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

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6

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

8

9 *Data Availability:* The data that support the findings of this study are openly available at the Open Science
10 Framework at [DOI 10.17605/OSF.IO/A9ZMY](https://doi.org/10.17605/OSF.IO/A9ZMY)

11

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22

23 **Abstract**

24 Together, the burden of hamstring and hip and groin injuries in soccer is substantial and the risk of re-injury in these
25 areas is high. Reduced muscle strength has been identified as an important modifiable intrinsic risk factor of injury.
26 However, little is known regarding the within-match changes in hip and hamstring muscle strength in order to
27 inform early detection and management strategies. Seventy-one male soccer players (age, 19.2 ± 0.9 yrs; height,
28 175.9 ± 5.8 cm; weight, 73 ± 8.2 kg) from an international academy completed a fixed soccer specific activity profile
29 (SAFT⁹⁰). Isometric hip and eccentric hamstring strength were measured after a standardised 5-min warm-up and
30 repeated at half time and full time. Repeated-measures ANOVA were used to determine changes in muscle strength
31 with magnitude-based decisions used to express probabilistic uncertainty. Findings indicate that i) there was likely
32 to very likely substantial changes in isometric hip strength (-9.9-15.7%) and ii) no substantial changes in eccentric
33 hamstring strength (-2.6-5.1%). By extrapolating these findings, it can be inferred that reduced isometric hip
34 strength during match play may be one risk factor for injury, especially during periods of fixture congestion and
35 practitioners should routinely assess muscle strength to inform training and match exposure based on player
36 readiness. In doing so, it is likely that practitioners may enhance player availability and minimise injury incidence.

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

38 **Introduction**

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

50

51 Sports injuries are multifactorial in nature and understanding contributing risk factors associated with them is
52 important for the early stages of systematic injury prevention frameworks (O'Brien et al., 2017; Van Tiggelen et

53 al., 2008). Understanding risk factors can then serve as a precursor to developing evidence and context informed
54 prevention strategies. Previous research has found several non-modifiable (e.g., age, previous injury, level of play)
55 and modifiable (e.g., range of movement, lumbo-pelvic control, altered trunk flexion, muscle strength) risk factors
56 to be associated with HSI and HGI (Engebretsen et al., 2010; Lahti et al., 2020; Whittaker et al., 2015). Of these
57 identified factors it is muscle strength, or more specially for the context of this study, eccentric hamstring and hip
58 adductor and abductor strength that has gained greatest research interest (Buckthorpe et al., 2019; Thorborg et al.,
59 2014).

60

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

74

75 While several studies (outlined above) have discussed the importance of managing congested periods of fixtures,
76 less is known about the within-match impact on muscle strength (i.e., pre-match, half-time, full-time) (Paul et al.,
77 2014). In other words, the extent to which isometric hip and eccentric hamstring strength is changed by the
78 physiological and mechanical load of a single dose of soccer activity (i.e. dose-response). Previous studies have
79 identified a reduction in eccentric hamstring peak torque or strength of 12-20% after acute soccer activity, which
80 may elevate hamstring injury risk late in matches and the following 48-72hrs (Bueno et al., 2021; Constantine et

81 al., 2019; Huygaerts et al., 2020; Small et al., 2010). However, no studies to our knowledge have explored the
82 combination of isometric hip and eccentric hamstring strength to offer a more complete insight into the lower limb-
83 dose-response. Further work in this area would be important given that fixture congestion means there is an
84 increased risk of playing in a match with residual muscle strength deficit (Carling et al., 2016; Engebretsen et al.,
85 2010), which may predispose athletes to both HGI or HSI later in matches. In turn, this research could inform
86 primary and secondary injury prevention practices during congested periods throughout the competitive season (e.g.
87 recovery planning, strength and conditioning programming) (Paul et al., 2014).

