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Comparing Hamstring Muscle Length Measurements of the Traditional Active Knee Extension Test and a Functional Hamstring Flexibility Test

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Abstract

Background: The hamstring muscles are regularly injured during high risk sports involving sprinting and kicking activities. Currently there is inconclusive evidence regarding hamstring muscle length measurements as a predictor for hamstring injury using the active knee extension test. A more functional hamstring flexibility test may be a better measure of hamstring muscle length compared to the active knee extension test as it more closely represents the position of the hamstrings during high risk activities.

Purpose: The aim of this study was to compare hamstring muscle length measurements determined using the traditional the active knee extension test and newly proposed functional hamstring flexibility test.

Study Design: Comparative single group cohort study

Methods: Thirty seven healthy males aged 18-40 years currently involved in rugby union, Australian football, soccer or sprinting were included in the study. Hamstring muscle length was measured using the active knee extension test and the functional hamstring flexibility test on both right and left legs.

Results: The functional hamstring flexibility test measured a significantly smaller knee extension angle ($p<0.001$) compared to the active knee extension test.

Conclusion: A functional position such as that in the functional hamstring flexibility test results in a significantly smaller measure of knee extension than a non-functional assessment position, such as the active knee extension test.

Keywords: Active knee extension test; Functional hamstring flexibility test; Hamstring muscle length; Hamstring injury

Introduction

Hamstring injuries are common and are responsible for 15% of rugby union injuries, 12-14% of soccer injuries, 16% of Australian Rules football injuries and 26% of track and field sprinting injuries [1]. These injuries range between microscopic tears to a full rupture with loss of function [1,2]. Hamstring injuries are associated with a high reoccurrence rate of 30% of Australian football injuries, 21% of rugby union injuries and 16% of soccer injuries [1,3]. Furthermore, hamstring injuries result in lengthy periods of absence from training and competition causing significant financial expenses to clubs [1,4]. In 2009 approximately $1.5 million was spent on hamstring injuries in the Australian Football League (AFL), which equals 1.2% of the total salary cap of the AFL [1]. Additionally, the prolonged absence and deconditioning these injuries cause can result in significantly reduced athletic performance on return to competition [1]. A better understanding of hamstring injuries and their associated risk factors is needed to enhance the management of these injuries and reduce the negative impact they have on athletes and their clubs.

There are multiple intrinsic and extrinsic risk factors associated with hamstring injury and these are complicated and multi-factorial [5-7]. Risk factors proposed include age, gender, ethnicity, neural tightness, hamstring muscle weakness, past injury history, posture, fatigue and poor warm up technique [3,7]. Another possible cause for muscle injury is reduced hamstring muscle length [1,3].

The active knee extension test (AKET) is one assessment technique that is used to measure hamstring muscle length as a risk factor for sustaining a hamstring injury [8] This test involves active knee extension, and is considered safe, as the patient dictates their end of range [8]. The AKET measures the knee extension angle once the hamstrings have been actively lengthened to end of range, giving an indication of hamstring muscle length [8]. This test is commonly used clinically and in research, and has excellent inter-rater and intra-rater reliability [8,9].

Current available evidence has produced inconclusive results using the AKET to measure hamstring muscle length as a predictor of hamstring injury [4,8,10]. Two cohort studies did not identify a significant relative risk when assessing hamstring muscle length as a predictor of hamstring injury using the AKET amongst Victorian AFL players [3,8]. Similarly, a prospective cross sectional study did not identify hamstring muscle length using the AKET as a predictor of hamstring injury when assessing soccer players [10].

A possible reason for the lack of findings in these studies may be that the AKET does not closely represent the position of the hamstrings during high risk sporting activities. Hamstrings are regularly injured whilst sprinting and kicking [1,3,11]. During these activities the hamstrings are actively lengthening to their maximum during the late swing phase of running and the end phase of kicking a ball, whilst the opposite hip is in extension [12-14]. This hip extension causes a lengthening of the hip flexors and can induce further stretching of the hamstring muscle, thereby putting the hamstrings at potential risk of injury [13]. This indicates the need for a hamstring muscle length test which more closely represents the functional position of the hamstrings when they are most vulnerable for injury during high risk activities of sprinting and kicking a ball.

The proposed functional hamstring flexibility test (FHFT) for this study more closely represents the position of the hamstrings during high injury risk activities. The FHFT also assesses hamstring muscle length by measuring the angle of knee extension with the hip in 90° of flexion. The difference is that the contralateral hip flexors are placed on more stretch by positioning the knee in 90° of flexion off the end of the plinth, further increasing the stretch of the hamstrings. As the assessment position of the FHFT closely represents the length of the hamstring muscles when they are most vulnerable to injury this test may produce a different knee extension angle compared to the AKET. Therefore, the aim of this study was to compare hamstring muscle length measurements of the traditional AKET to the proposed FHFT.

