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INTERSEASON VARIABILITY IN ISOKINETIC STRENGTH AND POOR CORRELATION WITH NORDIC HAMSTRING ECCENTRIC STRENGTH IN FOOTBALL PLAYERS

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ABSTRACT

Introduction

In elite sport, the use of strength testing to establish muscle function and performance is common. Traditionally, isokinetic strength tests have been used, measuring torque during concentric and eccentric muscle action. A device that measures eccentric hamstring muscle strength while performing the Nordic hamstring exercise is now also frequently used. The study aims to investigate the variability of isokinetic muscle strength over time, e.g. between seasons, and the relationship between isokinetic testing and the new Nordic hamstring exercise device. All teams (n=18) eligible to compete in the premier football league in Qatar underwent a comprehensive strength assessment during their periodic health evaluation at Aspetar Orthopaedic and Sports Medicine Hospital in Qatar. Isokinetic strength was investigated for measurement error, and correlated to Nordic hamstring exercise strength. Of the 529 players included, 288 players had repeated tests with one/two seasons between test occasions. Variability (measurement error) between test occasions was substantial, as demonstrated by the measurement error (approximately 25Nm, 15%), whether separated by one or two seasons. Considering hamstring injuries, the same pattern was observed among injured (n=60) and uninjured (n=228) players. A poor correlation ($r=0.35$) was observed between peak isokinetic hamstring eccentric torque and Nordic hamstring exercise peak force. The strength imbalance between limbs calculated for both test modes were not correlated ($r=0.037$). There is substantial intraindividual variability in all isokinetic test measures, whether separated by one or two seasons, irrespective of injury. Also, eccentric hamstring strength and limb-to-limb imbalance were poorly correlated between the isokinetic and Nordic hamstring exercise tests.

Introduction

In elite sport, the use of strength testing to establish muscle function and performance is common.^{1,2} Most professional football teams perform periodic health evaluations (PHE) or screening procedures to identify athletes at risk, with a view to target injury prevention programmes to the profile of each player, or the entire team.³ Muscle strength testing is believed to represent an important part of the PHE, to identify strength deficits and imbalances which can be addressed to decrease injury risk. A recent meta-analysis has shown that isokinetic strength testing has limited predictive value in determining future risk of hamstring strain injury.⁴ Still, strength testing is one of the three most commonly used screening methods in professional football,³ purportedly to determine the risk for various types of lower limb injuries, particularly to the thigh and knee.

Traditionally, isokinetic strength tests have been used, capable of measuring torque during both concentric and eccentric muscle action. A device specifically designed to measure eccentric muscle strength while performing the Nordic hamstring exercise has quickly gained popularity in elite sporting teams and sports medicine facilities. The Nordic hamstring exercise has been shown to effectively reduce the risk of hamstring injury,^{5,6} the most common injury type in football.⁷ Therefore, it seems intuitive that monitoring the force produced during this test might contribute to appropriately define muscle strength characteristics for football players.

Several studies have investigated the reliability of standard isokinetic strength measurements, reporting on test-retest reliability, as well as characterizing the minimal difference required between tests to be interpreted as a meaningful change.⁸⁻¹⁰ In these studies, the test-retest measures are performed within one to seven days. However, the variability of isokinetic muscle strength over time, e.g. between seasons, has not been investigated, nor has the relationship between isokinetic testing and the new Nordic hamstring exercise device. It is common practice to conduct preseason screening, or single time

point periodic health assessment that might include musculoskeletal strength testing.^{3,11} Although one would expect that the tests between seasons would differ, the amount of variability that might be expected is unknown, and therefore makes the clinical interpretation of these data difficult.

Therefore, the aim of this study was twofold, a) to describe the season-to-season variability of isokinetic strength testing in a group of professional male football players, and also determine the influence of hamstring injury on the stability of the variable; and b) to investigate the relationship between isokinetic muscle strength testing and eccentric strength testing using the novel Nordic hamstring exercise device.

Methods

Study design and participants

The analyses were performed on prospectively collected data from professional male football players as part of their annual PHE at Aspetar Orthopaedic and Sports Medicine Hospital in Doha, Qatar. All teams (n=18) eligible to compete in the Qatar Stars League (QSL), the highest level of competition in Qatar, agreed to participate in the study, with serial tests on all players from September 2010 to June 2014. As part of the musculoskeletal component of the PHE, players who provided informed consent performed a strength assessment of both lower limbs in the rehabilitation department at Aspetar. Players that did not consent or could not perform the strength assessment due to injury were excluded. Players who performed testing during consecutive seasons were identified for the current analyses, and grouped as players with one season and/or two seasons between tests.

Figure 1 depicts player inclusion. Ethical approval was obtained from the Institutional Review Board, Anti-doping Lab, Qatar (IRB project number 2012-020, IRB F2013000003).

Isokinetic strength testing

The same isokinetic strength battery was used for all tests. Knee flexion and extension strength were tested using an isokinetic dynamometer (Biodex Multi-joint System 3, Biodex Medical Systems Inc. New York, USA). After an explanation of the testing methodology, the player performed a 5-10 min warm up routine, consisting of either light running or cycling on a stationary exercise bike (Bike Forma, Technogym®, Cesena, Italy) at approximately 1 W/kg body weight, and familiarization with the test procedure. Each player was seated on the dynamometer so that the hip was flexed to 90°, ensuring that the dynamometer and knee joint angle were aligned. The trunk, waist and tested thigh were fixed with straps to minimize secondary joint movement. Range of motion was determined as 0 to 90°, with gravitational correction for each limb performed at 30° in the set range of motion. Vigorous verbal encouragement was provided by the assessors during the testing.¹²

Testing comprised of three different modes and speeds. Players were tested over five repetitions of concentric knee flexion and extension at 60°/s, followed by 10 repetitions of concentric knee flexion and extension at 300°/s. These test modes measure concentric strength of the quadriceps (knee extension) and hamstring (knee flexion) muscle groups. Subsequently, players performed five repetitions of eccentric knee extension at 60°/s to measure the eccentric strength of the hamstring muscle group. A 60 s rest period was observed between each set. The highest peak torque value observed from all repetitions performed for each of the three different tests was recorded.

