International Journal of Kinesiology & Sports Science
ISSN: 2202-946X
www.ijkss.aiac.org.au

Novel Supine Isometric Hamstring Test: A Reliability Study

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ARTICLE INFO

Article history
Received: August 25 2024
Revised: September 22 2024
Accepted: October 22 2024
Published: October 30 2024
Volume: 12 Issue: 4

Conflicts of interest: None
Funding: None

ABSTRACT

Background: Hamstring strain injuries are highly prevalent, particularly when the hamstrings are in a lengthened position; however, monitoring strength deficits and fatigue throughout a season is currently difficult due to a lack of practical, reliable tests that do not cause undue fatigue. **Objective:** The aim of the current study was to investigate the intersession reliability of a novel $90°_{hip}$: $40°_{knee}$ isometric hamstring test (IHT) in the supine position. **Methodology:** This was a prospective, observational cohort study conducted on nine male participants (24 ± 3 years, 81.9 ± 6.4kg, 181.8 ± 5.3cm). Each participant completed two testing sessions of the $90°_{hip}$: $40°_{knee}$ IHT using force platforms. Relative and absolute reliability of isometric peak force (IPF) were assessed using intraclass correlation coefficient (ICC) and coefficient of variation (CV%), respectively. **Results:** Relative reliability of the $90°_{hip}$: $40°_{knee}$ IHT was considered "good" in the dominant limb (ICC = 0.92, Lower bound 95% Confidence Interval (CI) = 0.72) and "poor" in the non-dominant limb (ICC = 0.76, Lower bound 95% CI = 0.28). Absolute reliability was "acceptable" in both legs with 5.81% in the dominant limb and 9.65% in the non-dominant limb. **Conclusion:** The $90°_{hip}$: $40°_{knee}$ IHT demonstrated moderate reliability overall, further research is required to discover the optimum IHT configuration which can be reliably executed at longer hamstring muscle lengths. This study provides foundational information for practitioners on a novel method of reliably testing hamstring isometric strength at longer muscle lengths.

Key words: Athletic Injuries, Reinjuries, Muscle Strength, Primary Prevention, Running, Hamstring Muscles

INTRODUCTION

"Hamstrung by Hamstring Strains: A review of the Literature", the title of a review conducted by Sutton in the year 1984, and yet 40 years later, hamstring strain injuries (HSIs) remain the most prevalent muscle injury, accounting for specifically 30.4% of all muscle injuries within elite Spanish soccer academies (Raya-González et al., 2020). Further, since the 2001/2002 season, the rate and burden of HSIs in soccer have doubled according to a recent audit conducted by the UEFA club injury study (Ekstrand et al., 2022). On average, a player will miss two weeks due to a HSI (Ekstrand et al., 2011), which could result in that player missing multiple fixtures depending on scheduling. The high re-injury rates (14-63%) (De Visser et al., 2012) and often prolonged symptom duration also add to the frustration when dealing with HSIs (Mendiguchia et al., 2012). This lack of improvement in HSI rates over the past three decades (Ekstrand et al., 2022; Ekstrand et al., 2011; Nielsen & Yde, 1989; Walden et al., 2005) may be suggestive of ineffective HSI prevention and rehabilitation programs, and therefore a new approach to the problem may be required.

Recent systematic reviews and meta-analyses have concluded that previous injury and age, two non-modifiable risk factors, are the only risk factors with strong levels of scientific evidence linking them to HSI risk (Freckleton & Pizzari, 2013; Green et al., 2020). Despite this, it is now well understood and accepted that HSI risk can be influenced by multiple interrelated modifiable and non-modifiable risk factors (Mendiguchia et al., 2012). Muscle strength is one of the modifiable risk factors that has been extensively, prospectively and retrospectively researched within the literature to date (Bennell et al., 1998; Bourne et al., 2015; Croisier et al., 2008; Green et al., 2018; Orchard et al., 1997; Worrell et al., 1991; Yeung et al., 2009). However, the findings of these studies are conflicting. This may be due to the differences in strength testing methods, testing equipment, testing populations, joint angles, contraction modes, and contraction speeds (Freckleton & Pizzari, 2013).

