Conception, development and validation of a software interface to assess human's horizontal intra-cyclic velocity with a mechanical speedo-meter

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SUMMARY

The aim of this paper was to: (i) calibrate the Swimsportec® speedo-meter; (ii) concept and develop a software's interface for it; (iii) validate the full system. Calibration was done with an industrial robot. The robot arm's performed a linear and horizontal path at a uniform movement for a set of wide range of velocities (0.5<v<4.5m/s) being the tension data acquire for each specific linear velocity. Software's interface was developed in LabVIEW® to acquire, display and process pair wises velocity-time data on-line during the subject's locomotion bout. To transfer data from speedo-meter to the software an acquisition card is used. System validation was done for a set of land-based human locomotion techniques (from slow walk to maximal running) in four subjects and comparing it with a Doppler radar gun. Linear regression models between speedo-meter system and radar gun where very high for both the coefficient of variation of the subject's velocity within the full gait cycle and his maximal velocity. The 95% of interval confidence agreement limits were very close together in both variables. More than 80% of the Bland-Altman plots were with the 1.96 standard-deviation criteria used on regular basis as rule thumb for techniques validation.

INTRODUCTION

Horizontal intra-cyclic velocity is a variable assessed on regular basis in several human movement sets. This data can be acquired with some kinematical techniques, e.g.: (i) computational digitizing of anatomical landmarks (i.e., videometry) [1; (ii) Doppler effect procedures (i.e., radar gun) [5] or; (iii) mechanical apparatus (i.e., speedo-meter) [7]. The videometric technique has as main advantage presents a high validity and accuracy when procedures are properly followed but, it is very complex, time consuming and expensive. The radar gun, compared to the videometry is as valid and accurate especially for land-based movements but, it is more easy tom apply, less expensive and data is obtained on-line. On the other hand, the speedo-meter seems to present the strengths of the radar added to a higher validity and accuracy for both human aquatic and land-based locomotion techniques.

Commercially it is available several videometric systems, radar guns and speedo-meter apparatus. One of the commercial available speedo-meters (Swim speedo-meter, Swimsportec®, Hildesheim, Germany) needs an acquisition card and a software interface to display and process data inputted when a subject is performing a locomotion technique. This apparatus voltage output, having available three different measurement ranges, which can be selected by the user depending on the maximum expected velocity.

The aim of this paper was to: (i) calibrate the Swimsportec® speedo-meter; (ii) concept and develop a software's interface and; (iii) validate the full system.

METHODS

For the Swimsportec® calibration it was used an industrial robot (IRB 1400, ABB, Karlskrona, Sweden) [4]. Speedo-meter cable was attached to the industrial robot. The robot arm's performed a linear path at a uniform movement for 1.5 [m]. The robot's horizontal velocity ranged in 3 sets of 15 tests between 0.1 [m/s] to 4.5 [m/s] increasing 0.1 [m/s] in each test. It was acquired the DC tension data in each test with an analogical dynamo-taquimiter.

Software's interface was developed in LabVIEW® (v. 2009) [2,4] to acquire, display and process pair wises velocity-time data on-line during the subject's locomotion bout. To transfer data from the hardware (i.e, speedo-meter) to the software an 12 bit resolution acquisition card (USB-6008, National Instruments, Austin, Texas, USA) is used with a sampling rate up to 10k [Hz].

The full system validation was done for land-based locomotion comparing it with a Doppler radar gun (Stalker Pro, Stalker Radar, Plano, Texas, USA) as gold-standard at a sampling rate of 32 [Hz]. Four subjects performed seven bouts of proximally 10 [m] 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 radar gun in each bout. After data re-sampling, two full gait cycles of each bout were analyzed computing its: (i) coefficient of variation of the subject's velocity within the full gait cycle and; maximal velocity in each gait cycle. For validation and accuracy assessment linear regression models and Bland-Altman plots [3] between speedo-meter versus radar gun data were performed.

RESULTS AND DISCUSSION

For the speedo-meter calibration, it was assessed the relationship between the DC tension and the linear velocity (fig 1). Fit lines were adjusted to the plots according to the model presenting the better good-of-fit and the lowest standard error of estimation.

