# The impact of simulated soccer match-play on hip and hamstring strength in academy soccer players

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*Running Head: Acute hip and hamstring strength in academy soccer*

*Data Availability:* The data that support the findings of this study are openly available at the Open Science Framework at DOI 10.17605/OSF.IO/A9ZMY

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**Abstract**

Together, the burden of hamstring and hip and groin injuries in soccer is substantial and the risk of re-injury in these areas is high. Reduced muscle strength has been identified as an important modifiable intrinsic risk factor of injury. However, little is known regarding the within-match changes in hip and hamstring muscle strength in order to inform early detection and management strategies. Seventy-one male soccer players (age, 19.2 ± 0.9 yrs; height, 175.9 ± 5.8 cm; weight, 73 ±8.2 kg) from an international academy completed a fixed soccer specific activity profile (SAFT$^{90}$). Isometric hip and eccentric hamstring strength were measured after a standardised 5-min warm-up and repeated at half time and full time. Repeated-measures ANOVA were used to determine changes in muscle strength with magnitude-based decisions used to express probabilistic uncertainty. Findings indicate that i) there was likely to very likely substantial changes in isometric hip strength (-9.9-15.7%) and ii) no substantial changes in eccentric hamstring strength (-2.6-5.1%). By extrapolating these findings, it can be inferred that reduced isometric hip strength during match play may be one risk factor for injury, especially during periods of fixture congestion and practitioners should routinely assess muscle strength to inform training and match exposure based on player readiness. In doing so, it is likely that practitioners may enhance player availability and minimise injury incidence.

Keywords: *Hip and groin, eccentric hamstring, strength, fatigue, soccer, youth*

## Introduction

The incidence of hamstring (HSI) and hip and groin injuries (HGI) in men's soccer is high and accounts for approximately 12-14% of all time-loss injuries (Ekstrand et al., 2016; Waldén et al., 2015; Werner et al., 2019), but up to 44% in youth soccer populations (Materne et al., 2020). Typically, a squad of 25 players can expect 3-6 HGI and HSI per season resulting in significant time loss from training and competition (>8-days) with a frequent risk of re-injury (11-13%) (Ekstrand et al., 2016; Werner et al., 2019). Incidence rates in youth cohorts are significantly higher, exceeding 16 occurrences per squad each year, contributing to approximately 12-30-days' time-loss per injury (Jones et al., 2021; Materne et al., 2020). Additionally, when non-time-loss injuries are accounted for, the incidence of these injuries may be even higher (Harøy et al., 2019; Whalan et al., 2020). Consequently, the overall burden of HSI and HGI has a detrimental effect on player and team-level performance (Drew et al., 2017; Hägglund et al., 2013). Therefore, the management of HSI and HGI represents a significant challenge for practitioners, and as a result, understanding the risk factors that precede onset are important.

Sports injuries are multifactorial in nature and understanding contributing risk factors associated with them is important for the early stages of systematic injury prevention frameworks (O'Brien et al., 2017; Van Tiggelen et al., 2008). Understanding risk factors can then serve as a precursor to developing evidence and context informed prevention strategies. Previous research has found several non-modifiable (e.g., age, previous injury, level of play) and modifiable (e.g., range of movement, lumbo-pelvic control, altered trunk flexion, muscle strength) risk factors to be associated with HSI and HGI (Engebretsen et al., 2010; Lahti et al., 2020; Whittaker et al., 2015). Of these identified factors it is muscle strength, or more specially for the context of this study, eccentric hamstring and hip adductor and abductor strength that has gained greatest research interest (Buckthorpe et al., 2019; Thorborg et al., 2014).