Furthermore, the current research surrounding HSI risk factors may be deemed "reductionist" and "simplistic" (Bittencourt et al., 2016; Mendiguchia et al., 2012) as most risk factor testing is completed at one single time point, usually

Published by Australian International Academic Centre PTY.LTD.

http://dx.doi.org/10.7575/aiac.ijkss.v.12n.4p.1

during the pre-season (Pizzari et al., 2020). Intrinsic and extrinsic risk factors fluctuate throughout the season and over time (Bahr & Holme, 2003; Meeuwisse et al., 2007), and therefore this method may fail to recognize an athlete's individual response to training or match-play and the subsequent association with HSI risk. Specifically, strength has been shown to fluctuate throughout gameplay (Charlton et al., 2018a; Charlton et al., 2018b; Wollin et al., 2017) and throughout the season (Carr et al., 2017). Instead of this once-off testing, frequent testing over a season may allow for the identification of strength reductions beyond the normal level (Pizzari et al., 2020; Wollin et al., 2018). This may be particularly beneficial during periods of congested game schedules as these periods may have a higher association with HSI risk (Page et al., 2023). Significant fluctuations in strength could be indicative of reduced recovery of an athlete's hamstrings after activity, allowing for early detection and subsequent facilitation of recovery prior to the next activity (Bahr, 2016; Wollin et al., 2018).

Although frequent testing of the hamstring muscles may give practitioners valuable insight into the athlete's hamstring status following matches or during their return to play from injury, implementation of such testing could prove difficult in a team sport setting (McCall et al., 2015). Isokinetic dynamometry is considered the gold standard in the assessment of muscle strength, but it is impractical, labour-intensive and time-consuming within the team sport environment. More time-efficient tests have been demonstrated throughout the literature, yet they have their limitations; repetitions until failure (Gasparin et al., 2022), maximal sprinting efforts (Mendiguchia et al., 2014) or maximum eccentric contractions (Opar et al., 2013). Due to the high demand of the aforementioned testing methods, muscle damage may occur, potentially increasing injury risk (Lieber et al., 1991; Nosaka et al., 2002). Furthermore, eccentric contractions have been shown to produce greater amounts of neuromuscular fatigue compared to isometric contractions (Royer et al., 2022) and therefore, isometric muscle strength tests may be considered a safer alternative during the busy season.

Studies have investigated the reliability of isometric hamstring tests (IHTs) at varying angles of hip and knee flexion using force platforms (Cuthbert et al., 2021; Matinlauri et al., 2019; McCall et al., 2015), as force platforms are deemed the gold standard for isometric strength assessment (Verdera et al., 1999). However, there is a lack of standard reporting relating to intersession relative reliability (Koo & Li, 2016). For example, Cuthbert et al. (2021) was the only IHT reliability study to report the lower bound (95% CI) intraclass correlation coefficient (ICC), reporting "poor" to "good" relative reliability of the 90° hip flexion, 90° hip: 90° knee flexion ($90°_{hip}$: $90°_{knee}$) and 30° knee flexion tests. It is critical that detailed reporting of reliability methods and the values obtained occurs, specifically the model, definition and type selections along with the ICC estimate and their 95% CIs, as suggested by Koo and Li (2016).