Nordic hamstring exercise testing

In 2014, the players also performed one set of three maximal repetitions on a device specifically designed to measure eccentric muscle strength while performing the Nordic hamstring exercise. The Nordic hamstring exercise was performed directly after the isokinetic testing, with at least three minutes between tests. The device allows for separate measurements of peak eccentric strength for each limb as described previously.¹³ The players were tested in a kneeling position on a padded board, with both ankles secured immediately above the lateral malleolus by individual ankle braces. The player was

instructed to keep the trunk and hips in a neutral position with his hands held across the chest, and then progressively lean forward at the slowest possible speed while resisting the movement with both limbs. The highest peak force measure was recorded, as well as the average of the peak force recorded for the three trials.

Injury surveillance

All participating QSL teams are provided with medical services by the National Sports Medicine Programme, a department within the Aspetar Orthopaedic and Sports Medicine Hospital. This centralized system, with a focal point for the medical care of each club competing in the QSL, allowed for standardization of the ongoing injury surveillance through the Aspetar Injury and Illness Surveillance Programme (AIISP).¹¹

The AIISP includes prospective injury data collected monthly, with regular communication with the responsible team physician/physiotherapist to encourage timely and accurate reporting. At the conclusion of each season, all the data from the individual clubs were collated into a central database.

A hamstring injury was defined as acute pain in the posterior thigh that occurred during training or match play, and resulted in immediate termination of play and inability to participate in the next training session or match.¹⁴ These injuries were confirmed through clinical examination (identifying pain on palpation, pain with isometric contraction and pain with muscle lengthening) by the club medical team.¹⁵ If indicated, the clinical diagnosis was supported by ultrasonography and magnetic resonance imaging at the study centre.

Statistical analyses

Data were analysed with IBM SPSS statistics, V.21 (IBM Corp, Armonk, New York, USA), using each limb as the unit of analysis. Paired t-test were used to assess whether there were systematic differences in

the isokinetic strength variables between different test occasions (one and two seasons in between tests). The significance level was set at $p < 0.05$. The variability (random error) was assessed using a two way mixed model to determine the intraclass correlation coefficient ($ICC_{3,1}$) with 95% CI, as well as the measurement error. The measurement error was determined by calculating the difference between the standard deviation (SD) of the mean for the two test occasions divided by the square root of 2, presented as the mean error and also expressed as a percentage of the mean value. Effect size, which is the quantitative measure of the strength of an observed occurrence, was calculated and interpreted as small (> 0.2), medium (> 0.5), or large (> 0.8).¹⁶ To describe the correlation between strength measured during the isokinetic and Nordic hamstring exercise, we calculated the Pearson correlation coefficient between the peak torque for isokinetic eccentric contraction at $60^\circ/s$, and the peak force produced during the Nordic hamstring strength test. Data are presented as means with SD or 95% CI unless otherwise stated. The between-limb strength imbalance was correlated between left and right limbs as a percentage imbalance, using the right limb as the base measure.

Results

Participants

Between 2010-2013, all elite male football players ($n=614$) that reported for screening were considered for isokinetic testing. Of the 529 players included, 241 players did not have at least two consecutive test measurements. The final sample therefore included 288 players (age 25 ± 5 yrs, height 177 ± 7 cm, weight 71.5 ± 8.7 kg, BMI 22.9 ± 2.0) that performed the isokinetic test procedure on two occasions, 240 players with one season between measurements and 86 players with two consecutive seasons between measurements (figure 1). Those players who were unable to perform the test due to injury, or did not consent to performing the test ($n=85$, age 27 ± 5 yrs, height 177 ± 7 cm, weight 73.8 ± 8.7 kg, BMI 23.6 ± 1.8), were excluded from the analyses. These players were significantly older and heavier ($p < 0.05$, Cohen's d of 0.4 and 0.2, respectively). Considering ethnicity, 64% of the players were Arabic, 30% black,

2% Asian, and 4% Caucasian. Playing position was documented in four categories, goalkeepers (n=37), defenders (n=98), midfielders (n=108) and forwards (n=45).

In 2014, 337 players (age 25.9 ± 5 years, height 176.7 ± 6.9 cm, weight 72.2 ± 9.2 kg, BMI 23.1 ± 2.1) performed Nordic hamstring exercise testing in addition to the isokinetic strength testing.

Interseason variability of the isokinetic tests

The mean time between measurements was 374 (226 to 560) days for players with one season between test occasions and 790 (551 to 867) days for players with two seasons between test occasions.

A significant increase in isokinetic strength measurements from the first to the second test was observed in both groups for some modes, with very small to small effect sizes (table 1 and 2).

Variability (random error) between test occasions was substantial, as demonstrated by the large measurement error for all the contraction modes, whether separated by one or two seasons. The same pattern was observed among players not suffering from any hamstring injuries between tests (n=228) as for those who did have one or more hamstring injuries (n=60) (table 1). The variability between two test occasions is illustrated for quadriceps concentric torque @ $60^\circ/s$ and hamstrings eccentric torque @ $60^\circ/s$ in figures 2 and 3.

Relationship between isokinetic and Nordic hamstring exercise test

A poor correlation ($r=0.35$) was observed between peak isokinetic hamstring eccentric torque @ $60^\circ/s$ (Nm) (mean 207.7 ± 44.1 , 82.0 to 348.4) and Nordic hamstring exercise peak force (N) (mean 298.6 ± 72.3 , 121.0 to 502.5), as illustrated in figure 4. The mean imbalance between limbs was 23.0 ± 19.8 Nm for isokinetic strength and 28.7 ± 27.4 N for Nordic hamstring strength. The percentage strength imbalance between limbs (left compared to right) was calculated for both test modes were not correlated ($r=0.037$), as shown in figure 5.