88

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

100

101 **Materials and Methods**

102 *Participants*

103 Seventy-one, adult male student-athletes from an open-age (18 – 23 years) international soccer academy of
104 university student athletes (age, 19.2 ± 0.9 years; height, 175.9 ± 5.8 cm; weight, 73 ± 8.2 kg) were recruited and
105 provided informed consent, in accordance with the declaration of Helsinki to participate in the study. Participants
106 were from various squads within the same full-time academy, and routinely completed a total of 4-5 training sessions
107 (including supervised strength sessions) and 1-2 competitive matches each week, meaning their training exposure

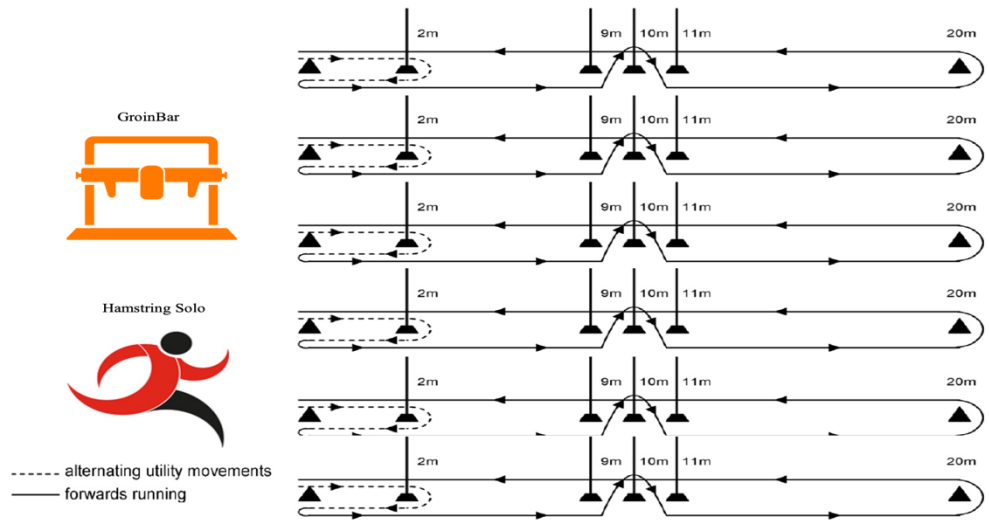
108 was comparable (12-14 hours) to the Elite Player Performance Plan (Premier League, 2011) guidelines for a
109 Category 1 Academy at the Professional Development Phase (PDP). Testing for each participant was conducted
110 during the early competitive season (September-October) no earlier than 72 hours following match-activity to
111 ensure adequate recovery. Only outfield players that were considered injury free and had completed all prescribed
112 training sessions in the two-weeks prior to data collection were included in the study. In the 24-hr period preceding
113 to the testing, all participants were informed to avoid alcohol intake and performed no vigorous exercise.

114

115 *Procedures*

116 In small groups ($n \sim 8$) over an eight-week period on a synthetic third-generation pitch, each participant completed
117 a 90-minute soccer-specific aerobic field test (SAFT⁹⁰). The 90-minute protocol was divided into two 45-minute
118 periods interceded with a 15-minute passive rest period (half time). The SAFT⁹⁰ is a multidirectional fixed activity
119 profile valid to simulate soccer match-play based on time-motion data obtained from the English Championship in
120 2007 (Small et al., 2009). The 20m shuttle course includes randomised multidirectional and utility movements (e.g.,
121 sidestepping, back peddling), with frequent acceleration and deceleration leading to an accumulated distance of
122 10.78 km including 1350 changes of direction and 1269 changes in speed during the 90-minute protocol (Small et
123 al., 2010). Players were required to perform backwards running or sidestepping around the first marker, followed
124 by forwards running through the course (Figure 1), with the intensity controlled by audio cues. Due to the inherent
125 differences between individual, positional and match-to-match variations of actual match-play, utilising a fixed
126 soccer specific activity profile that excludes contact actions (i.e., tackling and kicking) facilitates standardised
127 external loads. By standardising these loads to offer and reducing contextual variation, we were able to significantly
128 increase the sample size of the study across teams within the same international soccer academy and facilitate
129 assessment of inter-individual responses.