In the context of HGI, an increased risk of injury has been prospectively associated with low hip adductor and abductor muscle group strength, and/or the level of symmetry between the two (Engebretsen et al., 2010; Thorborg et al., 2014). By monitoring in-season muscle strength changes, practitioners may reduce secondary injury risk by considering decrements in isometric hip muscle strength of >15% or an adductor/abductor symmetry ratio of <0.90 as a meaningful precursor to the onset of HGI (Wollin et al., 2018). Additionally, 5-12% reduction in hip adductor strength was observed the week preceding and week of injury onset in elite junior Australian Football players (Crow et al., 2010). For HSI, the importance of eccentric strength is clear, with evidence indicating a significant (65-85%) reduction in primary and secondary HSI risk after targeted intervention to increase strength and fascicle length (Buckthorpe et al., 2019). We note that muscle strength is not a constant variable (i.e., prone to biological fluctuations) and that the demands of soccer (e.g., sprinting, change of direction) alters strength profiles in response to neuromuscular fatigue and induced muscle damage. For example, Wollin and colleagues (2018) found that fixture congestion (e.g., seven games in 14 days) was associated with substantial reductions in isometric hip strength, with Carling et al (2016) reporting >100% increase in both HGI and HSI incidence during congested periods.

While several studies (outlined above) have discussed the importance of managing congested periods of fixtures, less is known about the within-match impact on muscle strength (i.e., pre-match, half-time, full-time) (Paul et al., 2014). In other words, the extent to which isometric hip and eccentric hamstring strength is changed by the physiological and mechanical load of a single dose of soccer activity (i.e. dose-response). Previous studies have identified a reduction in eccentric hamstring peak torque or strength of 12-20% after acute soccer activity, which may elevate hamstring injury risk late in matches and the following 48-72hrs (Bueno et al., 2021; Constantine et al., 2019; Huygaerts et al., 2020; Small et al., 2010). However, no studies to our knowledge have explored the combination of isometric hip and eccentric hamstring strength to offer a more complete insight into the lower limb-dose-response. Further work in this area would be important given that fixture congestion means there is an increased risk of playing in a match with residual muscle strength deficit (Carling et al., 2016; Engebretsen et al., 2010), which may predispose athletes to both HGI or HSI later in matches. In turn, this research could inform primary and secondary injury prevention practices during congested periods throughout the competitive season (e.g. recovery planning, strength and conditioning programming) (Paul et al., 2014).

Therefore, the aim of the present study was to examine the changes in isometric hip and eccentric hamstring strength in response to fixed soccer specific activity profile. It is anticipated that both muscle groups will show a larger decline in strength as duration increases, with isometric hip strength declining more substantially. This study aims to offer a more complete examination of lower limb strength whilst building on previous important research in several ways. First, by using a contemporary strength testing system (i.e., GroinBar Hip Strength Testing System, Vald Performance, Albion, Australia) that may have greater measurement precision than previously used methods (e.g. hand-held dynamometer, sphygmomanometer) (Ryan et al., 2019). Second, by examining the impact of a fixed soccer specific activity profile on unilateral isometric hip and eccentric hamstring strength to ascertain the magnitudes of within-match changes. Last, by using an evidence informed protocol that simulates the activity profile of soccer to standardise the physiological and mechanical load on participants, reducing the variability of contextual factors that often influence match fatigue.

## Materials and Methods

### *Participants*

Seventy-one, adult male student-athletes from an open-age (18 – 23 years) international soccer academy of university student athletes (age, 19.2 ± 0.9 years; height, 175.9 ± 5.8 cm; weight, 73 ± 8.2 kg) were recruited and provided informed consent, in accordance with the deceleration of Helsinki to participate in the study. Participants were from various squads within the same full-time academy, and routinely completed a total of 4-5 training sessions (including supervised strength sessions) and 1-2 competitive matches each week, meaning their training exposure was comparable (12-14 hours) to the Elite Player Performance Plan (Premier League, 2011) guidelines for a Category 1 Academy at the Professional Development Phase (PDP). Testing for each participant was conducted during the early competitive season (September-October) no earlier than 72 hours following match-activity to ensure adequate recovery. Only outfield players that were considered injury free and had completed all prescribed training sessions in the two-weeks prior to data collection were included in the study. In the 24-hr period preceding to the testing, all participants were informed to avoid alcohol intake and performed no vigorous exercise.