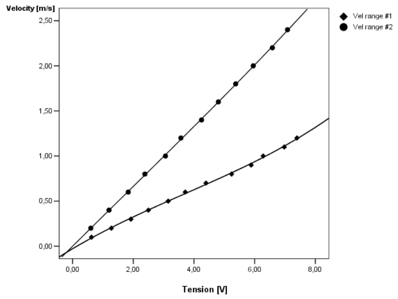

Figure 1: Relationship between DC tension and linear velocity

Software's application layout (fig 2) includes two panels: (i) main window – able the introduction of subjects information's, acquire and graphically show the v(t) function in SI units of the bio-signal. When the start button is pressed, begins the data acquisition in continuous mode and is shown graphically, in real time. Several additional functions were added for bio-signal analysis (e.g., save data, zoom, scroll, axes formatting, clean data, statistical analysis, etc). In terms of software code, these procedures are implemented using LabVIEW® structure called "Timed Loop" (v. 2009); (ii) configurations window (not shown in fig x) – includes all functions regarding the system configurations and a help pop-up. Additional information about the system, including photographs about electrical modes connections are also displayed. Data is sampled at 50 [Hz] and can be fully exported as a *csv* file for further analysis.

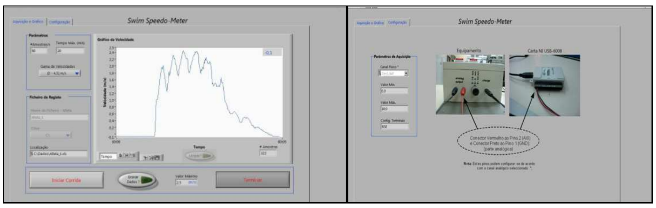

Figure 2: First version of the software's application (in Portuguese): left side panel – main window layout after a subjects gait test; right side panel – configurations window.

Linear regression models between speedo-meter system and radar gun where very high for both coefficient of variation ($R^2 = 0.85$; $p < 0.001$) and maximal velocity ($R^2 = 0.94$; $p < 0.001$) variables (figure 3). Moreover the 95 % interval confidence agreement limits were very close together. More than 80 % of the Bland-Altman plots were with the 1.96 standard-deviation criteria (i.e., 95 % interval confidence) used on regular basis as rule thumb for techniques validation (figure 4). In this sense, the speedo-meter system accomplished all the validation criteria adopted. Plus, data accuracy was very high for both the coefficient of variation variable and the maximal velocity. Although Doppler radar guns are designed to assess instantaneous velocity, its use is done mainly to assess peak velocities, such as throws, jumps and beats. So, possibly videometric systems can be even more suitable as gold-standard technique to compare the coefficient of variation accuracy and determine the speedo-meter's intra-cyclic variation good-of-fit.

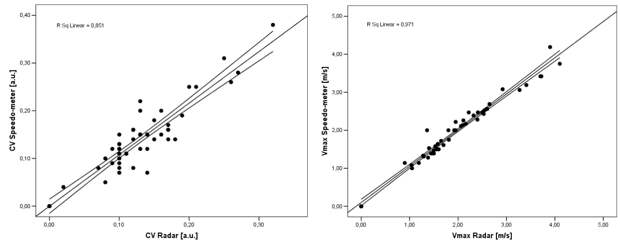

Figure 3: Linear regression models between speedo-meter system and radar gun coefficient of variation and maximal velocity within each gait cycle.

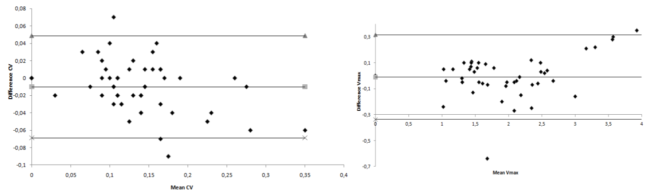

Figure 4: Bland-Altmant plot between speedo-meter system and radar gun coefficient of variation within each gait cycle.

CONCLUSIONS

It was conceived and developed an fully integrated system for acquisition and data analysis of bio-signal from a mechanical speedo-meter by Swimsportec®.

The software application developed using the LabVIEW® platform, is very robust, with a good performance, intuitive for the user, and with a very nice graphical environment.

After calibration and developing a software interface the integrated system (hardware plus software) presented a very high validation and accuracy. So, the system developed seems to be an appropriate apparatus to assess the human's horizontal intra-cyclic velocity during land-based locomotion techniques.

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