Materials and Method

Participants were healthy males (n=37) aged between 18 and 40 years who were involved in Australian football, soccer, rugby union or track and field sprinting. Participants had no history of any lower limb or back injuries in the previous six months, no hip or knee joint pathologies that restricted their range of movement and no lower back pain or neurological symptoms. (Mean ± standard deviation (SD); age: 20.8 ± 1.3 years, height: 181.4 ± 6.3 cm, weight: 81.8 ± 14.3 kg).

A sample size calculation was completed using a significance level of 0.05 and a power of 0.8. This calculation was based on data from a similar study involving the AKET [15] and determined at least 31 participants were needed for the study. Participants were recruited from a Queensland University and local community sporting clubs. Prior to participation written informed consent was gained from all participants. Ethics approval was granted by James Cook University Human Research Ethics Committee (H5874).

Testing procedures

Each participant performed the AKET and FHFT twice on both legs. The mean result for both hamstring muscle length tests was calculated and used for analysis. The order of testing for the two tests and the beginning test leg was randomised by selecting cards with FHFT or AKET, and right or left from an opaque cup. A standard universal goniometer was used for all measurements and all measurements were completed by the principal investigator and recorded onto a data collection sheet.

Participants were asked not to participate in any form of physical activity or exercise on the day of testing. They wore loose fitted clothing such as a T-shirt and shorts, to prevent any restrictions in range of movement. Testing sessions began with a two minute walk on a treadmill at five kilometers per hour. The participant then performed the first hamstring muscle length test. This was then followed by a two minute rest in supine on a plinth before walking for a further two minutes on a treadmill at five kilometres per hour. The participant then performed the second hamstring muscle length test.

For the AKET participants were positioned supine on a plinth so that the leg not being tested was flat on the plinth with the knee extended. A strap was placed over the mid-thigh of this leg to eliminate any elevation of the limb. An additional strap was positioned over the front of the participant's pelvis and around the plinth to maintain the pelvis in a neutral position during hamstring measurements. A wooden apparatus was then placed on the plinth in line with the participant's anterior superior iliac spine of the pelvis.

The participant was asked to flex the hip of the test leg so that their thigh was touching the wooden apparatus. The goniometer was used to ensure 90° hip flexion, with the axis of the goniometer placed over the greater trochanter, the stationary arm parallel to the midaxillary line of the trunk and the moveable arm parallel to the femur in line with the lateral femoral condyle [16].

The participant was then asked, "straighten your leg at the knee as far as you can while maintaining your thigh touching the wooden apparatus". The axis of the goniometer was then placed over the lateral knee joint line, the moveable arm was aligned with the lateral malleolus of the ankle and the stationary arm was aligned with the greater trochanter parallel to the femur (Figure 1) [16]. The goniometer measured the angle of knee extension in degrees giving an indication of hamstring muscle length.

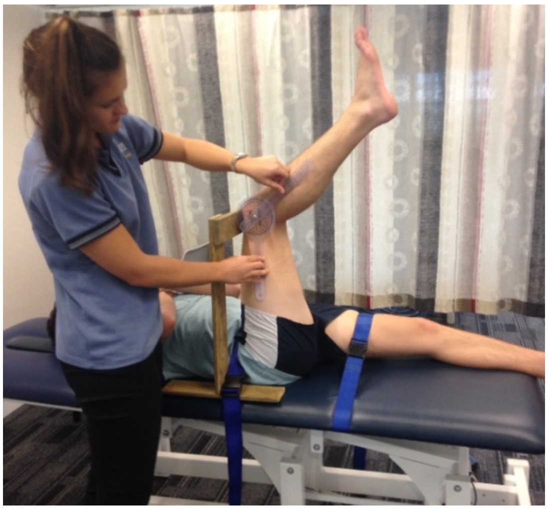

Figure 1: Active Knee Extension Test.

The FHFT was very similar to the AKET. Except for the FHFT participants were positioned with their thigh supported by the plinth, a knee brace maintained their knee in 90° flexion and their lower leg was in a vertical unsupported position off the plinth (Figure 2). The participant was then asked, "Straighten your leg at the knee as far as you can while maintaining your thigh touching the wooden apparatus," and the angle of the knee joint was measured as per the AKET.

Figure 2: Functional Hamstring Flexibility Test.

