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Original Research

Reliability and Validity of a New Eccentric Hamstring Strength Measurement Device

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KEYWORDS
Clinical decision-making;
Hamstring muscles;
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Abstract *Objective:* To investigate the reliability and establish validity of a new eccentric hamstring strength measurement device.
Design: A randomized double-crossover trial with intraclass correlation coefficients to analyze the outcomes. Participants attended 4 sessions, 7 days apart. They were randomly allocated into 2 groups. Session 1 was a familiarization session for all participants on the new eccentric hamstring strength measurement device and isokinetic dynamometer. The following 3 sessions were used to measure knee flexor (hamstring) eccentric strength on the isokinetic dynamometer and a further test-retest measurement using the new eccentric hamstring strength measurement device.
Setting: Institute of Technology Carlow, third level educational institution.
Participants: Male intercollegiate field-sport players completed the trial (N=19). Participants were 21±2 years, weighed 78.6±4.6 kg, and were 179.6±6.4 cm in height.
Interventions: N/A.
Main Outcome Measures: Peak torque (Nm) was recorded by the isokinetic device, and peak force (N) was recorded by the new eccentric hamstring strength measurement device and used to test for significant interdevice correlations (>0.7). Intraclass correlation coefficients were calculated using the peak force recorded from 2 separate trials of the new eccentric hamstring strength measurement device.
Results: High test-retest reliability was observed from the new eccentric hamstring strength measurement device, intraclass coefficient (ICC)=.910 (confidence interval [CI], .76-.96) and .914 (CI, .78-.96) for left and right peak forces, respectively. Typical error of measurement between trials was calculated to be 14.65 and 17.29N for the left and right limbs, respectively. Minimum detectable change (MDC) was also calculated to be 40.62N (MDC%=14.68%) and 39.63N (MDC%=13.31%) for left and right limbs, respectively. The interdevice correlation showed good validity, ICC=.823 (CI, .58-.93) and .840 (CI, .58-.93) for left and right peak torque/forces, respectively.

List of abbreviations: CI, confidence interval; CV, coefficient of variance; ICC, intraclass coefficient; MDC, minimum detectable change.
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Conclusion(s): The new eccentric hamstring strength measurement device is a reliable and valid device that provides an objective measurement of eccentric hamstring strength that may be used in combination with a comprehensive assessment to inform rehabilitation and management.

Hamstring strain injuries are prevalent in sports that involve sprinting such as soccer, rugby, and athletics.[1] Most hamstring strain injuries occur during the late swing phase in the gait cycle; it is at this stage of gait that the hamstring muscle group experiences the greatest amount of eccentric force.[2] Eccentric knee flexor strength is fundamental for performance because it allows for greater control of the descending limb during sprinting and jumping which leads to a faster change over from eccentric deceleration to concentric acceleration.[3] The Nordic Hamstring Exercise (NHE) is a commonly used eccentric strengthening exercise that the athlete performs in a high kneeling position with their ankles fixated, either by a second party or by a stationary object. From this start position the athlete inclines their torso, maintaining neutral hip alignment, for as far as possible and then uses their arms to contact the ground in front of them when the hamstrings can no longer control the movement. It is acknowledged that there are several modifiable risk factors for hamstring injury including strength imbalances between the hamstring antagonists on the same limb and asymmetries between right and left limbs.[4]

Decreased eccentric hamstring strength during the NHE has been shown to increase the risk of sustaining a hamstring injury fourfold as well as been linked to a higher risk of sustaining a noncontact anterior cruciate ligament injury.[5,6]

Consequently, objective measurement of eccentric hamstring strength may inform decision making for sporting selection, prognosis postinjury, and return to play timeframes, as well as contribute to the assessment and identification of those at potential risk of injury.

The Hamstring Solo Elite (HSE)[a] is a newly designed pressure feedback device that uses load cell technology to monitor individual limb eccentric knee flexor strength during an NHE.

The NHE is a valid means of developing hamstring strength[1,7]; however, up to this point the ability to obtain live and objective strength measures during this motion has not been possible. The availability of these additional objective data will inform practice and decision making in real time. The advantage of quantifying individual limb feedback allows imbalances, caused by limb dominance, or previous history of injury to be identified and considered in rehabilitation by the trainer or clinician.

To date, isokinetic dynamometry is considered the criterion standard for the assessment of hamstring strength.[8] Its lack of portability and cost inhibit its utility in practical and applied settings.[5] Therefore, research investigating the efficacy of alternative tests to objectively assess hamstring strength is warranted.

