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Validity and Reliability of Two Field-Based Leg Stiffness Devices: Implications for Practical Use

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Leg stiffness is an important performance determinant in several sporting activities. This study evaluated the criterion-related validity and reliability of 2 field-based leg stiffness devices, Optojump Next® (Optojump) and Myotest Pro® (Myotest) in different testing approaches. Thirty-four males performed, on 2 separate sessions, 3 trials of 7 maximal hops, synchronously recorded from a force platform (FP), Optojump and Myotest. Validity (Pearson's correlation coefficient, *r*; relative mean bias; 95% limits of agreement, 95%LoA) and reliability (coefficient of variation, CV; intraclass correlation coefficient, ICC; standard error of measurement, SEM) were calculated for first attempt, maximal attempt, and average across 3 trials. For all 3 methods, Optojump correlated highly to the FP (range r = .98–.99) with small bias (range 0.91–0.92, 95%LoA 0.86–0.98). Myotest demonstrated high correlation to FP (range r = .81–.86) with larger bias (range 1.92–1.93, 95%LoA 1.63–2.23). Optojump yielded a low CV (range 5.9% to 6.8%), high ICC (range 0.82–0.86), and SEM ranging 1.8–2.1 kN/m. Myotest had a larger CV (range 8.9% to 13.0%), moderate ICC (range 0.64–0.79), and SEM ranging from 6.3 to 8.9 kN/m. The findings present important information for these devices and support the use of a time-efficient single trial to assess leg stiffness in the field.

Keywords: hopping test, vertical stiffness, test-retest, sensitivity

Leg stiffness describes the response of the lower limbs to generate force and resist deformation during rebound activities.[1,2] Enhanced stiffness is beneficial to reduce metabolic cost of bouncing gait (ie, running, hopping)[3–5] as well as to attaining high sprinting speed,[6,7] whereas lower leg stiffness may lead to less storage and recoil of elastic energy, placing greater metabolic demand during push-off, and to a reduced ability to sustain impact loads, raising injury risk.[2,8,9]

Two field-based devices that can assess leg stiffness are the Optojump Next (Microgate, Bolzano, Italy; henceforth Optojump) and Myotest Pro (Myotest, Sion, Switzerland; henceforth Myotest).[10,11] Optojump is an optical measurement system consisting of 2 infrared photocell bars that can derive contact and flight times from the breaking of the transmitted beam, whereas Myotest is a wireless lightweight portable triaxial accelerometer that can be fixed on the athlete. Both are portable and practical, allowing athletes to jump on any given surface, used largely because of their versatility and reasonable cost.[12–14]

The aim of the current study was 2-fold. Criterion-related validity, reliability, and sensitivity of Optojump and Myotest for measuring leg stiffness in hopping were assessed. These aspects were then examined with 3 different procedures: the first trial executed, the average across 3 trials, and the maximal stiffness value, to explore whether a single trial is sufficient.

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Methods

Participants

Thirty-four males (age 21.8 ± 3.9 y, height 1.83 ± 0.07 m, mass 79.0 ± 11.4 kg) took part in the study. They were physically active and free from lower limbs injuries for at least 6 months prior. Participants were instructed to refrain from strenuous exercise, alcohol, and caffeine for 2 days, 24 hours, and 2 hours before testing, respectively. Procedures were approved by the University ethical committee and informed consent was given by all participants.

Procedures

Participants visited the laboratory twice, 1 week apart, at the same time of the day. Following a standardized warm up, participants were familiarized with the test. Following a 5-minute rest, 3 trials of the 7 maximal hopping test (7MH) were performed, with 2 minutes resting between trials. Participants were instructed to jump as high as possible, with minimal contact time, and with arms akimbo at all times.