Discussion

In this study of professional football players, substantial individual season-to-season variability was identified for isokinetic strength measurements, unrelated to any hamstring injury during the interval. Additionally, the results from standard (isokinetic) and novel (Nordic hamstring exercise) eccentric hamstring strength testing were poorly correlated.

Variability of isokinetic strength measurements

Isokinetic assessments are often used to establish strength profiles of athletes. The results are used for different purposes, such as performance training, return to sport and to determine risk of injury, particularly hamstring injuries.^{1,2,12,17-24} However, there seems to be a discrepancy in the literature between intervention studies testing the effect of eccentric strength training on hamstring injury risk and prospective cohort studies examining the association between eccentric hamstring strength and the risk of injury. Several intervention studies have reported a reduction in hamstring injuries after implementing various strengthening regimes.^{25,26} By far the largest effect has been demonstrated with the Nordic hamstring exercise. Three large intervention studies (two randomized and one non-randomized) have shown that injuries can be reduced by approximately 70% by implementing the Nordic hamstring exercise in a team's training regime.^{17,27,28} The results from these intervention studies suggest that eccentric strength must represent a key risk factor for hamstring injuries. However, a recent meta-analysis²⁹ documents that prospective cohort studies have failed to consistently identify hamstring strength as a strong risk factor associated with injury.^{12,26,30-33}

The large variability observed in this study might explain the apparent incongruity between intervention studies, consistently showing the positive effect of eccentric strengthening, and the lack of strong evidence to support this in prospective cohort studies. Prospective studies are based on a one-time baseline strength test, and with a variability (measurement error) of approximately 25 Nm (15%)

between strength tests separated by one season as observed in this study, it seems that large fluctuations in hamstring strength occur within seasons. This would make it difficult to identify any relationship between hamstring strength and injury risk, if such a relationship even exists.

An obvious question is how much of the observed variability is due to measurement error and how much is real. The reliability of standardized isokinetic testing has been reported previously, claiming high reproducibility if adequate calibration, gravity correction, and patient positioning were standardized.⁸⁻¹⁰

In a previous study from our centre that matches the methods used in this present investigation, Otten et al reported on the reliability of isokinetic testing, utilizing the same isokinetic dynamometer, and with the same skilled assessors conducting the testing.³⁴ In this study, tests were performed on four occasions with a minimum of 48 h of rest between each testing session. Although the ICC for quadriceps and hamstrings peak torque was again interpreted as reliable (>0.8), the standard error of the measurement was reported as 16.4 Nm and 10.5 Nm, respectively. The measurement errors in our study were 24.5 Nm and 15.7 Nm, suggesting an additional 50% variability in these two measures. In other words, both studies identify substantial random error when performing these isokinetic tests, and it seems clear that this increases when tests are separated by one or two seasons.

A potential explanation for the variability observed is injuries incurred during the season, particularly hamstring injuries. However, the season-to-season variability observed was similar for uninjured and injured players across all the modes of testing. All the players were deemed fit to play at the time of testing, but it should be noted that we have only investigated the effect of hamstring injuries, not any other injuries between test occasions. However, as hamstring injuries are the most likely to affect hamstring strength, it seems highly unlikely that the variability observed is due to inter-test injuries.

Correlation of isokinetic torque and Nordic hamstring eccentric force

The Nordic hamstring exercise is today often used to measure hamstring strength, and determining risk of lower limb injury.^{23,24,35} This is the first study to determine the correlation between the Nordic

hamstring exercise and conventional isokinetic strength test using a dynamometer. Unexpectedly, we found a poor correlation between the Nordic hamstring exercise and isokinetic tests, as well as no correlation between the bilateral imbalances identified in either test.

These tests are biomechanically different in nature, and muscle activation patterns will be different,^{36,37} which may influence how well they correlate. Bourne et al reported that Nordic hamstring exercise provide the largest stimulus to changes in biceps femoris fascicle length,³⁸ which might explain the effect of the intervention on reducing injury risk, since decreased fascicle length has been reported as a risk factor for hamstring injury.²⁴ Unfortunately, none of the intervention studies measure the effect of the intervention on muscle architecture, or any other factor, and are therefore not able to identify the mechanism responsible for the preventative effect.

Although the effect of reducing risk of hamstring injury using the Nordic hamstring exercise has been well established,⁵ when implemented as a screening tool, it has yielded mixed results.^{19,21,23,24} Engebretsen et al found no significant association when it was used as a simple visual assessment of test performance.²¹ Subsequent studies positively identified players with inferior eccentric strength (measured by a novel device) as being at increased risk of hamstring injury.^{23,24} However, in a cohort of rugby players, between-limb imbalances and not eccentric strength was associated with the risk of hamstring injury.¹⁹

The quantification of this exercise by Opar et al¹³ provided the opportunity to test how well it compares to other forms of measuring strength, in particular isokinetic testing, which has been described as the gold standard of strength testing.³⁹

Although both tests are assumed to measure the same trait, eccentric force production, the low correlation suggests that they do not.

Importantly, there are two main differences between the test modes. Firstly, the position in which the two tests are performed have opposing features. For the isokinetic test, the strength is measured as the limb performs a unilateral movement in a seated position, with the hip in flexion. In contrast, the Nordic hamstring exercise test measures the strength of both limbs in a bilateral movement, with the player in a kneeling position and the hips extended. Secondly, the units of measurement are also different; isokinetic strength is measured as torque and Nordic hamstring strength as force. Perhaps these central differences can explain why we do not find any correlation between isokinetic and Nordic hamstring strength testing.