***Procedures***

In small groups (*n* ~ 8) over an eight-week period on a synthetic third-generation pitch, each participant completed a 90-minute soccer-specific aerobic field test ($SAFT^{90}$). The 90-minute protocol was divided into two 45-minute periods interceded with a 15-minute passive rest period (half time). The $SAFT^{90}$ is a multidirectional fixed activity profile valid to simulate soccer match-play based on time-motion data obtained from the English Championship in 2007 (Small et al., 2009). The 20m shuttle course includes randomised multidirectional and utility movements (e.g., sidestepping, back peddling), with frequent acceleration and deceleration leading to an accumulated distance of 10.78 km including 1350 changes of direction and 1269 changes in speed during the 90-minute protocol (Small et al., 2010). Players were required to perform backwards running or sidestepping around the first marker, followed by forwards running through the course (Figure 1), with the intensity controlled by audio cues. Due to the inherent differences between individual, positional and match-to-match variations of actual match-play, utilising a fixed soccer specific activity profile that excludes contact actions (i.e., tackling and kicking) facilitates standardised external loads. By standardising these loads to offer and reducing contextual variation, we were able to significantly increase the sample size of the study across teams within the same international soccer academy and facilitate assessment of inter-individual responses.

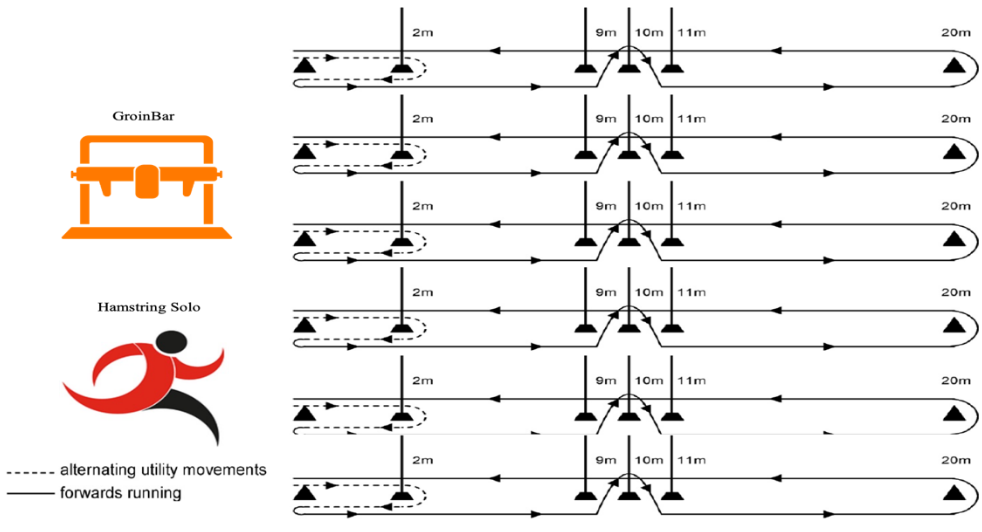


Figure 1. Diagrammatic representation of the SAFT$^{90}$ setup

***Measures***

All data was collected by the authors (JS and DF), both experienced and accredited practitioners (i.e., Sport Scientist and Strength and Conditioning). Following a standardised 5-minute warm-up of dynamic stretches targeting the major lower limb muscle groups and prior to completing the SAFT$^{90}$, isometric hip strength was measured using the GroinBar Hip Strength Testing System (Vald Performance, Albion, Australia), more recently termed 'ForceFrame'. The GroinBar system has previously demonstrated excellent test-retest reliability with intraclass correlation coefficients (ICC) for hip adduction and abduction of 0.97 and 0.98 respectively and an acceptable level of coefficient of variation (CV%), 4.65-6.3%, with hips at 45º (Rees & Opar, 2018; Ryan et al., 2019). Players were requested to lay in a supine position under the GroinBar system with the femoral condyle of their knees on the padded load cell (50Hz) at the specific angle (short lever, hips at 45º). Bar height was individually adjusted to ensure knees aligned with the load cell pad for the duration of the test. Players were given a verbal cue (3, 2, 1….) and instructed to '*push*' (abductors) or '*squeeze*' (adductors) their femoral condyles against the padded load cells continuously for 5-seconds, which produced a force (Newtons) for both legs simultaneously. All participants were verbally encouraged to ensure maximal effort and strict monitoring of technique was observed by researchers throughout to ensure data fidelity. Eccentric hamstring strength was then assessed using the Nordic hamstring exercise using a Hamstring Solo Elite (ND Performance, Kilkenny, Republic of Ireland). This device has demonstrated excellent test-retest reliability (0.91) which is comparable with other well researched eccentric knee flexor devices, namely isokinetic dynamometry (0.86-0.95) and handheld dynamometers (0.90) (Lodge et al., 2020; Maffiuletti et al., 2007). Participants knelt on the padded plinth, with ankles secured on the superior aspect of the lateral malleolus by individual limb braces containing pressure gauges with Bluetooth connection to a handheld device. Knee position on the pad was standardised for each individual's leg-length based for consistency in each assessment. Participants were instructed to place their hands crossed on their chest and gradually lean forward whilst keeping their trunk and hips neutral, until they were unable to sustain the position and fell to the padded mat (Bourne et al., 2015). Players completed two partial warm-up repetitions followed by a single set of three maximal repetitions for strength assessment, with the peak force in absolute (N) and relative terms ($N/kg^{-1}$) used for analysis (Bourne et al., 2015). Each protocol was repeated at the half time (HT) interval and immediately post $SAFT^{90}$ (termed full-time; FT) to assess strength differences. All players were measured in a systematic order (alphabetically) to standardise the protocol and all assessments for all players were completed within a 10-minute period of the activity profile at both HT and FT. All tests were administered by the same research team to preserve reliability (Paul et al., 2014).