Furthermore, Matinlauri et al. (2019) was the only study to employ an assessment of isometric hamstring strength at the outer range of hamstring muscle length. This is an important position to assess as the majority of HSIs occur in *Bicep Femoris* long head (BF_{LH}) within the terminal swing phase of running (Chumanov et al., 2012). During this phase of high hip flexion and minimal knee flexion (30-45°), the BF_{LH} is placed under substantial stretch due to the larger hip extension moment arm compared to the knee flexion moment arm (Thelen et al., 2005). This hip flexion generates greater relative BF_{LH} lengthening compared to any of the other hamstring muscles (Thelen et al., 2005). Moreover, immediately following the cessation of a simulated soccer game, the largest reduction in eccentric hamstring peak torque has been seen at this outer range position, with the hip flexed to 90° and the knee flexed to 10° (Cohen et al., 2015). Matinlauri et al. (2019) specifically examined the reliability of a standing $90°_{hip}$: $20°_{knee}$ IHT and its sensitivity to fatigue following a simulated soccer game. They reported the overall absolute reliability as "high" with coefficients of variation (CV%) ranging from 7.3%-11%. This CV% range is higher than other studies of Cuthbert et al. (2021) (6.5%-10.2%) and McCall et al. (2015) (4.3%-6.3%), however they both conducted their isometric hamstring tests in a supine position with knees flexed to 30° and 90°, respectively. The higher CV% of Matinlauri et al. (2019) may have been due to the test being executed while standing, which is a more unstable position than supine lying and exposes the test to a great deal of confounding factors. Standing incorporates a reliance on balance, which may compromise the ability to generate force maximally and/or consistently, and subsequently may require more familiarization trials. Further, this position also allows for rotation of the pelvis during each repetition, making it difficult to solely isolate the action of the hamstring muscles. Therefore, due to the rise in HSIs and limitations of other IHTs, we have devised an isometric hamstring test that tests the hamstring muscles at outer range but negates the reliance on balance and better isolates the force produced by the hamstring muscles. The aim of this exploratory study is to investigate intersession reliability of a $90°_{hip}$: $40°_{knee}$ IHT in the supine lying position.

METHODOLOGY

Study Design & Participants

This was a prospective, observational cohort design study conducted at the Sports Medicine Department at UPMC Sports Surgery Clinic (Dublin, Republic of Ireland). To assess the intersession reliability, IPF data were collected from each participant during the supine $90°_{hip}$: $40°_{knee}$ IHT on two separate occasions one week apart. A sample size of 10 was determined to be optimal for detecting an ICC of 0.7 (two observations per subject) with a power of 80% and an alpha level of 0.05 according to reference table 1a of Bujang & Baharum (2017). Ethical approval was granted on the 24th of April 2023 by the Setanta College Ethics Committee. Inclusion criteria included healthy active males over the age of 18. Participants were excluded if they met any of the following criteria (adapted from McCall et al. (2015) and Foster (1998)): injury in the previous two months, pain in the lower limb muscles, currently on any medications or drugs, elevated lower limb muscle soreness or had completed a

Table 1. Relative reliability of the $90°_{hip}$: $40°_{knee}$ IHT from ICC calculation using single-rating, absolute-agreement and a 2-way random effects model

Limb		Intraclass Correlation	95% Confidence Interval		F Test (true value 0)			
			Lower Bound	*Upper Bound*	Value	*df*1	*df*2	Sig
Dominant Limb	Single Measures	0.92	0.72	0.98	26.14	8	8	< 0.001
Non-Dominant Limb	Single Measures	0.76	0.28	0.94	8.79	8	8	0.003

hard (>4/10 RPE) training session or a session longer than 60 minutes in the previous three days. Each participant was explained the benefits and risks of taking part in the study. Participants then completed an informed consent form and PAR-Q. They were asked again if they wished to continue, if so initial testing began, if not, their informed consent was withheld and they were excluded from the study. Participants attended the location on two separate occasions between the 22nd of May 2023 and the 5th of July 2023. In total, 10 participants completed the initial testing session; however, due to an injury, only nine participants (Mean age: 24 ± 3 years, weight: 81.9 ± 6.4kg, height: 181.8 ± 5.3cm, Body Mass Index: 25.2 ± 1.4, years of consistent resistance training: 7 ± 3 years) completed the second testing session and were subsequently included in the data analysis.

