The effects of a soccer-specific fitness test on eccentric knee-flexor strength

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Abstract

Context: Physiological fitness testing, such as the Yo-Yo Intermittent recovery test (YYIR) is a key requirement of the Elite Player Performance Plan, introduced by the English Premier League. Eccentric hamstring strength has been identified as a risk factor for hamstring injuries in soccer players, with fatigue highlighted to further exasperate this issue. **Objective:** The aim of the current study was to examine the effect of the YYIR level 1 (YYIR1) on eccentric knee-flexor strength assessed using the NordBord in youth soccer players. **Design:** Experimental design. **Setting**: Soccer club academy. **Participants:** 67 male academy soccer players (Age = 16.58 ± 0.57 years; Height = 175.45 ± 5.85 cm; Mass = 66.30 ± 8.21 kg) volunteered to participate in the current study during the English competitive soccer season. **Main Outcome Measures:** Participants conducted eccentric hamstring strength assessments using the NordBord prior to and immediately post completion of the YYIR1, with outcome measures of peak force and peak force relative to body mass recorded. **Results:** Paired T tests highlighted increased absolute eccentric knee flexor strength values ($P < 0.001$) immediately post YYIR1 for both the dominant and non-dominant limbs, with the same trend ($P < 0.001$) observed for eccentric strength relative to body mass. **Conclusions:** The results of this study indicate that the YYIR1 does not induce eccentric knee-flexor fatigue and as such is not a valid assessment method to assess the effects of fatigue on hamstring function. However, results do suggest that the NordBord may be considered a viable and more accessible alternative to detect pre-post fitness test/fatigue protocol differences in eccentric knee flexor peak strength whilst working in the field.

Keywords: Soccer, Hamstring, Fatigue, Eccentric, Strength

Introduction

Hamstring strain injuries (HSI) are the most common non-contact injury in adult [1] and adolescent soccer populations [2] with incidence rates ranging from 12 - 37% [3,4]. This in turn has had a resultant effect on player availability for match-play, which has been associated with a negative impact upon team success [5] and club finances [1].Consequently, HSI have received plentiful research attention [7,8], however despite this, injury incidence appears unchanged [3] and reoccurrence rates remain high with incidence in soccer shown to increase annually by 2.3% between 2001 and 2014 [4].

Team sports such as soccer are characterised by accelerations and fast changes of direction [8] thus increasing the possibility of HSI due to the enhanced eccentric forces applied to the hamstring musculature during high speed running, which is commonly acknowledged as the most common mechanism of injury [9]. The ability to produce eccentric force has been shown to be further exasperated in the later stages of soccer-specific protocols when measured using an isokinetic dynamometer (IKD) [10,11] which is in line with the temporal increase in HSI during match-play [4.12]. Consequently, eccentric hamstring strength represents an appealing and modifiable risk factor for HIS [13], with research demonstrating HSI to reduce by ~ 70% when Nordic hamstring curl (NHC) exercises are adopted as part of injury prevention programmes [14].

The isokinetic dynamometer (IKD) [15] has been proposed as the gold standard measure of eccentric hamstring strength. However, the cost of these devices, lack of portability in the case of the IKD and the need for highly skilled practitioners to operate these apparatuses has led to other field testing devices such as the NordBord to be developed [16]. The Nordbord allows eccentric knee flexor strength to be assessed quickly and efficiently in a more ecologically valid environment [17], with various studies [13, 16] identifying reduced eccentric hamstring strength

when measured on the NordBord to be a risk factor for HSI. However, these studies have all been conducted in a state of rest or non-fatigue, whereas HSI has been demonstrated to display a temporal pattern with soccer match duration [4, 12].

The Yo-Yo Intermittent Recovery level 1 test (YYIR1), is a physiological fitness test designed to replicate the intermittent nature of soccer activity and has been shown to elicit a fatigue response in elite soccer players [18]. Regular, physiological fitness benchmark performance testing is a key requirement of the Elite Player Performance Plan (EPPP) [19] which was introduced to increase the number of high-quality home-grown soccer players graduating from English football academies. Such tests are commonly conducted testing by professional soccer clubs, thus providing ample opportunity not only to provide benchmark data to meet EPPP guidelines, but also assess risk factors associated with HSI whilst players are in a state of fatigue. Therefore, the aim of the current study was to examine the effect of the YYIR1 test on eccentric knee-flexor strength assessed using the NordBord in youth soccer players. The authors hypothesised that the soccer-specific fitness test would reduce both absolute and relative peak eccentric knee-flexor strength immediately post protocol.

