Article

Test-retest reliability of the isometric soleus strength test in elite male academy footballers.

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ABSTRACT

BACKGROUND

Currently there is no reliability data is available for the isometric soleus strength test (ISST), commonly used as a monitoring tool in elite football settings. ISST for other muscle groups, most notably the hamstrings, is utilised to identify injury risk and readiness to train/play.

PURPOSE

To profile athletes efficiently, performance practitioners require optimal measures that are reliable. The aim of this study was to investigate the test-retest reliability of the ISST of the soleus and validate a standardised protocol for its use within an elite male football population.

STUDY DESIGN

The present study represents a test-retest reliability single cohort study.

METHODS

Thirty elite male footballers (age = 22.8±5.0 years, height = 180.0±0.08 cm, weight = 70.57±4.0 kg) performed the ISST, through 3 maximum 3-second hold efforts with 1-minute rest between repetitions and 48 hours between tests, in each test. The test was performed mid-competitive season. All data bilaterally was checked for normality through a Shapiro-Wilk Test before a Pearson's Correlation and Bland-Altman's analysis was performed.

RESULTS

Test-retest reliability demonstrated high reliability for ISST bilaterally (Right: ICC 0.89; Left: ICC 0.79, $p<0.05$). Standard errors of measurement (SEM) (%) was 8.75% and minimal detectable change (MDC) was 35.55 (N) for Peak Force (PF) measures of the ISST. Levels of

agreement were found bilaterally for ISST (Right: *p=0.09, CI: -153.21-10.95*; Left: *p=0.52, CI: -139.81-72.33*).

CONCLUSION

This study demonstrated high reliability for the ISST. The ISST is a valid and reliable method for assessing PF characteristics of the soleus in elite male academy footballers. This test may be beneficial for performance practitioners for profiling soleus function of athletes. Findings indicate that the ISST displays high test-retest reliability in elite male academy football populations and should be considered in performance profiling of the athlete.

KEY WORDS

Football, Soccer, Muscle Strength, Isometric, Reliability, Soleus

INTRODUCTION

An important issue in elite football settings is quantifying muscle function for performance. Identifying muscular dysfunction/weakness through appropriate testing related to injury aetiology can also mitigate the negative impact injuries can have on team performance through time loss and financial cost.[1] The physical demands of football are known to have increased[2] and risk of injury is high.[3, 4] Consequently, performance practitioners in elite settings aim to implement testing protocols to identify an athlete's readiness to train/play, maximising performance and minimising potential injury risk factors. Muscle strength has been a key aetiological factor associated with injury risk.[5, 6] Muscle injuries are a predominant feature in football-related investigations.[7] The use of ISST to identify reductions in muscle strength is common practice,[8] and integral for the decision-making process that takes place on a daily basis in a practical environment to maximise performance and increase availability.

Literature has focussed heavily on quantifying hamstring and quadricep muscle function and the reliability of such measures are well reported[5, 6]. This has led to widespread use of these measures in practical settings, particularly in elite football, where this type of equipment is widely available. This focus has been predominantly driven by injury occurrence, identifying risk in athletes, and increasing performance. Although less, occurrence of posterior lower leg injuries is prevalent in elite football and team sports.[4, 9]. It is important to note the key contribution of the posterior lower leg, particularly the soleus, on function and its influence on running performance[10, 11, 12]. Thus, highlighting the need within practical settings to identify reliable methods to quantify soleus function. Reliability of quantification methods is essential for effective monitoring or athlete profiling and provides practitioners with data that can influence decision making in relation to readiness to train/play, training prescription and rehabilitation processes.[13]

Isometric muscle strength testing is utilised practically to determine musculoskeletal status, markers for return to play and reduce strength deficits affecting performance.[14] The use of isometric muscle strength testing is utilised more freely within practical settings, due to it being less provocative than eccentric testing. [15, 16] Allowing testing to be completed more frequently and during heavy fixture congested periods, identifying any deficits that may be associated with reductions in performance or potential injury risk factors. Isometric contractions are a highly reliable and efficient way of measuring and monitoring changes in the generation of force.[17] The isometric soleus strength test (ISST) aims to determine the strength of plantar flexors, notably the soleus muscle. No standardisation of testing or reliability data is available to our knowledge however, for the ISST. A reliable measure and standardised test for isometric soleus strength may provide medical and performance practitioners with the utility to optimally monitor and profile athletes. Therefore, the aim of this study was to investigate the test-retest reliability of the ISST and potentially validate a standardised protocol for its use within an elite male academy football population.

