Between-day reliability of the Hamstring Solo device during the Nordic Hamstring curl.
Journal of Australian Strength & Conditioning. 29(02):5-11. 2021 @ ASCA

Original Scientific Research Study

BETWEEN-DAY RELIABILITY OF THE HAMSTRING SOLO DEVICE DURING THE NORDIC HAMSTRING CURL

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BLUF

The Hamstring Solo device is reliable between-days when measuring peak eccentric knee flexor force in professional rugby union players.

ABSTRACT

The purpose of this study was to determine the between-day reliability of the Hamstring Solo for measuring peak eccentric knee flexor force (EKF) during the Nordic hamstring curl. Data were collected on 18 male Professional rugby union players across two testing sessions separated by 7 days. There was no between-session difference in EKF force for left (p = 0.440 – 0.580) or right (p = 0.477 – 0.656) leg when using the best of 1 (left = 405.3±88.2 N vs. 412.8±92.7 N; right = 408.0±88.1 N vs. 416.7±85.2 N), 2 (left = 409.9±87.6 N vs. 415.0±96.2 N; right = 413.0±87.5 N vs. 418.3±86.2 N), or 3 repetitions (left = 411.2±88.2 N vs. 417.3±92.7 N; right = 417.7±87.4 N vs. 417.7±87.4 N). The between-day reliability of EKF peak force was acceptable for left (7.2 to 8.3%) and right (8.3 to 9.8%) leg, with the typical error lowest when using the best of three repetitions. The smallest worthwhile change (SWC) was similar for left (4.2 – 4.3%) and right (3.6 – 3.7%) when using the best of 3 repetitions. As the typical error was greater than the SWC for both the left (1.71 x the SWC) and right (2.24 x the SWC) legs, changes of 2.71 (∆ 41 N; 11%) and 3.24 (∆ 47 N; 12%) xSWC are required to detect a small change in EKF peak force, taking into account the typical error. Practitioners can use the reliability statistics from this study to monitor EKF peak force in professional rugby union players, when using the Hamstring Solo device. It is recommended that when monitoring EKF peak force with the Hamstring Solo, practitioners use the best of 3 repetitions.

Key Words - Hamstring, strength, reliability, monitoring.

INTRODUCTION

Testing of physical qualities is commonplace in professional sport to profile individuals against normative data (8, 9), assist in the prescription and evaluation of training (27) and to identify individuals who may be at risk of injury (3, 17, 18, 24). These data can then be used to guide individual physical preparation strategies to improve performance and mitigate injury risk. Following such interventions, it is important that practitioners re-assess physical qualities to evaluate the effectiveness of the training intervention that was applied. This may happen several times during the pre-season preparation period, periodically throughout the playing season, and during rehabilitation (1, 20).

It is important when conducting these evaluations that practitioners are aware of the typical error (TE) associated with each assessment (i.e., the *noise* of the test), and that they are able to use such statistics to determine whether a change in performance is *real* (greater than the TE) (14, 20). The TE of an assessment is characterised by both technological (error associated with the technology used to measure) and biological variation (variance in physical output), (25) and is normally determined by completing a between-day reliability study (7, 22, 26) using the group of athletes that will be assessed. Where this is not possible, due to scheduling or concerns about multiple assessments in close proximity, data from reliability studies using similar athletes can be used to infer changes in performance (21). Furthermore, understanding when a change in performance is of practical significance is also important and can be characterised by the smallest worthwhile change (SWC) statistic (0.2 x between-subject *SD*; the equivalent to a *small* effect size (13)) which is also calculated alongside the TE during a reliability study. Both the TE and SWC are used together (TE+SWC) to determine if a change is both *real* (> TE) and of practical significance (>SWC).

Although using data from similar groups of athletes is accepted practise (21), reliability statistics need to be generated for new technology that comes to market for use in high-performance sporting environments. Oftentimes, such technology is integrated into daily practice prior to such statistics being generated (4, 11, 19). In a recent review of equipment used to provide biofeedback, monitor stress and sleep, only 5% of the technologies appraised had been validated (19). Without knowing whether a technology is reliable, decision making based on data collected may be hindered, especially if practitioners use different technologies to those used in published research.