Even if the force and torque measurements do not correlate between test modes, one might expect any limb-to-limb strength imbalance to favour the same side using both devices; however, these did not correlate at all (Figure 5). One hypothesis to explain this is the bilateral deficit, the reduction in amount of force produced from bilateral movements compared to the sum of forces produced unilaterally by the left and right limbs when tested alone.^{40,41} The Nordic hamstring test measures the imbalance when both legs are tested together, in contrast to the isokinetic test, where unilateral strength tested for each leg separately.

Strengths and Limitations

A major strength of this study is that all tests performed utilized the same isokinetic testing system with highly experienced assessors, and it was performed in a single clinical setting for professional athletes. This reflects a “real world” scenario and might contribute to the external validity of the study.

Limitations to this investigation includes no recording of exposure to football training and match play, specific strength training or interventions aimed at prevention across the different clubs. This study was performed in a multinational, multi-language setting, and while every effort was made to guarantee that players comprehended the test procedure and directions, it is possible that some players did not fully

understand the instructions. In our clinical setting, a formal familiarization procedure was not possible, and the change we observe between seasons may partly be due to a learning effect between the test sessions. We also acknowledge the homogeneity of our study population of professional male football players, which limits the generalization of these findings to other sports, age groups, or female players.

Conclusion

There is substantial intraindividual variability in all isokinetic test measures, whether separated by one or two seasons, and irrespective of injury. Also, eccentric hamstring strength and limb-to-limb imbalance were poorly correlated between the isokinetic and Nordic hamstring exercise test.

Perspective

The use of strength testing to establish muscle function and performance in elite sport is common.^{1,2} Muscle strength testing is believed to represent an important part of the PHE, identifying strength deficits and imbalances which can be addressed to decrease injury risk. Strength testing is one of the three most commonly used screening methods in professional football,³ to determine the risk for various types of lower limb injuries, particularly to the thigh and knee. The large variability observed in this study might explain the apparent incongruity between intervention studies, consistently showing the positive effect of eccentric strengthening, and the lack of strong evidence to support this in prospective cohort studies. The variability (measurement error) of approximately 25 Nm (15%) between strength tests separated by one season as observed in this study, indicating that large fluctuations in hamstring strength occur within seasons, makes it difficult to identify any relationship between hamstring strength and injury risk. There is substantial intraindividual variability in all isokinetic test measures, whether separated by one or two seasons, and irrespective of injury. This might explain the disparity we observe between prospective cohort and intervention studies considering eccentric strength, and suggest that other mechanisms might be responsible for the preventative effect of

eccentric training. Eccentric hamstring strength and limb-to-limb imbalance were poorly correlated between the isokinetic and Nordic hamstring exercise test, indicating that these tests might measure different characteristics of strength.

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LEGENDS OF TABLES AND FIGURES

Figure 1 Flow chart demonstrating the inclusion of players over different seasons

Figure 2 Scatter plot presenting the isokinetic quadriceps concentric torque @60°/s for injured (n=51, closed symbols) and uninjured (n=189, open symbols) for season 1 (test 1) and season 2 (test 2). The hatched line represents the identity line.

Figure 3 Scatter plot presenting the isokinetic hamstrings eccentric torque @60°/s for injured (n=51, closed symbols) and uninjured (n=189, open symbols) for season 1 (test 1) and season 2 (test 2). The hatch line represents the identity line.

Figure 4 Scatter plot with correlation between isokinetic hamstring eccentric peak torque @ 60°/s and Nordic hamstring exercise peak force for injured (n=31, closed symbols) and uninjured (n=306, open symbols).

Figure 5 Scatter plot illustrating the correlation of between-limb imbalance (expressed as a percentage of left compared to right for isokinetic hamstring eccentric peak torque @ 60°/s (x-axis) and Nordic hamstring exercise peak force (y-axis) for injured (n=31, closed symbols) and uninjured (n=306, open symbols) players.

Table 1 Interseason comparison of isokinetic strength testing for players with one season between measurements (n=240).

Table 2 Interseason comparison of the isokinetic strength tests for players with two seasons between measurements (n=86).