MATERIALS AND METHODS

Participants

An *a priori* power calculation using G-power indicated that a total of 30 participants would be required to detect a *high* correlation with an alpha of 5% and power of 80%. Thirty male elite academy footballers (age = 22.76±5.0 years, height = 180.0±0.8 cm, weight = 70.57±4.0 kg) participated in this study during the 2019-2020 season. Participants were advised of the advantages and risks of the study and the testing protocol was clearly defined verbally before participants provided written and verbal consent to participate, with the option to withdraw from testing at any point. Participants had a minimum of 4-years' experience in resistance training and strength-based testing protocols and met the inclusion criteria of healthy with no current injury and were of male gender. All players eligible for the study were in full training, free from injury and available for competitive selection. The host football club permitted the dissemination of anonymous data for publication of the study findings and the study commenced in accordance with the 2013 Declaration of Helsinki and was approved by the University of Central Lancashire ethical committee (STEMH).

This study evaluated the test-retest reliability of the ISST and the correlations within an elite male academy football population using a correlation design. Data collection was performed in a temperature-controlled physiology laboratory on site at the host football club training ground by the same two researchers throughout. Testing occurred at the same time of day for the re-test data 72hrs apart to account for potential diurnal or circadian rhythm that may affect performance.[18] Players refrained from strenuous exercise between these two testing periods and completed their normal daily routine.

151 *Study Design*

152 Participants were familiar with the test protocol, as it has been utilised within the previous
153 season consistently throughout the clubs regular screening, testing and readiness to train/play
154 protocols. Testing for the present study took place within pre-season. Test procedures for the
155 ISST were appropriately standardised following previous recommendations in the literature.[19]
156 Before the commencement of ISST bar height was determined for each individual participant,
157 based on seating position and maintenance of hip, knee and ankle joints at 90-degrees, to
158 achieve the correct body position for each test.[19] Seating position, rack bar, crocodile pin and
159 bar position were recorded for protocol standardisation ahead of scheduled testing. This was
160 then repeated for both testing sessions completed. Although there is no standardised warm up
161 for the ISST, it is apparent from other isometric tests that a derivative of the movement
162 performed should be incorporated.[15, 16, 19, 20] Participants therefore completed a standardised
163 warm-up comprising of a 10-minute of supervised stationary cycling 1.5 W kg −1, cadence of
164 60 rpm on a cycle ergometer (Wattbike Ltd, Nottingham, UK), followed by 5-minutes of
165 dynamic stretching, before advancing to two warm-up sets of IMTP soleus lifts at 50% and
166 75%.
167
168 The BTS-6000 force decks platform (VALD Performance, Newstead, Queensland Australia)
169 were calibrated by the manufacturer to evenly distribute bodyweight across the two platforms.
170 The participant was seated with 90-degree hip and knee flexion, feet hip-width apart and of
171 equal distance from the centre of the platform. While the use of a "self-selected" body position
172 is likely to be advantageous for testing performance, it is not recommended without ensuring
173 that the hip, knee, and ankle joint angles are at 90 degrees, due to the influence of body
174 positioning on force generation.[19, 21] An Airex (Airex AG Sins, Switzerland) cushion was
175 placed on top of the participants' thighs, with the bar placed on top. The individual was then

asked to position the metal bar in line with their pre-recorded position, within the crocodile pins on the Sorinex XL racking system (Sorinex, Lexington, SC, USA), with the bar placed directly over the lateral malleolus. Participants were encouraged to maintain a vertical posture throughout the movement, with hands away from the bar due to interference previously recognised. Before each test, this position was ascertained, with the joint angle verified using a goniometer. The width of the participants' foot position was measured using a standard measuring tape to ensure consistency between tests. After performing two warm-up efforts for the ISST at 50 and 75%, the participant performed 3 maximum efforts (3-second hold with 1-minute rest between reps). Participants were advised to maintain a neutral foot position and minimal pre-tension on the bar until verbal instruction was given. Before each rep the athlete was counted down (3, 2, 1) and instructed to push for 3-seconds up and against the bar as hard and as fast as possible.[18]