### *Data Analysis*

Initially, raw data was visually inspected for normal distribution using Q-Q plots and statistically through Shapiro-Wilk tests, from which no significant deviation from normal occurred. Subsequently, a repeated-measures (ANOVA) were employed using Jeffreys Amazing Statistics Program (JASP) computer software (v0.11.1, University of Amsterdam, Netherlands) to determine the impact of the $SAFT^{90}$ upon measures of hip and hamstring strength across three levels of time (i.e., baseline, HT and FT). Data are presented as mean ± standard deviation (SD). Post-hoc Bonferroni adjusted statistical significance was set at <0.05 and utilised 95% confidence intervals (CI), Cohen *d* and percentage change to illustrate magnitude of the effect. A priori power analysis for a repeated measures study design such as this indicated that utilising a Cohens-*d* effect size of 0.5 (moderate) and a power of 0.8 with alpha set at 0.05 would require a minimum of 54 participants. Due to the larger sample size, observed power was approximately 0.98. To facilitate practical interpretations and express uncertainty, nonclinical magnitude based decisions (MBD) were also applied (Hopkins, 2019a, 2019b). In the absence of test-retest data in the current study, and established minimal clinically important differences (MCID) in the literature, a consistent distribution-based approach to determine the smallest magnitude of effect from between-participant SD (0.2 SD) for each measure was conducted (Hopkins et al., 2009; Lovell et al., 2016). Probabilities and qualitative inferences of substantial effects were reported using standardised thresholds: *most unlikely*, <0.5%; *very unlikely*, 0.5-5%; *unlikely*, 5-25%; *possibly*,25-75%; *likely*, 75-95%; *very likely*, 95-99.5%; and *most likely*, >99.5% (Hopkins, 2019a).

## Results

*Isometric hip strength*

The magnitude of changes in isometric hip strength for each measurement period are reported in Table 1. Analysis indicates that there were likely substantial differences in both isometric hip strength for both abduction and adduction at HT (-20 to -25N), with very likely substantial differences at FT (-30 to -47N). Within this population, the right limb was more negatively impacted (-13.6 to 15.7%; $d$ = 0.77-0.82) than the left side (-9.9 to 12.6%; $d$ = 0.77-0.81) (Table 1). The magnitude of strength decline in both abduction and adduction in both limbs increased linearly with exercise duration, with lowest strength values observed at FT (Figure 2).

*Eccentric Hamstring Strength*

The magnitude of changes in eccentric hamstring strength for each measurement period are reported in Table 1. Analysis from probability distribution indicated that data for both absolute (12.9 to 14N) and relative measures (0.1 to 0.2 N/kg) were trivial or unclear, although there were small significant reductions in eccentric strength between HT and FT (-4.9 to -5.6%, $d$ = 0.33-0.46). There were also less between-limb differences to that seen in isometric hip strength, with the trend of strength deficits being comparable in both left and right limbs (Table 1). However, similarly to hip strength, there was an exponential decline in eccentric hamstring strength as activity duration increased, albeit below levels considered statistically substantial (Figure 2).