Hamstring strength and injury risk has been extensively studied (2, 10, 18, 23), with data obtained for eccentric knee flexor peak force when performing the Nordic Hamstring curl (NHC), using the NordBord device, highlighting injury risk thresholds for various sports (3, 18, 24). Furthermore, the NordBord device has been assessed for between-day reliability and displays acceptable TE when assessing left (27.5 N; 8.5%) and right (21.7 N; 5.8%) leg eccentric knee flexor peak force when performing the NHC; suggesting it can be used to effectively monitor hamstring strength (16).

More recently, a similar device to the NordBord has been made available; the Hamstring Solo, which is also able to measure eccentric knee flexor peak force. The Hamstring Solo has not been validated against the NordBord, therefore it is unknown whether the injury risk thresholds from the previously mentioned studies (3, 18, 24) can be applied to athletes who are monitored using the Hamstring Solo. Despite this the Hamstring Solo has been adopted by the English Institute of Sport, England Rugby, Scottish Rugby and other professional sports organisations within the United Kingdom & Ireland to monitor hamstring strength. Despite this adoption of technology, there is currently no data published describing the between-day reliability of the Hamstring Solo to measure eccentric knee flexor peak force during the NHC. The availability of such data is likely very important so that changes in hamstring strength and injury risk can be assessed effectively; i.e., changes that account for the noise of the test, and that are of practical significance.

Since 2012-13 hamstring strain injuries (HSI) are the first and second most common and burdensome of all rugby union training and match injuries respectively, with the exception of the 2016-17 season (15). The severity of HSI was 29 and 41 days for training and match injuries, with HSI incurred in the ruck having double the severity (64 days) than those incurred when running (15).

Data are available that provide eccentric knee flexor peak force measures in 75 elite rugby union players from Australia (3) in absolute (367 ± 77 N) and relative to body mass (3.65 ± 0.7 N·kg-1), with risk of HSI increased 2.4 and 3.4 fold when the imbalance between limbs was > 15% and > 20% respectively. Furthermore, an equation that takes into account the body mass of athletes is available and should provide a minimum standard of eccentric knee flexor peak force that practitioners should aim for with their athletes (5). This is represented in the following equation;

$$N = 4 \times BM + 26.1$$

where N is Newtons and BM is body mass measured in kilograms. Therefore, using this equation, minimum peak force measures when completing the NHC should range 346 N – 546 N for rugby union players with body mass' between 80 – 130 kg respectively.

Despite the prevalence of HSI, and the use of the Hamstring Solo in professional rugby union, there is currently no between-day reliability data published using this cohort. These statistics are important to understand when an observed change in performance is *real*. Therefore, the aim of the present study was to assess the between-day reliability of the Hamstring Solo in professional rugby union players to generate statistics that can be used to assess changes in performance. A secondary aim of the study was to assess the reliability of peak eccentric knee flexor strength using the Hamstring Solo when using the best of 1, 2 or 3 repetitions.

METHODS

Approach to the Problem

Professional rugby union players from a Premiership club in England were assessed for eccentric knee flexor peak force when completing the NHC on two occasions with seven days between measures. The players had 2.5 days complete rest prior to each testing occasion and maintained normal dietary habits prior to assessment. Testing was completed at the same time of the day, prior to any training. The reliability of eccentric knee flexor peak force between the sessions was assessed using the TE in both raw units (newtons) and as a percentage coefficient of variation (CV%).

