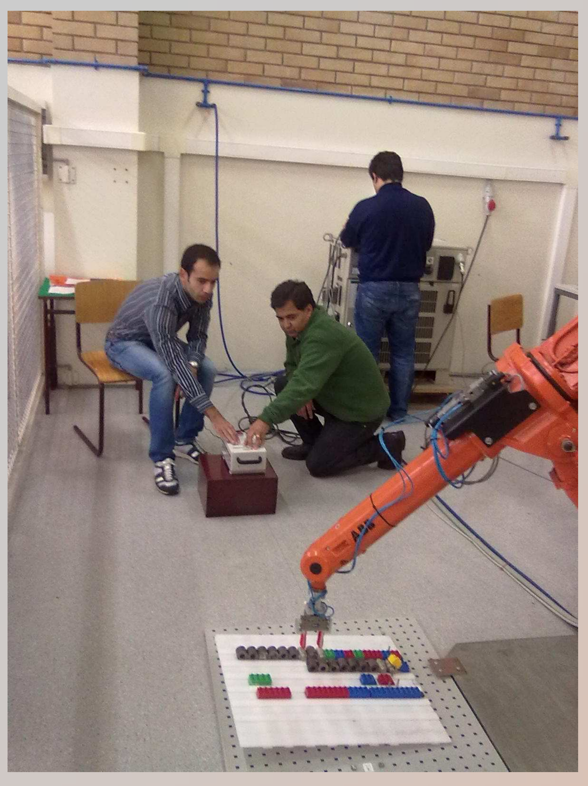


Figure 2 The system calibration.

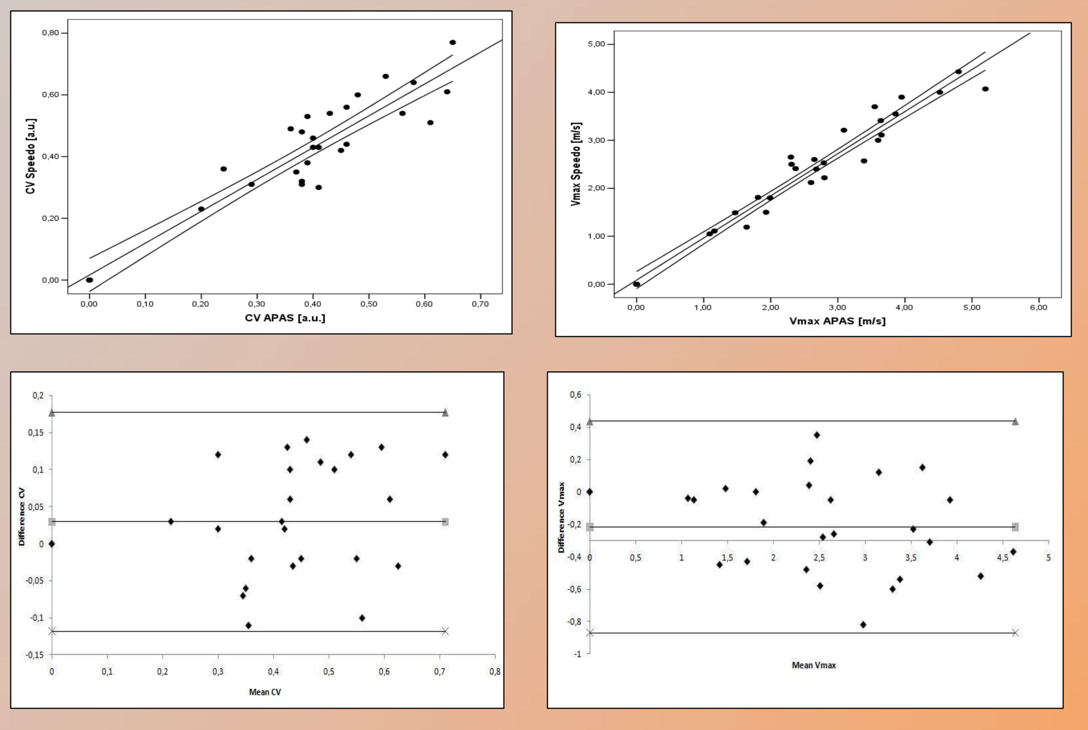
RESULTS AND DISCUSSION

There were not statistically significant differences for pair wise data between speedo-meter system and videometric system in both velocity coefficient of variation ($p > 0.05$) and maximal velocity ($p > 0.05$).

Linear regression models between speedo-meter system and videometric system had very high correlation for both coefficient of variation ($R^2 = 0.87$; $p < 0.001$) and maximal velocity ($R^2 = 0.97$; $p < 0.001$) variables (Fig 6).

A close inspection of the 95 % of interval confidence reveals that the agreement limits were very close together. More than 80 % of the Bland-Altman plots were within the 1.96 standard-deviation criterion (i.e., 95 % of the interval confidence) used on regular basis as rule of thumb for technique validation (Fig 6). In this sense, the integrated speedo-meter system accomplished all the three validation criteria selected.

Figure 4. Speedo-meter and image recording setup.



CV

Vmax

Figure 6. Linear regression models and Bland-Altman plots between speedo-meter system and APAS coefficient of variation and maximal velocity within each gait cycle

RESULTS AND DISCUSSION

At least another research group made the development and the validation of a similar speedo-meter, but only for competitive swimming techniques (Capitão et al., 2006; Morouço et al., 2006).

There were not significant differences between pair wise data ($p > 0.05$). There were very high relationships between data collected with both techniques ($0.87 \leq R^2 \leq 0.97$). More than 80 % of the Bland-Altman plots were within the 1.96 standard-deviation criterion. So, all the validation criteria were accomplished. When this same integrated system was validated with another gold-standard technique (i.e., Doppler procedure) there was the same trend. In this sense, the integrated system is valid for kinematical assessment of the subject's hip horizontal intra-cyclic velocity and maximal velocity assessment at least in land-based locomotion techniques.

Analyzing the interval confidence of the scatter grams, set at 95 %, its agreement limits were very close together for both variables. Even so, maximal velocity data seems to be more accurate than the coefficient of variation. Analyzing the same phenomena between integrated system and the Doppler procedure, the 95 % interval confidence was even closer. This slight bias 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 as much as possible the bias, a passive target was attached to the subjects' hip, subjects wear black clothes that were similar to background color, environment light was reduced and the evaluator performing the digitalization has a large experience with such technique.

Figure 5. APAS' digitizing module.

CONCLUSION

The three validation criteria adopted were accomplished. So, the integrated system developed is an appropriate apparatus to assess the human's horizontal intra-cyclic velocity and maximal velocity during land-based locomotion techniques.

In a near future similar validation procedures could be done regarding aquatic locomotion techniques (e.g., shallow- and deep-water walking/running or competitive swim strokes).

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Figure 3. First version of the software's application (in Portuguese)