All jumps were performed on a force platform (FP) (AccuPower, AMTI, Watertown, MA, USA; 200 Hz sampling rate). Average contact and flight times from all jumps, and participants' body mass, obtained from the resulting vertical force–time trace, were used to calculate leg stiffness (kN/m) using Equation 1 shown below.[15]

$$\text{Leg stiffness} = \frac{\text{Mass} \times \pi\ (\text{flight time} + \text{contact time})}{\text{contact time}^2 \times \left(\left(\frac{\text{flight time} + \text{contact time}}{\pi}\right) - \left(\frac{\text{contact time}}{4}\right)\right)} \quad (1)$$

Data were synchronously collected by Optojump and Myotest (Figure 1). Optojump 1-m bars (resolution of 96 diodes, 1 kHz sampling rate) were placed on the lateral edges of the FP. Average contact and flight times from all jumps and the participant's body mass were used in Equation 1 to calculate leg stiffness.[15] Myotest (500 Hz sampling rate) was fixed on the participants with an elastic Velcro waistband, fastened around both great trochanters and the medium part of the gluteal region, as per manufacturer instructions. Myotest calculates leg stiffness, taking into account the average of the best 3 hops from any given trial. Leg stiffness values were displayed on the device screen immediately after the trial.

Data Analysis

Leg stiffness was examined for all 3 devices from (a) the first trial from each session (K_{First}), (b) the average across 3 trials from each session (K_{Avg}), and (c) the maximal value from each session (K_{Max}).

For the K_{Max} approach, Wilcoxon signed-rank test was used to check for conformity of the trial number wherein the maximum stiffness value occurred between each device and FP, revealing no significant difference for any comparison. For the K_{Avg} approach, within-subject variation over the 3 trials was assessed via 1-way repeated-measures ANOVA before averaging, reporting no significant differences. Therefore, stiffness results for each subject were collapsed to a single value per session.

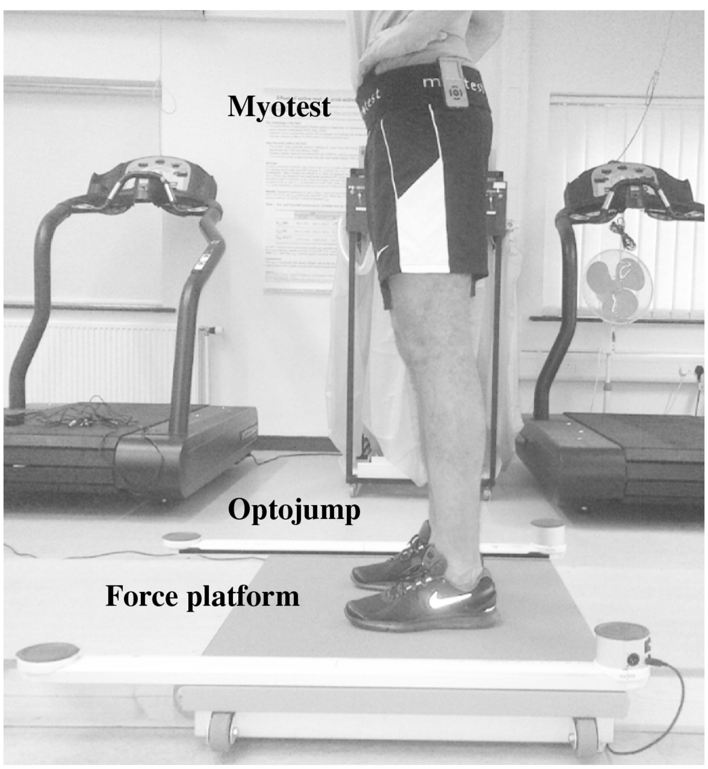

Figure 1 — Experimental setup of the devices for synchronous data collection.

Criterion-Related Validity Assessment Procedures

As no significant test-retest differences (examined with paired *t* test) between the first and second sessions were reported for any of the devices, results were collapsed to a single participant value for each of the K_{First}, K_{Max}, and K_{Avg} procedures,[16] which were then used for criterion-related validity of the Optojump and Myotest in comparison with the FP. Data were checked for heteroscedasticity by correlating the test score differences between either Optojump or Myotest and the FP to their mean value, for each procedure.[17] As significant correlations were found, raw data were transformed using the natural logarithm before further analysis occurred.[17] Normality of residuals (log test score differences between either Optojump or Myotest and FP) was confirmed for each device and procedure using the Shapiro-Wilk test, with normality defined as the ratio of skewness and kurtosis to the respective standard error not exceeding ± 2.0.[18] Criterion-related validity of each device to the FP was assessed via Pearson's correlation coefficient and relative mean bias. In addition, 95% limits of agreement (95%LoA) were reported.[17] Pearson's correlation coefficient (r) was interpreted as indicating high correlation for an r value above .8.[19] Relative mean bias was calculated as the difference between the logarithmic transformed score means of either Optojump or Myotest and FP, and reported as antilog, meaning it was interpreted as the ratio between the average outcome of the examined device and that of the FP. Likewise, 95%LoA were calculated on the logarithmic scale, and reported as antilogs as mean difference ± 1.96 standard deviations of the differences.

