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The reliability and validity of a video-based method for assessing hamstring strength in football players

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ABSTRACT

Background/Objective: Evaluating hamstring strength by isokinetic dynamometry is limited by various practical issues such as time and cost. A video-based Nordic hamstring exercise is introduced as an alternative option. The aims of this study are to evaluate 1.) the between-session reliability and 2.) concurrent validity of the testing method compared to a standardized isokinetic dynamometry.

Methods: Thirty male elite footballers were recruited for the study. From the Nordic hamstring exercise, the video-analysis-determined Nordic break-point angles where the participant could no longer withstand the force of the fall (eccentric mode) and the number of seconds that the player could hold at 30° forward flexion angle (isometric mode) were measured. Intra-class correlation coefficients for between-session reliability, Pearson r correlations between the current method and isokinetic dynamometry were calculated.

Results: The reliability of the eccentric mode was moderate ($ICC_{(2,1)} = 0.82$) while that of isometric mode was poor ($ICC_{(2,1)} = 0.57$). The Nordic break-point angle of the eccentric mode significantly correlated with the concentric and eccentric hamstring peak torque ($r = 0.48$ and 0.58, $p < 0.001$), while the isometric was not ($r = 0.02$ - 0.07, $p > 0.05$).

Conclusion: The eccentric mode of the video-based hamstring strength test was a moderately reliable and valid method to measure the eccentric hamstring strength in elite football players.

1. Introduction

Hamstring strain injury (HSI) is the major musculoskeletal problem in team sports, accounting for 6% - 16% of overall injuries in professional football, rugby, Australian football, and baseball.[1–6] In elite football, the HSIs accounting for more than one-third of all time-loss muscle injuries sustained and its training related injury rates have increased substantially over the past decade.[7] Previous hamstring history generated a 2-fold higher risk of sustaining recurrent injuries. These recurrence rates ranged from 12% to 41% during the first year of returning to sports.[2,8,9]

Understanding multifactorial risk factors and mechanisms of this injury are crucial for developing effective injury prevention measures.[10,11] The majority of the HSI in elite football players occurs during high speed running.[2,12,13] A large prospective cohort study on professional football players has shown lower hamstring eccentric strength and lower quadriceps concentric strength as weak risk factors. Two studies on Australian football players have shown that low levels of hamstring strength in the preseason increased the risk for future HSI.[14,15] However, the between-limb strength imbalance seems not a prominent risk factor.[15] A meta-analysis study suggested that hamstring peak torque and hamstring-to-quadriceps (H/Q) ratio require further research to warrant their involvement in HSI because of inconclusive results, or small sample sizes.[16]

To date, isokinetic dynamometry had been widely adopted by previous prospective cohort studies investigating hamstring strength and strength ratios as risk factor of future HSI.[17–19] However, this method is limited by various factors, including time, cost, and lack of portability of device.[20] Players may also experience a high level of delayed onset of muscle soreness after the test. Due to the above drawbacks, the clinical applicability of this test method in elite and amateur football population can be limited. Few practical field-based tests have been proposed to be the alternative measurement tools to determine hamstring injury risk. Measures

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include maximal hamstring eccentric strength,[21] hamstring strength endurance,[14] and isometric hamstring strength.[22] The usage of these tests may present some limitation, such as some techniques rely heavily on the skills and strength of the operator,[20,23] while some strength measures' concurrent validity is yet to be determined.[14,15,22] A previous study adopted the Nordic hamstring exercise as a field-based assessment of eccentric hamstring strength.[24] Their result has shown that the Nordic break-point angle that measured from a video-based motion analysis was related to eccentric hamstring peak torque.[24] This method allowed athletes to complete 3 trials of the test within 5 minutes. It seems to overcome many of the practical limitations of isokinetic testing. However, before using this test routinely, it is essential to investigate the reliability and concurrent validity among the elite football players.

This study aimed to evaluate 1) the between-session reliability and 2) concurrent validity of a video-based hamstring strength testing method compared to a traditional isokinetic hamstring strength testing method among semi-professional male football players.