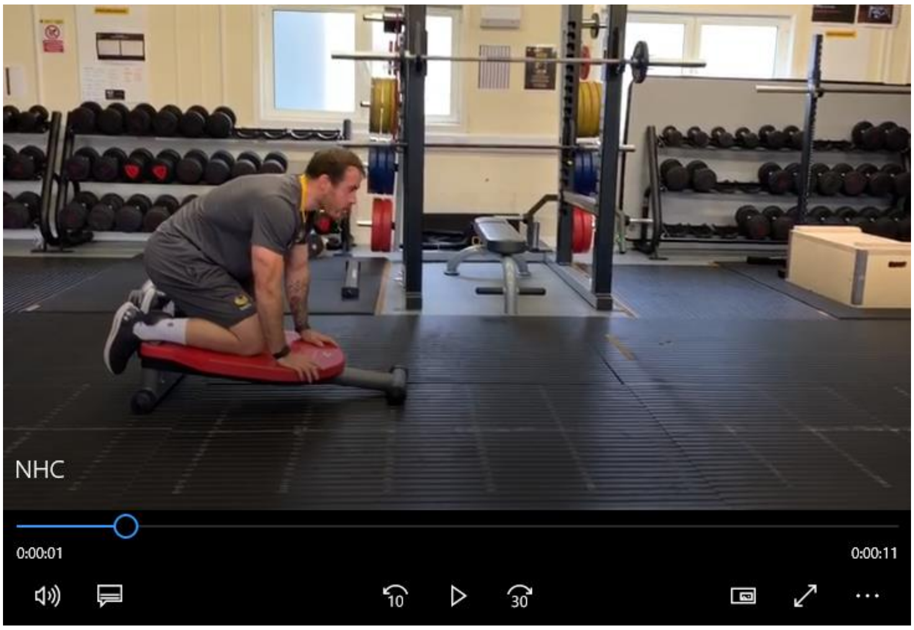
Subjects

Eighteen professional male rugby union players (mean ± *SD*; age, 20 ± 2 y; height, 1.85 ± 0.05 m; body mass, 97.6 ± 13.6 kg; sum of seven skinfolds, 65.9 ± 13.1 mm) were recruited from one Premiership club in England, during the pre-season preparation phase of training (July). All participants were familiar with the NHC, as it had been completed weekly as part of normal training practices for the previous twelve months. All experimental procedures were approved by an institutions ethics committee with informed consent obtained.

Procedures

Eccentric knee flexor strength. Peak eccentric knee flexor strength was assessed via the NHC using the Hamstring Solo Elite (ND Sports Performance, Thomastown, Ireland). Data from the Hamstring Solo were sampled at 5Hz, recorded live and uploaded via Bluetooth connection to a smart device, and stored using proprietary software. Peak data for both left and right leg were extracted for every repetition completed for reliability analysis.

The Nordic Hamstring curl. The NHC was performed with the participants kneeling on a padded board, with their ankles secured immediately superior to the lateral malleolus (16). The starting position was approximately 90° knee flexion and 0° hip extension. To perform the NHC the participants were encouraged to maintain a neutral hip and trunk position and instructed to fall forward at the slowest speed possible, whilst maximally resisting the falling motion with both limbs (16). Throughout the NHC, the participants were encouraged to maintain postural technique and to pull as hard as possible into the attachments at the ankle. See supplementary video.



Video 1 – The Nordic hamstring curl.

Warm up. Prior to maximal NHC assessment all participants completed one set of three submaximal repetitions of the NHC. Repetitions one, two and three were performed at the following intensities; ~ 50%, ~ 70% and ~ 90% of perceived maximal effort, with 15 seconds rest between repetitions (6).

Reliability. Between-day reliability data were collected using a cross-sectional design, whereby maximal eccentric knee flexor peak force data were collected from 1 set of 3 maximal NHC on two occasions separated by seven days. Prior to each assessment, the participants had 2.5 days of complete rest.

Statistical Analyses

Data are presented as mean ± standard deviation (*SD*) or mean with 90% confidence intervals (90% CI) where specified. Difference between the best of one, two or three repetitions of Nordic hamstring curl peak force for day 1 and day 2 were assessed. The magnitude of any difference was expressed using Cohen's *d* effect size, alongside *p* values which were generated using paired samples t-test's in SPSS version 26.0 and assessed at an alpha level of 0.05.

Between-day reliability of peak force from the Nordic hamstring curl for the best of 1, 2 or 3 repetitions was determined, alongside the SWC and the minimum detectable change (MDC) at the 95% confidence level. The between-day reliability of the Hamstring Solo was determined by calculating the typical error using a freely available spreadsheet (12), using the following equation;

$TE = S_{diff} / \sqrt{2}$

where S_{diff} is the *SD* of the difference score between assessment days 1 and 2; the TE was also expressed as a percentage CV.