Reliability Assessment Procedures

The residuals (raw first – second session score differences) and the respective pair means for each piece of equipment and procedures were correlated and homoscedastic distribution was confirmed. Thus, data were further analyzed as raw values. Normality of the residuals was then confirmed for each procedure and device.

Indices of both absolute and relative reliability were used for the investigation, for each procedure. Absolute intersession reliability was assessed via coefficient of variation and standard error of measurement (CV and SEM, respectively). The CV threshold was set at 10%, with values below suggesting high consistency.[20,21] SEM was calculated as the square root of the mean square error term in a repeated-measures ANOVA.[18] SEM is of practical importance, allowing coaches to determine the minimum difference (MD; Equation 2) needed for a performance change to be considered real (95% confidence) rather than a measurement error.[18,22]

$$\text{MD} = \text{SEM} \times 1.96 \times \sqrt{2} \quad (2)$$

Finally, relative intersession reliability was assessed by intraclass correlation coefficient (ICC), calculated as shown below in Equation 3.[23]

$$\text{ICC} = 1 - \left(\frac{\text{SEM}^2}{\text{mean of subjects' standard deviation between trials}^2}\right) \quad (3)$$

The threshold was set at 0.8, with values above indicating small measurement error.[24] In addition, 95% confidence intervals for ICCs were also calculated.[25]

Statistical significance level was set at $P < .05$. All statistical tests were performed using SPSS software (version 20; IBM Inc., Chicago, IL, USA).

Results

Leg stiffness calculated from Optojump demonstrated high correlation to FP (Table 1) in all analysis procedures (range $r = .98–.99$, $P < .001$) with bias ranging from 0.91 to 0.92 (Table 1). Limits of agreement (Table 1, Figure 2) were not substantially different between procedures. Leg stiffness calculated from Myotest (Table 1) also showed high correlation to leg stiffness calculated from FP in all methods (range $r = .81–.86$, $P < .001$). However, bias ranged between 1.92 and 1.93 (Table 1), resulting in increased 95%LoA (Figure 2).

FP exhibited low CV, suggesting good absolute reliability (Table 2). However, when relative reliability was considered, only K_{Max} procedure reported an ICC ≥ 0.8, with K_{First} and K_{Avg} ICCs of 0.74 and 0.79, respectively. Optojump revealed high absolute and relative reliability in all 3 analysis procedures, shown from relatively low values of group mean CV and high ICC (Table 2). For Myotest, the K_{Avg} procedure was the more consistent with a low CV but moderate ICC, whereas K_{First} and K_{Max} reported lower consistency (Table 2). For all procedures, Myotest yielded higher SEM than the FP and Optojump (Table 2).

Discussion

The aim of this study was to determine criterion-related validity and reliability of 2 commonly used field-based devices (ie, Optojump and Myotest) in measuring leg stiffness. In addition, 3 different analysis procedures were examined (ie, K_{First}, K_{Max} and K_{Avg}) to provide practical information in terms of timing requirements to assess leg stiffness. Optojump showed underestimated and correlated leg stiffness measurement compared with FP, with all analysis procedures being reliable. Myotest showed overestimated and correlated leg stiffness measurement compared with FP, with moderate reliability for all 3 procedures.

Leg stiffness values measured with Optojump agreed well with the FP values and are within the range reported from previous literature.[15,26–28] When the 3 different procedures were considered, all showed high reliability, with similar indexes to earlier research using the FP.[29,30] The systematic bias of Optojump was most likely due to the placement of Optojump bars on the FP (Figure 1), meaning the infrared beams were 0.3 cm higher than the FP surface,[31] resulting in increased contact time and reduced flight time compared with those of FP, and, in turn, lower leg stiffness.[15,32] Although this height discrepancy may appear as a methodological concern, this approach was adopted as in field testing, where the beams will inherently be raised on a given surface (eg, ground, court, track).

