

A novel device using the Nordic hamstring exercise to assess eccentric knee flexors strength:  
a reliability and retrospective injury study

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All testing procedures were approved by the Queensland University of Technology Human  
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**Study design:** Reliability and case-control injury study.

**Objectives:** 1) To determine if a novel device, designed to measure eccentric knee flexors strength via the Nordic hamstring exercise (NHE), displays acceptable test-retest reliability; 2) to determine normative values for eccentric knee flexors strength derived from the device in individuals without a history of hamstring strain injury (HSI) and; 3) to determine if the device could detect weakness in elite athletes with a previous history of unilateral HSI.

**Background:** HSIs and reinjuries are the most common cause of lost playing time in a number of sports. Eccentric knee flexors weakness is a major modifiable risk factor for future HSIs, however there is a lack of easily accessible equipment to assess this strength quality.

**Methods:** Thirty recreationally active males without a history of HSI completed NHEs on the device on 2 separate occasions. Intraclass correlation coefficients (ICCs), typical error (TE), typical error as a co-efficient of variation (%TE), and minimum detectable change at a 95% confidence interval (MDC<sub>95</sub>) were calculated. Normative strength data were determined using the most reliable measurement. An additional 20 elite athletes with a unilateral history of HSI within the previous 12 months performed NHEs on the device to determine if residual eccentric muscle weakness existed in the previously injured limb.

**Results:** The device displayed high to moderate reliability (ICC = 0.83 to 0.90; TE = 21.7 N to 27.5 N; %TE = 5.8 to 8.5; MDC<sub>95</sub> = 76.2 to 60.1 N). Mean±SD normative eccentric flexors strength, based on the uninjured group, was 344.7 ± 61.1 N for the left and 361.2 ± 65.1 N for the right side. The previously injured limbs were 15% weaker than the contralateral uninjured limbs (mean difference = 50.3 N; 95% CI = 25.7 to 74.9N; P < .01), 15% weaker than the normative left limb data (mean difference = 50.0 N; 95% CI = 1.4 to 98.5 N; P = .04) and 18% weaker than the normative right limb data (mean difference = 66.5 N; 95% CI = 18.0 to 115.1 N; P < .01).

**Conclusions:** The experimental device offers a reliable method to determine eccentric knee flexors strength and strength asymmetry and revealed residual weakness in previously injured elite athletes.

**KEY WORDS:** Dynamometry, hamstring, strain injury

Hamstring strain injuries (HSIs) are the most common injury type to occur in a number of sports,<sup>4,9,17</sup> and are notorious for high recurrence rates. A high proportion of HSIs are thought to occur during the terminal swing phase of high speed running<sup>5</sup> when the hamstrings are required to perform a forceful eccentric contraction.<sup>20,23</sup> Lower eccentric knee flexors strength has been reported as a risk factor for future HSI,<sup>8,19</sup> indicating the importance of eccentric strength for HSI avoidance.<sup>3,18</sup> Further, previously strained hamstrings display reduced levels of eccentric knee flexor strength compared to the uninjured contralateral limb,<sup>7,13</sup> which may partially explain why a previous HSI is the primary risk factor for future injury.<sup>2</sup> Currently the gold standard measure for the assessment of eccentric knee flexors strength is through isokinetic dynamometry,<sup>1</sup> however this technique is limited by the high cost of the device and therefore its lack of widespread availability. While hand held dynamometers have become a popular field based alternative they are dependent on operator skill and strength to collect reliable and valid data.<sup>22</sup> The purpose of this investigation was 1) To determine if a novel device, designed to measure eccentric knee flexors strength via the Nordic hamstring exercise (NHE), displays acceptable test-retest reliability; 2) to determine normative values for eccentric knee flexors strength derived from the device in individuals without a history of HSI and; 3) to determine if the device could detect weakness in elite athletes with a previous history of unilateral HSI.