Methods

Participants

Sixty-seven academy male soccer players (Age = 16.58 ± 0.57 years; Height = 175.45 ± 5.85 cm; Mass = 66.30 ± 8.21 kg) volunteered to participate in the current study during the English competitive soccer season. Eligibility criteria required participants to be male, 16 – 18 years old, with no previous hamstring injury in the past 6 months. Each participant was required to be an outfield player contracted to an academy football club with a training volume of > 14 hours per week in addition to their weekly matches. All data was collected in-season, with at

least 3 days rest provided since the previous match. Players were all familiar with the Nordic exercise, which was included as part of their weekly lower-limb strength and conditioning program at their respective club. Participants were informed of the risks and procedures involved in the testing and were required to provide informed consent or child assent in addition to primary carer consent prior to the commencement of the study. The study was previously approved by the university ethics committee and conformed to the Declaration of Helsinki. All equipment was calibrated in accordance to the manufacturer guidelines prior to testing commencing.

Experimental Design

The current study consisted of a pre-post-test design to investigate the effect of a soccer-specific field test on measures of eccentric knee flexor strength. The dependent variable was chosen from existing contemporary literature, which has analysed measures of athletic performance shown to influence HSI.

Procedures

Participants were required to attend one 90-minute testing session at their football club. Participants were instructed on how to complete the eccentric knee flexor strength test and the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1). Participants arrived wearing their normal training apparel and footwear in a 3-h post absorptive state following 24 h abstinence from alcohol, caffeine and vigorous exercise. Participants then undertook their normal warm up, involving a 10-minute aerobic block and dynamic stretches of the lower limb muscles. Measures of eccentric knee flexor strength and rate of perceived exertion (RPE) were recorded immediately prior to and post completion of the Yo-Yo IR1. All tests were conducted at the same time of day to avoid any variation in circadian rhythms.

Yo-Yo IR1

The Yo-Yo IR1 was used to measure the participant's ability to perform intense intermittent exercise that required involvement of high aerobic energy production and large contributions from the anaerobic energy systems [20]. The Yo-Yo IR1 was performed on an outdoor football pitch where participants repeated 40 m sequential runs at progressively increasing speeds as dictated by the auditory bleeps from a portable CD player. Between each 40 m run, participants were provided with 10 seconds of active recovery. To ensure that participants covered the required distance, testers were positioned at each end of the course. All Yo-Yo tests were carried out by the same testers in order to minimise inter-rater variability. Participants either volunteered termination of test if they were unable to reach the finishing line before the bleep or were instructed to cease exercise if they failed to reach the finishing line for the second time before the auditory bleep sounded. The number of 40 m runs the participant completed was recorded and the cumulative total represented the test result [18].

Eccentric Knee-Flexor Strength Testing

Assessment of eccentric knee flexor strength using the NordBord has been previously reported [13,16,17]. Participants were asked to position themselves in a kneeling position on a padded board, with their ankles then secured superior to the lateral malleolus by singular ankle braces that were held over custom made uniaxial load cells (Delphi Force Measurement, Gold Coast, Australia). To ensure that a force was always measured through the long axis of the load cells, the ankle braces and load cells were secured to a pivot.

To perform the Nordic hamstring exercise, participants were instructed to gradually lower their torso towards the ground, whilst maintaining a straight back, and resisting the effects of gravity

using their hamstring muscles for as long as possible [7]. The participants were instructed to use their hands to break the forward fall, followed by a push to return to the initial knee loading position to minimize concentric loading [14]. After completing a standardised warm-up consisting of 5 minutes submaximal intensity cycling, and a combination of dynamic lower limb exercises [21] participants then completed their experimental testing. On the day of testing, participants were provided with a warm up of three submaximal efforts, superseded by a one-minute rest before performing three maximal bilateral repetitions of the Nordic hamstring exercise [21]. Verbal encouragement was provided throughout the three repetitions to ensure that maximal effort was provided. A trial was deemed valid when the force output trace achieved a prominent peak, immediately followed by an instant decline in force, indicating that the participant was no longer able to sustain the contraction. Peak force and peak force relative to body mass were recorded for both the dominant and non-dominant limbs, with the dominant limb defined as the participant's preferred ball kicking leg. In addition to these variables, a limb dominance ratio was calculated by dividing the dominant limb peak force by the non-dominant limb peak force.

Rate of Perceived Exertion

Borg's 6-20 point scale was used to record the participants RPE immediately upon cessation of the Yo-Yo IR1 test.

Data Analysis

Eccentric knee flexor force data for both the dominant and non-dominant limb were transferred to a university computer at 100 Hz using a wireless USB station receiver (Mantacourt, Devon, United Kingdom). From this, the peak force for the three repetitions for each limb (left and right leg) was determined using LabChart 7.3 (ADInstruments, New South Wales, Australia).