Figure 1. $90°_{hip}$: $40°_{knee}$ IHT testing position

Procedures

The first visit involved completion of the PAR-Q and informed consent along with a familiarization session of the $90°_{hip}$: $40°_{knee}$ IHT, which involved three trial repetitions on each leg. During the first testing session, age, height, weight, dominant leg, predominant sport played and years of resistance training were also recorded, and the initial testing session (T1) of the $90°_{hip}$: $40°_{knee}$ IHT was completed. The dominant limb was considered as the leg the participant used when kicking a football (Virgile & Bishop, 2021). The second testing session (T2) mirrored T1 barring the anthropometric measurements. T1 and T2 were completed within a week of each other and at the same time of day as circadian rhythm, which has been shown to influence IPF output (Teo et al., 2011).

Prior to testing, participants completed a five-minute warm-up consisting of cycling at 90 watts for three minutes and 120 watts for two minutes on a cycle ergometer (Wattbike Ltd, Nottingham, UK). Following two minutes, participants were asked to lie supine and then using a goniometer (SaehanTM), their testing hip and knee were flexed to 90° and 40° respectively. Knee angle was measured from the greater trochanter to the lateral tibial condyle, and lateral tibial condyle to the lateral malleolus. The participant's heel was ensured to be in contact with one of the ForceDecksLite dual force platforms (ForceDecks, VALD Performance Pty Ltd, Brisbane, Queensland, Australia). The test was performed with the shoes on, ankle in neutral, arms placed across the chest and contralateral leg fully extended and in contact with the ground. A visual representation of the testing position can be seen in Figure 1. The primary investigator applied external pressure over the participant's pelvis and contralateral knee to ensure they remained in contact with the ground throughout each repetition. Each participant was then given the same verbal instruction: "exert maximal force into the force plate as fast and as hard as possible for five seconds", the primary investigator informed the participant when the five seconds had elapsed. A trial was considered invalid and repeated if a countermovement was produced (identified through inspection of force-time curve after the repetition), or if a participant's hips lifted from the ground during the repetition. Three successful repetitions were completed on the non-dominant limb followed by the dominant limb, with 30 seconds rest between each repetition.

Data Analysis

Raw force-time data were measured using the ForceDecksLite dual force platforms with a 1000 Hz sampling frequency. No smoothing or filtering was applied. Data were transmitted to the ForceDecks app on a Gigabyte Aorus AERO 15 computer and subsequently processed in an Excel spreadsheet (version 16.75) to identify the IPF produced during each repetition. The force plates were zeroed prior to data collection, and the participant's foot was not in contact with the plate. The IPF was identified as the highest resultant peak force produced in all three planes. An average IPF value was then calculated from the three trials for each limb and used for analysis. IPF was the only variable used in the analysis.

Statistical Analysis

Statistical analyses were executed using GraphPad Prism (version 9.4.1 GraphPad Software, San Diego, USA). Descriptive statistics were denoted as mean ± standard deviation (SD). ICC was utilized as the measure of inter-session relative reliability as it is preferred when the sample size is small (Shrout & Fleiss, 1979). ICC estimates were based on mean-rating, absolute agreement and a 2-way mixed-effects model. The lower bounds of the 95% CI of the ICC were used to interrupt the relative reliability with ≤0.39, 0.4-0.69, 0.7-0.89 and ≥0.9 respectively representing poor, fair, good and excellent relative reliability, as according to Koo and Li (2016). Absolute reliability was assessed using CV%, with a CV% less than 10% considered to be "acceptable" absolute reliability (Cormack et al., 2008). The 95% limits of agreement (LOA) were calculated along with mean bias, providing a description of the homoscedasticity and heteroscedasticity. Typical error of measurement (TEM), TEM%, standard error of measurement and minimal detectable change (MDC) were also computed. Statistical significance was set at $p < 0.05$. Bar charts and tables were utilized to illustrate the data.