## **METHODS**

### **Participants**

Thirty sub-elite male athletes, most competing in Australian football, rugby (league, union, or touch), soccer, or sprinting, participated in the reliability section of the study. In addition, 20 professional elite athletes from Australian football, rugby union, and track and field, with a history of HSI within the previous 12 months were tested on a single occasion. Athletes who

did not have magnetic resonance imaging (MRI) performed to confirm the hamstring injury, who did not show a lesion on MRI, or had a history of traumatic knee injury were excluded from the study. All participants were free of any current injury to the lower limbs and were fully active in their chosen sport at the time of testing. All testing procedures were approved by the Queensland University of Technology Human Research Ethics Committee and participants gave informed written consent prior to testing after having all procedures explained to them.

### **Experimental design**

For the collection of reliability and normative data on subjects without a history of HSI in the previous 12 months, all participants reported to the laboratory on 3 separate occasions. The first occasion was a familiarisation session and the following 2 occasions were used to determine eccentric knee flexors strength via the novel device. All participants with a history of a HSI within the prior 12 months, who participated in the second part of the study, were performing NHEs as part of their regular training routine, negating the need for a familiarisation session. Therefore they completed a single testing session.

### **Experimental device**

For the reliability and normative data section of the study, participants were positioned in a kneeling position over a padded board (**FIGURE 1**), with the ankles secured superior to the lateral malleolus by individual lockable braces which were affixed atop commercially available uniaxial load cells (MLP-1K, Transducer Techniques, CA, USA) (**FIGURE 2**). The ankle braces and load cells were mounted on a pivot which allowed the load cells to be positioned perpendicular to the shank at all times. Following a warm up set of submaximal bilateral NHEs, participants were asked to perform 2 sets of 3 maximal NHEs bilaterally and

unilaterally. For unilateral contractions only the tested limb was secured in the ankle brace. Bilateral NHEs were always performed first with the order of limbs tested for unilateral NHEs randomised among participants. The amount of rest between sets was 2 minutes. Testing of subjects with a history of HSI differed in that only bilateral NHE were performed and the load cells employed were custom made (Delphi Force Measurement, Gold Coast, Australia) and fitted with wireless data acquisition capabilities (Mantracourt, Devon, UK).

For both parts of the study, for testing, participants were instructed to gradually lean forward at the slowest possible speed while maximally resisting this movement with both limbs while keeping the trunk and hips held in a neutral position throughout, and the hands held across the chest (**FIGURE 1**). The investigators gave verbal encouragement throughout the range of motion to ensure maximal effort. There was no minimum requirement regarding the range of motion that participants needed to achieve during the NHE. Technique for all repetitions was monitored visually by the investigators and individual repetitions were rejected if participants displayed excessive hip movement, or if the participant did not control the descent from the beginning of the movement.

### **Injury history**

For all athletes recruited to the second part of the study, details of any prior injury for the preceding 12 months was ascertained from their club clinician. Details obtained included which limb was injured (dominant/non dominant limb), muscle injured (biceps femoris long head/biceps femoris short head/semimembranosus/semitendinosus), location of injury (proximal/distal, muscle belly/muscle-tendon junction), activity type performed at time of injury (ie, running, kicking) and grade of injury (I, II, or III).

## **Data analysis**

For the reliability and normative part of the study, force data were transferred to a personal computer at 1000 Hz through a 16-bit PowerLab26T AD recording unit (ADInstruments, New South Wales, Australia). Subsequently, the peak force for each trial for both limbs (left and right) and conditions (bilateral and unilateral), was determined using LabChart 7.3 (ADInstruments, New South Wales, Australia). The maximal force generation was expressed both as the average of the peak force from the 6 trials (average peak force) and as the single highest peak of 6 trials (peak force). The between limb force ratio was calculated as left limb:right limb ratio. The between limb force ratios were calculated as recommended<sup>12</sup> using log transformed raw data followed by back transformation.

For the group of subjects with a recent history of HSI, force data were transferred to a personal computer at 100 Hz through a wireless USB base station receiver (Mantracourt, Devon, UK). In this group, only the average peak force was determined based on the peak force from each of the 6 bilateral trials.

