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The impact of simulated soccer match-play on hip and 1 hamstring strength in academy soccer players 2 Salter, J.¹, Cresswell, R.² and Forsdyke, D.¹ 3 ¹ School of Sport, York St John University, York, UK 4 ² i2i International Soccer Academy, York, UK 5 6 7 Running Head: Acute hip and hamstring strength in academy soccer 8 Data Availability: The data that support the findings of this study are openly available at the Open Science 9 Framework at DOI 10.17605/OSF.IO/A9ZMY 10 11 Corresponding Author: 12 Jamie Salter 13 School of Sport 14

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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. However, little is known regarding the within-match changes in hip and hamstring muscle strength in order to 26 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 hamstring strength (-2.6-5.1%). By extrapolating these findings, it can be inferred that reduced isometric hip 33 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 of re-injury (11-13%) (Ekstrand et al., 2016; Werner et al., 2019). Incidence rates in youth cohorts are significantly 43 44 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 45 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 et al., 2013). Therefore, the management of HSI and HGI represents a significant challenge for practitioners, and as 48 49 a result, understanding the risk factors that precede onset are important.

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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

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).

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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 strength was observed the week preceding and week of injury onset in elite junior Australian Football players (Crow 66 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.

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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 limbdose-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).

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

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 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.

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115 Procedures

116 In small groups $(n \sim 8)$ over an eight-week period on a synthetic third-generation pitch, each participant completed a 90-minute soccer-specific aerobic field test (SAFT⁹⁰). The 90-minute protocol was divided into two 45-minute 117 periods interceded with a 15-minute passive rest period (half time). The SAFT⁹⁰ is a multidirectional fixed activity 118 profile valid to simulate soccer match-play based on time-motion data obtained from the English Championship in 119 2007 (Small et al., 2009). The 20m shuttle course includes randomised multidirectional and utility movements (e.g., 120 121 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 differences between individual, positional and match-to-match variations of actual match-play, utilising a fixed 125 126 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.



139 Measures

All data was collected by the authors (JS and DF), both experienced and accredited practitioners (i.e., Sport Scientist 140 141 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 SAFT⁹⁰, isometric hip strength was measured using 142 143 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 lateral malleolus by individual limb braces containing pressure gauges with Bluetooth connection to a handheld 158 device. Knee position on the pad was standardised for each individual's leg-length based for consistency in each 159 160 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).

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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 (ANOVA) were employed using Jeffreys Amazing Statistics Program (JASP) computer software (v0.11.1, 173 University of Amsterdam, Netherlands) to determine the impact of the SAFT⁹⁰ upon measures of hip and hamstring 174 175 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 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*, 0.55%; *unlikely*, 5-25%; *possibly*,25-75%; *likely*, 75-95%; *very likely*, 95-99.5%; and *most likely*, >99.5%
(Hopkins, 2019a).

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189 Results

190 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).

197

198 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).

	Pre	НТ	Р	% Change	Inference (Probability)	НТ	FT	Р	% Change	Inference (Probability)	Pre	FT	Р	% Change	Inference (Probability)
			<i>(d</i>)	enange	Mean Diff 95% CI			(d)	onunge	Mean Diff 95% CI			(d)	enunge	Mean Diff_95% CI
Isometric hi	p strength														
Abduction Left	313 ± 60	293 ± 58	<0.001*	-6.7	Likely substantial	293 ± 58	283 ± 57	0.02*	-3.3	Likely trivial	313 ± 60	283 ± 57	< 0.001*	-9.9	Very likely substantial
Abduction Right	294 ± 70	269 ± 78	(0.54) <0.001*	-8.5	-20.632.2 to -9.1 Likely substantial	269 ± 78	254 ± 73	(0.28) 0.009*	-5.6	-9.918 to -1.6 Likely trivial	294 ± 70	254 ± 73	(0.81) <0.001*	-13.6	-30.542.1 to -19.1 Very likely substantial
Adduction	293 ± 64	277 ± 65	(0.51) 0.003*	-5.8	-25.440.4 to -10.3 Likely substantial	277 ± 65	257 ± 64	(0.33) <0.001*	-7.2	-14.625 to -3.8 Likely substantial	293 ± 64	257 ± 64	(0.77) <0.001*	-12.6	-40.1 -55.8 to -24.2 Very likely substantial
Adduction	298 ± 78	274 ± 84	(0.41) <0.001*	-8	-16.6 -28.3 to -4.8 Likely substantial	274 ± 84	251 ± 81	(0.49) <0.001*	-8.3	-19.631 to -8.2 Likely substantial	298 ± 78	251 ± 81	(0.77) <0.001*	-15.7	-36.2 -50.1 to 22.4 Very likely substantial
Right			(0.49)		-24.1 -38.7 to -9.5			(0.46)		-22.835 to -9.6			(0.82)		-47.1 -63.9 to -30.1
Eccentric ha	amstring stre	ngth													
Left (N)	282 ± 70	285 ± 66	0.99	1.1	Unclear	285 ± 66	269 ± 66	0.001*	-5.6	Likely trivial	282 ± 70	269 ± 66	0.148	-4.7	Likely trivial
Right (N)	285 ± 65	285 ± 65	(0.06) 0.99	0	3.012.2 to 18.2 Unclear	285 ± 65	271 ± 66	(0.46) 0.02*	-4.9	-15.925 to -6.7 Likely trivial	285 ± 65	271 ± 66	(0.25) 0.107	-4.9	-12.930 to 4.7 Likely trivial
Left	3.8 ± 0.91	3.9 ± 0.85	(0.04) 0.99	2.6	-0.315.4 to 15.4 Unclear	3.9 ± 0.8	3.7 ± 0.88	(0.33) 0.002*	-5.1	-1426 to -2.3 Unclear	3.8 ± 0.91	3.7 ± 0.88	(0.27) 0.165	-2.6	-14.131 to 3.1 Unclear
(N/Kg ⁻¹) Right	2.0 . 0.00	2.0 . 0.70	(0.06) 0.99	0	0.040.17 to 0.26 Unclear	20.00	27.001	(0.45)	5.1	-0.210.34 to -0.01 Unclear	20.000	27.001	(0.24) 0.108	5 1	-0.170.39 to 0.09 Unclear
(N/kg ⁻¹)	3.9 ± 0.88	3.9 ± 0.78	(0.00)	0	0.00, -2.17 to 2.17)	3.9 ± 0.8	3.7 ± 0.91	0.03*	-3.1	-0.19, -0.36 to -0.19	3.9 ± 0.88	5.7 ± 0.91	(0.27)	-5.1	-0.19, -0.42 to 0.03

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

*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 25-75th 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 fulltime (FT) intervals

212 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.

218

219 Isometric hip strength

Completing the SAFT⁹⁰ produced very likely substantial reductions in isometric hip strength for both abductor and 220 221 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 9.9-15.7% from a relatively large sample identified strength decreases in excess of those regarded as substantial for 226 227 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 result of performing the SAFT⁹⁰. There was evidence of small reductions in strength at FT (Figure 2), however these 251 252 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 $\sim 17\%$ 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' (>20.4km/h⁻¹) (Small et al., 2010), the protocol setup excludes the required distance for the most mechanically demanding gait-patterns (Higashihara et al., 2018). 262 263 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

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.

300

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