Table 1. Pooled mean ± SD, *p*-values, effect size (Cohens' *d*), percentage change, mean difference (95% confidence intervals) qualitative inference for substantiality (probabilities) for isometric hip and eccentric hamstring strength and pre, half-time and full-time intervals

| | **Pre** | **HT** | **P (*d*)** | **% Change** | ***Inference (Probability)* Mean Diff, 95% CI** | **HT** | **FT** | ***P* (*d*)** | **% Change** | ***Inference (Probability)* Mean Diff, 95% CI** | **Pre** | **FT** | ***P* (*d*)** | **% Change** | ***Inference (Probability)* Mean Diff, 95% CI** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Isometric hip strength** | | | | | | | | | | | | | | | |
| Abduction Left | 313 ± 60 | 293 ± 58 | <0.001* (0.54) | -6.7 | ***Likely substantial*** -20.6, -32.2 to -9.1 | 293 ± 58 | 283 ± 57 | 0.02* (0.28) | *-3.3* | *Likely trivial* -9.9, -18 to -1.6 | 313 ± 60 | 283 ± 57 | <0.001* (0.81) | -9.9 | ***Very likely substantial*** -30.5, -42.1 to -19.1 |
| Abduction Right | 294 ± 70 | 269 ± 78 | <0.001* (0.51) | -8.5 | ***Likely substantial*** -25.4, -40.4 to -10.3 | 269 ± 78 | 254 ± 73 | 0.009* (0.33) | *-5.6* | *Likely trivial* -14.6, -25 to -3.8 | 294 ± 70 | 254 ± 73 | <0.001* (0.77) | -13.6 | ***Very likely substantial*** -40.1 -55.8 to -24.2 |
| Adduction Left | 293 ± 64 | 277 ± 65 | 0.003* (0.41) | -5.8 | ***Likely substantial*** -16.6 -28.3 to -4.8 | 277 ± 65 | 257 ± 64 | <0.001* (0.49) | *-7.2* | ***Likely substantial*** -19.6, -31 to -8.2 | 293 ± 64 | 257 ± 64 | <0.001* (0.77) | -12.6 | ***Very likely substantial*** -36.2 -50.1 to 22.4 |
| Adduction Right | 298 ± 78 | 274 ± 84 | <0.001* (0.49) | -8 | ***Likely substantial*** -24.1 -38.7 to -9.5 | 274 ± 84 | 251 ± 81 | <0.001* (0.46) | -8.3 | ***Likely substantial*** -22.8, -35 to -9.6 | 298 ± 78 | 251 ± 81 | <0.001* (0.82) | -15.7 | ***Very likely substantial*** -47.1 -63.9 to -30.1 |
| **Eccentric hamstring strength** | | | | | | | | | | | | | | | |
| Left (N) | 282 ± 70 | 285 ± 66 | 0.99 (0.06) | 1.1 | *Unclear* 3.0, -12.2 to 18.2 | 285 ± 66 | 269 ± 66 | 0.001* (0.46) | *-5.6* | *Likely trivial* -15.9, -25 to -6.7 | 282 ± 70 | 269 ± 66 | 0.148 (0.25) | -4.7 | *Likely trivial* -12.9, -30 to 4.7 |
| Right (N) | 285 ± 65 | 285 ± 65 | 0.99 (0.04) | 0 | *Unclear* -0.3, -15.4 to 15.4 | 285 ± 65 | 271 ± 66 | 0.02* (0.33) | *-4.9* | *Likely trivial* -14, -26 to -2.3 | 285 ± 65 | 271 ± 66 | 0.107 (0.27) | -4.9 | *Likely trivial* -14.1, -31 to 3.1 |
| Left ($N/kg^{-1}$) | 3.8 ± 0.91 | 3.9 ± 0.85 | 0.99 (0.06) | 2.6 | *Unclear* 0.04, -0.17 to 0.26 | 3.9 ± 0.8 | 3.7 ± 0.88 | 0.002* (0.45) | *-5.1* | *Unclear* -0.21, -0.34 to -0.01 | 3.8 ± 0.91 | 3.7 ± 0.88 | 0.165 (0.24) | -2.6 | *Unclear* -0.17, -0.39 to 0.09 |
| Right ($N/kg^{-1}$) | 3.9 ± 0.88 | 3.9 ± 0.78 | 0.99 (0.00) | 0 | *Unclear* 0.00, -2.17 to 2.17) | 3.9 ± 0.8 | 3.7 ± 0.91 | 0.03* | *-5.1* | *Unclear* -0.19, -0.36 to -0.19 | 3.9 ± 0.88 | 3.7 ± 0.91 | 0.108 (0.27) | -5.1 | *Unclear* -0.19, -0.42 to 0.03 |