## **Statistical analysis**

For the group without a history of HSI, descriptive statistics were calculated independently for the left and right side for all force variables and between limb force ratios. Intraclass correlation coefficient (ICC), typical error (TE), and TE as a co-efficient of variation (%TE) were calculated to determine the magnitude of variability from the first to the second testing occasion.<sup>10,11</sup> Minimum detectable change at a 95% confidence interval (MDC<sub>95</sub>) was calculated as  $[TE \times 1.96 \times \sqrt{2}]$ . We subjectively considered the data based on previously published quantitative guidelines where: an ICC  $\geq 0.90$  was regarded as high, between 0.80 and 0.89 as moderate, and  $\leq 0.79$  as poor<sup>21</sup> and; a %TE of  $\leq 10\%$  was set as the level at which

a measure was considered reliable.<sup>6</sup> Effect size (ES) was determined by comparing data from the first and second testing occasion (test 1 minus test 2) to evaluate the magnitude of systematic bias. An ES (mean difference/pooled SD) of < 0.2 was expected.

For the data collected on the group with a prior history of HSI, statistical analysis was performed using JMP version 10.02 (SAS Institute, Inc). The data from these previously injured elite athletes were compared to the normative data set from the first group using a restricted maximum likelihood method with the fixed factors being group (uninjured/injured) and limb (left/right or uninjured/injured depending on group) and the random factor being subject identification number. Where significant effects were detected, post hoc least squares difference (LSD) testing was used to identify which variables differed. Significance was set at  $P < .05$  and ES was calculated using Cohen's *d*. Data are reported as mean  $\pm$  standard deviation (SD).

## **RESULTS**

### **Group without a previous history of HSI**

Descriptive statistics, ES, and test-retest reliability data for all force variables are presented in **TABLE 1**. Overall, using ICC as the measure of test-retest reliability, absolute force measurements taken during the bilateral condition (ICCs ranged from 0.83 to 0.90) were more reliable than those collected during the unilateral condition (ICCs ranged from 0.56 to 0.80). For between limb force asymmetries, only the average peak force during the bilateral condition had acceptable reliability (ICC = 0.85, 95% CI = 0.71 to 0.93). Similarly, when using %TE to examine reliability, the results from the bilateral conditions (%TE ranged from 5.8 to 8.5) were more reproducible than those from the unilateral conditions (%TE ranged from 7.9 to 11.0). Furthermore, results from between limb strength asymmetries were most



highly reliable for the average peak force calculated from the bilateral condition (%TE = 4.6, 95% CI = 3.7 to 5.9).

### **Athletes with a history of HSI**

For the 20 injured athletes, HSI were most common in the non-dominant limb (13 of 20), in the biceps femoris long head (15 of 20), and at the proximal or distal muscle-tendon junction (14 of 20), were predominately grade I strains (13 of 20), and most often occurred during high speed running (16 of 20). The average time since the most recent HSI was 5.7 months.

A group by limb interaction effect was detected ( $P = 0.0378$ ), with post hoc LSD testing determining that the previously injured limb was weaker than the contralateral uninjured limb (mean difference = 50.3 N; 95% CI = 25.7 to 74.9 N;  $P = 0.0002$ ; ES = 0.46) and also weaker than the left (mean difference = 50.0 N; 95% CI = 1.4 to 98.5 N;  $P = 0.0437$ ; ES = 0.60) and right limb (mean difference = 66.5N; 95%CI = 18.0 to 115.1N;  $P = 0.0080$ ; ES = 0.79) of the uninjured normative group (**TABLE 2**). No differences existed between the uninjured limb from the group with a history of HSI and the left ( $P = 0.9891$ ) and right ( $P = 0.5064$ ) from the normative uninjured group (**TABLE 2**).

### **DISCUSSION**

The major findings from the current study are: 1) the experimental device displayed high to moderate test-retest reliability for measurements when the NHE was performed bilaterally, but poor reliability during unilateral testing; 2) elite athletes with a unilateral history of HSI within the previous 12 months displayed significant eccentric knee flexors weakness in their injured limb compared to their uninjured limb and to uninjured recreational athletes.