Reliability testing

Intra-rater reliability assessment was performed prior to data collection for both hamstring muscle length tests with ten healthy volunteers. The order of testing for the two tests and the beginning test leg was randomized as per the main study's protocol. To ensure the principle investigator was blinded to the measurements the dial of the goniometer was covered with a piece of paper. A second investigator was present for all testing sessions reading and recording the angle of knee extension on the goniometer onto a data collection sheet. To establish intra-rater reliability testing was conducted on two occasions one week apart. Hamstring muscle length tests were performed in the same order at each testing session for each participant.

Statistical analysis

Data was analysed using Statistical Package of Social Sciences (SPSS) programmer version 22. Intra-class correlation coefficient (ICC) and 95% confidence intervals were calculated to establish intra-rater reliability for the tests. The standard error of measurement (SEM) was calculated to describe the precision of hamstring muscle length measurements using the formula SEM=SDx√1-ICC, where SD is the standard deviation of the difference between test and retest scores for each test [17] Paired T tests were performed to analyze the results of the main study and compared the mean result between the two hamstring muscle length tests. The significance level was set at 0.05 and a power of 80%.

Results

Intra-class correlation coefficient, 95% confidence intervals and SEM for intra-rater reliability are presented in Table 1. The ICC demonstrated excellent intra-rater reliability with results ranging from 0.926 to 0.98 for both hamstring muscle length tests [18]. The SEM for the AKET and the FHFT ranged from 0.2676° to 1.2098° indicating a high precision of hamstring muscle length measurements with minor variances between actual measurements and true measurements.

Test	ICC (95% CI)	SEM
AKET Left leg	0.972 (0.888-0.993)	0.6768
AKET Right Leg	0.926 (0.703-0.982)	1.0691
FHFT Left leg	0.943 (0.771-0.986)	1.2098
FHFT Right leg	0.98 (0.920 -0.995)	0.2676
ICC: Intra-class correlation coefficient; CI: Confidence interval		

Table 1: Intra-rater Reliability for the Active Knee Extension Test and the Functional Hamstring Flexibility Test (n=10).

Of the participants included, 53% played rugby union, 6% of participants were involved in track and field sprinting events, 16% played Australian football and 23% of participants played soccer. Six (14%) of the participants highlighted that they were currently involved in two of the included sports.

Results of the paired T tests revealed a significant difference between hamstring muscle length measurements of the AKET and the FHFT (Table 2). The FHFT produced a significantly smaller mean knee extension angle compared to the AKET for both left, ($p<0.001$) and right lower limbs ($p<0.001$).

	AKET Mean (SD)	FHFT Mean (SD)	Mean Difference (95% CI)	P Value
Left Leg	140.49 (9.95)	125.26 (10.27)	15.23 (13.25-17.21)	<0.001*
Right Leg	140.43 (10.80)	125.23 (11.50)	15.2 (13.36-17.05)	<0.001*
CI: Confidence intervals; *Significant difference				

Table 2: Results of Paired T Tests Comparing the Active Knee Extension Test and the Functional Hamstring Flexibility Test (n=37).

Discussion

The results of this study demonstrated a significant difference between the hamstring muscle length measurements of the AKET and the FHFT. The FHFT produced a smaller knee extension angle, indicating reduced hamstring muscle length for both right and left legs. This finding indicates the FHFT may be a more appropriate test to use clinically when assessing an individual who plays AFL, rugby union, soccer or sprinting's functional hamstring muscle length. This more functional test may also be more suitable to use in the assessment of hamstring muscle length to determine risk for hamstring injury.

The reason the FHFT produces a smaller knee extension angle may be due to its more functional assessment position. The position of the non-test leg was the only difference in testing positions between the two hamstring muscle length tests. The FHFT has the knee of the non-test leg positioned to 90° off the end of the plinth in a knee brace which places the hip flexors on stretch. This position closely represents the position of the lower limbs during high risk activities such as sprinting and kicking a ball [1,3]. During the late swing phase of running and kicking a ball, the hamstrings are actively lengthening to their maximum whilst the opposite hip is positioned in extension [12,14]. This hip extension places the hip flexors on stretch and this induces further stretching of the contralateral hamstring muscle, putting the hamstrings at potential risk of injury [13]. Therefore, both hamstring muscle length and hip flexor muscle length are important during these high risk activities [13]. This may explain why the FHFT produces a smaller knee extension angle, as hamstring muscle length is assessed with the contralateral hip flexors on more stretch, and thus reducing the functional length of the hamstrings.

The findings of this study may explain the inconclusive results in studies using the AKET for assessment of hamstring muscle length as a predictor of hamstring injury. The AKET assesses hamstring muscle length with the opposite lower limb flat on a plinth in neutral. The opposite hip flexors are not placed on stretch while the hamstrings are actively lengthened to end of range. This is not considered end of range for functional hamstring muscle length, as biceps femoris muscle-tendon unit maximum length occurs at contralateral peak hip extension during running and sprinting. Therefore the AKET may not be an appropriate technique to measure to assess hamstring muscle length as a risk factor for hamstring injury as this is not a position in which there is a high risk of injury.

