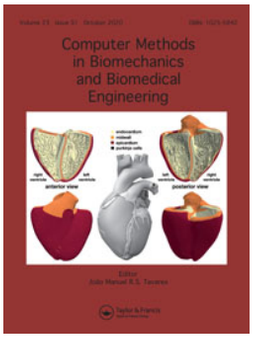

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Intra- and inter- session reliability of a new method for evaluating toes flexor strength: preliminary study

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1. Introduction

Running economy is a key determinant of performance in running (Millet et al. 2012) and may be affected by several biomechanical factors (e.g., stiffness) as well as equipment (e.g., shoe mass, cushioning) (Roy and Stefanyshyn 2006). Several studies have recently highlighted that the longitudinal bending stiffness of the shoes is associated with a decrease in running energy cost (Madden et al. 2016). More specifically, McLeod et al. (2020) have reported that shoe construction needs to be personalised in regard to longitudinal bending stiffness when running economy is valued. Consequently, the ability to measure foot muscle strength and particularly at the metatarsophalangeal (MTP) joint is necessary for researchers and shoe companies. Previous studies have used a variety of methods to measure the strength of intrinsic foot muscles (Ridge et al. 2017). The main limitation of existing methods is the positioning of the toes during the strength testing in relation to their position during the walking or running stance phase. Consequently, the aim of this study was to evaluate the intra- and inter- session reliability of a new method evaluating toe flexors.

2. Methods

2.1. Subjects

Thirteen healthy volunteers (10 men and 3 females, 25 ± 5 years, 1.76 ± 0.09 m, 68.3 ± 13.7 kg) performed the strength test during three testing sessions spaced 24 hours apart. All participants were healthy and free from foot pain or deformity at the time of the study.

2.2. Experimental protocol

For each of the three testing sessions, after a 10-minute warm-up consisting of submaximal toe flexors (TF) contractions, participants performed a series of three maximal voluntary contractions (MVCs) separated by 2 minutes of rest to avoid fatigue. In order to measure TF strength, the toes were placed on a 6 components sensor, with the MTP joint line parallel to the edge of the sensor (Nano 25, ATI Industrial Automation, Garner, NC) (Figure 1).

The chair seat was adjusted so that participants' knee flexion were at 90° and ankle joint in full plantar flexion.

2.3. Data analysis and statistics

Maximal force was determined as the highest peak force recorded from three MVCs. In order to assess intra-session reliability, the 3 trials performed during the first session were considered. Inter-session reliability was calculated from the maximum value of each testing sessions. Intraclass correlation coefficient ($ICC_{(3,1)}$) and coefficient of variation (CV) define as the standard deviation between trials/sessions divided by the mean, were used to analyse the intra-session (within-session comparisons) and inter-session (between-sessions comparisons) relative and absolute reliability, respectively. Values > 0.9, 0.8 to 0.9, and 0.7 to 0.8 for ICCs, reliability were considered high, good, and questionable, respectively. Based on previous studies, an arbitrary acceptable boundary of $<$ 10% for reliability was used for CV. Finally, calculation of the standard error of measurement (SEM) was used to determine the minimal detectable difference (MDD) to be confident that a true change in an individual's performance has occurred. Values were expressed as mean ± SD and 95% confidence interval (CI). All statistical calculations were performed using Matlab R2018a software (MathWorks, Natick, MA). The significance level was set at $\alpha < 0.05$.

3. Results and discussion

Concerning the intra-session, the maximal force was 312 ± 93 [261 – 362], 308 ± 91 [258 – 356] and 308 ± 89 N

Figure 1. Set up for toe flexors evaluation.

Table 1. Reliability for the intra- and inter-sessions.

	ICC	CI (95%)	CV (%)	SEM (N)	MDD 95% (N)
Intra-session	0.975	0.939 – 0.992	3.7	11.7	32.4
Inter-sessions	0.961	0.906 – 0.987	4.2	14.1	39.0

ICC, intraclass correlation coefficient; CI (95%), confidence interval 95%; CV, coefficient of variation; SEM, standard error of measurement; MDD, minimal detectable difference.

[259 – 356] for the trial 1, 2 and 3, respectively. The maximal force was 321 ± 90 [272 – 370], 317 ± 84 [272 – 363] and 324 ± 87 N [277 – 372] for the session 1, 2 and 3, respectively. Intra and inter-session reliability results for the maximal force parameter are summarized in Table 1.

The three maximal forces performed on the same day presented 'high' reliability scores. In the same way, reliability scores for the maximal values of the three trials performed on different session were also 'high'. Compared to intra-session, minimal detectable differences were on average 20.4% higher for inter-session. On average, toe flexors values were higher than those measured by Ridge et al. (2017). This difference can be explained by the method of measurement as well as the placement of the toes during the test. Contrary to our study, the foot in Ridge et al. (2017) was adjusted so that the hallux was aligned with a dynamometer. Then, subjects gripped T-shaped metal bar with their toes that were attached to the dynamometer via a turnbuckle. This change in position could influence the involvement of the foot intrinsic muscles as well as their muscular moment arms, which results in different force-capacity of the MTP joint. Kappel-Bargas et al. (1998) reported that MTP dorsiflexion allows the plantar fascia to wind around the metatarsal heads which results in an increase the plantar fascia tension and a greater force production. Erdemir et al. (2004) showed that plantar aponeurosis forces gradually increased during the walking stance phase and peaked in late stance. To our knowledge, the present study is the first one that proposes a method to evaluate the toe flexors strength in a configuration close to the walking or running stance phase. More precisely, during our testing the MTP joint was dorsiflexed. Our data indicate that the evaluation of the toes flexor strength performed with the new method is highly reliable for both intra- and inter-sessions experiments. From a practical point of view, this method may be useful to better understand the interaction between the shoe construction and toes muscle strength. It may be also important to detect any changes of TF strength over time.

4. Conclusions

The present method is reliable to assess TF forces either in the same session and between days.

Disclosure statement

No potential conflict of interest was reported by the authors.

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KEYWORDS Toe flexion; strength evaluation; running

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