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Validity and reliability of two field-based leg stiffness devices: implications for practical use

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Abstract

Leg stiffness is an important performance determinant in several sporting activities. This study evaluated the criterion-related validity and reliability of two field-based leg stiffness devices, Optojump Next® and Myotest Pro® in different testing approaches. Thirty-four males performed, on two separate sessions, three 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 three trials. For all three methods, Optojump correlated highly to the FP (range r = 0.98-0.99) with small bias (range 0.91-0.92, 95%LoA 0.86-0.98). Myotest demonstrated high correlation to FP (range r = 0.81-0.86) with larger bias (range 1.92-1.93, 95%LoA 1.63-2.23). Optojump yielded a low CV (range 5.9%-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%-13.0%), moderate ICC (range 0.64-0.79) and SEM ranging from 6.3-8.9 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.

Word Count: 2043

Introduction

Leg stiffness describes the response of the lower limbs to generate force and resist deformation during rebound activities.[8,9] Enhanced stiffness is beneficial to reduce metabolic cost of bouncing gait (i.e. running, hopping)[12-14] as well as to attaining high sprinting speed[15-16], 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.[9,11,17]

Two field-based devices that can assess leg stiffness are the Optojump Next® (Microgate, Bolzano, Italy) and Myotest Pro® (Myotest, Sion, Switzerland).[21-22] Optojump is an optical measurement system consisting of two 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.[23-25]

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

Methods

Participants

Thirty-four males (age 21.8 ± 3.9 years, 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 six months prior. Participants were instructed to refrain from strenuous exercise, alcohol, and caffeine for 2 days, 24 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 standardised warm up, participants were familiarised with the test. Following a 5-minute rest, 3 trials of the 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, United States; 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.[18]

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

Data were synchronously collected by Optojump and Myotest (Figure 1). Optojump 1-meter 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 was used in Eq. 1 to calculate leg stiffness.[18] 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 three 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 three devices from a) the 1st trial from each session (K_{First}), b) the average across three 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 three 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.

Criterion-related validity assessment procedures

As no significant test-retest differences (examined with paired *t*-test) between the 1st and 2nd 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,[28] which were then used for criterion-related validity of the Optojump and Myotest in comparison to the FP. Data was checked for heteroscedasticity by correlating the test score differences between either Optojump or Myotest and the FP to their mean value, for each procedure.[29] As significant correlations were found, raw data was transformed using the natural logarithm before further analysis occurred.[29] 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.[30] Criterion-related validity of each device to the FP was assessed via Pearson's correlation coefficient and relative mean bias. Additionally, 95% limits of agreement (95%LoA) were reported.[29] Pearson's correlation coefficient (r) was interpreted as indicating high correlation for an r value above 0.8.[31] 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 1st – 2nd session score differences) and the respective pair means for each piece of equipment and procedures were correlated allowing homoscedastic distribution to be confirmed. Thus, data was 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.[33,34] SEM was calculated as the square root of the mean square error term in a repeated measures ANOVA.[30] SEM is of practical importance, allowing coaches to determine the minimum difference (MD; Eq. 2) needed for a performance change to be considered real (95% confidence) rather than a measurement error[30,35]

$$\mathrm{MD} = \mathrm{SEM} \times 1.96 \times \sqrt{2} \qquad \text{(Eq. 2)}$$

Finally, relative intersession reliability was assessed by interclass correlation coefficient (ICC), calculated as[36]:

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

The threshold was set at 0.8, with values above indicating small measurement error.[37] 95% confidence intervals for ICCs were also calculated.[38]

Statistical significance level was set at $P < 0.05$. All statistical tests were performed using SPSS software (IBM SPSS Statistics, version 20, Inc., Chicago, IL, USA).

Results

Leg stiffness calculated from Optojump demonstrated high correlation to FP (Table 1) in all analysis procedures (range r = 0.98-0.99, $P < .001$) with bias ranging from 0.91 to 0.92 (Table 2). 95%LoA (Table 2, 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 = 0.81 – 0.86, $P < .001$). However, bias ranged between 1.92 and 1.93 (Table 2), resulting in increased 95%LoA (Figure 2).

FP exhibited low CV, suggesting good absolute reliability (Table 3). 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 three analysis procedures, shown from relatively low values of group mean CV and high ICC (Table 3). 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 3).

