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ORIGINAL RESEARCH

SPRINT PERFORMANCE IN FOOTBALL (SOCCER) PLAYERS WITH AND WITHOUT A PREVIOUS HAMSTRING STRAIN INJURY: AN EXPLORATIVE CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Hamstring strain injuries are common in many sports. Following a hamstring injury, deficits in peak and explosive strength may persist after return to sport potentially affecting sprint performance. Assessment of repeated-sprint ability is recognized as an important part of the return to sport evaluation after a hamstring injury.

Purpose: This purpose of this exploratory cross-sectional study was to compare sprinting performance obtained during a repeated-sprint test between football players with and without a previous hamstring strain injury.

Methods: Forty-four fully active sub-elite football players, 11 with a previous hamstring strain injury during the preceding 12 months (cases; mean age, SD: 25.6 $\pm$ 4.4) and 33 demographically similar controls (mean age, SD: 23.2 $\pm$ 3.7), were included from six clubs. All players underwent a repeated-sprint test, consisting of six 30-meter maximal sprints with 90 seconds of recovery between sprints. Sprint performance was captured using high-speed video-recording and subsequently assessed by a blinded tester to calculate maximal sprint velocity, maximal horizontal force, maximal horizontal power, and mechanical effectiveness.

Results: A significant between-group difference was seen in favor of players having a previous hamstring injury over 6 sprints for maximal velocity (mean difference: 0.457 m/s, 95% CI: 0.059-0.849, $p = 0.025$) and mechanical effectiveness (mean difference: 0.009, 95% CI: 0.001-0.016, $p = 0.020$)

Conclusion: Repeated-sprint performance was not impaired in football players with a previous hamstring strain injury; in fact, higher mean maximal sprinting velocity and better mechanical effectiveness were found in players with compared to without a previous hamstring injury. The higher sprinting velocity, which likely increases biomechanical load on the hamstring muscles, in previously injured players may increase the risk of recurrent injuries.

Level of evidence: 3b

Keywords: Hamstring injury, return to play, repeated-sprint performance, injury prevention, re-injury, soccer

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All authors declare no conflicts of interests..

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INTRODUCTION

Hamstring strain injuries are common in many sports, constituting up to 37% of all muscle injuries encountered in professional football.[1] Consequently, the burden of hamstring strain injuries results in substantial lay-off times for players potentially leading to reduced team performance.[2] Hamstring strain injuries are thought to occur during the late swing phase or early stance phase of maximal sprint running, which are characterized by peak hamstring musculotendon strain or large ground reaction forces, respectively.[3] Following a hamstring strain injury, previous research has documented deficits in peak eccentric hamstring muscle strength,[4] rate of torque development,[5] and hamstring muscle fatigue resistance[6] as well as alterations in hamstring muscle activation patterns.[7,8]

In football (soccer), sprinting performance, both acceleration[9] and at maximal velocity,[10] is crucial for match performance. During sprinting, the hamstring muscles work by eccentrically decelerating knee extension during the swing phase, followed by a hip extension and knee flexion moment in the stance phase to generate horizontal forces.[11,12] Thus, previous studies have found associations between sprint performance with 1) eccentric hamstring strength and biceps femoris long head activation,[11] and with 2) explosive knee flexion torque.[13] These observations highlight the importance of the hamstring muscles for sprinting performance.[14,15] Consequently, neuromuscular deficits as a consequence of a hamstring injury[16] could impair sprint performance.[11,13] In line with this, some studies have observed reduced horizontal force production during both a single sprint[17] and repeated sprinting[18] in football players with a previous hamstring strain injury indicative of impaired sprint acceleration. However, comprehensive analysis of sprinting performance in football players with a hamstring strain injury involving both acceleration and maximal velocity measures, have not been conducted but is considered important for return to play decisions.[19] Therefore, the purpose was to compare sprinting performance obtained during a repeated-sprint test between football players with and without a previous hamstring strain injury.