The SWC was determined as 1/5th of the between-subject *SD*, as this is threshold for a *small* effect size according to Hopkins' modified Cohen scale (13). The MDC was calculated using the following equation;
$MDC^{95} = TE \times 1.96 \times \sqrt{2}$

where 1.96 is the *z* score associated with a 95% confidence interval, and √2 accounts for the testing error during both assessments (28).

RESULTS

Peak eccentric knee flexor values for left and right leg, when using the best of 1, 2 or 3 repetitions of the Nordic hamstring curl for day 1 and day 2 are displayed in Table 1, alongside the differences in measures. The magnitude of difference between days was trivial when using the best of 1, 2 or 3 repetitions for both legs, and were not significantly different ($p > 0.05$).

Table 1 - Eccentric knee flexor peak force from the Nordic hamstring curl measured using the Hamstring Solo when assessed using the best of 1, 2 or 3 repetitions to determine peak values.

	Day 1 Peak Force (N)	Day 2 Peak Force (N)	Difference (Day 2 – Day 1; N)	Effect Size (90% CI)	*p* value
Left (1)	405.3 ± 88.2	412.8 ± 92.7	7.4 ± 37.5	0.07 (-0.14; 0.28)	0.440
Left (2)	409.9 ± 87.6	415.0 ± 96.2	5.1 ± 36.3	0.04 (-0.18; 0.26)	0.580
Left (3)	411.2 ± 88.2	417.3 ± 92.7	6.1 ± 32.8	0.06 (-0.13; 0.25)	0.466
Right (1)	408.0 ± 88.1	416.7 ± 85.2	8.7 ± 47.7	0.10 (-0.16; 0.37)	0.477
Right (2)	413.0 ± 87.5	418.3 ± 86.2	5.3 ± 46.8	0.06 (-0.20; 0.33)	0.656
Right (3)	417.7 ± 87.4	424.2 ± 87.7	6.5 ± 42.6	0.07 (-0.16; 0.31)	0.549

Data are presented as mean ± *SD* or Effect size with 90% confidence interval. Left and Right 1, 2, 3 correspond to the peak measures of eccentric knee flexor force when using the best of 1, 2 or 3 repetitions of the Nordic hamstring curl. N = Newtons.

Reliability statistics for peak eccentric knee flexor force for left and right leg when using the best of 1, 2 or 3 repetitions of the Nordic hamstring curl are displayed in Table 2. The TE improved (decreased) when more repetitions were used to determine peak eccentric knee flexor force for left (TE; 1 rep, 8.1%; 3 reps 7.2%) and right leg (TE; 1 rep, 9.8%; 3 reps 8.3%). The SWC remained stable across repetitions for left (SWC; 1 rep, 4.3%; 3 reps 4.2%) and right leg (SWC; 1 rep, 3.6%; 3 reps 3.7%). The TE%/ SWC% ratio was greater than the SWC for all repetitions, with the TE% 1.71 and 2.24 times greater than the SWC when using the best of 3 repetitions for left and right leg respectively. Therefore, to detect a *small* change in eccentric knee flexor force a change 2.71 and 3.24 times the SWC would be required to account for the typical error of the assessment (Figure 1).

The values in raw (N) units and as percent change to detect a *small, moderate* and *large* change in eccentric knee flexor force are displayed in Table 2. *Small* corresponds to the SWC + TE, *moderate* three times the SWC + TE, and *large* six times the SWC + TE. Lastly the MDC^{95} is also displayed.

Table 2 - Between-day reliability statistics for measures of eccentric knee flexor peak force from the Nordic hamstring curl measured using the Hamstring Solo when assessed using the best of 1, 2 or 3 repetitions to determine peak values.