It is therefore important that the HSE device's reliability and validity are established against the criterion standard, isokinetic dynamometer.[9] The aim of this study was to determine the reliability and validity of the HSE.

Methods

Ethical clearance was obtained by the ethics committee at the Institute of Technology Carlow. A randomized double-crossover trial was executed with participants reporting to the isokinetic laboratory for 4 sessions that occurred 7 days apart.

Participants (N=26) were recruited from the student body at the Institute of Technology Carlow using the following inclusion criteria: (1) participates in lower limb strength training twice weekly, as a minimum, for the last 12 months and (2) competitive field sport male college students. Exclusion criteria included (1) lower extremity injury in the last 3 months, (2) any health conditions that would contraindicate performing maximal strength testing, and (3) history of recurrent low-back, hip, or knee injuries. Some participants (n=7) were excluded on the basis of the above criteria. All participants signed informed consent and completed a thorough medical screening form in the presence of the tester.

They were randomly allocated into 2 groups using a random number generator by the laboratory technician to ensure randomization of the groups was adequate and to determine the order in which their testing was to be carried out.

To achieve an acceptable intraclass coefficient (ICC) of at least 0.70 (alpha level, $\alpha=0.05$ and beta level, $\beta=0.20$), at least 19 participants were needed for data analysis.[10] The required sample size was calculated by performing power calculations based on recommendations and data from a previous research article that used similar measurement methods in comparable populations.[5] *Familiarization* (day 1) was composed of a 3-minute warmup on a Wattbike[b] at 60 rpm. During the familiarization session, the participants were required to perform repetitions of eccentric knee flexion on the Biodex System[c] (fig 1) isokinetic device at 30°/s, with maximum effort, until they could perform consistent repetitions (minimum: 5 repetitions, maximum: 10 repetitions with a 10-s rest between reps) with a coefficient of variance (CV) value of <15. During familiarization, participants also performed a minimum of 10 repetitions of the NHE, with maximum effort, on the HSE pressure feedback (fig 1). Verbal cueing was supplied to reinforce the technique during test repetitions.

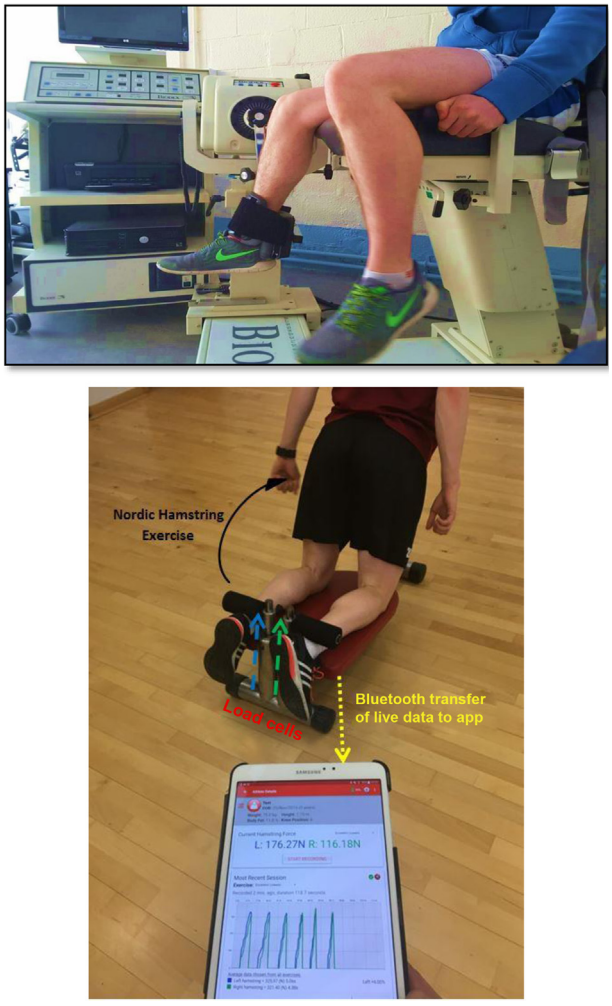

Figure 1 Biodex System 3 eccentric knee flexion apparatus setup (Top). Hamstring Solo Elite pressure feedback device (Bottom).

Isokinetic strength testing (days 2-4)

Data collection on the Biodex System consisted of 1 set of 5 maximum eccentric knee flexions on each leg at 30°/s with 10-second rest between repetitions. The participants performed a 3-minute warmup on a Wattbike at 60 rpm before commencing testing. Instruction was given to perform a maximal knee flexion contraction against the extension force applied by the device until the isokinetic arm returned to the start position.