For all procedures, Myotest yielded higher SEM than the FP and Optojump (Table 3).

Discussion

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

Leg stiffness values measured with Optojump agreed well with the FP values and are within the range reported from previous literature.[10,18-20] When the three different procedures were considered, all showed high reliability, with similar indexes to earlier research using the FP.[39,40] 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,[26] resulting in increased contact time and reduced flight time compared to those of FP, in turn lower leg stiffness.[4,18] Although this height discrepancy may appear as a methodological concern, this approach was adopted as in field testing, the beams will inherently be raised on a given surface (e.g. 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. [10,18-20] Further, reliability for all three procedures was moderate. Our results contradict the study by Choukou et al.[22] 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.[22] (all 5, compared to best 3 in the present investigation) could have reduced within-subject variability[36]. 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, and establishes the time interval of integration when the accelerations are null.[22] As maximal descending and ascending velocities are not achieved at those exact points, contact time and centre of mass displacement are underestimated, while flight time, force and jump height are overestimated[22,24]; 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.

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.[35,42] 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 3) in Eq. 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 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 the practical aspects of the assessment (e.g. 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 short time frames are available or large populations are to be tested.

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Tables

Table1. Leg stiffness (mean ± SD) for Session 1 and Session 2.

		Leg Stiffness (kN/m)	
		Session 1	**Session 2**
$\mathbf{K_{First}}$	**FP**	26.3± 5.1	26.6± 5.6
	Optojump	24.2± 4.4	24.2 ± 5.1
	Myotest	53.0± 15.2	50.7± 14.0
$\mathbf{K_{Avg}}$	**FP**	26.0± 5.2	26.2± 5.0
	Optojump	24.1 ± 4.6	23.9 ± 4.4
	Myotest	52.0 ± 14.3	50.2 ± 12.4
$\mathbf{K_{Max}}$	**FP**	27.6± 5.6	27.6± 5.9
	Optojump	25.1± 4.7	24.8± 5.4
	Myotest	55.0± 15.1	51.8± 13.6

Note. First attempt procedure (K_{First}); maximal value procedure (K_{Max}); session average value procedure (K_{Avg}); force platform (FP).

Table 2. Criterion-related validity statistics, compared to FP.

		r	Relative mean bias	95% LoA
K_{First}	**Optojump**	0.99	0.91	0.86 – 0.96
	Myotest	0.82	1.93	1.63 – 2.23
K_{Avg}	**Optojump**	0.99	0.92	0.86 – 0.98
	Myotest	0.86	1.92	1.64 – 2.19
K_{Max}	**Optojump**	0.98	0.92	0.87-0.97
	Myotest	0.81	1.93	1.67 – 2.19

Note. First attempt procedure (K_{First}); maximal value procedure (K_{Max}); session average value procedure (K_{Avg}); force platform (FP); Pearson's product moment correlation coefficient (r); limits of agreement (LoA). All r values were statistically significant at the level of $P < .001$.

Table 3. Test-retest reliability statistics for every device

		CV ± SD (%)	SEM (kN/m)	ICC (95% CI)
$\mathbf{K_{First}}$	**FP**	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)
$\mathbf{K_{Avg}}$	**FP**	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)
$\mathbf{K_{Max}}$	**FP**	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. First attempt procedure (K_{First}); maximal value procedure (K_{Max}); session average value procedure (K_{Avg}); force platform (FP); intraclass correlation coefficient (ICC); confidence intervals (CI); coefficient of variation (CV); standard deviation (SD); standard error of measurement (SEM).