2. Methods

2.1. Participants

A cross-sectional study design was used to determine the relationship between the performance of the video-based hamstring strength test and the isokinetic hamstrings muscle strength test among elite football players. Power analysis demonstrated that a sample of 29 was sufficient to detect an R value of 0.5.[24] Thirty male players (mean age = 20.4 ± 1.3 y; body weight = 64.3 ± 5.5 kg; height = 175.3 ± 5.2 cm) from 2nd division football league participated in this test. They were semi-professionals who had received training 5 times and participated in official matches once a week respectively. The exclusion criteria were a) Those had sustained a hamstring injury less than 6 months before testing. b) Those with prolonged hamstring problems, such as discomfort and inhibition during an athletic activity that hindered their participations in any tests in this study. Informed consent was signed and collected from each participant who were 18 years old or above. Informed assent was signed and gathered for athletes who were under the age of 18 years. All procedures described in this study were approved by the University clinical research ethics committee (Reference number: CRE - 2011.610 - T) and conducted in accordance with the Declaration of Helsinki.[25]

2.2. Procedure and measurements

The video-based hamstring strength test and isokinetic strength tests have been done on two separate occasions 7 - 10 days apart. Based on Nordic hamstring exercise, the video-based hamstring strength test consisted of 2 modes: eccentric and isometric mode. Our test protocol was modified based on previous studies.[9,24] Video demonstration and familiarization trials were provided. The two modes were tested in a randomized order. Each athlete started with a kneeling position on a yoga mat, and a tester stabilized the athlete's legs by pressing on his plantar-flexed ankles. In the eccentric mode, the athlete was instructed to lean forward in a slow, smooth, and controlled manner, with full extension of the back and hips, until he reached a maximum point where he could no longer withstand the force of the fall. Then, he was instructed to use arms and hands to buffer the landing (Fig. 1c). The Nordic break-point angle was defined as the angle between the line joining hip and knee markers and initial vertical position of each participant (Fig. 1b). The angle was determined by the first appearance of the angular velocity that is greater than 10 °/s. The choice of 10°°/s as a cut-off point was based on our pilot study. In the pilot study, by visual inspection, the time that the participants could not withstand the force of fall during the Nordic hamstring exercise was estimated. By referring to the graph of angular velocity against time, it is observed that the angular velocity of 10 °/s was consistent to determine the Nordic break-point angle in the pilot study. In the isometric mode, the athlete was stabilized by pressing by tester 1 and held in front by tester 2 at 30°, which is the angle between the trunk and the vertical line that perpendicular to the floor. The result of isometric mode was the time (s) that athletes could maintain before the first appearance of the angular velocity of 10 °/s. Three trials of each mode were performed, and the best result was used in statistical analysis.

The athlete was videoed from the sagittal plane with a high-speed camera (Casio EX-F1, Japan) sampling at 300 frames per second. The camera set 3 m away and at 0.5 m from the floor. Three reflective circular markers were attached to the right greater trochanter, right lateral femoral condyle, and right lateral malleolus to calculate knee joint kinematics. Minimal clothing was recommended to avoid movement of markers. Video clips were digitized and transformed into a two-dimensional space using the motion analysis computer software (Ariel Performance Analysis System, Ariel Dynamics, Inc., CA, USA). All data were digitally filtered using a 4th order low-pass filter with a cutoff frequency of 5 Hz. The current motion analysis protocol was adopted from a previous study.[26]

Gravity-corrected hamstring peak torque of the isokinetic hamstring strength test was used as the criterion for validity. Strenuous exercise was avoided 48 hours before the test. The athlete was instructed to have a 5-minute warm up by pedaling on a stationary bike and a 5-minute dynamic stretching on lower limb muscles. The measurement was taken by using a Biodex III dynamometer (Biodex Medical Systems, USA). This study adopted the testing protocol from Croisier study, which included the concentric performance of hamstring groups at 60 °/s (5 repetitions) and the eccentric performance of the hamstrings groups at 30 °/s (5 repetitions).[17] The eccentric exertion of the hamstrings groups at 120 °/s was excluded from the protocol to minimize measurement error.[17] Before each assessment, the participant performed four submaximal trials to familiarize himself with the protocol. All sets of testing were separated by a 1-minute rest. The tester provided verbal encouragement. The highest peak torque in Newton meters (N·m) for each measure was used. The both dominant and non-dominant legs were tested. Since there was no significant difference between the peak torques in both legs at all angular velocities ($p > 0.05$), the average peak torques were used for statistical analyses.