RESULTS

The mean IPF for the dominant leg during T1 was 155.9 ± 35.4 N and during T2 was 161.3 ± 35.2 N. The mean IPF for the non-dominant leg was 148.9 ± 26.4 N and 161.6 ± 41.8 N during T1 and T2 respectively. Relative reliability results of both the dominant and non-dominant limbs are presented in Table 1. Absolute reliability for both the dominant and non-dominant limbs (Figure 2) were below the 10% CV% threshold.

Bland-Altman plots containing the difference and average IPF between T1 and T2 for the dominant limb indicated a slight positive systematic bias (5.36 ±13.56) and homoscedastic variance (r = 0.01). The non-dominant limb indicated a strong positive systematic bias (12.71 ± 22.33) and heteroscedastic variance (r = 0.71). Table 2 presents a summary of the $90°_{hip}$: $40°_{knee}$ IHT IPF reliability data in the dominant and non-dominant limbs.

DISCUSSION

The main aim of this exploratory study was to investigate the intersession reliability of a novel $90°_{hip}$: $40°_{knee}$ IHT in the supine lying position. Results indicate that the dominant and non-dominant limbs had "good" and "poor" relative reliability respectively as determined by the lower bound (95% CI) ICC estimates (0.72 and 0.28 respectively) (Koo & Li, 2016). Absolute reliability (CV%) for both limbs was below the 10% CV% threshold and are considered "acceptable" (dominant limb: 5.81%, non-dominant limb: 9.65%).

One cannot underestimate the importance of reliability, especially within the novel, emerging field of load management using IHTs. The reliability of a given device and its associated measurement can contain vital knowledge for practitioners, allowing them to decide whether a certain measurement provides any meaningful value (Hopkins et al., 2000). The relative reliability for the current $90°_{hip}$: $40°_{knee}$ IHT was shown to be "good" in the dominant limb but "poor" in the non-dominant limb with absolute reliability demonstrated to be acceptable in both limbs. These results are similar to the work of Matinlauri et al. (2019) who reported CV%s ranging from 7.3% to 11%, but higher than the work of McCall et al. (2015) (4.3% to 6.3%). A comparison to the work of McCall et al (2015) is made difficult by the fact that the testing positions are very different from those of our study. For example, during the 30° IHT they employed, the influence of the gluteal muscles must be considered. Further, while the testing positions are similar, a true comparison to the results of Matinlauri et al. (2019) is also difficult given the difference in the testing populations. It is possible the professional athletes of Matinlauri et al. (2019) were more accustomed to isometric testing procedures compared to the participant group involved in this current study. The heteroscedastic variance and strong positive bias seen in the non-dominant limb in this current study may be evidence of this learning effect. Therefore, it is possible the reliability results may be improved with further familiarisation sessions or within a cohort of professional athletes.

There are a few limitations identified within this exploratory study that should be taken into consideration, particularly with respect to the feasibility of such a protocol in real-world situations. Limited access to solid, yet adjustable surfaces resulted in the use of a BLX BOX to bear the force platform during the testing sessions, which may have caused some force to be lost through the box between testing sessions, resulting in slightly different IPF values. However, similar limitations may be experienced by teams or practitioners who do not have extensive access to such equipment either. While the supine lying position of the current $90°_{hip}$: $40°_{knee}$ IHT can be considered more stable compared to the standing position of Matinlauri et al. (2019), it didn't allow for optimal heel contact with the force platform in some individuals. This was primarily due to the footwear that the participants wore and particularly if the shoe had a protruding heel tab or counter. However, shoes were necessary as direct heel-to-plate contact may have caused discomfort for the participants, which could have also affected the force output. Future studies should take this into consideration and if shoes were to be worn, the same model of shoe should be used across testing sessions. It should be considered that the limitation of heel contact was exacerbated in an earlier pilot study when we conducted this IHT in a longer position involving even

Table 2. Summary of the relative and absolute reliability of IPF in the dominant and non-dominant limb for the $90°_{hip}$: $40°_{knee}$ IHT