METHODS

Study design

This pre-registered (ClinicalTrials.gov ID: NCT03306511) exploratory cross-sectional study compared mechanical sprint variables related to sprint acceleration performance and peak sprint velocity[20] assessed during a repeated 30-meter sprint test in football players with and without a self-reported previous hamstring strain injury in the preceding 12 months. Participants included in the study were Sub-elite senior football players from six football clubs located in the Greater Copenhagen area by convenience sampling. The reporting adheres to the Strengthening the Reporting of Observational Studies in Epidemiology.[21] Approval was obtained from the Danish Ethics Committee of the Capital Region (Identifier: 17018805). All participants gave their informed written consent according to the Declaration of Helsinki.

Study setting

All data were collected at the facilities of the respective football clubs located in the Greater Copenhagen area between 19th of October 2017 and 23rd of November 2017. Sprint performance measures were performed outdoor on either artificial turf or natural grass depending on the facilities of the specific football club. Participants wore football boots during testing. Prior to sprint testing, all participants underwent a standardized and supervised warm-up procedure consisting of running and sprinting drills with progressive intensity for a duration of 15-minutes. Prior to testing players were asked if they felt ready for maximal sprinting, and if not they were instructed to perform an additional few sprints as warm-up until ready. All participants were instructed to refrain from high-intensity physical activity 24-h prior to testing.

Participants. To be eligible for inclusion, participants had to participate fully in football training and be available for match play at the time of testing (minimum three training/match sessions per week). Participants were categorized as players with a previous hamstring injury if they reported a previous hamstring strain injury (acute onset of pain to the posterior thigh) resulting in time-loss from regular football training or football matches in the preceding 12 months. Injury severity was categorized as mild (< 1 week), moderate (1-4 weeks), or severe

(> 4 weeks).[22] Exclusion criteria for both players with and without a previous hamstring injury were: Any self-reported longstanding injury other than hamstring injury (> 6 weeks) in the lower extremities or trunk in the preceding 12 months; any pain in the lower extremity, pelvis, or spine during testing. Furthermore, to increase the generalizability of the findings to outfield players, goal keepers were excluded.

Outcome measures

Due to the explorative study design, the outcome variables follow a flat outcome structure. Outcomes of interest were the between-group (players with versus without a previous hamstring injury) difference in mechanical sprint variables obtained during a repeated-sprint test consisting of 6 x 30-meter maximal sprints. Mechanical sprint variables were: maximal horizontal force production (F_{H0}; N/kg), maximal theoretical sprinting velocity (V_0; m/s), maximal horizontal power output (Pmax; W/kg), and mechanical effectiveness measured as the rate of decrease (slope) in ratio of force with increasing speed (D_{RF}).[20] Furthermore, we also analyzed the between-group difference in horizontal force production and maximal theoretical sprinting velocity extracted from the first sprint, since a single sprint effort is also considered important for match play.[10]

Data collection

Thirty-meter repeated sprint performance was measured using a high-speed 240 Hz iPhone 6 camera (Apple Inc., USA) and the *MySprint* application.[23] *MySprint* has shown high inter-tester reliability (intraclass correlation coefficient (ICC): 0.998) and concurrent validity with timing photocells (Pearson's product-moment correlation (*r*): 0.989-0.999) and radar gun measurement (*r*: 0.974-0.999).[23] Participants performed a repeated sprint test consisting of 6 × 30-meter maximal sprints, while starting from a crouched position (staggered-stance) with one hand placed on the starting line.[23] Each sprint trial was separated by 90 seconds of rest to ensure adequate recovery of heart rate and thus facilitate maximal intensity in each sprint trial.[24] A rater blinded to previous hamstring strain injury history, analyzed sprint data in the *MySprint* application, which then automatically calculated the mechanical sprint variables (F_{H0}, V_0, Pmax, D_{RF}) for each trial using a field-based method.[25]

Bias

To reduce potential bias related to sampling of participants, at least one player with and without a previous hamstring injury in each club were included.

Sample size considerations

Due to the convenience sampling and explorative nature of this study, an a priori sample size calculation was not performed. Thus, the sample size was based on the number of initial contacted clubs and participants who accepted to participate in the study.