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Figure 1. Diagrammatic representation of the SAFT⁹⁰ setup

139 **Measures**

140 All data was collected by the authors (JS and DF), both experienced and accredited practitioners (i.e., Sport Scientist
141 and Strength and Conditioning). Following a standardised 5-minute warm-up of dynamic stretches targeting the
142 major lower limb muscle groups and prior to completing the SAFT⁹⁰, isometric hip strength was measured using
143 the GroinBar Hip Strength Testing System (Vald Performance, Albion, Australia), more recently termed
144 ‘ForceFrame’. The GroinBar system has previously demonstrated excellent test-retest reliability with intraclass
145 correlation coefficients (ICC) for hip adduction and abduction of 0.97 and 0.98 respectively and an acceptable level
146 of coefficient of variation (CV%), 4.65-6.3%, with hips at 45° (Rees & Opar, 2018; Ryan et al., 2019). Players were
147 requested to lay in a supine position under the GroinBar system with the femoral condyle of their knees on the
148 padded load cell (50Hz) at the specific angle (short lever, hips at 45°). Bar height was individually adjusted to ensure
149 knees aligned with the load cell pad for the duration of the test. Players were given a verbal cue (3, 2, 1....) and
150 instructed to ‘push’ (abductors) or ‘squeeze’ (adductors) their femoral condyles against the padded load cells
151 continuously for 5-seconds, which produced a force (Newtons) for both legs simultaneously. All participants were
152 verbally encouraged to ensure maximal effort and strict monitoring of technique was observed by researchers
153 throughout to ensure data fidelity. Eccentric hamstring strength was then assessed using the Nordic hamstring
154 exercise using a Hamstring Solo Elite (ND Performance, Kilkenny, Republic of Ireland). This device has
155 demonstrated excellent test-retest reliability (0.91) which is comparable with other well researched eccentric knee

156 flexor devices, namely isokinetic dynamometry (0.86-0.95) and handheld dynamometers (0.90) (Lodge et al., 2020;
157 Maffiuletti et al., 2007). Participants knelt on the padded plinth, with ankles secured on the superior aspect of the
158 lateral malleolus by individual limb braces containing pressure gauges with Bluetooth connection to a handheld
159 device. Knee position on the pad was standardised for each individual's leg-length based for consistency in each
160 assessment. Participants were instructed to place their hands crossed on their chest and gradually lean forward whilst
161 keeping their trunk and hips neutral, until they were unable to sustain the position and fell to the padded mat (Bourne
162 et al., 2015). Players completed two partial warm-up repetitions followed by a single set of three maximal repetitions
163 for strength assessment, with the peak force in absolute (N) and relative terms (N/kg^{-1}) used for analysis (Bourne
164 et al., 2015). Each protocol was repeated at the half time (HT) interval and immediately post SAFT⁹⁰ (termed full-
165 time; FT) to assess strength differences. All players were measured in a systematic order (alphabetically) to
166 standardise the protocol and all assessments for all players were completed within a 10-minute period of the activity
167 profile at both HT and FT. All tests were administered by the same research team to preserve reliability (Paul et al.,
168 2014).

169

170 *Data Analysis*

171 Initially, raw data was visually inspected for normal distribution using Q-Q plots and statistically through Shapiro-
172 Wilk tests, from which no significant deviation from normal occurred. Subsequently, a repeated-measures
173 (ANOVA) were employed using Jeffreys Amazing Statistics Program (JASP) computer software (v0.11.1,
174 University of Amsterdam, Netherlands) to determine the impact of the SAFT⁹⁰ upon measures of hip and hamstring
175 strength across three levels of time (i.e., baseline, HT and FT). Data are presented as mean \pm standard deviation
176 (SD). Post-hoc Bonferroni adjusted statistical significance was set at <0.05 and utilised 95% confidence intervals
177 (CI), Cohen d and percentage change to illustrate magnitude of the effect. A priori power analysis for a repeated
178 measures study design such as this indicated that utilising a Cohens- d effect size of 0.5 (moderate) and a power of
179 0.8 with alpha set at 0.05 would require a minimum of 54 participants. Due to the larger sample size, observed
180 power was approximately 0.98. To facilitate practical interpretations and express uncertainty, nonclinical magnitude
181 based decisions (MBD) were also applied (Hopkins, 2019a, 2019b). In the absence of test-retest data in the current
182 study, and established minimal clinically important differences (MCID) in the literature, a consistent distribution-
183 based approach to determine the smallest magnitude of effect from between-participant SD (0.2 SD) for each

184 measure was conducted (Hopkins et al., 2009; Lovell et al., 2016). Probabilities and qualitative inferences of
185 substantial effects were reported using standardised thresholds: *most unlikely*, <0.5%; *very unlikely*, 0.5-
186 5%; *unlikely*, 5-25%; *possibly*, 25-75%; *likely*, 75-95%; *very likely*, 95-99.5%; and *most likely*, >99.5%
187 (Hopkins, 2019a).