*denotes statistical significance; 95% CI, 95% confidence interval; pre, baseline; HT, half-time; FT, full-time; N, newtons; N/kg, newtons per kilogram body-mass

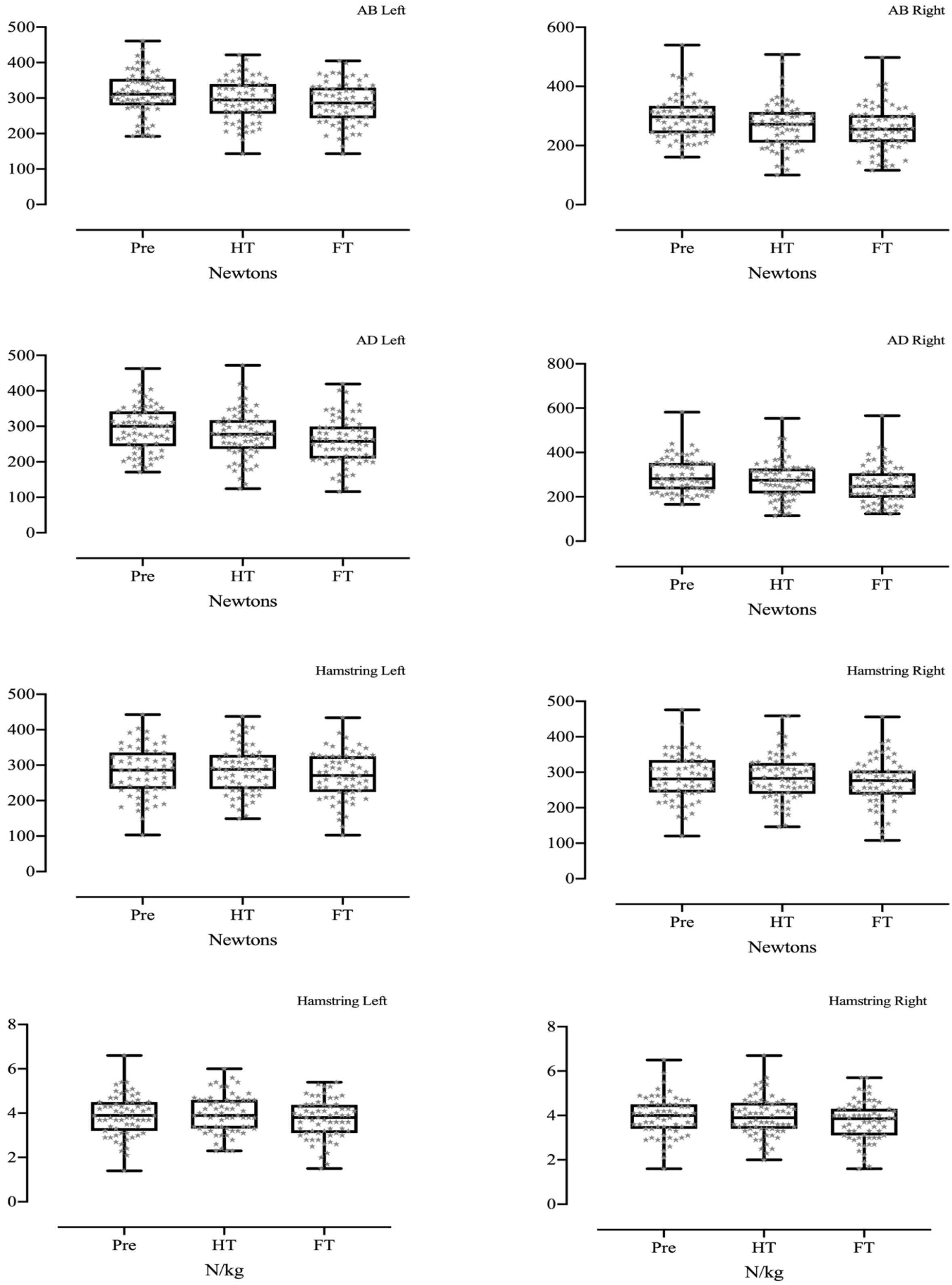


Figure 2. Box-and-whisker shows median with 25-75$^{th}$ percentiles (box) with minimum and maximum values (whisker) for left and right-side hip abduction (AB), hip adduction (AD), absolute and relative eccentric hamstring strength for pre, half-time (HT) and full-time (FT) intervals

## Discussion

The aim of the present study was to examine the changes of isometric hip and eccentric hamstring strength in response to fixed soccer specific activity profile. The two primary findings of this study were: (i) simulated soccer activity led to very likely substantial reductions in isometric hip strength that linearly decreases with exercise duration; and (ii) eccentric hamstring strength showed a decreasing trend in-line with duration, however there were no substantial reductions and minimal inter-limb differences.

*Isometric hip strength*

Completing the SAFT$^{90}$ produced very likely substantial reductions in isometric hip strength for both abductor and adductor muscle groups. This clear negative trend in isometric hip strength over the simulated 90-minutes is comparable with previous research looking at between match changes (Wollin et al., 2018) and in excess of the values that precede groin injury onset (Crow et al., 2010). Such studies, completed in similar cohorts using handheld dynamometers, suggest that a reduction of 5-15% is substantial and may be a precursor to groin pain and/or HGI (Crow et al., 2010; Paul et al., 2014; Thorborg et al., 2014; Wollin et al., 2018). Our results, indicating deficits of 9.9-15.7% from a relatively large sample identified strength decreases in excess of those regarded as substantial for injury risk (Paul et al., 2014; Wollin et al., 2018) and clearly greater than the typical error associated with the measurement system (6.3%) (Ryan et al., 2019). This in conjunction with previous research, may indicate an increased injury risk during congested