2.3. Data analysis

Descriptive data (means and SDs) for each variable, i.e. isokinetic hamstring peak torques and video-based strength test results were calculated. Normality of data was confirmed by the Shapiro-Wilks test. Intra-class correlation coefficient was used to examine the inter-test reliability ($ICC_{(2,1)}$) in both modes of the video-based hamstring strength test. The standard error of measurement (SEM) and minimal detectable difference (MDD) were calculated using the formulas standard deviation $[(SD) \times \sqrt{(1 - ICC)}]$ and $(1.96 \times SEM \times \sqrt{2})$ respectively.[27] According to previous guidelines, an ICC of 0.90 or greater was regarded as high, between 0.80 and 0.89 as moderate, and 0.79 or less as poor.[28] Criterion validity was calculated using the bivariate Pearson product-moment correlation coefficient (r). Correlation of the measurements from the video-based hamstring strength test and isokinetic dynamometry have been computed. The magnitudes of these correlations were described as trivial described as trivial (0.0 - 0.1), small (0.1 - 0.3),

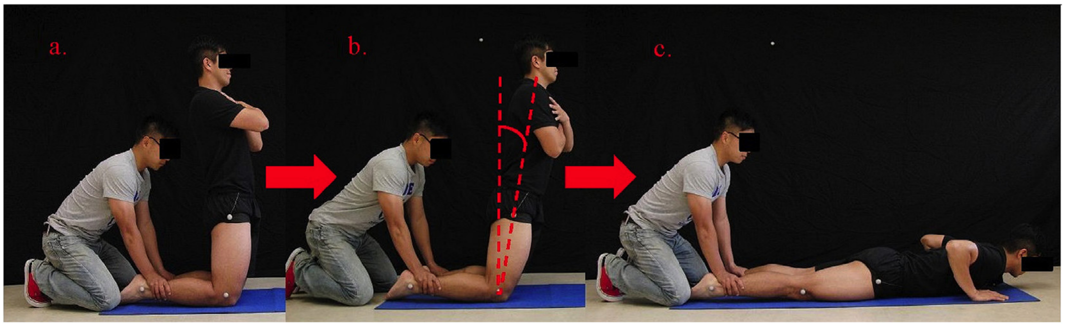

Fig. 1. (a) Participant performs a Nordic hamstring exercise in the novel hamstring strength test. A tester stabilizes the athlete's legs by pressing on plantar-flexed ankles. (b) Participant leans forward in a slow and controlled manner, maintaining minimal movement of the hip until he reaches a maximum point where the hamstring could no longer sustain the posture. (c) Participant is instructed to land with a push-up arms position from a crossed arms position.

moderate (0.3 - 0.5), large (0.5 - 0.7), very large (0.7 - 0.9), or extremely large (0.9 - 1.0). Statistical significance was determined at $p < 0.05$. SPSS (Version 12.0, SPSS Inc. Chicago, IL) was used for all calculations.

3. Results

Descriptive statistics for each variable are shown in Table 1. The eccentric mode was a moderately reliable test ($ICC_{(2,1)} = 0.82$, SEM = 2.84°) while that of the isometric mode was poor ($ICC_{(2,1)} = 0.57$, SEM = 5.64 s) (Table 2).

The Nordic break-point angle of the eccentric mode significantly correlated with isokinetic hamstring peak torques at concentric action of 60 °/s ($r = 0.48$, $r^2 = 0.23$, $p < 0.001$) and at eccentric action of 30°/s ($r = 0.58$, $r^2 = 0.34$, $p < 0.001$). Previous literature suggested that these correlation values are in the range of medium (0.3 − 0.5) to large (0.5 − 0.7).[29] The results of the isometric mode were not significantly correlated with peak torques measured in the isokinetic dynamometry ($r = 0.02 - 0.07$, $r^2 = 0.0004 - 0.0048$, $p > 0.05$).

4. Discussion

This study demonstrated that the higher Nordic break-point angle (i.e. a higher angle would indicate closer to the floor) is related to an increased isokinetic concentric and eccentric hamstring strength ($r = 0.48$ and 0.58, $p < 0.01$). By following the test protocol suggested in the present study, researchers and clinician can be confident that valid and reliable hamstring strength data can be obtained when implementing the eccentric mode of the video-based hamstring strength test.

Table 1
Measures of the isokinetic dynamometry and the video-based hamstring strength test.

Variables	Mean ± SD
Isokinetic dynamometry	
Hamstring peak torque at concentric 60 °/s − Dominant leg (N m)	113.97 ± 18.15
Hamstring peak torque at concentric 60 °/s − Non-dominant leg (N m)	111.01 ± 23.36
Hamstring peak torque at eccentric 30 °/s − Dominant l eg (N m)	137.81 ± 35.67
Hamstring peak torque at eccentric 30 °/s − Non-dominant leg (N m)	135.26 ± 34.98
Video-based hamstring strength test	
Nordic break-point angle in eccentric mode (°)	17.76 ± 6.61
Duration in isometric mode (s)	17.17 ± 8.65

Table 2
Between-session reliability of the video-based hamstring strength test.