188

189 **Results**

190 *Isometric hip strength*

191 The magnitude of changes in isometric hip strength for each measurement period are reported in Table 1. Analysis
192 indicates that there were likely substantial differences in both isometric hip strength for both abduction and
193 adduction at HT (-20 to -25N), with very likely substantial differences at FT (-30 to -47N). Within this population,
194 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%; $d =$
195 $0.77-0.81$) (Table 1). The magnitude of strength decline in both abduction and adduction in both limbs increased
196 linearly with exercise duration, with lowest strength values observed at FT (Figure 2).

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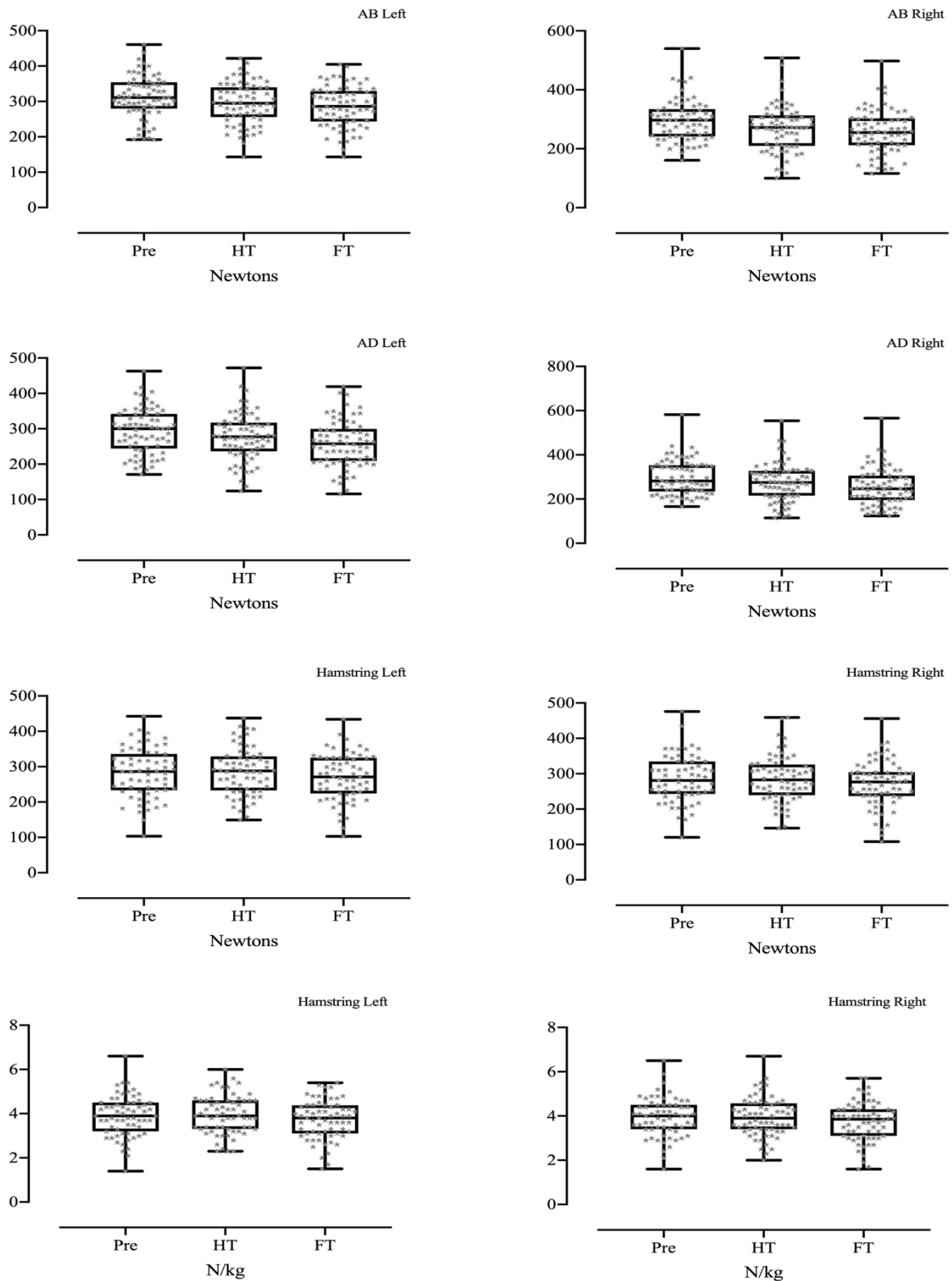
198 *Eccentric Hamstring Strength*