fixture periods (Bueno et al., 2021; Carling et al., 2016; Constantine et al., 2019; Wollin et al., 2018), as players may be participating in matches with residual localised fatigue from previous activity (Silva et al., 2018). Figure 2 illustrates that there were inter-individual hip strength differences at all time points, with some participants experiencing more fatigue than others. These findings concur with others (Roe et al., 2016) that reported high individual variation in adductor strength post-match, who also reported that some athletes remained in a fatigued state 24h and 48h post-match. The large individual variation observed in Roe et al. (2016) was associated with the volume of sprint distance completed during a match, in that greater volume resulted in superior deficits in adductor strength (Roe et al., 2016). In contrast, the locomotive and mechanical demands in the current study were standardised, yet high individual variability in isometric hip strength still exists, suggesting that individual responses may well be exclusive to locomotive characteristics. Additionally, our findings are based on fixed, audio-controlled movement patterns alone and the protocol disregarded soccer specific kicking action, reactive movements and contact with opponents. These sport specific and maximal actions have been associated with increased load on anatomical structures around the hip and groin and potentially increased injury risk (Charnock et al., 2009; Falvey et al., 2009; Thorborg et al., 2014). Consequently, it could be proposed that the SAFT$^{90}$ may underrepresent the true anatomical and biomechanical stress placed on the hip and groin and that true match-play may accentuate deficits in hip strength. Therefore, we suggest that the true magnitude of strength decay exceeds that found here, which is important as accumulative reductions in hip strength have been associated with the onset of hip and groin pain (Wollin et al., 2018), increased risk of HGI (Engebretsen et al., 2010) and injury occurrence at the later stages of match-play (Falkenmire et al., 2019; Liu et al., 2012)