In the current study, eccentric hamstring strength is reported in absolute terms (N) and relative to body mass ($N.kg^{-1}$), using the peak force from the three repetitions for both limbs, providing measure of dominant and non-dominant measures of eccentric knee flexor strength. The between-limb fore ratio was calculated as the dominant-non-dominant ratio, calculated using log transformed raw data followed by back transformation (Impellizerri et al .2012)

Statistical Analysis

All statistical analysis was completed using PASW Statistics editor 23.0 for Windows (SPSS inc, Chicago, Il, USA) with statistical significance set a $P < 0.05$. All data is reported as mean ± SD standard deviation (SD) unless otherwise reported. Data was checked for normality *a priori* using histograms, q-q plots, skewness and kurtosis, and a Shapiro-Wilk test. For the analysis of all eccentric hamstring test outcome measures, a paired t test was used. Pearson's correlations were conducted for the absolute and relative difference of pre and post YYIR1 measures of eccentric strength differences and the distance covered upon cessation of the protocol. Where appropriate, 95% confidence intervals for difference are reported. Cohen's *d* effect sizes were calculated using pooled SD data and classified as trivial (< 0.20 – 0.49), moderate (0.50 – 0.79) and/or large (>0.80).

Results

Distance covered

Participants covered an average distance of (1321.13 ± 323.03 m) during the YYIR1 protocol, achieving an average YYIR1 score of (16.46 ± 1.20 a.u.).

Absolute eccentric knee flexor strength

As highlighted in Table 1, significantly (P < 0.001) lower absolute eccentric knee flexor strength values were observed in the dominant limb, pre Yo-Yo IR1 (284.18 ± 72.54 N; 95% CI = - 39.51 to – 10.10; d = - 0.38) when compared to the post Yo-Yo IR1 test (308.99 ± 58.68 N). The same trend was observed for the non-dominant limb (P < 0.001), with lower absolute eccentric knee flexor strength values observed pre Yo-Yo IR1 (269.25 ± 76.48 N) when compared to post Yo-Yo IR1 (291.12 ± 62.87 N; 95% CI = -41.51 to – 2.22; d = - 0.31).

Eccentric knee flexor strength relative to body mass

As demonstrated in Table 1, significantly lower (P < 0.001) dominant limb eccentric knee flexor strength relative to body mass was observed in the pre Yo-Yo IR1 testing session (4.31 ± 0.93 $N.Kg^{-1}$) when compared to the post testing session (4.61 ± 0.91 $N.Kg^{-1}$; 95% CI = -0.46 to – 0.15; *d* = -0.33). However, a converse relationship was displayed for the non-dominant limb, with no significant (P = 0.07) differences highlighted between pre (4.10 ± 1.07) and post Yo-Yo IR1 exercise (4.33 ± 0.89).

****Insert Table 1 here****

Eccentric knee flexor strength as a ratio

As highlighted in Table 1, no significant differences (P = 0.43) were observed between pre (1.01 ± 0.03) and post (1.01 ± 0.03) Yo-Yo IR1 exercise for dominant/non-dominant limb ratios

Bilateral differences absolute eccentric knee flexor strength

Paired means comparisons highlighted significant (P < 0.001) bilateral differences between the dominant (284.18 ± 72.54 N) and non-dominant limb (269.25 ± 76.48 N; 95% CI = 6.94 to

23.53; *d* = 0.20) for measures of pre-exercise eccentric knee flexor strength. The same relationship was displayed for the same metrics post exercise, with increased values observed in the dominant limb (308.99 ± 58.68 N) when compared to the non-dominant limb (291.12 ± 62.87 N; P = 0.01; 95% CI = 6.08 to 32.98; *d* = 0.29).

Bilateral differences eccentric knee flexor strength relative to body mass

A significant difference (P < 0.01) was highlighted between dominant pre-exercise eccentric knee flexor strength relative to body mass (4.31 ± 0.93 N. Kg^{-1}) when compared to the same metric at the same timepoint for the non-dominant limb (4.10 ± 1.09 N. Kg^{-1}; 95% CI = 0.09 to 0.35; *d* = 0.21). A similar relationship was highlighted for the same metric post exercise, with the dominant limb (4.61 ± 0.91 N. Kg^{-1}) displaying significantly (P = 0.01) higher eccentric knee flexor strength relative to body mass values when compared to the non-dominant limb (4.33 ± 0.89 N. Kg^{-1}; 95% CI = 0.07 to 0.48; *d* = 0.31).