Participants were securely fixed to the device and performed 1 practice repetition. Peak torque (Nm) for both limbs was recorded for data analysis. Repetitions were only recorded if the CV value was observed to be <15.

HSE testing (days 2-4)

The testing procedure on the HSE[3] consisted of 1 set of 5 NHE repetitions, as slowly as possible, with a 10-second rest between repetitions.

The participants performed a 3-minute warmup on a WattBike at 60 rpm before commencing testing. The participants were given visual and detailed verbal coaching cues on performance technique before commencing.

The participants were then positioned in a kneeling position on the cushioned surface of the HSE with their ankles fixed beneath the load cells, just superior to the medial and lateral malleoli; this setting was specific to each participant and consistent across all testing days. The participants were then instructed to lower their torso as slowly as possible toward the ground by only extending at the knee joint until they could no longer sustain the eccentric hamstring contraction and land on their palms on the floor. The technique required the participants to maintain a straight line from the shoulder to the knee by minimizing hip flexion and lumbar lordosis (to the best of their ability) during the repetitions. There was no minimum range of motion set and repetitions were excluded if the participants demonstrated lack of control on descent or excessive hip movement during the repetition. After each repetition, the peak force (N) generated for the left and right limbs was recorded through wireless data acquisition from the load cells

Statistical analyses

The peak torque (Nm) recorded by the isokinetic device and peak force (N) recorded by the HSE were analyzed to determine if there was a significant correlation ($r>0.7$) between devices for each limb individually. ICCs (2,1) were calculated using the mean peak torque and mean peak force data from both the isokinetic device and the HSE respectively, for each limb, to determine the validity of the HSE device when compared to the Biodex isokinetic device. ICCs (2,1) were calculated using the mean peak force recorded for each of the 2 separate testing days for the right and left limbs, respectively, on HSE to determine if the device demonstrated acceptable test-retest reliability. SEM, minimum detectable change (MDC), and percentage MDC were also calculated at a confidence level of 95%.

The statistical analysis was performed using the IBM SPSS Statistics, version 22.[d]

Results

Male participants were 21±2 years of age, weighed 78.6±4.6 kg, and were 179.6±6.4 cm in height and were all active members of the college hurling team.

Test-retest reliability of the HSE

Descriptive statistics and the HSE test-retest data for each variable are displayed in table 1 and fig 2 below. The HSE displayed high test-retest reliability between the 2 trials. The ICCs displayed between both trials ranged from .910 (CI, .76-.96) and .914 (CI, .78-.96) for the left and right limbs, respectively. Standard error of measurement (typical error of measurement) between trials was calculated to be 14.65 and 14.29N for the left and right limbs, respectively. MDC was also calculated to be 40.62N (14.68%) and 39.63N (13.31%) for left and right limbs, respectively.

Table 1 Descriptive statistics and test-retest reliability data for the HSE (N=19)

Bilateral Limb Testing	Between-Session Reliability (N)		ICC (95% CI)	TEM	MDC	MDC
	Session 1*	Session 2*		(N)	(N)	(%)
Left	268.56±51.45	269.99±48.75	.910 (.76-.96)	14.65	40.62	14.68
Right	268.72±57.12	269.57±48.84	.914 (.78-.96)	14.29	39.63	13.31
Left:right ratio	0.99±0.02	0.99±0.10	1.0 (.98-1.0)	1.0	1.02	1.1

Abbreviation: TEM, typical error of measurement.
* Values are mean ± standard deviation.

Interdevice validity

Correlations between the Biodex System3 and HSE for each variable are displayed in table 2 and fig 3 below. The validity between the Biodex and HSEs respective peak torque and peak force was observed to be very good ($r>0.7$). ICCs displayed between the devices ranged from 0.823 (CI, .586-.938) to 0.840 (CI, .586-.938) for the left and right limbs, respectively.

Discussion

The HSE displayed good ($r>0.7$) interdevice validity when ICCs with the Biodex isokinetic dynamometer were observed. When eccentric knee flexor strength was assessed for the left and right limbs by both devices; it resulted in a correlation of 0.823 (CI, .586-.938) and 0.840 (CI, .586-.938), respectively. The above results indicate that we can accept the hypothesis that the HSE is a reliable and valid device for measuring eccentric hamstring strength when compared to the Biodex isokinetic dynamometer, for at least this population of healthy athletes.