*Eccentric Hamstring Strength*

Unlike isometric hip strength, there was no evidence of substantial changes in eccentric hamstring strength as a result of performing the SAFT$^{90}$. There was evidence of small reductions in strength at FT (Figure 2), however these were not deemed substantial (Table 1). There appears to be a paucity of evidence that illustrates acute changes in hamstring strength following soccer-specific activity utilising eccentric hamstring-based activities, against which to compare our findings. However, our data do oppose deductions observed by Small et al. (2010) who identified ~17% reduction in eccentric hamstring peak torque, although methodological differences in the measurement of eccentric hamstring strength convolute comparisons. This apparent large discrepancy in acute response between the groin and hamstring muscle groups is likely best explained in reference to the locomotive demands of the SAFT$^{90}$. Research suggests that the most demanding activities performed by the hamstrings are maximal speed running and rapid decelerations which are common mechanisms for injury (Buckthorpe et al., 2019). However, the SAFT$^{90}$ set-up (Figure 1) prevents maximal speed running and therefore rapid decelerations. Despite the protocol including a 'sprint' cue and indicating there is a total of 340m 'sprinting' (>20.4km/h$^{-1}$) (Small et al., 2010), the protocol setup excludes the required distance for the most mechanically demanding gait-patterns (Higashihara et al., 2018). Instead, we propose that this 'sprint' distance is derived from gait kinematics typically comprised of those normally referred to as 'acceleration' (~15m), reducing kinetic forces acting on the hamstring muscles compared to 'maximal speed' kinematics (~40m) (Higashihara et al., 2018; Schache et al., 2012; Yu et al., 2008).

*Strengths and limitations*

The sample size (*n* = 71) in the current study is strength, and larger than many other cross-sectional hamstring and hip studies (Paul et al., 2014; Roe et al., 2016; Small et al., 2010; Thorborg et al., 2014; Wollin et al., 2018). The applied environment often limits the control of such studies and prevents repeated observations before, during and after soccer specific activity, with sample size often directly impacted by squad size. However, in the absence of a widely accepted and context specific (i.e., measurement tool) minimal clinically importance differences our results are interpreted using a distribution based meaningful threshold, which is population specific. This facilitated secondary analysis above and beyond significance testing for applied purposes but should be handled with caution by those looking to more broadly apply findings. Although the sample is considered a strength for this reason, one limitation is the apparent heterogeneity of the players included from the academy. Despite the participants being part of the same development programme with similar training schedules and loads, the variability in baseline strength was less than homogenous. It emerged that baseline strength (in both hip and hamstring muscle groups) was varied within the sample, which may have influenced the conclusions obtained. However, this may well also represent norm within soccer, as often teams constitute of players with varied status of readiness (recovery), injury histories, ages and ethnicities all of which may influence isometric hip strength (Mosler et al., 2017; Whittaker et al., 2015). Additionally, Due to the resource and time intensive nature of data collection, there is potential that baseline strength levels of players may have changed during the 8-week data collection period, therefore those assessed towards the end may have accumulated more in-season fatigue. Follow-up strength measurements 24-72 hrs post activity would have provided useful information regarding the time course of recovery and residual fatigue of both muscle groups, which may have implications for congested fixture periods, however this was not practically possible. Finally, the $SAFT^{90}$ excludes key soccer specific actions (i.e., kicking, tackling, high-speed running) and as such limits the ecological validity of the protocol. However, it offers an appropriate mechanism by which to standardise the external load across a large sample often not afforded within applied sport.

### *Practical Applications*

These findings should stimulate attention for practitioners when considering injury risk in soccer players, particularly around periods of fixture congestion. The substantial dose-response reductions in isometric groin strength may compromise athletes within the training micro-cycle and lead to greater strength deficits than eccentric hamstring strength (Carling et al., 2016). Our findings may also underrepresent the true anatomical and biomechanical stress placed on the hip, groin and hamstring during actual match-play, suggesting actual strength deficits may exceed those showed here. Therefore, we encourage practitioners to routinely monitor isometric hip and eccentric hamstring strength to establish thresholds of strength deficit to help inform decision making around training/match exposures. Subsequently, these thresholds may be used to inform injury risk and maximise player availability over the course of a competitive season.

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***Disclosure of interest***

The authors report no conflict of interest.

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