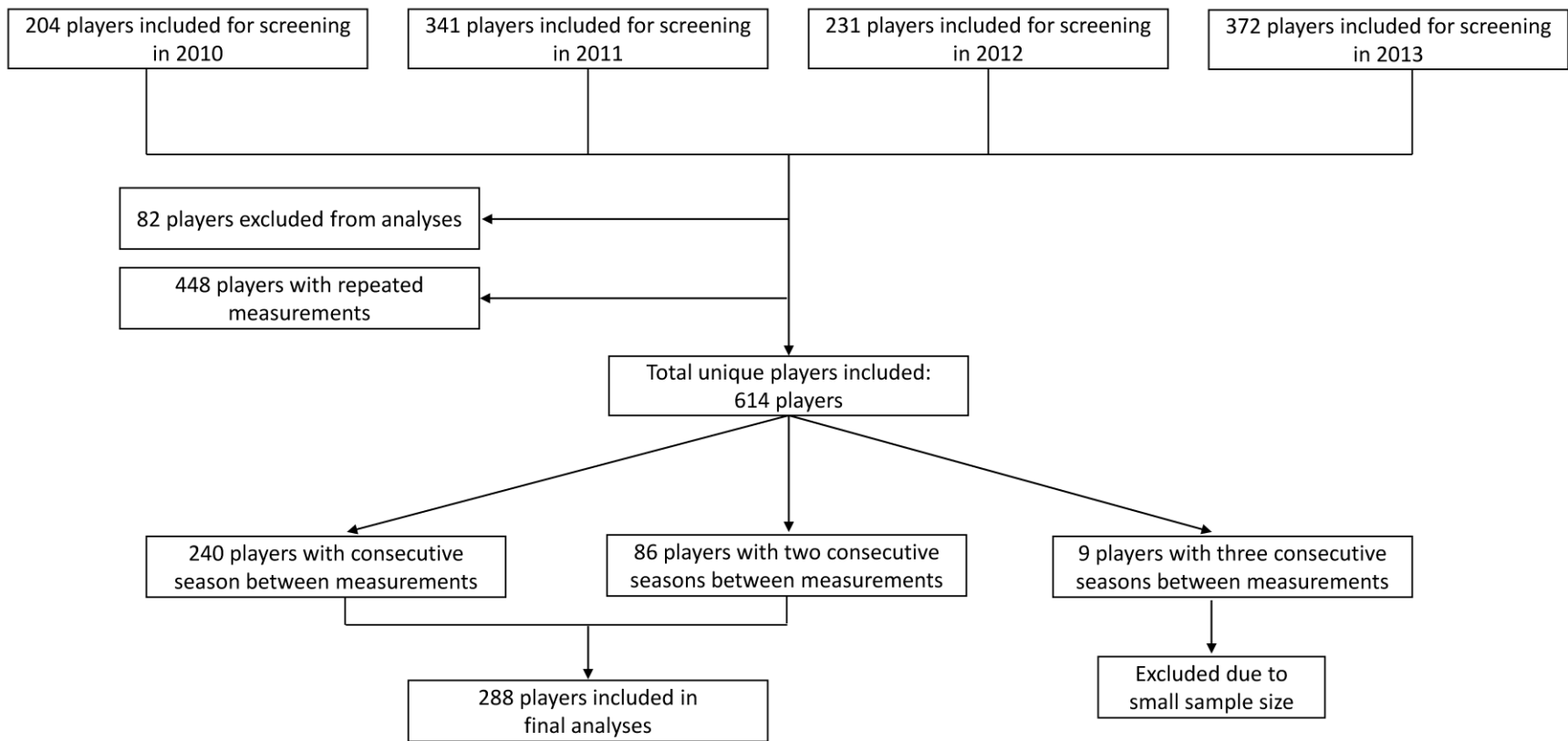


Figure 1 Flow chart demonstrating the inclusion of players over different seasons

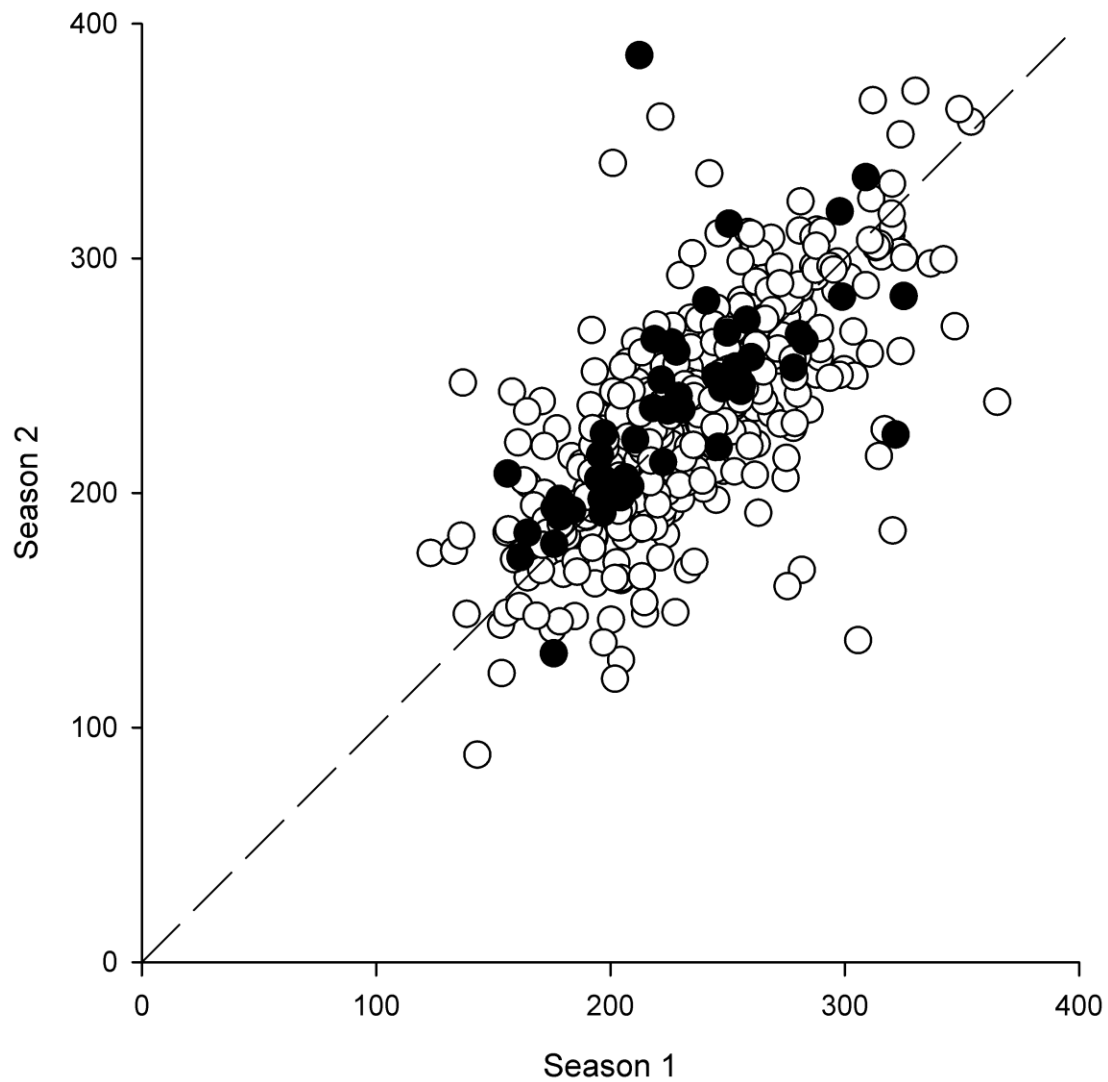


Figure 2 Scatter plot presenting the isokinetic quadriceps concentric torque @60°/s for injured (n=51, closed symbols) and uninjured (n=189, open symbols) for season 1 (test 1) and season 2 (test 2). The hatched line represents the identity line.