Correlations

As highlighted in Table 2, no significant correlations were highlighted for any of the absolute or relative measures of eccentric knee flexor strength and distance covered in the YYIR1

Insert Table 2 near here

Discussion

The purpose of this study was to investigate the effect of a soccer-specific fitness test, commonly used to meet the requirement of EPPP guidelines benchmark performance testing, on eccentric knee-flexor strength assessed using the NordBord in youth academy soccer players. The key findings of the study demonstrate that the soccer-specific fitness test does not

negatively reduce either absolute or relative eccentric knee flexor peak strength post protocol, rather it appears to improve force output for both metrics, thus rejecting the study hypothesis. These findings demonstrate that the NordBord is sensitive enough to determine strength differences post exercise, however the differences observed between pre and post testing did not exceed the MDD. Furthermore, the Yo-Yo IR1 is not a valid method of assessment to induce a reduction in eccentric knee-flexor strength.

Increased values ranging between 5 and 8% were observed post Yo-Yo IR1 for measures of absolute and relative eccentric knee flexor peak strength, when compared to their respective pre-protocol scores. These differences in results were associated with trivial effect sizes. Direct comparisons with previous studies is difficult, however recent literature [10,11], has reported isokinetic eccentric knee flexor peak torque recorded at 60°/s to decrease by ~ 17 – 19% after a soccer-specific protocol. Isokinetic speeds of 60°/s are the most likely speed to replicate the contraction speed of the Nordic hamstring curl, compared to speeds of ≥ 120°/s which are often recorded in the literature [10,11]. Due to differences in isokinetic testing speeds and protocols, it is not possible to make direct comparisons with all relevant studies associated with eccentric knee flexor peak strength and soccer specific-fatigue. However, studies which have utilised isokinetic testing speeds of 120 and 160°/s have demonstrated similar decrements in eccentric strength post fatigue [22,23].

Differences in results between the current study and previous literature [10,11,22,23] may be further attributed to the type of protocol used to elicit fatigue, with the previously aforementioned studies using soccer-specific protocols lasting 90 minutes in duration, mimicking the short duration bouts of exercise and providing frequent acceleration and deceleration speed changes and the mechanical demands of soccer. Protocols which replicate the nature, duration and demands of match-play may induce a reduction in eccentric knee flexor strength due to role

that the hamstrings play in controlling the intermittent running profile and frequent changes in acceleration and deceleration [10]. This contrasts with the YYIR1 protocol used within the current study, which has been shown to have a high aerobic energy turnover and that the anaerobic energy system contributes significantly towards the final stages of the test in elite soccer players [24]. Although the protocol may mimic the physiological demands of soccer match-play, it does not replicate the stochastic nature of soccer match-play, duration nor the number of accelerations and decelerations required with a match/protocol simulation, thus potentially not stressing the eccentric requirements of the hamstring muscles during the acceleration and deceleration phases of the running cycle. Consequently, if academies wish to optimise the opportunity to assess for injury risk whilst assessing physiological fitness as part of the EPPP guidelines, they may be advised to consider tests and or protocols which better reflect the mechanical load required during soccer activity, thus providing greater levels of ecological validity.

Significant but trivial increases in absolute and relative strength observed post-protocol in this study are potentially a result of the gradual and incremental nature of the YYIR1, facilitating a warm-up effect. Warm-ups which begin at a submaximal aerobic intensity, similar to that observed during the early stages of the YYIR1 have been demonstrated to improve short-term performance measures [25] including increased quadriceps peak torque values, with authors hypothesising that this is potentially as a result of heightened muscle spindle activation [26] post activation potentiation [27], thus increasing the rate of cross-bridge formation and muscle efficiency to produce force after a conditioning contractile activity [28]. Generalising the results of the current study should be treated with caution. The increase in absolute and relative eccentric knee flexor strength are likely to be specific to the exercise protocol, method of assessment and population utilised. However, the NordBord as method of assessment was sensitive enough to determine pre-post difference in absolute, relative and limb dominance

eccentric knee flexor peak strength variables, and thus may be considered a more accessible and field-based alternative to the gold standard IKD methods of assessment. When assessing how fatigue affects risk factors associated with HSI, future research should consider researching the effects of ecologically valid protocols/fitness tests which provide a greater mechanical emphasis similar to that observed within soccer match-play.

Conclusion

Increased relative and absolute measures of eccentric knee flexor peak strength were observed post YYIR1 when compared to pre-test scores in youth academy soccer players. These findings differ to previous literature which have used soccer-specific protocols and the IKD as a method of assessing eccentric knee flexor peak torque. The differences observed are a likely result of the incremental activity profile of the YYIR1 test in contrast to the stochastic and intermittent nature of more ecologically valid protocols which better replicate soccer-match play. These results therefore suggest that practitioners cannot use the YYIR1 test to determine the effects of fatigue on measures of eccentric knee flexor torque. However, the NordBord may be considered a viable and more accessible alternative to detect pre-post fitness test/fatigue protocol differences in eccentric knee flexor peak strength whilst working in the field.

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