199 The magnitude of changes in eccentric hamstring strength for each measurement period are reported in Table 1.
200 Analysis from probability distribution indicated that data for both absolute (12.9 to 14N) and relative measures (0.1
201 to 0.2 N/kg) were trivial or unclear, although there were small significant reductions in eccentric strength between
202 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
203 hip strength, with the trend of strength deficits being comparable in both left and right limbs (Table 1). However,
204 similarly to hip strength, there was an exponential decline in eccentric hamstring strength as activity duration
205 increased, albeit below levels considered statistically substantial (Figure 2).

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



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

212 **Discussion**

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

218

219 *Isometric hip strength*

220 Completing the SAFT⁹⁰ produced very likely substantial reductions in isometric hip strength for both abductor and
221 adductor muscle groups. This clear negative trend in isometric hip strength over the simulated 90-minutes is
222 comparable with previous research looking at between match changes (Wollin et al., 2018) and in excess of the
223 values that precede groin injury onset (Crow et al., 2010). Such studies, completed in similar cohorts using handheld
224 dynamometers, suggest that a reduction of 5-15% is substantial and may be a precursor to groin pain and/or HGI
225 (Crow et al., 2010; Paul et al., 2014; Thorborg et al., 2014; Wollin et al., 2018). Our results, indicating deficits of
226 9.9-15.7% from a relatively large sample identified strength decreases in excess of those regarded as substantial for
227 injury risk (Paul et al., 2014; Wollin et al., 2018) and clearly greater than the typical error associated with the
228 measurement system (6.3%) (Ryan et al., 2019). This in conjunction with previous research, may indicate an
229 increased injury risk during congested fixture periods (Bueno et al., 2021; Carling et al., 2016; Constantine et al.,
230 2019; Wollin et al., 2018), as players may be participating in matches with residual localised fatigue from previous
231 activity (Silva et al., 2018). Figure 2 illustrates that there were inter-individual hip strength differences at all time
232 points, with some participants experiencing more fatigue than others. These findings concur with others (Roe et al.,
233 2016) that reported high individual variation in adductor strength post-match, who also reported that some athletes
234 remained in a fatigued state 24h and 48h post-match. The large individual variation observed in Roe et al. (2016)
235 was associated with the volume of sprint distance completed during a match, in that greater volume resulted in
236 superior deficits in adductor strength (Roe et al., 2016). In contrast, the locomotive and mechanical demands in the
237 current study were standardised, yet high individual variability in isometric hip strength still exists, suggesting that
238 individual responses may well be exclusive to locomotive characteristics. Additionally, our findings are based on
239 fixed, audio-controlled movement patterns alone and the protocol disregarded soccer specific kicking action,

240 reactive movements and contact with opponents. These sport specific and maximal actions have been associated
241 with increased load on anatomical structures around the hip and groin and potentially increased injury risk
242 (Charnock et al., 2009; Falvey et al., 2009; Thorborg et al., 2014). Consequently, it could be proposed that the
243 SAFT⁹⁰ may underrepresent the true anatomical and biomechanical stress placed on the hip and groin and that true
244 match-play may accentuate deficits in hip strength. Therefore, we suggest that the true magnitude of strength decay
245 exceeds that found here, which is important as accumulative reductions in hip strength have been associated with
246 the onset of hip and groin pain (Wollin et al., 2018), increased risk of HGI (Engebretsen et al., 2010) and injury
247 occurrence at the later stages of match-play (Falkenmire et al., 2019; Liu et al., 2012)