Variable	$ICC_{(2.1)}$ (95% CI)	SEM	MDD
Eccentric mode	0.815 (0.637–0.993)	2.84°	7.87°
Isometric mode	0.574 (0.290–0.858)	5.64 s	14.97 s

Note. ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDD: minimal detectable difference.

Our results are consistent with the findings of Sconce et al.[24] that the Nordic break-point angle during Nordic hamstring exercise is related to eccentric hamstring peak torque. From their result, they have reported a higher reliability and shared common variance between Nordic break-point angle and eccentric knee flexor peak torque ($ICC = 0.97$, $r = -0.81$, $r^2 = 0.65$) compared to our result ($ICC_{(2,1)} = 0.82$, $r = 0.58$, $r^2 = 0.34$). The discrepancy between two studies may be due to the sample size, gender, and the competition level of the participants. In the present study, 30 male elite football players have been recruited while seven male and nine female soccer players of various experience have been recruited in Sconce et al. study.[24] Results from both studies provide support for the routine use of this field-based test on elite football players.

We have proposed the video-based hamstring strength test as an alternative method to overcome the shortcomings of isokinetic dynamometry and hand-held dynamometry (HHD).[20,30,31] Measurements performed with the use of HHD demonstrated a similar or higher level of reliability ($ICC = 0.90 - 0.91$).[20] When testing large muscle groups, e.g. hamstrings, examiners may be overpowered by participants.[23] The reproducibility and accuracy of the measures may be questionable. A previous study reported that the correlation between HHD and eccentric isokinetic measures was approximately 0.55.[20] The current video-based testing method requires low-cost equipment, e.g. digital camera and a computer with a 2D motion analysis software. Practitioners can obtain quantitative and continuous data for evaluations of athletes' hamstring performances. Others advantages include examiner-independence and does not require a high level of skill for data collection and analysis. Also, the participants in our investigation did not complain about delay onset of muscle soreness as they performed the test with less than 6 repetitions of Nordic hamstring exercise. A previous study showed that using the 2-D video analysis during a unipodal functional screening test was found to be reliable to measure lateral trunk motion ($ICC = 0.98 - 1$).[32] Another study advocated the clinical utility of 2-D video analysis to provide objective measures of movement patterns at the hip and knee during a dynamic functional task ($ICC = 0.79 - 0.91$).[33]

Our testing method was inspired by a novel screening test, namely, Nordic hamstring strength test, which employed by a large prospective cohort study on risk factors of HSI in elite footballers.[9] Hamstring strength performance was categorized as good if he can maintain at 30° of forward flexion in a Nordic hamstring exercise. The result demonstrated that there was no association between such ability and increased risk of HSI. The authors suggested that poor reliability ($K = 0.24$) was a possible explanation.[9] Based on our result, the reliability of the isometric mode was poor (ICC $_{(2,1)} = 0.57$). The duration of time in the isometric mode was insignificantly correlated to isokinetic hamstring strength ($r = 0.02$ - 0.07, $p > 0.05$). It is speculated that the participants were more familiar with the eccentric mode which is a dynamic movement. Also, the time of holding in the isometric mode measures muscle endurance while peak torque in isokinetic dynamometry measures muscle power. It may explain the weak relationship between these two variables.

The minimal detectable difference of this test suggested that more than 7.87° change in threshold angle during the eccentric mode is needed to denote clinical improvement or significant difference. From our experience, monitoring the quality of the movement, such as avoiding excessive hip movement and ensuring a very slow descending speed, are crucial. It is recommended that providing a video demonstration to follow by at least two submaximal trials of familiarization.

Some limitations of this study should be noted. The data outputs were not instantly obtainable. However, it seemed not problematic as the time required to obtain the data was less than three minutes, which was acceptable. Compared to isokinetic dynamometry, this testing method can be carried out in clinics or at training grounds. These factors should be carefully taken into account when considering its clinical applications. It is also important to note that the result from our study is not the same as directly predicting hamstring strain injury risk, nor providing normative threshold values. Despite this, our study included only semi-professional footballers and to generalize these findings to other athletic groups should be done with caution.

5. Conclusion

In light of these results, it can be concluded that measuring the Nordic break-point angle in the video-based hamstring strength test is a moderately reliable and valid field-based assessment among elite male football players. These findings support that the current method might be an alternative method to assess hamstring performance objectively in the preseason or during the competitive season if the isokinetic dynamometry could be difficult to conduct.

Conflicts of interest

The authors have no conflicts of interest to declare.

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