The HSE also displayed high test-retest reliability for consecutive measurements of the NHE for eccentric knee flexor strength for each limb on 2 consecutive trials, high correlations of .910 (CI, .76-.96) and .914 (CI, .78-.96) for the left and right limbs, respectively, were reported. The test-retest reliability of the HSE device is similar to the ICCs observed in previous research executed on isokinetic test-retest reliability studies (r values ranging from 0.86 to 0.95) and the test-retest reliability of handheld dynamometers ($r=0.90$).[11,12]

The test-retest reliability of a similar device, namely the Nordbord, was observed with comparable results (ICCs=0.85-0.89) in this study reported.[5] These results infer that the HSE demonstrates a good level of consistency when assessing eccentric hamstring strength during the performance of the NHE.

Reliability is essential for a device such as this, with any changes in strength observed being attributed to the intervention rather than an associated error with the

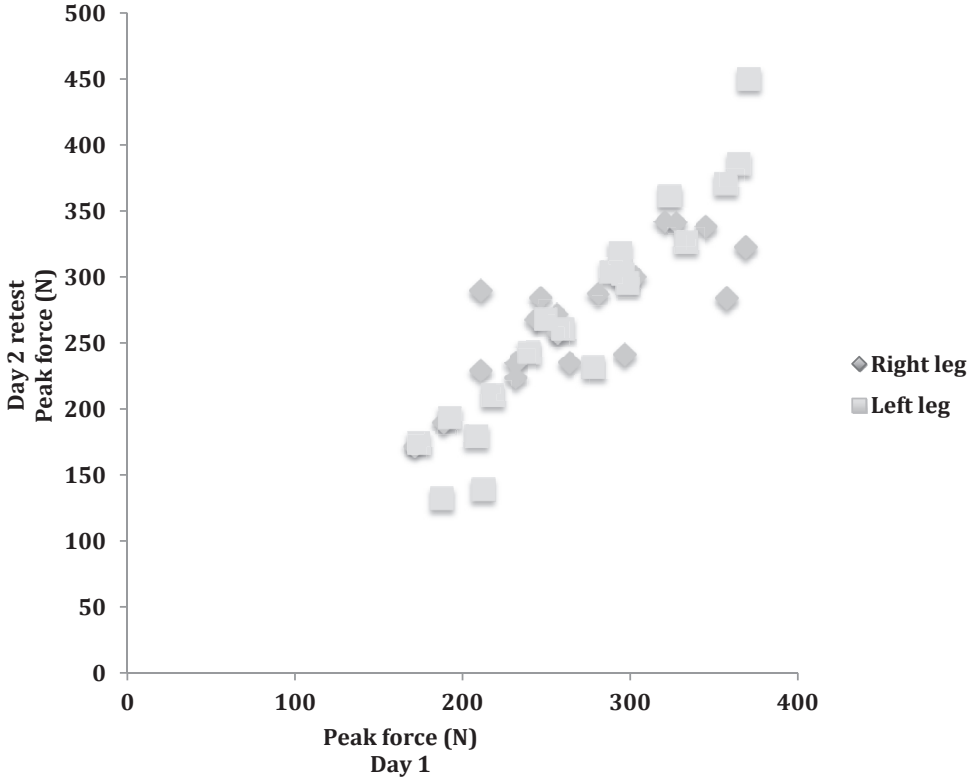

Figure 2 Scatter plot representing the correlation between participants test retest data on the HSE.

Table 2 Descriptive statistics and interdevice validity data (N=19)

Bilateral Limb Testing Eccentric Knee Flexion	Biodex System3* Peak Torque (Nm)†	Hamstring Solo Elite Peak Force (N)†	ICC (95% CI)
Left	184.71±33.61	268.56±51.45	0.823 (.586-.938)
Right	185.45±34.29	268.72±57.12	0.840 (.586-.938)
Left:right ratio	0.99±0.02	0.99±0.10	1.0 (.98-1.0)

* Biodex System3 tested eccentric knee flexion at 30°/s.
† Values are mean ± standard deviation.

device. This has significant implications in a clinical setting where accuracy is essential to prevent a misrepresentation of clinical findings. The use of accurate and highly calibrated load cell technology, in the HSE's design, means that the device should display mechanical consistency when tested repeatedly. This was confirmed by the high correlation values .910 (CI, .76-.96) and .914 (CI, .78-.96) when test-retest reliability was examined.

An externally fixed dynamometer such as the HSE has not been validated against an isokinetic dynamometer such as the Biodex System3 until now, and therefore the literature lacks comparative ICCs for this study. The significant correlations observed are vital in validating the device; these results show that the HSE displays good (>0.7) validity when compared to the Biodex, a reliable criterion standard method of assessing strength, previously shown ICCs ranging from 0.86 to 0.95.[11-14] The results of this study infer that the HSE may be used as a valid mean of assessing eccentric knee flexor strength through the performance of the NHE.

