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How long is required to undertake step variability analysis during running? A pilot study

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Abstract.
BACKGROUND: The accurate assessment of step variability remains problematic.
OBJECTIVE: To determine the minimum time required for assessing spatiotemporal variability during continuous running.
METHODS: Seventeen endurance runners performed a running protocol on a treadmill, with a 3-min recording period at 12 km/h. Spatiotemporal parameters (contact and flight times, step length and step frequency) were measured using the OptoGait system and step variability was considered for each parameter, in terms of within-participants standard deviation (SD) and coefficient of variation (CV%). Step variability was calculated over 6 different durations: 0–10 s, 0–20 s, 0–30 s, 0–60 s, 0–120 s and 0–180 s.
RESULTS: The repeated measures ANOVA revealed no significant differences between measurements in mean spatiotemporal gait parameters ($p \geqslant 0.396$, ICC $\geqslant 0.90$ in all parameters). The post-hoc analysis confirmed no significant differences in step variability (of each spatiotemporal parameter) between measurements. The Bland-Altman limits of agreement method showed that longer recording intervals yield smaller systematic bias, random errors, and narrower limits of agreement.
CONCLUSIONS: The duration of the recording interval plays an important role in the accuracy of the measurement (i.e. variability in spatiotemporal gait parameters), with longer intervals (180 s) showing smaller systematic bias and narrower limits of agreement than shorter intervals (10 s, 20 s, 30 s, 60 s or 120 s).

Keywords: Biomechanics, endurance runners, gait variability, movement variability

1. Introduction

Step variability seems to be related to both injuries [1,2] and endurance performance [3]. Nevertheless, the accurate assessment of step variability remains problematic. In 1995, Belli et al. [4] indicated that step variability during running was difficult to estimate due to the lack of measurement de-

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vices. Today, many devices provide real-time feedback on spatiotemporal parameters while running (e.g., OptoGait™, Stryd™ or Myotest™). Therefore, the limitation is not how to collect the data but how long should last the data collection to obtain accurate assessments of step variability.

Belli et al. [4] suggested that 32–64 consecutive steps are required to assess step variability, which represents approximately 15–20 s when running at submaximal velocities. To the best of the authors' knowledge, the evidence available about how many steps or how long should last the data collection to obtain accurate assessments of step variability is limited, and no more studies have reconsidered this topic adapted to the new devices. However, some studies have addressed this analysis during walking [5–7]. A previous work examined the minimum number of steps required to accurately estimate spatial and temporal step kinematic variability of subjects walking on a treadmill [5], concluding that at least 400 steps are required. To further examine the step variability during running, the aim of this study was to determine the minimum time required for assessing spatiotemporal variability during continuous running on an instrumented treadmill. The authors hypothesised that the variability in spatiotemporal gait parameters during running would be very similar in short recording intervals (e.g. 10 s, 20 s, 30 s, 60 s or 120 s) compared to a longer recording interval (180 s).

2. Methods

2.1. Participants

Seventeen trained male endurance runners (age: 34 ± 7 years; height: 1.74 ± 0.04 m; body mass: 71.2 ± 4.3 kg) participated in this study. Participants met the inclusion criteria: (i) older than 18 years old, (ii) able to run 10 km in < 40 min (36.1 ± 1.9 min), (iii) training on a treadmill at least once per week, (iv) free from injury (points 3 and 4 refer to the 6 months preceding the study). After receiving information on the objectives and procedures of the study, participants signed an informed consent form, which complied with the ethical standards of the World Medical Association's Declaration of Helsinki (2013). The study was approved by the local ethics committee (San Jorge University, Zaragoza, Spain).

2.2. Procedures

Participants were tested on a motorized treadmill (HP cosmos Pulsar 4P, HP cosmos Sports and Medical, Gmbh, Germany). A standardized 10-min warm-up (running at 10 km/h) was performed since previous studies on human locomotion have shown that accommodation to a new condition occurs in ∼ 6–8 min [8]. After warming-up, running velocity was increased 1 km/h every min until a speed of 12 km/h was reached. The participants ran at 12 km/h for 3 min with a complete recording period. Note that 12 km/h is a normal pace for these athletes and is consistent with previous studies [9]. All participants verbally reported feeling comfortable running at the set speed.

2.3. Measures

Spatiotemporal parameters were measured using the OptoGait™ system (Optogait; Microgate, Bolzano, Italy), which was previously validated for the assessment of spatiotemporal parameters of the gait of young adults [10]. The OptoGait™ system is able to measure both contact time (CT) and flight time (FT) at 1000 Hz. The two parallel bars of the OptoGait™ system were placed on the side edges of the treadmill at the same level of the contact surface. CT, FT, step length (SL) and step frequency (SF) were measured for every step [11].

Step variability was assessed for each spatiotemporal parameter through the within-participant standard deviation (SD) and the coefficient of variation (CV%). Since previous studies have used indistinctly the SD [12] or CV% [3], we incorporated both measures to make comparisons easier. Step variability was examined over 6 recording intervals within the 3-min recording period: 0–10 s, 0–20 s, 0–30 s, 0–60 s, 0–120 s and 0–180 s.

2.4. Statistical analysis

Descriptive statistics are represented as mean (SD). Tests of normal distribution and homogeneity (Kolmogorov-Smirnov and Levene's test, respectively) were conducted on all data before analysis. One-way repeated measures ANOVA with Bonferroni post-hoc corrections were conducted on the magnitude of each spatiotemporal parameter as well as on variability outcomes (i.e., SD and CV%) to examine possible differences between the recording intervals (0–10 s, 0–20 s, 0–30 s, 0–60 s, 0–120 s, 0–180 s). Effect sizes were calculated using partial eta squared (Eta^2) [13]. The association of the magnitude and variability of the spatiotemporal parameters between the recording intervals was quantified through the intraclass correlation