Statistical analyses

Data analyses was performed in SPSS (v. 23, IBM Corporation, New York, USA). Mean differences in mechanical sprint variables (F_{H0}, V_0, Pmax, D_{RF}) obtained during the repeated-sprint test was analyzed using a mixed model analysis of variance (Mixed ANOVA) to test for interaction between groups (players with versus without a previous hamstring injury) and time (repeated sprints). As Mauchly's test of sphericity was violated for all variables, the Greenhouse-Geisser correction was applied to adjust p-values for all interaction effects. If no significant interaction effect was observed, main effects of group was analyzed to investigate if an overall mean difference existed between groups. Independent t-tests were applied to test between-group differences in F_{H0} and V_0 extracted from the first sprint. Effect sizes were calculated for main effects using Cohen's d as $\frac{Between-group\ difference}{Pooled\ standard\ deviation}$ and interpreted as trivial ($d < 0.2$), small ($d \geq 0.2$), medium ($d \geq 0.5$), and large ($d \geq 0.8$).[26] A significance level of 0.05 was applied for all statistical tests. Data are presented as mean values (SD, standard deviation), unless otherwise stated.

RESULTS

Participants

Forty-four sub-elite football players were included in the study from six football clubs during the in-season football period between October 2017 and November 2017. Thirty-three players reported no previous hamstring strain injury in the preceding 12 months, whereas eleven players reported a time-loss hamstring strain injury in the preceding

12 months; most injuries (81.8%) being of moderate severity. One to three players with a previous hamstring injury in each club and corresponding two to 10 players without a previous hamstring injury were included. At the time of testing, all participants had an average of 3-5 football training sessions each week including one match. An overview of demographic data, playing position, and injury severity is reported in Table 1.

Mechanical sprint variables

Sprint performance of the first sprint showed no between-group difference for horizontal force production (mean difference: -0.27 N/kg [-0.67; 0.13], $d = 0.35$, $p = 0.174$) or maximal sprinting velocity (mean difference: 0.43 m/s [-0.19; 1.04], $d = 0.77$, $p = 0.155$). An overview of absolute values is provided in Table 2.

For the repeated-sprint test, no significant interactions between groups and time were observed for any of the mechanical sprint variables ($p = 0.682$-0.860) (Figure 1 A-D, Table 2).

Main effects of groups showed a significant mean difference, corresponding to a medium effect size, for mean maximal theoretical sprinting velocity (V_0) in favor of players with a previous hamstring strain injury (mean difference: 0.45 m/s, 95% CI [0.06;0.85], $p = 0.025$, $d = 0.77$) and for mechanical effectiveness (Drf) (mean difference: 0.009, 95% CI: 0.001-0.016, $p = 0.020$, $d = 0.50$) (Table 3). The remaining variables showed no significant main effects with trivial to moderate effect sizes ($p = 0.099$-0.853, $d = 0.06$-0.51) (Table 3).

DISCUSSION

The results of the current study indicate that no interaction was present between football players with and without a previous self-reported hamstring strain injury for mechanical sprint variables obtained during a repeated 30-meter sprint test. This indicates that sprint acceleration performance (F_{H0}), maximal theoretical sprinting velocity (V_0), maximal horizontal power output (Pmax), and mechanical effectiveness behaved similarly from first to last sprint regardless of a previous hamstring strain

Table 1. *Demographic data, playing positions, and hamstring strain injury severity of included football players ($n = 44$).*

	Self-reported hamstring strain injury in preceding 12 months	
	No (n=33)	Yes (n=11)
Demography		
Age, years (SD)	23.2 (3.7)	25.6 (4.4)
Body mass, kg (SD)	77.5 (9.6)	79.6 (9.6)
Height, cm (SD)	181.6 (5.5)	181.2 (6.5)
Playing position		
Central defenders, no. (%)	6 (18.2)	1 (9.1)
Full-backs, no. (%)	4 (12.1)	3 (27.3)
Central midfielders, no. (%)	12 (36.4)	1 (9.1)
Wide midfielders, no. (%)	4 (12.1)	3 (27.3)
Attackers, no. (%)	7 (21.2)	3 (27.3)
Hamstring strain injury severity*		
Mild (< 1 week), no. (%)	-	1 (9.1)
Moderate (1-4 weeks), no. (%)	-	9 (81.8)
Severe (> 4 weeks), no. (%)	-	1 (9.1)