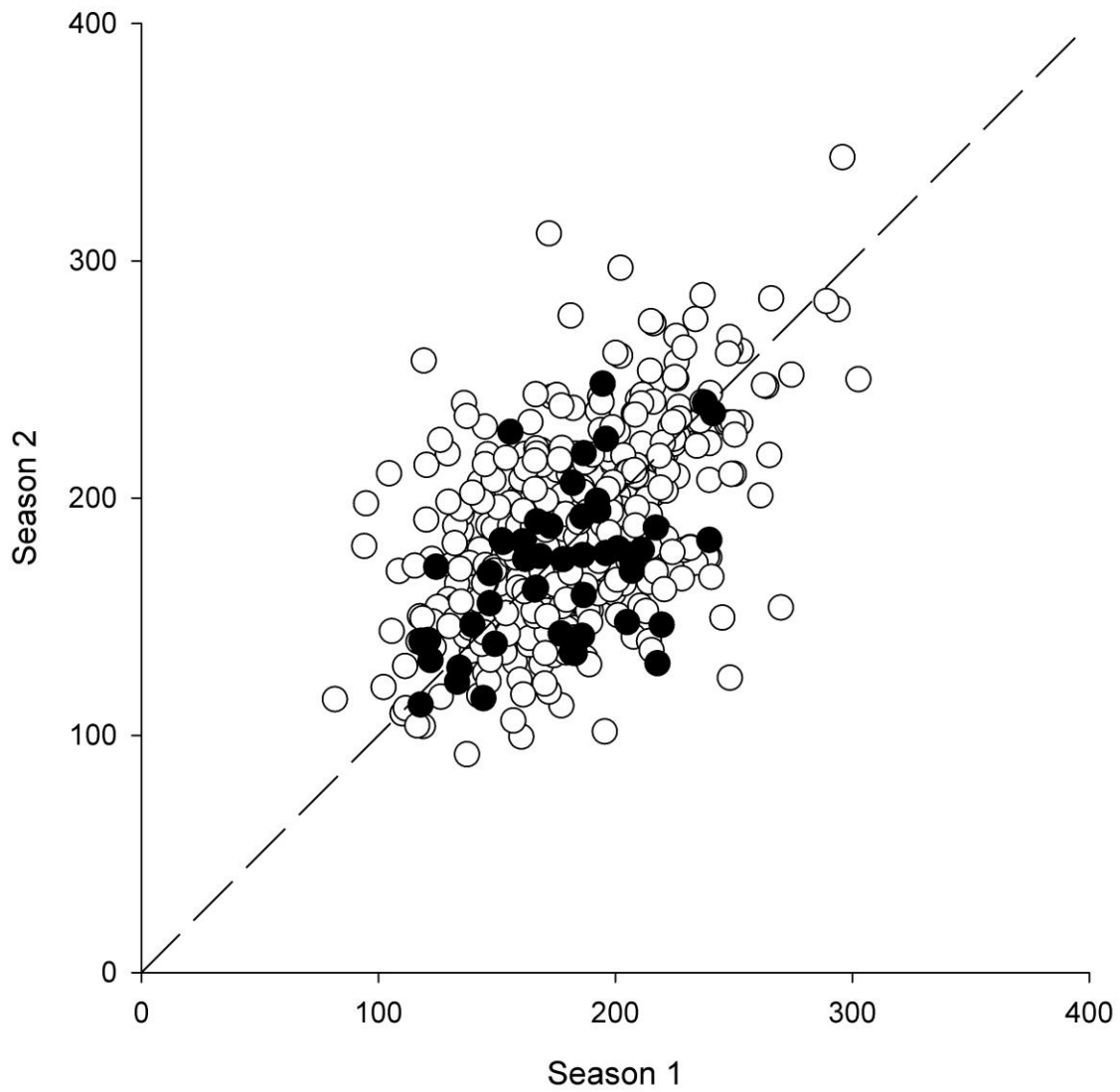


Figure 3 Scatter plot presenting the isokinetic hamstrings eccentric torque @60°/s for injured (n=51, closed symbols) and uninjured (n=189, open symbols) for season 1 (test 1) and season 2 (test 2). The hatch line represents the identity line.

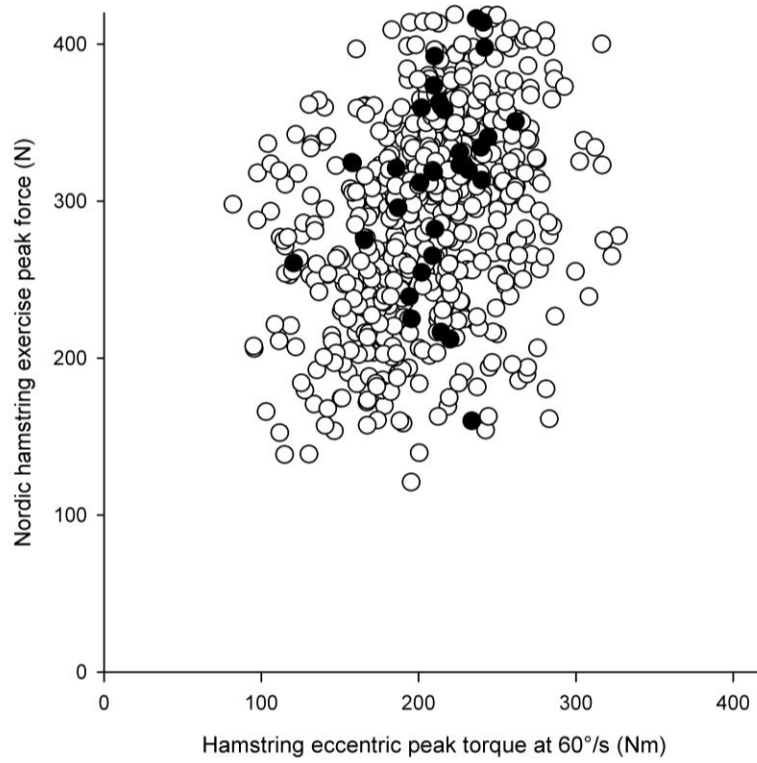


Figure 4 Scatter plot with correlation between isokinetic hamstring eccentric peak torque @ 60°/s and Nordic hamstring exercise peak force for injured (n=31, closed symbols) and uninjured (n=306, open symbols).