Figure and Captions

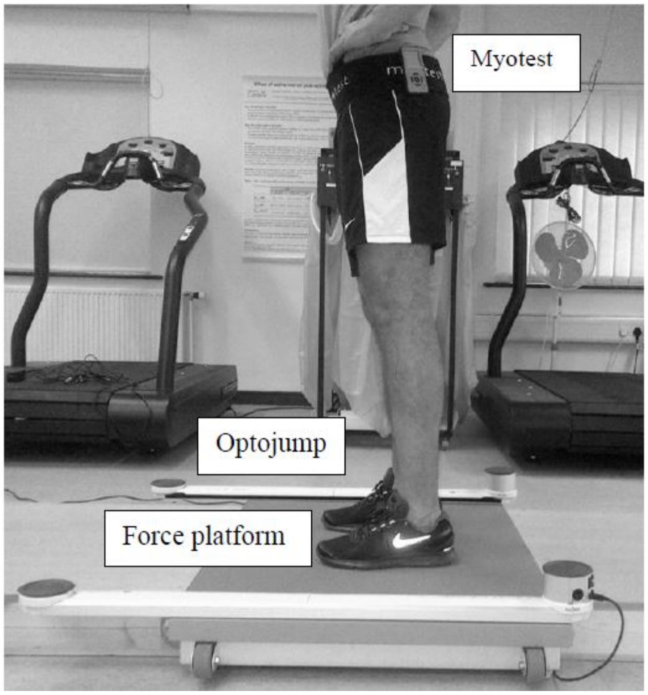

Figure 1. Experimental setup of the devices for synchronous data collection. Note that, custom-made wooden blocks were aligned behind and ahead of the force platform.

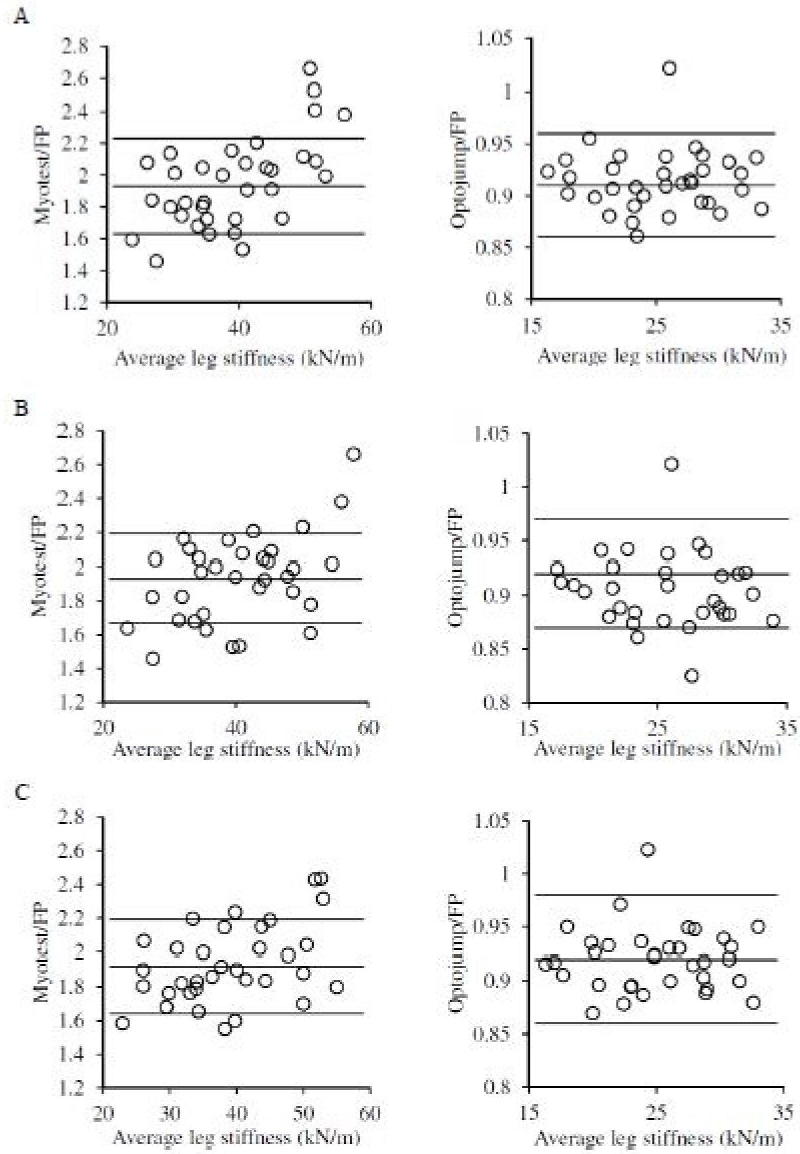

Figure 2. Limits of agreement. Ratio of leg stiffness measurements outcome between either Myotest (left side) or Optojump (right side) and Force platform (FP), plotted against their average. The continuous line represents the mean relative bias between the examined device and the FP. Dashed lines represents lower and upper limits with 95 % confidence. A) The 1st trial per session was considered (K_{First}). B) The average across the three trials per session was retained (K_{Avg}). C) The maximal stiffness value per session was considered (K_{Max}).