DATA ANALYSIS

Initial data analysis was performed using Forcedecks software (VALD Performance, Newstead, Queensland Australia) and transferred to a spreadsheet program (Microsoft Excel, Microsoft Corp., Redmond, WA, USA). Data was recorded for each of the 3 maximum efforts of 3 seconds over the 2 tests. An average was taken for each participant and relative reliability was calculated using intraclass correlation coefficient (ICC) to identify the relationship unilaterally for the two tests. The following parameters were followed in accordance with classifications by Munro (2005),[22] for data interpretation: >0.9 (very high), 0.7 to 0.9 (high), 0.5 to 0.69 (moderate), and < 0.5 (poor), with statistical significance set at $p \leq 0.05$ and 95% confidence interval. A Pearson's correlation measured the relationship between the 2 tests. Re-test reliability was expressed in terms of units of measurement (newtons) and ratios (coefficient of reliability). Reliability in units of measurement was calculated for the interpretation of group

mean scores and the individual scores of PF (N). Standard error of measurement (SEM) and minimal detectable change (MDC) identified absolute reliability for ISST. The formula's used for both SEM and MDC followed previous calculations described by Ransom et al (2020).[14] To analyse for levels of agreement unilaterally for the test-retest a Bland-Altman method was completed.[23] Pre completing statistical analyses the distribution of data was assessed for normality using the Shapiro-Wilk Test and found to be suitable for parametric statistical testing. All statistical analysis was completed utilising SPSS software version 26.0 (SPSS, Chicago, IL, USA)

RESULTS

A significant correlation was demonstrated between tests ($p<0.001$). A very high correlation between the two tests performed bilaterally was demonstrated for the ISST measure (Right: ICC 0.89; Left: ICC 0.79) (Table 1). Figure 1 highlights the linear relationship bilaterally between the two tests performed.

****insert table 1 here****

****insert figure 1 here****

Figure 2 and 3 display the mean differences between the test-retest bilaterally for the ISST with the upper and lower 95% confidence intervals displayed for the measures taken.

****insert figure 2 here****

****insert figure 3 here****

No significant difference between the mean scores for the right (*p=0.09, CI: -153.21-10.95*) or left (*p=0.52, CI: -139.81-72.33*) test-retest mean scores were found. Detailing that levels of agreement were identified between the two tests bilaterally.

DISCUSSION

The aim was to evaluate the reliability of the ISST in an elite academy football population. We hypothesised that reliability would be high for the ISST in this population. The primary findings from this study demonstrated high reliability in male academy footballers for the ISST. High levels of agreement were demonstrated between the two ISST tests bilaterally with 95% of differences demonstrated to be less than 2 standard deviations away from the mean.[23] Indicating that the ISST is a highly reliable test and can be utilised in a practical setting to quantify isometric strength of the soleus, to inform readiness to train, training prescription or utilised within the rehabilitation of injury. SEM (%) and MDC values indicated absolute reliability across measures suggesting small changes in strength in an individual athlete can be determined from this test (Table 1). Therefore, findings indicate that the ISST is a highly reliable assessment tool used to quantify the strength and power characteristics of the soleus muscle in male academy football athletes.

Relevant departments within the football club should be confident in utilising the ISST for assessment of isometric force-time characteristics for the monitoring of training interventions and modifiable risk factors for injury. Isometric muscle strength testing is commonly used within identifying modifiable injury risk factors or performance enhancement programs and confidence within the test in terms of repeatability is important for sports medicine and performance practitioners to consider. The ability to evaluate an athlete's lower limb capacity

to generate force is an integral part of strength profiling and evaluating the efficacy of training interventions.[24] The strength of plantar flexors, notably the soleus muscle may be determined through the ISST. Test position in 80-90° knee flexion has been shown to inhibit the force generated by gastrocnemius, therefore primarily evaluating the strength of the soleus.[19] Currently no standardised testing protocol exists for ISST. Recently Ransom et al (2020)[14] indicated the importance of repeatability in terms of detecting true changes in response to injury or load over time to enhance athlete profiling. Consequently, it is important to report both test-retest and absolute reliability. This provided variability between repeated measures and level of agreement in PF data, as highlighted by Ransom et al, (2018).[14] Current results provide confidence in the measure of isometric soleus muscle strength through the ISST by highlighting normal variance and levels of agreement between the test-retest bilaterally.[23] Evidently isometric soleus PF measures in the current study were reproducible both within and between sessions. Results from the current study, although not comparable to previous investigations on isometric soleus strength testing, support similar findings by De Witt (2018)[25] (ICC=0.89) and Haff et al., (1997)[26] (ICC=0.99) who report consistency with previous results on reliability and demonstrated the effectiveness of the IMTP test to efficiently assess longitudinal strength modifications. PF metrics previously establish within-session and between-session reliability; ICC=0.99[19], ICC=0.96[15], ICC=0.95.[16] The current study agrees that PF is a useful metric in quantifying maximum strength from isometric strength test protocols.