For the measurement of absolute strength, only when the NHE was completed bilaterally, and peak force was averaged across 6 trials, did the measure display moderate reliability (ICC = 0.85 to 0.89). Measurements made with an isokinetic (ICC range from 0.83 to 0.97)<sup>12,14,15</sup> or hand-held dynamometers (ICC = 0.90)<sup>22</sup> have been reported to have similar or slightly higher levels of reliability. The only previous study, to our knowledge, examining the reliability of between limb eccentric knee flexors strength ratios using and isokinetic dynamometry reported lower test-retest reliability (ICC = 0.69)<sup>12</sup> than in this study (average peak force with bilateral testing, ICC = 0.85).

Findings that a previously strained hamstring still displayed weakness of the knee flexors in comparison with the uninjured side when testing eccentrically, despite ‘successful’ rehabilitation, is consistent with data previously published.<sup>13,16</sup> The percentage difference in eccentric strength between limbs reported here in the injured cohort (15%) is similar to previously reported data using isokinetic dynamometry (11-13%).<sup>13,16</sup>

It may be argued that it would have been appropriate to normalise the force measurements derived from the experimental device to the stature and weight of the participant, however we don’t believe this to be critical. Due to the nature of the NHE, all athletes reach a critical point in the range of motion, where the ever increasing external load from gravity acting on the upper body, exceeds the maximal eccentric hamstring strength of the athlete. While the position in the range of motion where this critical point occurs will be influenced by individual anthropometric characteristics and strength level, by reaching this critical point it will require maximal force generation of the knee flexors. We have noted low correlations between height or weight and maximal eccentric knee flexors force from the novel device ( $r^2 = 0.01$  to  $0.13$ ).

The major limitation of the current study is the retrospective nature of data collection on those with a previous history of HSI, which does not allow for the determination of whether the eccentric weakness seen in the previously injured limb was the cause or the result of injury. It should also be noted that all participants in the reliability aspect of the current study undertook a familiarisation session and as such the reliability data presented is only applicable to individuals with some exposure to the NHE. The device itself is limited as it cannot control movement speed or determine angle of peak torque of the knee flexor muscle group, which is possible through the use of an isokinetic dynamometer.

## **CONCLUSION**

A novel field testing device using the NHE as a vehicle to measure eccentric knee flexors strength and between limb strength asymmetry has demonstrated high to moderate levels of test-retest reliability during bilateral testing. Using the device, residual eccentric weakness of previously injured elite athletes, of a magnitude similar to what has been previously measured with other methods, was also identified. This portable device offers an alternative to current dynamometry based techniques for the assessment of eccentric knee flexors strength.

## REFERENCES

1. Aagaard P, Simonsen EB, Magnusson SP, Larsson B, Dyhre-Poulsen P. A new concept for isokinetic hamstring: quadriceps muscle strength ratio. *Am J Sports Med.* 1998;26:231-237.
2. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. *Am J Sports Med.* 2004;32:5-16.
3. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports.* 2003;13:244-250.
4. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med.* 2006;34:1297-1306.
5. Chumanov ES, Schache AG, Heiderscheit BC, Thelen DG. Hamstrings are most susceptible to injury during the late swing phase of sprinting. *Br J Sports Med.* 2012;46:90.
6. Cormack SJ, Newton RU, McGuigan MR, Doyle TLA. Reliability of measures obtained during single and repeated countermovement jumps. *Int J Sports Physiol Perform.* 2008;3(2):131-144.
7. Croisier JL, Forthomme B, Namurois MH, Vanderthommen M, Crielaard JM. Hamstring muscle strain recurrence and strength performance disorders. *Am J Sports Med.* 2002;30:199-203.
8. Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med.* 2008;36:1469-1475.

9. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med.* 2011; 45(7):553-558
10. Hopkins W. A new view of statistics. In: Internet Society for Sports Science, 2000. [www.sportsci.org/resource/stats.html](http://www.sportsci.org/resource/stats.html) (accessed Nov 2010).
11. Hopkins WG. Measures of reliability in sports medicine and science. *Sports Med.* 2000 Jul;30(1):1-15.
12. Impellizzeri FM, Bizzini M, Rampinini E, Cereda F, Maffiuletti NA. Reliability of isokinetic strength imbalance ratios measured using the Cybex NORM dynamometer. *Clin Physiol Funct Imaging.* 2008;28(2):113-119.
13. Lee MJ, Reid SL, Elliott BC, Lloyd DG. Running biomechanics and lower limb strength associated with prior hamstring injury. *Med Sci Sports Exerc.* 2009;41:1942-1951.
14. Li R, Wu Y, Maffulli N, Chan KM, Chan J. Eccentric and concentric isokinetic knee flexion and extension: a reliability study using the Cybex 6000 dynamometer. *Br J Sports Med.* 1996;30:156-160.
15. Maffiuletti NA, Bizzini M, Desbrosses K, Babault N, Munzinger U. Reliability of knee extension and flexion measurements using the Con-Trex isokinetic dynamometer. *Clin Physiol Funct Imaging.* 2007;27:346-353.
16. Opar DA, Williams MD, Timmins RG, Dear NM, Shield AJ. Knee flexor strength and bicep femoris electromyographical activity is lower in previously strained hamstrings. *J Electromyogr Kinesiol.* 2013;[Epub ahead of print] doi: 10.1016/j.jelekin.2012.11.004.
17. Orchard J, Seward H. Injury Report 2009: Australian Football League. *Sport Health.* 2010;28(2):10-19.

18. Petersen J, Thorborg K, Nielsen MB, Budtz-Jorgensen E, Holmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *Am J Sports Med.* 2011;39:2296-2303.
19. Sugiura Y, Saito T, Sakuraba K, Sakuma K, Suzuki E. Strength deficits identified with concentric action of the hip extensors and eccentric action of the hamstrings predispose to hamstring injury in elite sprinters. *J Orthop Sports Phys Ther.* 2008;38:457-464.
20. Thelen DG, Chumanov ES, Hoerth DM, Best TM, Swanson SC, Li L, et al. Hamstring muscle kinematics during treadmill sprinting. *Med Sci Sports Exerc.* 2005;37:108-114.
21. Vincent WJ. *Statistics in kinesiology*: Human Kinetics Publishers; 2005.
22. Whiteley R, Jacobsen P, Prior S, Skazalski C, Otten R, Johnson A. Correlation of isokinetic and novel hand-held dynamometry measures of knee flexion and extension strength testing. *J Sci Med Sport.* 2012;15:444-450.
23. Yu B, Queen RM, Abbey AN, Liu Y, Moorman CT, Garrett WE. Hamstring muscle kinematics and activation during overground sprinting. *J Biomech.* 2008;41:3121-3126.

**TABLE 1.** Descriptive statistics and test-retest reliability data for variables derived from the experimental device (N=30).

