ACCURACY OF A SHOE-WORN DEVICE TO MEASURE RUNNING MECHANICS

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INTRODUCTION

Commercial availability of wearable fitness trackers has grown in recent years, and devices to track variables relating to physical activity have become popular. Some running-specific devices are able to collect sophisticated information relating to running injury and performance variables that have been identified in biomechanics research literature, such as cadence, ground contact time, and vertical oscillation. Additionally, running speed, step length, and loading rates have been associated with running performance, injury, or both [1,2,5]. The general population of runners does not have regular access to instrumented gait analysis, in which cases running-specific devices can provide an affordable and portable alternative for those interested in measuring, tracking, and improving these variables to reduce the high incidence of running-related injuries and improve performance.

Accuracy of measurement is an important factor of a device and may increase its use, in turn improving outcomes for users [3]. The purpose of this study was to compare the accuracy of running metrics from a shoe-worn accelerometer for fitness tracking (the Milestone Pod) to analogous running data from instrumented gait analysis. We specifically tested the accuracy of the Pod for running velocity (VEL), cadence (CAD), ground contact time (GCT), peak knee angle in swing (KA), and vertical average loading rate (VALR).

METHODS

Institutional approval was obtained and each participant gave written consent. Thirty-nine healthy adults participated in the study (12 males, 27 females, age 29 ± 13 yrs). Subjects were fitted with 33 reflective markers on the pelvis, lower extremity of the dominant leg and non-dominant foot. The Pod (mass ~ 13 g) was attached to the shoe on the dominant foot by a small rubber carriage. Kinematic data was captured using a 13-camera VICON motion capture system sampling at 200 Hz. Ten embedded force plates recorded ground reaction forces (GRF) at 1000 Hz. Subjects ran around a 50-m indoor track for 3 laps each at 3 speeds: self-selected "normal", "slow", and "fast" paces to capture a range of the subject's typical running mechanics. Running trials were conducted while subjects wore their own running shoes (RS) and standard lab shoes (LS) (New Balance 780v5).

Kinematic and GRF data were processed using Visual3D and MATLAB to determine average VEL, CAD, GCT, KA, and VALR. Data were averaged over all speeds and both shoes to represent intra-subject variance in running training. Raw data were filtered using a Butterworth low-pass filter at 6 Hz for kinematic and 50 Hz for GRF. VALR was calculated as the change in force over the change in time between 20-80% of the time period between initial contact and impact peak and scaled by body weight [4].

A paired-samples *t*-test compared the measurement difference between the Pod and Lab data to zero for all variables ($\alpha = 0.05$). Additionally, a paired-samples two one-sided test (TOST) of equivalence was done between Pod and Lab data ($\alpha = 0.05$). The TOST allows a specified range of difference between variables known as the practical difference (PD). The within trial standard deviation was calculated for both the Pod and Lab system. The average standard deviation of Pod data was used for VEL, CAD, and GCT, and the average standard deviation of Lab data for KA and VALR. Finally, the percent of subjects whose measurement difference fell within the PD was determined.

RESULTS AND DISCUSSION

Results of the t-test revealed:

- No significant difference between Pod and Lab measurements for GCT (p = 0.235, ES = 0.12) and KA ($p = 0.770$, ES = 0.11).
- Significant differences for VEL ($p = 0.001$, ES = 0.41), CAD ($p = 0.001$, ES = -0.25), and VALR ($p < 0.001$, ES = -0.51).

The TOST between Pod and Lab data showed equivalence for all variables tested:

- VEL, PD = 0.25 m/s ($p < 0.001$)
- CAD, PD = 7.83 steps/min ($p < 0.001$)
- GCT, PD = 20.0 ms. ($p < 0.001$)
- KA, PD = 3.03 deg. ($p < 0.005$)
- VALR, PD = 8.51 BW/s ($p < 0.001$)

Representative scatterplots of the variables that showed the smallest and greatest differences between Pod and Lab are shown in Fig. 1. The percentage of subjects whose difference between Pod and Lab measurements fell within the practical difference is shown in Figure 1c. The practical difference of KA captured the least number of subjects (17.1%), followed by VEL (52.1%) and VALR (40.6%). CAD and GCT both captured the highest percentage of subjects (both 69.8%).

These results support the general accuracy of the device. The Pod estimates of GCT and KA were most accurate, showing no significant difference from zero. Pod estimates of VEL, CAD, and VALR were equivalent, showing significant differences between Pod and Lab, but the size of the difference was on average smaller than natural within-subject variance in running mechanics. Although there was no significant difference between the measurement difference and zero for KA, the percentage of subjects whose average KA fell within the practical difference was low. The means of Pod and Lab data were very similar which led to good performance in the *t*-test (93.7 ± 9.1 deg. and 95.1 ± 16.0 deg., respectively). However there was a fairly large (10.3 degree) average within subject difference between Pod and Lab measurements compared to relatively low individual standard deviation within speed and shoe conditions from the Lab data that defined the practical difference (3.03 deg.).

CONCLUSIONS

The Milestone Pod is effective for measuring kinematic and kinetic running variables. However, refinement of the Pod's capabilities to estimate VEL, CAD and VALR are necessary to improve its versatility and applicability to a greater percentage of users.

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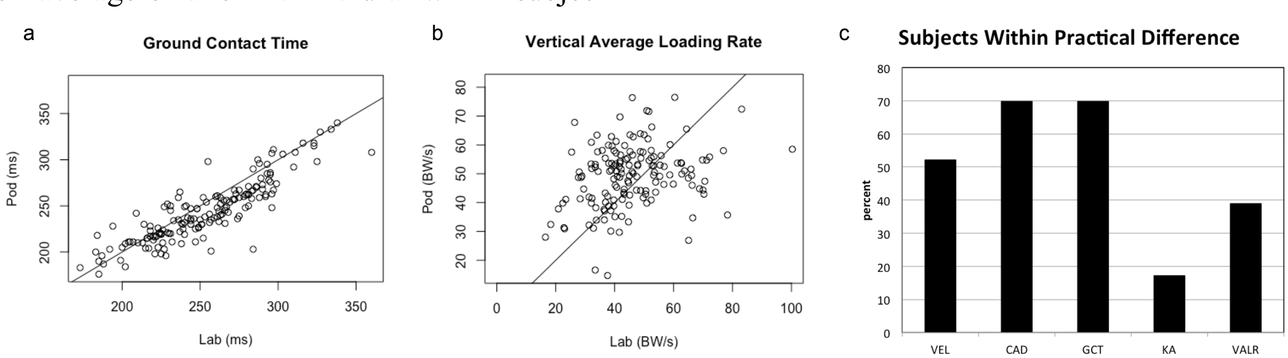

Figure 1: a. Pod GCT vs. Lab GCT with a line of perfect fit. **b.** Pod VALR vs. Lab VALR with a line of perfect fit. **c.** Percentage of subjects whose difference between Pod and Lab measurements was within the practical difference.