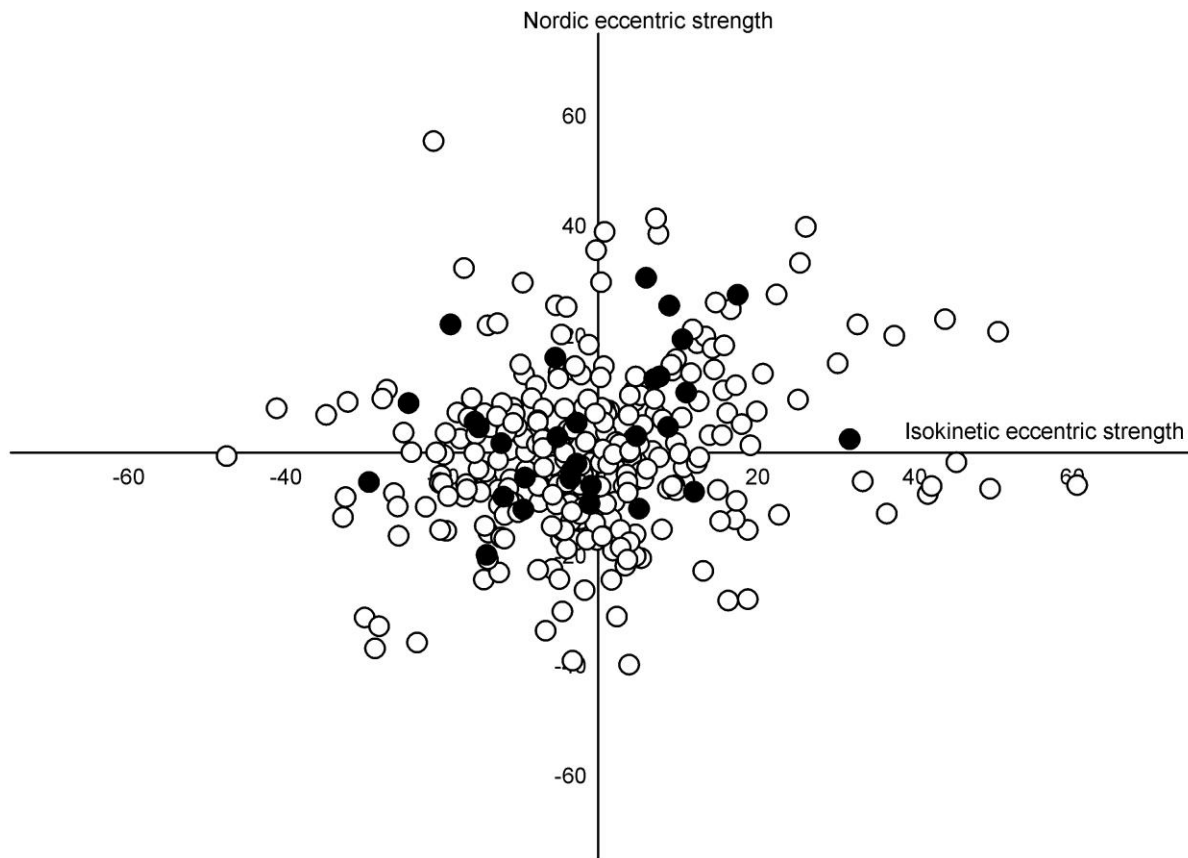


Figure 5 Scatter plot illustrating the correlation of between-limb imbalance (expressed as a percentage of left compared to right for isokinetic hamstring eccentric peak torque @ 60°/s (x-axis) and Nordic hamstring exercise peak force (y-axis) for injured (n=31, closed symbols) and uninjured (n=306, open symbols) players.

Table 1 Interseason comparison of isokinetic strength testing for players with one season between measurements (n=240).