SD, standard deviation; *self-reported

Table 2. *Interaction effect of mechanical sprint performance variables during repeated sprints between football players with and without a previous hamstring strain injury (HSI) in the preceding 12 months.*

	30-meter sprint trials						Interaction effect, p-value
	1	2	3	4	5	6	
F_{H0} (N/kg)							
Previous HSI (n=11)	8.18 (0.43)	7.90 (0.38)	7.79 (0.76)	7.88 (0.77)	7.86 (0.59)	7.68 (0.61)	0.860
No previous HSI (n=33)	8.45 (0.84)	8.42 (1.00)	8.27 (0.99)	8.30 (0.90)	8.20 (0.91)	8.14 (0.68)	
V_0 (m/s)							
Previous HSI (n=11)	8.26 (0.90)	8.34 (1.00)	8.32 (0.97)	8.31 (0.96)	8.24 (0.89)	8.21 (0.91)	0.682
No previous HSI (n=33)	7.83 (0.40)	7.85 (0.41)	7.84 (0.42)	7.77 (0.44)	7.85 (0.56)	7.82 (0.43)	
Pmax (W/kg)							
Previous HSI (n=11)	16.92 (2.35)	16.46 (1.97)	16.20 (2.52)	16.40 (2.74)	16.22 (2.40)	15.85 (2.72)	0.782
No previous HSI (n=33)	16.55 (1.88)	16.50 (1.98)	16.23 (2.16)	16.14 (2.06)	15.97 (1.97)	15.90 (1.69)	
D_{RF}							
Previous HSI (n=11)	-0.093 (0.010)	-0.089 (0.013)	-0.088 (0.014)	-0.089 (0.012)	-0.089 (0.011)	-0.088 (0.008)	0.687
No previous HSI (n=33)	-0.101 (0.011)	-0.099 (0.014)	-0.092 (0.039)	-0.100 (0.011)	-0.098 (0.011)	-0.097 (0.009)	

F_{H0} (N/kg), maximal horizontal force production; V_0 (m/s), maximal theoretical sprinting velocity; Pmax (W/kg), maximal horizontal power output; D_{RF}, mechanical effectiveness measured as the rate of decrease (slope) in ratio of force with increasing speed.

injury. Despite no interaction effect, we observed a significant main effect of group, that is a between-group mean difference for repeated sprints, for maximal theoretical sprinting velocity (V_0) and mechanical effectiveness favoring the group of players with a previous hamstring strain injury (higher V_0 compared to controls). For the remaining variables, no main effects of group were observed for horizontal force production ($d = 0.51$), maximal horizontal power production ($d = 0.06$). Collectively, these findings indicate that players with a previous hamstring strain injury seem to maintain a higher maximal sprinting velocity during repetitive sprinting, whereas no difference seem to exist for sprint acceleration, strength and power.

Sprint acceleration performance

Sprint performance is considered an important parameter for football players[9] with assessment recommended as a vital part of the return to play criteria after a hamstring strain injury.[19] Few studies have investigated single and repeated-sprint