Leg stiffness values obtained from Myotest were significantly greater than the FP and outside the values seen from hopping in previous reports.[15,26–28] Further, reliability for all 3 procedures was moderate. Our results contradict the study by Choukou et al,[11] who reported the 5-hop test as valid and reliable in measuring leg stiffness using Myotest. The higher number of total hops considered in Choukou et al[11] (all 5, compared with best 3 in the present investigation) could have reduced within-subject variability.[23] The overestimation of leg stiffness and poorer reliability of Myotest in relation to the FP might be attributed firstly to the Myotest leg stiffness computation being based on integration of acceleration, with respect to mass and time, establishing the time interval of integration when the accelerations are null.[11] As maximal descending velocity is achieved shortly after touchdown, whereas maximal ascending velocity is attained slightly before take-off,[11] contact time and center of mass displacement are underestimated, while flight time, force, and jump height are overestimated,[11,13] in turn magnifying leg stiffness values. Secondly, the fast transition between braking and push-off phase during the maximal hopping task is likely to have caused vibrations of the device and in turn erroneous acceleration detections.

Table 1 Leg stiffness (mean ± standard deviation) for session 1 and session 2, and criterion-related validity statistics, compared with FP

		Leg Stiffness (kN/m)				
		Session 1	Session 2	r	Relative Mean Bias	95%LoA
K_{First}	Force platform	26.3 ± 5.1	26.6 ± 5.6			
	Optojump	24.2 ± 4.4	24.2 ± 5.1	.99	0.91	0.86–0.96
	Myotest	53.0 ± 15.2	50.7 ± 14.0	.82	1.93	1.63–2.23
K_{Avg}	Force platform	26.0 ± 5.2	26.2 ± 5.0			
	Optojump	24.1 ± 4.6	23.9 ± 4.4	.99	0.92	0.86–0.98
	Myotest	52.0 ± 14.3	50.2 ± 12.4	.86	1.92	1.64–2.19
K_{Max}	Force platform	27.6 ± 5.6	27.6 ± 5.9			
	Optojump	25.1 ± 4.7	24.8 ± 5.4	.98	0.92	0.87–0.97
	Myotest	55.0 ± 15.1	51.8 ± 13.6	.81	1.93	1.67–2.19

Note. K_{First} = first attempt procedure; K_{Avg} = session average value procedure; K_{Max} = maximal value procedure; Optojump = Optojump Next; Myotest = Myotest Pro; r = Pearson's product moment correlation coefficient; 95%LoA = 95% limits of agreement. All r values were statistically significant at the level of $P < .001$.