The significant correlations observed between the Biodex and the HSE, 0.823 (CI, .586-.938) and 0.840 (CI, .586-.938), may be due to the similar nature of the test where the participants perform maximal eccentric contractions until they can no longer control the movement. Using mean peak values as a comparison eliminates outliers in the measurements such as shorter or longer contraction durations causing large differences in average strength values.

Study limitations

The main limitations of the study were the relatively low sample size (N=19). Recruiting participants with the ability to perform maximal eccentric repetitions consistently as well as controlling their activities between testing, such as team training, proved to be a challenge and may have affected the results. Varying levels of participant fatigue while testing or minor injuries elsewhere in the kinetic chain may also have negatively affected the results. Future research should look to increase the sample size tested and also carry out greater familiarization to encourage optimal consistency in recorded repetitions as well as establish the

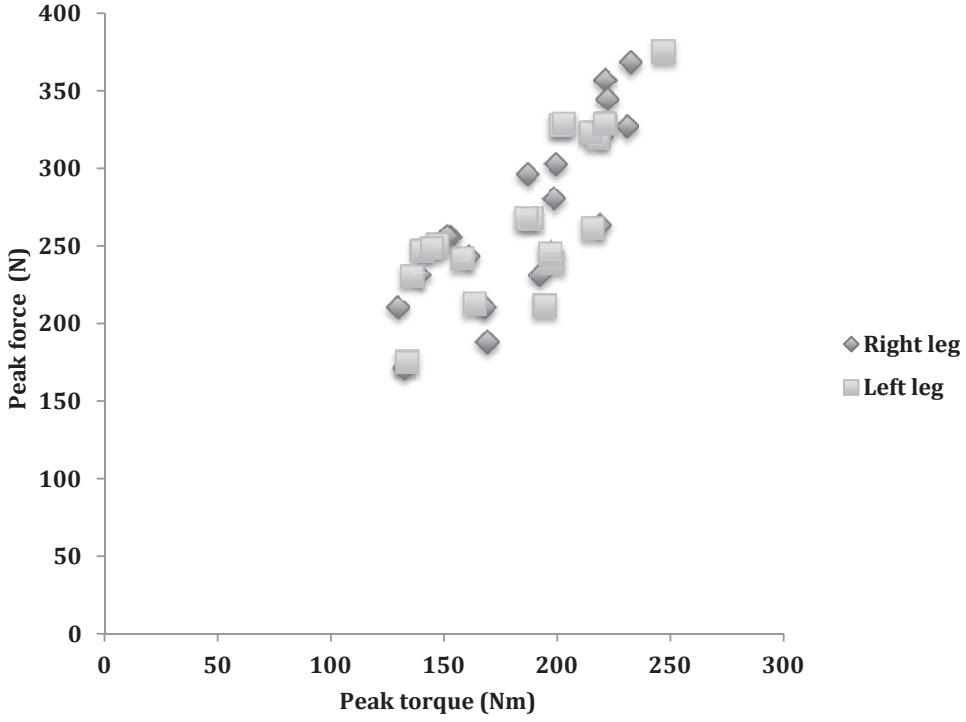

Figure 3 Scatterplot representing the inter device correlation for Isokinetic peak torque (Nm) and the HSE peak force (N) for each participant.

participants' leg dominance; this information would be valuable and is recommended in future studies. This study did not monitor lost data points due to participants' poor control or incomplete repetitions on the HSE; this would be valuable information in the future and may provide further insight into the devices' applicability to a wider population.

It is acknowledged that the HSE device itself has limited capacity because it cannot control repetition speed or provide an angle of peak torque which would be useful when targeting strength improvements at a specific joint angle where injury is common, for example, late swing phase of gait as previously alluded to in the literature. The issue of repetition speed could be addressed using a metronome to set the tempo at which the contraction should be carried out; however, this would require participants to have a high level of eccentric control. The device does not provide a CV value to determine if a repetition is valid, which is an important feature of isokinetic dynamometers and one must consider, given its portable quality, whether the device would need to be recalibrated over time with repeated transportation.

Conclusions

The HSE provides a reliable and valid means of assessing eccentric hamstring strength. Its portable and accessible design allows for easy implementation in multiple settings. The incorporation of this device as an adjunct to eccentric hamstring assessment to guide rehabilitation could play a key role in detecting, quantifying, and addressing strength deficits in patients and athletes.

Suppliers

a. Hamstring Solo Elite; ND Sports Performance.
b. Wattbike; T+F Fitness Systems Ltd.
c. Biodex System; Biodex Medical Systems, Inc.
d. IBM SPSS Statistics, version 22; IBM.

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