	<b>Test 1</b>	<b>Test 2</b>	<b>Effect Size</b>	<b>ICC</b>	<b>TE</b>	<b>%TE</b>	<b>MDC<sub>95</sub>*</b>
	<b>Mean±SD*</b>	<b>Mean±SD*</b>	<b>(95% CI)</b>	<b>(95% CI)</b>	<b>(95% CI)*</b>	<b>(95% CI)</b>	
<b>Bilateral testing peak force**</b>							
<b>Left</b>	366.4±67.7	374.1±60.5	-0.12 (-0.35 to 0.11)	0.83 (0.67 to 0.91)	27.5 (21.9 to 36.9)	8.5 (6.7 to 11.6)	76.2
<b>Right</b>	378.4±68.4	391.6±67.0	-0.20 (-0.36 to -0.03)	0.90 (0.81 to 0.95)	21.7 (17.3 to 29.2)	5.8 (4.6 to 7.9)	60.1
<b>Left:right ratio</b>	0.97±0.11	0.96±0.13	0.09 (-0.20 to 0.37)	0.76 (0.55 to 0.88)	0.06 (0.05 to 0.08)	6.0 (4.8 to 8.2)	0.17
<b>Unilateral testing peak force**</b>							
<b>Left</b>	351.3±55.5	356.8±65.6	-0.09 (-0.37 to 0.19)	0.73 (0.51 to 0.86)	32.3 (25.7 to 43.5)	10.2 (8.1 to 14.0)	89.5
<b>Right</b>	380.9±60.4	370.4±54.7	0.18 (-0.17 to 0.54)	0.56 (0.26 to 0.76)	38.8 (30.9 to 52.1)	11.0 (8.7 to 15.1)	107.5
<b>Left:right ratio</b>	0.92±0.13	0.96±0.13	-0.31 (-0.70 to 0.08)	0.40 (0.05 to 0.66)	0.09 (0.07 to 0.11)	10.1 (8.0 to 13.9)	0.25
<b>Bilateral testing average peak force***</b>							
<b>Left</b>	336.3±63.8	344.7±61.1	-0.13 (-0.34 to 0.07)	0.85 (0.71 to 0.93)	24.7 (19.7 to 33.2)	8.4 (6.6 to 11.5)	68.5
<b>Right</b>	349.4±64.8	361.2±65.1	-0.18 (-0.36 to 0.00)	0.89 (0.78 to 0.95)	22.1 (17.6 to 29.7)	6.5 (5.1 to 8.8)	61.3
<b>Left:right ratio</b>	0.96±0.11	0.95±0.13	0.11 (-0.08 to 0.29)	0.85 (0.71 to 0.93)	0.04 (0.04 to 0.06)	4.6 (3.7 to 5.9)	0.11
<b>Unilateral testing average peak force***</b>							
<b>Left</b>	321.4±54.0	323.6±64.2	-0.04 (-0.28 to 0.21)	0.79 (0.61 to 0.90)	27.6 (22.0 to 37.2)	9.5 (7.5 to 13.0)	76.5

<b>Right</b>	341.8±50.9	335.8±54.7	0.11 (-0.13 to 0.35)	0.80 (0.63 to 0.90)	24.1 (19.2 to 32.5)	7.9 (6.2 to 10.7)	66.8
<b>Left:right ratio</b>	0.94±0.12	0.96±0.14	-0.19 (-0.54 to 0.15)	0.55 (0.24 to 0.76)	0.08 (0.06 to 0.10)	8.7 (6.9 to 11.9)	0.22

Abbreviations: ICC, intraclass correlation coefficient; MDC<sub>95</sub>, minimal detectable change at 95% confidence interval; N, Newtons; SD, standard deviation; TE, typical error; 95% CI, 95% confidence interval; %TE, typical error as a co-efficient of variation.

\* Units for left and right limbs in Newtons

\*\*Peak force is the highest maximal force recorded from 6 trials.

\*\*\*Average peak force is the mean of maximal force recorded from each of the 6 trials.



1 **TABLE 2.** Comparisons of eccentric strength within and between groups.

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	Control (normative) group		History of injury group	
	Left limb	Right limb	Uninjured limb	Previously Injured limb
Eccentric knee flexors strength (N)	344.7±61.1	361.2±65.1	345.0±115.9	294.7±100.3 <sup>a</sup>

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<sup>a</sup> Significantly weaker than the other 3 groups,  $P < .05$ .

4 **FIGURE 1.** Performing the Nordic hamstring exercise using the novel device (progressing from  
5 left to right). The participant controls the speed of the fall by forceful eccentric contraction of the  
6 knee flexors. After the completion of the exercise the participant slowly returns to the starting  
7 position by pushing back up with both hands (not shown). The ankles are secured independently  
8 in individual custom made braces.

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10 **FIGURE 2.** A) The experimental device with individual ankle braces, padded cushion for knee  
11 support, and wooden base; and B) close up view of the ankle brace, load cell organisation, and  
12 pivot.

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