The FHFT has not yet been investigated in research as an assessment of hamstring muscle length, thus this is the first study to compare measurements of the AKET to the FHFT. However previous studies have compared hamstring muscle length measurements of the AKET to the passive knee extension test and the straight leg raise (SLR) test.

A cohort study aimed to determine whether a relationship existed between the AKET and the active SLR test [19]. Unlike the current study, this study assessed both males and females, did not assess a population at high risk of hamstring injury and measurements were recorded from images taken by a camera [19]. This study found a negative significant relationship between the AKET and the active SLR test ($r=-0.718$, $p<0.001$) with the common variance between the tests being slightly greater than 50% [19]. This is similar to the results of the current study as a large significant difference between measurements of the AKET and the FHFT was identified. It is possible a greater common variance would be found between the FHFT and the active SLR test.

A second study investigated whether differences existed in knee flexion angles of the AKET and the passive knee extension test [20]. This study assessed a similar sample of healthy males aged 18 to 40 years comparing the passive knee extension test and the AKET. The tests were also performed in a randomized order with the use of straps to stabilize the pelvis and left thigh and a wooden apparatus to maintain hip flexion. This study identified that the AKET assessed hamstring muscle length as shorter compared to the passive knee extension test ($p<0.001$) [20]. Based on the outcome of this study and the current study it is likely that the FHFT would produce a significantly smaller knee extension angle compared to the passive knee extension test.

Similar to the AKET, both the active SLR test and the passive knee extension test have produced inconclusive results as a predictor of hamstring injury [10,21-23] Limitations with the active SLR test which may have contributed to the inconclusive results include inconsistency of pelvic position, posterior pelvis rotation during measurements, hip joint capsule stretch and possible neural stretch [20]. Similar to the AKET, the passive knee extension test is not a functional assessment of hamstring muscle length and does not closely represent the position of the lower limbs during high risk activities which may explain the lack of significant findings in high risk sports.

The results of these two studies and the current study indicate that different assessment techniques represent different hamstring muscle length measurements. Considering the AKET, passive knee extension test and the SLR test have not produced conclusive results as a predictor of hamstring injury, and the FHFT represents a more functional measurement of hamstring muscle length it may be a more useful test to predict hamstring injury.

Limitations of this study include that only males between the ages of 18 and 25 years participated. Therefore these results cannot be generalized to females or older males. The results of this study are also more generalizable to males who play rugby union as more than half of the participants were involved in this sport compared to the much smaller numbers involved in soccer, Australian football and sprinting. This suggests further research is needed in these particular populations. Finally, the criteria only excluded those who sustained a hamstring injury in the six months leading up to the commencement of the study without any screening of injury prior to this period. Further research is required to determine whether differences in these two measures of hamstring injury would occur in an injured group or those with an older hamstring injury (greater than six months).

Identifying that the FHFT produces a significantly smaller knee extension angle compared to the AKET, has important implications for clinical practice such as enhancing the management of hamstring injuries in high injury risk sports. From this evidence it is recommended that the FHFT be used clinically when assessing the hamstring muscle length of Australian football, rugby union and soccer players or sprinters. Additionally, this may lead to this test being used in research when assessing hamstring muscle length to predict hamstring injury in high risk sports.

It is suggested that future research compare hamstring muscle length measurements of the FHFT and the AKET of individuals with current hamstring injuries to determine whether a significant difference is present in this population. Further research is also recommended using the FHFT to assess hamstring muscle length as a risk factor for sustaining a hamstring injury in high risk sports such as rugby union, Australian football, soccer and sprinting as this test may produce more conclusive results compared to the AKET. Further research has the capacity to improve the assessment of risk and hence prevention of hamstring injuries, thereby reducing the negative impact these injuries has on athletes and their clubs.

In conclusion, this study found that assessment of hamstring muscle length using the FHFT produced a significantly smaller knee extension angle compared to the AKET, indicating reduced hamstring muscle length. This is due to the more functional assessment of hamstring muscle length with the FHFT compared to the AKET. The FHFT may be a more appropriate assessment technique to determine functional hamstring muscle length of an individual who is involved in high risk sports. This test may improve the management of hamstring injuries and reduce the negative impact these injuries have on athletes and their clubs. Further research is recommended to identify whether the FHFT will produce different results in regards to assessing hamstring muscle length as a risk factor for hamstring injury in high risk sports.

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