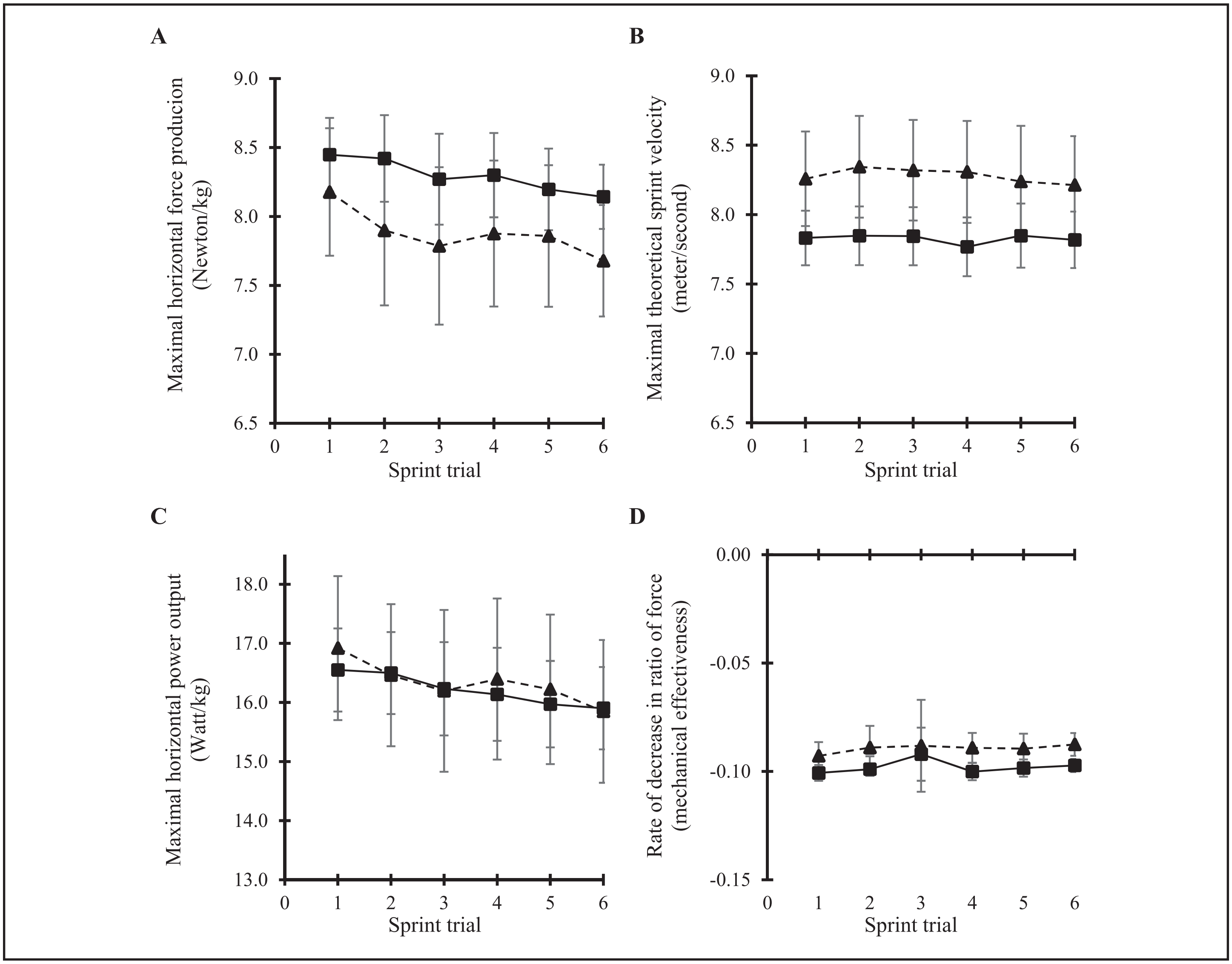

Figure 1. *Repeated sprint performance in players with (dotted lines) and without (thick lines) a previous hamstring strain injury measured during 6 30-meter sprint. A) Maximal horizontal force production; B) Maximal theoretical sprint velocity; C) Maximal horizontal power output; D) Rate of decrease in ratio of force (mechanical effectiveness). Error bars depict 95% Confidence Intervals.*

performance in football players following a hamstring strain injury.[17,18,27] Mendiguchia et al.[17] observed a large deficit ($d = 0.85$) in horizontal force production during a single sprint effort at the time of return to football after a hamstring strain injury compared to non-injured players; however, this was normalized after two months indicating that regular football play is sufficient to restore sprint acceleration performance. In the present study the authors observed a lower, but non-significant, horizontal force production in the first sprint in previously injured players corresponding to a small effect size ($d = 0.35$). Since the time from return to play is unknown in the present study, this may explain the discrepancy between study findings.[17] Interestingly, the potential deficit in horizontal force production observed in the present study was more pronounced during the repeated-sprint test with a medium ($d = 0.51$) between-group difference. Thus, it could be speculated if a single sprint effort is adequate to capture potential performance deficits after injury. Røksund et al.[27] observed a higher drop in

Table 3. *Main effect of group on mechanical sprint performance variables during repeated sprints between football players with and without a previous hamstring strain injury (HSI) in the preceding 12 months.*