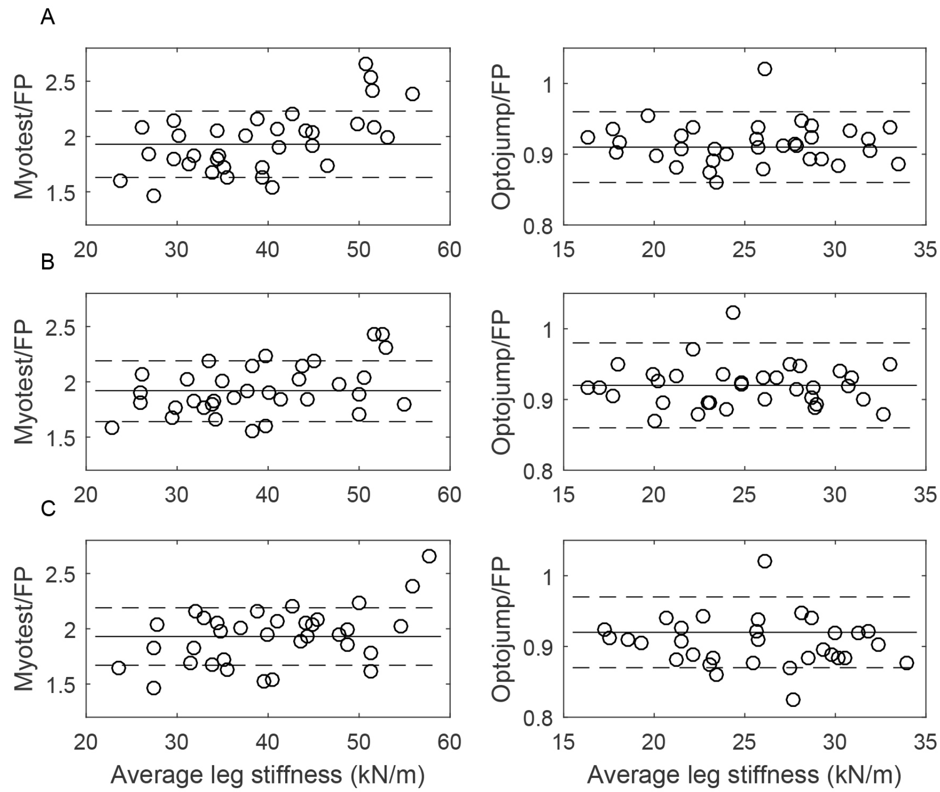

Figure 2 — Limits of agreement. Ratio of leg stiffness measurements outcome between either Myotest (left side) or Optojump (right side) and force platform (FP), plotted against their average. The continuous line represents the mean relative bias between the examined device and the FP. Dashed lines represent lower and upper limits with 95% confidence. (A) The first trial per session was considered (K_{First}). (B) The average across the 3 trials per session was retained (K_{Avg}). (C) The maximal stiffness value per session was considered (K_{Max}).

Table 2 Test-retest reliability statistics for every device

		CV ± SD (%)	SEM (kN/m)	ICC (95% CI)
K_{First}	Force platform	7.7 ± 7.5	2.8	0.74 (0.57–0.84)
	Optojump	6.6 ± 5.4	2.1	0.82 (0.70–0.90)
	Myotest	12.4 ± 7.0	7.6	0.74 (0.57–0.84)
K_{Avg}	Force platform	6.5 ± 7.7	2.4	0.79 (0.64–0.88)
	Optojump	5.9 ± 5.2	1.8	0.86 (0.74–0.92)
	Myotest	8.9 ± 7.1	6.3	0.79 (0.64–0.88)
K_{Max}	Force platform	7.3 ± 7.8	2.6	0.80 (0.66–0.88)
	Optojump	6.8 ± 6.7	2.1	0.83 (0.71–0.90)
	Myotest	13.0 ± 9.4	8.7	0.64 (0.44–0.78)

Note. K_{First} = first attempt procedure; K_{Avg} = session average value procedure; K_{Max} = maximal value procedure; Optojump = Optojump Next; Myotest = Myotest Pro; CV = coefficient of variation; SD = standard deviation; SEM = standard error of measurement; ICC = intraclass correlation coefficient; CI = confidence intervals.

High sensitivity of a device allows for better determining differences resulting from true changes of the physical characteristic evaluated rather than from a measurement error.[22,33] For this purpose, we calculated SEM to determine MD and construct confidence intervals, which can detect, with 95% confidence, real changes in the variable being measured. The importance of this is illustrated in the following example. Let us assume that an athlete achieves a stiffness score of 25 kN/m at pre-intervention assessment, and a value of 33kN/m at post-intervention assessment. Replacing the respective SEM from the K_{First} procedure (Table 2) in Equation 2, the MD will be 5.8 kN/m for Optojump and 21.1 kN/m for Myotest. As the test-retest difference (8 kN/m) lies outside the MD for Optojump, we would be confident of a true increase post-intervention, whereas we would be unable to reach such a conclusion using Myotest.

Assessing many athletes within the time restrictions of a training or an assessment session requires use of scientifically rigorous methods and consideration of the practical aspects of the assessment (eg, time availability, set-up, and feedback time). Our results showed that leg stiffness assessment can be completed in a valid and reliable manner in the field. Further, leg stiffness can be confidently assessed with the use of a single trial, allowing time-efficient testing, in particular when short time frames are available or large populations are to be tested.

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