	TE N (90% CI)	TE% (90% CI)	SWC N (90% CI)	SWC% (90% CI)	$\frac{TE}{SWC}$	*Small* (%)	*Moderate* (%)	*Large* (%)	MDC^{95} (%)
Left (1)	26.5 (20.6; 38.2)	8.1 (6.2; 11.8)	17.3 (10.1, 22.3)	4.3 (2.4, 5.6)	1.88	43.8 (12.4)	78.4 (21.0)	130.3 (33.9)	73.5 (22.5)
Left (2)	25.7 (19.9, 36.9)	8.3 (6.3, 12.1)	17.7 (10.4, 22.7)	4.3 (2.4, 5.6)	1.93	43.4 (12.6)	78.8 (21.2)	131.9 (34.1)	71.2 (23.0)
Left (3)	23.2 (18.0, 33.3)	7.2 (5.6, 10.6)	17.5 (10.5, 22.4)	4.2 (2.4, 5.4)	1.71	40.7 (11.4)	75.7 (19.8)	128.2 (32.4)	64.3 (20.0)
Right (1)	33.8 (26.1, 48.5)	9.8 (7.5, 14.4)	16.0 (8.7, 20.8)	3.6 (1.8, 4.8)	2.72	49.8 (13.4)	81.8 (20.6)	129.8 (31.4)	93.7 (27.2)
Right (2)	33.1 (25.6, 47.5)	9.5 (7.3, 14.0)	16.1 (8.8, 20.9)	3.6 (1.8, 4.8)	2.63	49.2 (13.1)	81.4 (20.3)	129.7 (31.1)	91.7 (26.3)
Right (3)	30.2 (23.4, 43.3)	8.3 (6.4, 12.1)	16.4 (9.3, 21.3)	3.7 (2.0, 4.9)	2.24	46.6 (12.0)	79.4 (19.4)	128.6 (30.5)	83.7 (23.0)

TE N = Typical error in Newtons; TE% = Typical error expressed as a percentage; SWC N = Smallest Worthwhile Change in Newtons; SWC% = Smallest Worthwhile Change as a percentage; TE/SWC = the typical error/ smallest worthwhile change ratio; *Small, Moderate* and *Large* = change in Newtons and percent (%) required to identify a *Small, Moderate* and *Large* change in eccentric knee flexor peak force whilst accounting for the typical error of the assessment; MDC^{95} = the minimum detectable change at the 95% confidence level.