	Previous HSI (n=11)	No previous HSI (n=33)	Between-group mean difference, [95% CI], Cohen's *d*	Main effect, p-value
F_{H0} (N/kg)	7.88 (0.60)	8.30 (0.89)	- 0.42 [-0.92; 0.08], *d*=0.51	0.099
V_0 (m/s)	8.28 (0.90)	7.83 (0.44)	0.45 [0.06; 0.85], *d*=0.77	0.025
Pmax (W/kg)	16.34 (2.39)	16.21 (1.98)	0.13 [-1.24; 1.49], *d*=0.06	0.853
D_{RF}	-0.089 (0.012)	-0.098 (0.019)	0.009 [0.001; 0.016], *d*=0.50	0.020

F_{H0} (N/kg), maximal horizontal force production; V_0 (m/s), maximal theoretical sprinting velocity; Pmax (W/kg), maximal horizontal power output; D_{RF}, mechanical effectiveness measured as the rate of decrease (slope) in ratio of force with increasing speed.

20-meter sprint performance from the first to last sprint during eight repetitive sprints in players with a previous hamstring strain injury compared to controls. Lord et al.[18] observed a greater loss of horizontal force production, indicating impaired sprint acceleration ability, in previously injured Australian football players following a repeated-sprint test consisting of ten 6-second sprints. Greater loss of sprint acceleration performance during repetitive sprinting after a hamstring strain injury, could be linked to the essential role of the hamstring muscles to generate forward oriented ground reaction forces.[28] In that regard, lower maximal eccentric hamstring strength,[4] early knee-flexion rate of torque development,[5] and biceps femoris long head activation in the late swing-phase [29] have been observed after a hamstring strain injury; factors that could all negatively affect sprint acceleration performance.[11,13] Additionally, altered hamstring muscle activation have also been documented during fatiguing exercises[8] leading to reduced fatigue resistance.[6] Since maximal sprinting is associated with substantial hamstring muscle activation,[30] it can be speculated if repeated maximal sprint efforts may amplify neuromuscular deficits in the previously injured leg,[31] leading to reduced sprint performance.[18,27] Furthermore, it could be speculated if injury severity - being the duration from onset of injury until return to sport – could affect sprint performance. Thus, football players with a hamstring injury lasting > three weeks have considerably lower eccentric hamstring muscle strength in the beginning of the season compared to players with no or less severe hamstring injuries.[45] Since most injuries in the present study were classified as moderate severity (one to four weeks) with only one injury > four weeks, sprint performance in more severe cases was unable to be analyzed.

Surprisingly, no interaction between groups on horizontal force production were observed, indicating that players with a previous hamstring strain injury did not show different sprint acceleration performance over time compared to the control group. This is in contrast to previous studies but may be explained by the longer rest period of 90 seconds between each sprint in the present study compared to only 24-30 seconds in previous studies.[18,27] Longer rest periods could minimize metabolic muscle depletion and fatigue from first to last sprint compared to shorter rest periods.[24]

Maximal sprinting velocity

No interaction for maximal theoretical sprinting velocity were observed, indicating that maximal velocity did not change differently from first to last sprint between groups. Despite this, a significantly higher mean maximal theoretical sprinting velocity was observed over the six repeated sprints in players with a previous hamstring strain injury; a similar difference, although not significant, was also observed for the first sprint (first sprint

$d = 0.77$ vs. repeated sprint $d = 0.77$). This could indicate that a single sprint effort is sufficient to assess maximal sprinting velocity after injury. The observation of no deficit in maximal theoretical sprinting velocity in previously injured players are consistent with previous research reports; in Røksund et al.,[27] football players with a previous hamstring strain injury showed slightly lower, although not significant, sprint time (5.25 s vs. 5.35 s) during a 40-meter sprint, whereas only a small deficit in maximal theoretical sprinting velocity seem to exist at the time of return to play after a hamstring injury in football players.[17] Collectively, these data suggest that players with a previous hamstring strain injury do not seem to be severely affected on maximal sprinting velocity.[17,27] From a performance point-of-view, this is an important observation considering that the majority of goals in football are preceded by a maximal or near-maximal sprint effort of the scoring or assisting player.[10] Given the role of the hamstring muscles during sprinting it may, however, seem surprising that maximal sprinting velocity appear to be unaffected by a previous hamstring strain injury in our cohort despite likely impairments in maximal[4] and explosive[5] hamstring strength. Several explanations may account for this observation; from the sprint acceleration phase to the maximal velocity phase, the body transits from a crouched position to an upright position potentially limiting the hamstring muscles in effectively applying horizontal forces onto the ground to increase sprinting velocity. In that regard, lack of association has been observed between maximal and explosive hamstring muscle torque and maximal sprinting velocity,[13] while contradicting data exists for the role of hamstring muscle strength training on sprint performance at long distances (>30 meter).[14,32] Thus, the ability to rapidly transfer horizontal propulsive force onto the ground at high sprinting velocity could likely rely on other muscle groups as well[33] or be achieved by improved technical ability of the athlete rather than exclusively reflecting hamstring muscle function per se.[20] In line with this, slightly better mechanical effectiveness, that is less loss of horizontal force application with increasing sprinting velocity,[20] were observed in players with a previous hamstring strain injury.