248

249 *Eccentric Hamstring Strength*

250 Unlike isometric hip strength, there was no evidence of substantial changes in eccentric hamstring strength as a
251 result of performing the SAFT⁹⁰. There was evidence of small reductions in strength at FT (Figure 2), however these
252 were not deemed substantial (Table 1). There appears to be a paucity of evidence that illustrates acute changes in
253 hamstring strength following soccer-specific activity utilising eccentric hamstring-based activities, against which
254 to compare our findings. However, our data do oppose deductions observed by Small et al. (2010) who identified
255 ~17% reduction in eccentric hamstring peak torque, although methodological differences in the measurement of
256 eccentric hamstring strength convolute comparisons. This apparent large discrepancy in acute response between the
257 groin and hamstring muscle groups is likely best explained in reference to the locomotive demands of the SAFT⁹⁰.
258 Research suggests that the most demanding activities performed by the hamstrings are maximal speed running and
259 rapid decelerations which are common mechanisms for injury (Buckthorpe et al., 2019). However, the SAFT⁹⁰ set-
260 up (Figure 1) prevents maximal speed running and therefore rapid decelerations. Despite the protocol including a
261 ‘sprint’ cue and indicating there is a total of 340m ‘sprinting’ ($>20.4\text{km/h}^{-1}$) (Small et al., 2010), the protocol setup
262 excludes the required distance for the most mechanically demanding gait-patterns (Higashihara et al., 2018).
263 Instead, we propose that this ‘sprint’ distance is derived from gait kinematics typically comprised of those normally
264 referred to as ‘acceleration’ (~15m), reducing kinetic forces acting on the hamstring muscles compared to ‘maximal
265 speed’ kinematics (~40m) (Higashihara et al., 2018; Schache et al., 2012; Yu et al., 2008).

266 *Strengths and limitations*

267 The sample size ($n = 71$) in the current study is strength, and larger than many other cross-sectional hamstring and
268 hip studies (Paul et al., 2014; Roe et al., 2016; Small et al., 2010; Thorborg et al., 2014; Wollin et al., 2018). The
269 applied environment often limits the control of such studies and prevents repeated observations before, during and
270 after soccer specific activity, with sample size often directly impacted by squad size. However, in the absence of a
271 widely accepted and context specific (i.e., measurement tool) minimal clinically importance differences our results
272 are interpreted using a distribution based meaningful threshold, which is population specific. This facilitated
273 secondary analysis above and beyond significance testing for applied purposes but should be handled with caution
274 by those looking to more broadly apply findings. Although the sample is considered a strength for this reason, one
275 limitation is the apparent heterogeneity of the players included from the academy. Despite the participants being
276 part of the same development programme with similar training schedules and loads, the variability in baseline
277 strength was less than homogenous. It emerged that baseline strength (in both hip and hamstring muscle groups)
278 was varied within the sample, which may have influenced the conclusions obtained. However, this may well also
279 represent norm within soccer, as often teams constitute of players with varied status of readiness (recovery), injury
280 histories, ages and ethnicities all of which may influence isometric hip strength (Mosler et al., 2017; Whittaker et
281 al., 2015). Additionally, Due to the resource and time intensive nature of data collection, there is potential that
282 baseline strength levels of players may have changed during the 8-week data collection period, therefore those
283 assessed towards the end may have accumulated more in-season fatigue. Follow-up strength measurements 24-72
284 hrs post activity would have provided useful information regarding the time course of recovery and residual fatigue
285 of both muscle groups, which may have implications for congested fixture periods, however this was not practically
286 possible. Finally, the SAFT⁹⁰ excludes key soccer specific actions (i.e., kicking, tackling, high-speed running) and
287 as such limits the ecological validity of the protocol. However, it offers an appropriate mechanism by which to
288 standardise the external load across a large sample often not afforded within applied sport.

289

290 ***Practical Applications***

291 These findings should stimulate attention for practitioners when considering injury risk in soccer players,
292 particularly around periods of fixture congestion. The substantial dose-response reductions in isometric groin
293 strength may compromise athletes within the training micro-cycle and lead to greater strength deficits than eccentric
294 hamstring strength (Carling et al., 2016). Our findings may also underrepresent the true anatomical and

295 biomechanical stress placed on the hip, groin and hamstring during actual match-play, suggesting actual strength
296 deficits may exceed those showed here. Therefore, we encourage practitioners to routinely monitor isometric hip
297 and eccentric hamstring strength to establish thresholds of strength deficit to help inform decision making around
298 training/match exposures. Subsequently, these thresholds may be used to inform injury risk and maximise player
299 availability over the course of a competitive season.

300

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304

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306 The authors report no conflict of interest.

307

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