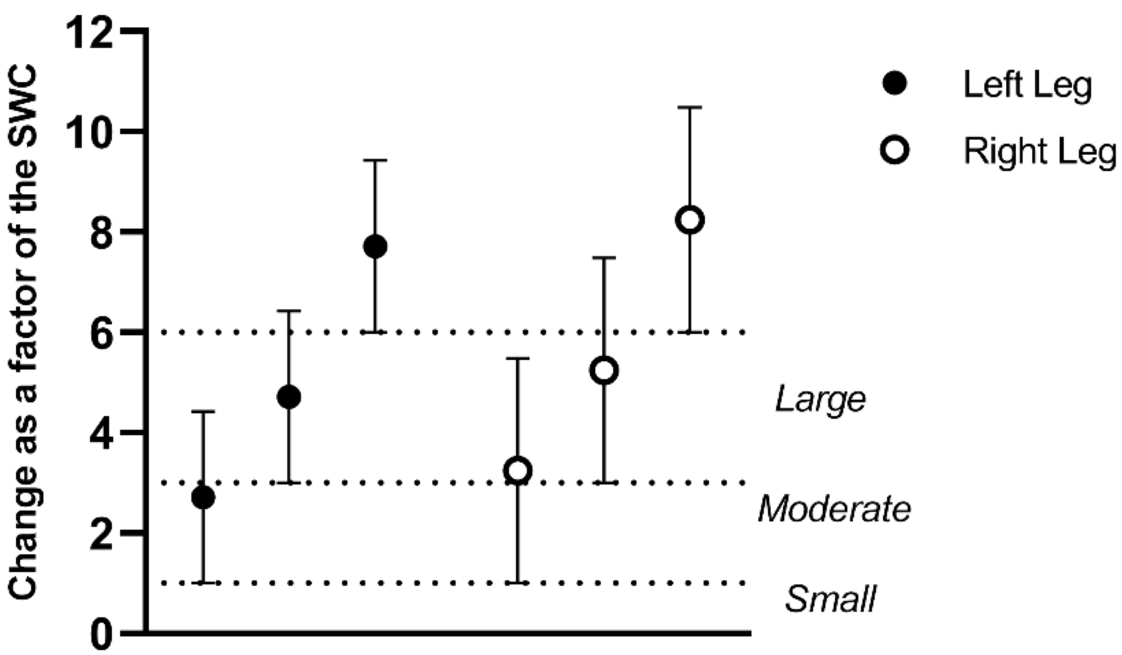


Figure 1 - Graph showing how many multiples of the SWC an individual must improve by before a *small, moderate* or *large* change can be determined as *real*, i.e., greater than the SWC and TE. Dashed lines represent a small (1 x SWC), moderate (3 x SWC) or large (6 x SWC) change in eccentric knee flexor peak force. Black and white circles represent left and right leg respectively and show the change as a factor of the SWC required to be greater than the TE+SWC. Error bars represent the typical error statistics generated from the study for each leg.

DISCUSSION

This is the first study to establish the between-day reliability of the Hamstring Solo device when assessing peak eccentric knee flexor force when completing the NHC. The study showed that the Hamstring Solo demonstrated acceptable reliability (TE < 10%) for the assessment of eccentric knee flexor strength for both the left (TE; 7.2%) and right (8.3%) leg when completing the NHC in professional rugby union players. Furthermore, the reliability of test-retest assessment is improved when players are afforded to complete 3 repetitions to demonstrate peak eccentric knee flexor strength and is demonstrated by the improved (decreased) TE values as repetitions increased (Table 2).

Data have been generated that correspond to a *small* (1 x SWC) + TE), *moderate* (3 x SWC) + TE), or *large* (6 x SWC) + TE), changes in eccentric knee flexor peak force (Table 2; Figure 1), which can be directly applied to other professional rugby union environments that use the Hamstring Solo device. These data demonstrate that a *small* change in performance in left and right leg peak force corresponds to 11.4% and 12.0% increases respectively. These thresholds can be used as targets for improvement in eccentric knee flexor strength by practitioners working in rugby union when using the Hamstring Solo device. The MDC^{95} is also reported for the left and right leg, corresponding to 20.0% and 23.0% respectively. This latter measure does not use the SWC, but constructs a 95% confidence interval (TE x 1.96) using the TE and takes into account the error in measures in both assessments ($\sqrt{2}$) (28).

A similar study (16) investigated the between-day reliability of a prototype of the NordBord hamstring device, reporting both left (27.5 N; 8.5%) and right leg (21.7 N, 5.8%) were reliable (TE < 10%). These measures are not dissimilar to those reported in the current study with left (23.2 N, 7.2%) and right (30.2 N, 8.3%) leg measures of peak force also deemed reliable. Whilst the latter study did not report the SWC, the MDC^{95} was reported for the NordBord for left (76.2 N) and right leg (60.1 N), with the present study reporting the MDC^{95} for left (64.3 N) and right leg (83.7 N). Although both the TE and MDC^{95} differ between devices, it has been shown that both are reliable, whilst clear threshold targets are reported to determine positive changes in eccentric knee flexor strength.

In conclusion, the present study investigated the reliability of the Hamstring Solo device for measuring eccentric knee flexor peak force when completing the NHC. The findings show that at least 3 repetitions of the Nordic hamstring curl are required to determine individual athletes peak force data, and that the Hamstring Solo is reliable (TE < 10%). The reliability data (TE, SWC, MDC^{95}) from the present study can be implemented in monitoring systems in other rugby union organisations who use the Hamstring Solo to detect changes in performance, and thus evaluate training interventions and assess injury risk factors. We recommend that until the Hamstring Solo is validated against the NordBord, practitioners use the data previously generated regarding injury risk, and aim for imbalances < 15% (3) whilst setting minimum targets that equate to 4 x BM + 26.1 N (5).

PRACTICAL APPLICATIONS

Practitioners can use the reliability statistics provided to monitor eccentric knee flexor peak force in professional rugby union organisations whilst accounting for sampling error, to make better informed decisions with regards to the effectiveness of training interventions. Threshold targets are provided that detect a small, moderate or large change in eccentric knee flexor peak force and can be easily implemented into monitoring systems. The integration of such statistics within the proprietary software may make the monitoring process more efficient for practitioners working with professional rugby union players.

Acknowledgment

The authors would like to thank the players who were involved in the research study.

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