	Test 1 (mean±SD)	Test 2 (mean±SD)	Difference test 2 to test 1 (mean, 95% CI)	ICC (95% CI)	Effect size (d)	p-value	Measurement Error
	Nm	Nm	Nm				Nm (%)
Quadriceps concentric at 60/s							
All	234.1 (42.5)	235.1 (45.4)	1.0 (-5.8 to 3.7)	0.71 (0.67 to 0.81)	0.02	0.72	24.5 (10.5)
Injured	227.0 (41.9)	235.9 (45.3)	8.9 (-8.3 to 26.0)	0.68 (0.51 to 0.96)	0.2	0.31	24.7 (10.9)
Uninjured	235.0 (42.5)	235.1 (45.5)	0.1 (-5.8 to 6.0)	0.69 (0.67 to 0.82)	0.02	0.98	24.4 (10.4)
Hamstrings concentric at 60/s							
All	123.7 (23.0)	128.6 (26.1)	4.9 (1.7 to 8.1)	0.63 (0.60 to 0.76)	0.2	0.002	15.7 (12.7)
Injured	121.3 (20.5)	127.1 (27.8)	5.8 (-3.7 to 15.5)	0.57 (0.46 to 1.09)	127	0.23	16.4 (13.6)
Uninjured	124.0 (42.5)	128.7 (25.9)	4.7 (1.5 to 8.1)	0.60 (0.59 to 0.76)	0.2	0.005	15.6 (12.6)
Quadriceps concentric at 300/s							
All	131.9 (24.6)	136.3 (26.8)	4.4 (1.9 to 6.9)	0.79 (0.78 to 0.90)	0.2	0.01	12.4 (9.4)
Injured	129.3 (23.7)	135.7 (27.8)	6.4 (-3.7 to 16.6)	0.75 (0.67 to 1.11)	0.3	0.21	13.0 (10.1)
Uninjured	132.2 (24.7)	136.4 (26.8)	4.2 (0.7 to 7.7)	0.78 (0.72 to 0.91)	0.2	0.02	12.3 (9.3)
Hamstrings concentric at 300/s							
All	93.9 (21.3)	98.6 (21.4)	4.7 (2.3 to 7.8)	0.56 (0.55 to 0.75)	0.2	0.0003	14.5 (15.4)
Injured	92.4 (21.2)	98.7 (20.5)	6.3 (-1.9 to 14.5)	0.66 (0.43 to 0.85)	0.3	0.13	12.2 (13.2)
Uninjured	94.1 (21.3)	98.6 (21.6)	4.5 (2.0 to 7.8)	0.55 (0.48 to 0.64)	0.2	0.001	14.8 (15.7)
Hamstrings eccentric at 60/s							
All	181.7 (37.0)	185.5 (39.5)	3.8 (-0.9 to 9.1)	0.52 (0.47 to 0.64)	0.1	0.1	26.6 (14.6)
Injured	176.4 (32.5)	170.4 (33.4)	5.8 (-7.3 to 19.4)	0.52 (0.25 to 0.78)	0.2	0.37	23.2 (13.2)
Uninjured	182.3 (37.4)	187.2 (39.8)	4.9 (-0.1 to 10.5)	0.52 (0.46 to 0.64)	0.1	0.05	26.9 (14.8)

*Mean ± SD for test 1 (season 1) and test 2 (season 2), mean interseason difference, measurement error (ME) from test 1 (season 1) to test 2 (season 2) are reported. ICC, intraclass correlation coefficient, Nm, Newton-meter, d, Cohen's d.

Table 2 Interseason characteristics of the isokinetic strength tests for players with two seasons between measurements (n=86)*

	Test 1 (mean±SD)	Test 2 (mean±SD)	Difference test 2 to test 1 (mean, 95% CI)	ICC (95% CI)	Effect size (d)	p-value	Measurement Error
	Nm	Nm	Nm				Nm (%)
Quadriceps concentric at 60/s							
All	225.2 (40.3)	238.5 (44.1)	13.3 (4.3 to 22.3)	0.69 (0.63 to 0.87)	0.3	0.004	23.8 (10.6)
Injured	215.1 (42.5)	220.9 (41.6)	5.8 (-35.2 to 47.8)	0.78 (0.22 to 1.31)	0.1	0.77	19.6 (9.1)
Uninjured	225.8 (40.3)	239.6 (44.2)	13.8 (4.5 to 23.0)	0.68 (0.62 to 0.87)	0.3	0.003	24.0 (10.6)
Hamstrings concentric at 60/s							
All	122.3 (22.8)	128.4 (22.1)	6.1 (0.9 to 11.1)	0.65 (0.51-0.74)	0.3	0.01	13.3 (10.9)
Injured	123.5 (20.1)	128.5 (16.8)	5.0 (-13.5 to 23.4)	0.50 (-0.23 to 1.1)	0.3	0.58	13.2 (10.7)
Uninjured	122.1 (23.0)	128.3 (22.4)	6.2 (0.6 to 11.5)	0.65 (0.52 to 0.75)	0.3	0.02	13.4 (10.9)
Quadriceps concentric at 300/s							
All	129.2 (25.7)	135.0 (26.5)	5.8 (0.3 to 11.4)	0.67 (0.58 to 0.81)	0.2	0.04	15.0 (11.6)
Injured	128.8 (33.9)	127.6 (20.4)	1.2 (-26.8 to 29.1)	0.40 (-0.25 to 0.73)	0.04	0.93	22.5 (17.5)
Uninjured	129.2 (25.3)	135.4 (26.8)	6.2 (0.5 to 12.0)	0.69 (0.61 to 0.85)	0.2	0.03	14.5 (11.2)
Hamstrings concentric at 300/s							
All	93.4 (20.8)	96.2 (20.6)	2.8 (-1.1 to 7.8)	0.53 (0.41-0.66)	0.1	0.14	14.1 (15.1)
Injured	94.8 (19.0)	97.1 (16.7)	2.3 (-15.6 to 20.1)	0.67 (0.01 to 1.17)	0.1	0.79	10.3 (10.9)
Uninjured	93.3 (21.0)	95.9 (20.9)	2.9 (-1.2 to 8.0)	0.53 (0.40 to 0.67)	0.1	0.15	14.3 (15.3)
Hamstrings eccentric at 60/s							
All	176.2 (38.0)	187.9 (38.9)	11.7 (5.3 to 21.7)	0.51 (0.39-0.65)	0.3	0.001	26.5 (15.0)
Injured	175.1 (37.5)	191.6 (48.5)	16.5 (-23.0 to 63.6)	0.43 (-0.63 to 1.79)	0.4	0.35	34.0 (19.4)
Uninjured	176.3 (38.1)	187.7 (38.4)	11.4 (4.6 to 21.5)	0.52 (0.39 to 0.65)	0.3	0.002	26.2 (14.9)

*Mean ± SD for test 1 (season 1) and test 2 (season 3), mean interseason difference, measurement error (ME) from test 1 (season 1) to test 2 (season 3) are reported. ICC, intraclass correlation coefficient, Nm, Newton-meter, d, Cohen's d.