Medical and performance practitioners working within an elite performance setting may consider using the ISST to evaluate athletes' optimum and PF capabilities due to the high reliability of the test identified in the current study. Practitioners that may be reluctant to conduct maximal functional repetition testing due to the potential risk of injury and should consider the implementation of the ISST as an alternative measure to determine maximum

strength and / or PF. The ISST being isometric in nature, decreases the risk of fatigue and subsequent risk of injury. Thus providing a measure that can be utilised in fixture congested periods.[25] Earlier literature advocates that in-depth analysis of players should include isometric muscle strength albeit in the hamstrings as an example,[27] thought to benefit high-risk players subsequently influencing optimal training prescription.[28] Identifying potential injury risk factors or performance deficits may be quantified through the application of the ISST protocol suggested in the current study. From an applied perspective ISST quantifies vertical forces which are essential mechanical components for specific athletic functions such as acceleration, sprinting, distance jumping and directional changes.[29] Reliable screening techniques such as the ISST support the identification of at-risk players and consequently the adaptation of preventative interventions or programmes targeting both individual and squad groups can be derived from such information. This initial study only considered PF as a metric, due to its strong association to functional activities and movement patterns.[19] Any future work in the area should consider other metrics, such as rate of force development (RFD).

SEM (%) and MDC data provided measurement error for absolute reliability (Table 1). The monitoring of PF before and after interventions may be assisted by the MDC data from the current study findings. For the ISST, SEM demonstrated 155.44N and a small relative index of 8.75%, with any individual PF changes above 34.55N being noted as 'real' change. Further investigation in other populations and ages within elite or normative populations may be beneficial to determine agreement. Although this type of data may provide sports medicine and performance practitioners with guidance on 'real' changes in strength that may occur, as presented in recent similar studies.[14]

Due to the high reliability demonstrated within the present study the ISST for soleus may be a useful objective marker in quantifying posterior lower limb function. Furthermore, it allows the distinction between dominant and non-dominant legs through metrics derived from the Forceplate software (VALD Performance, Newstead, Queensland Australia). Future studies may consider further investigation of dominant or non-dominant limb through utilisation of the ISST. Utilisation of such measures are utilised in practice to identify training needs, performance deficits or potential injury risk factors. For example, recovery of lower limb muscle strength in the dominant leg is reported to be compromised for up to 72 hours after competitive fixture.[6, 30] While a specific definition of muscle imbalance has yet to be assigned, debate continues as to the risk factor for professional football injury,[31] this is an important consideration and as such, any reliable test for lower limb muscle strength, such as the ISST may be a valuable addition.

Limitations require highlighting, despite the results of this study demonstrating high absolute and relative test-retest reliability. The sample utilised in the study were not random, a convenience sample was gained within a specific male, academy age elite population. Data therefore may not be extrapolated to other genders, age groups, sports or non-sporting populations. Further investigation is required to determine whether equivalent findings exist. Bilateral limb testing as utilised by Ransom et al (2020)[14] in their investigation on lower limb strength, was also applicable in the current study. In agreement with Ransom et al, (2020)[14] we acknowledge that bilateral limb deficit phenomenon[32] may exist, but measures to minimise the likelihood were highlighted in the methodological approach.

CONCLUSION

The ISST is a valid and reliable method for assessing maximal isometric PF in an elite academy male football setting. This test can be comparable to other isometric tests highlighting PF production using Forcedecks (VALD Performance, Newstead, Queensland Australia). Results also help to determine efficacy and practicality of the ISST as a screening test to ascertain changes in performance and potential injury risk factors. Results demonstrate high test-retest reliability of the ISST, which advocates its use in practical settings and may provide beneficial information regarding detectable changes in muscle strength.

PRACTICAL IMPLICATIONS

1. Isometric soleus muscle strength can be assessed in elite male academy footballers with high reliability using the isometric soleus strength test.
2. Assessment of isometric soleus strength using dynamometry (Forcedecks) may provide sports medicine and performance practitioners with beneficial means for the musculoskeletal profiling of athletes.
3. A change in isometric soleus strength (PF) above 34.55(N) represents the necessary 'real change' required for individual players. This minimal detectable change for PF is beneficial for practitioners working in performance teams for the interpretation of test data.

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FIGURES AND TABLE CAPTIONS

Table 1. Mean±SD for isometric soleus PF for whole group.