Clinical implications

Hamstring reinjury rate is estimated to be approximately 13% within a two month period from return to football play,[34] and more than 50% of reinjuries occur within the first month after return to football play with 79% being in the same anatomical location as the index injury.[35] This suggests incomplete healing of the tissue, which may predispose an athlete to increased risk of reinjury. Most acute hamstring strain injuries happen during high-speed running[36] with large and rapid increases in high-speed running load, likely present in the initial phase after return to play, predisposing the athlete to the potential for a hamstring injury.[37] The combination of high maximal sprinting velocity and neuromuscular deficits after a hamstring injury could likely put players at increased risk of sustaining a recurrent injury due to the high musculotendon load/strain associated high sprinting velocity.[38] Thus, lower eccentric hamstring strength is often found after injury,[4] which could lower the capacity of the muscle fibers to absorb energy before failure occurs.[39] Furthermore, lower electromyography activity has been reported during sprinting in athletes with a previous hamstring strain injury,[29] potentially increasing the susceptibility to injury due to a lower tolerance of the myotendinous junction to withstand force.[40] This means that post-injury deficits may not necessarily be manifested as impaired sprint performance after return to play as observed in the present study. Thus, preventions programs such as the Nordic Hamstring protocol, that have been shown to lower the risk of recurrent hamstring injuries by up to 85%,[41,42] should be considered essential after return to play despite no apparent reductions in sprint performance. In addition, focusing on gradually improving sprinting capacity by exposing the athlete to maximal sprinting velocity during rehabilitation to prepare return to sport, may also be a viable way to improve the resilience of the hamstring muscles, and potentially target the muscle activation deficits.[30,43] Based on the present study, it could also be speculated if football players with a higher sprinting velocity is at increased risk of initial hamstring injury, due to the higher biomechanical load associated with higher sprinting velocity.[38,44] For such players, improving hamstring capacity using both high-load exercises and regular exposure to high-speed running may be essential.

Methodological considerations

The present study is not without limitations: first, due to the explorative approach no a-priori sample size calculation was performed, and instead eligible players were recruited based on convenience sampling from clubs in the Greater Copenhagen area. Thus, the present study may be under-powered to detect differences between groups. Based on previous findings of lower horizontal force production/sprint acceleration performance after a hamstring injury[17,18,27] it could be speculated if the lower ($d = 0.51$), but non-significant ($p = 0.099$), horizontal force production observed in the present study may represent a type-2 error. Second, due to the cross-sectional design, no causal inference can be made between previous hamstring injury and sprinting performance. Third, since all injuries were self-reported and obtained retrospectively the present study is prone to recall bias. Fourth, although all players participated fully in football training and matches at the time of testing, the variation in injury duration and time since return to play may have influenced their sprinting ability.[17]

CONCLUSION

Football players with and without a previous hamstring strain injury did not differ on sprint acceleration performance and maximal horizontal power whereas higher mean maximal theoretical sprinting velocity and better mechanical effectiveness during six repeated sprints were found for the players with a previous injury. Thus, common post-injury deficits are not manifested as impaired performance cross-sectionally compared to matched controls. The combination of higher sprinting velocity and neurophysiological deficits commonly found after a hamstring injury may increase the risk of recurrent injuries.

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