Limb	ICC	CV% ± 95% CI	Bias±SD	+95% LOA	-95% LOA	TEM	TEM%	SEM	MDC	Sced
Dominant	0.92	5.81±1.68	5.36±13.56	31.93	-21.22	9.80	6.18	6.70	18.57	0.01
Non-Dominant	0.76	9.65±3.88	12.71±22.33	56.47	-31.06	17.39	11.20	11.65	32.30	0.71

Sced=scedasticity

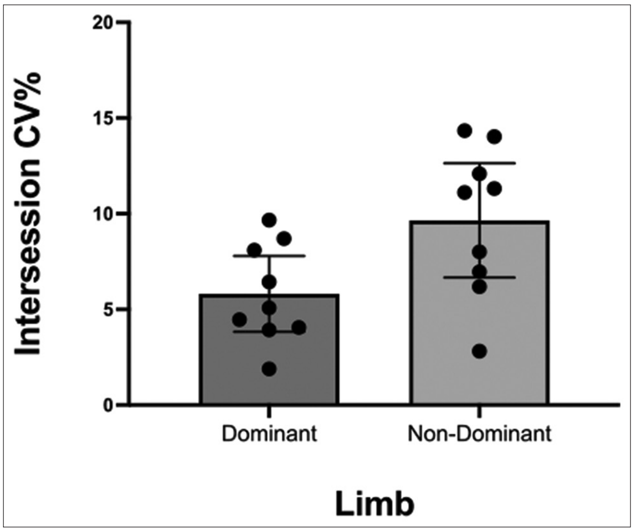

Figure 2. Intersession CV% distributions containing 95% CIs of the Dominant and Non-Dominant limbs during the 90°_{hip}: 40°_{knee} IHT

less knee flexion (30°). Despite these limitations, the dominant limb still demonstrated reliable assessments of IPF generated by the hamstrings, suggesting there is promise for this specific testing protocol. The ease of testing isometric hamstring strength with this current 90°_{hip}: 40°_{knee} IHT may provide medical teams with greater insight into hamstring fatigue following activity and also aid in the detection and monitoring of strength deficits following, and leading up to HSIs. Wollin et al. (2018) called for a proactive medical model established on timely identification and subsequent management of players with deficient hamstring function as a means of assisting in player preparation and HSI risk management, a model in which this 90°_{hip}: 40°_{knee} IHT may form a part of in the future.

CONCLUSION

Taking into consideration that the incidence of HSI is not improving and instead appears to be increasing and that fixture schedules are becoming more congested, an alternative method focusing on reducing HSI is obviously required. The 90°_{hip}: 40°_{knee} IHT may form part of this alternative method as it can reliably assess IPF of the hamstrings. This pilot study builds on the previous research conducted previously by Matinlauri et al. (2019) and taking the results of both studies into consideration, further research is warranted to investigate whether IHTs should be completed in greater degrees of combined hip flexion and knee extension.

ACKNOWLEDGEMENTS

All authors declare they have no interests in the products, product distribution or results within this study. The results of the current study do not constitute endorsement of any products by the authors.

DATA AVAILABILITY

Raw data is available on the Open Science Framework (https://doi.org/10.17605/OSF.IO/6AS8M).

AUTHOR CONTRIBUTIONS

Conceptualisation, B.T.G; methodology, B.T.G. and A.S.; software, B.T.G., N.W. and A.S.; validation, B.T.G. and A.S.; formal analysis, B.T.G. and A.S.; investigation, B.T.G.; resources, N.W and S.K.; data curation, B.T.G.; writing—original draft preparation, B.T.G.; writing—review and editing, B.T.G., N.W., S.K. and A.S.; supervision, A.S. All authors have read and agreed to the published version of the manuscript.

ETHICAL APPROVAL

Ethical approval was granted on the 24th of April 2023 by the Setanta College Ethics Committee and the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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