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Title: **Sprint Running Mechanics are associated with Hamstring Strain Injury: a 6-month prospective cohort study of 126 Elite Male Footballers**

Contributorship Statement: All authors have been active in reviewing the manuscript and have given final approval for publication. CB led the conception of the research design, delivery and writing of the manuscript. TDS was involved in the initial conception of the research design, data collection, analysis and revising the manuscript. SR was involved in the participant recruitment process, data collection and revising the manuscript, ACC was involved in the data analysis, interpretation of the data, reviewing and revising the manuscript. CB is the principal investigator and guarantor.

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Data Sharing Statement: All data relevant to the study are included in the article or uploaded as supplementary information.

What is already known on this topic:

- Sprint running mechanics have been suggested as a consideration in hamstring injury prevention practices.
- Evidence of an association between sprint running mechanics and hamstring injury using prospective designs is limited.

What this study adds:

- This is the first study to identity sprint running mechanics to be associated with future hamstring strain injury in elite men's English Football.
- Higher scores on the Sprint Mechanics Assessment Score (S-MAS) were associated with new hamstring injuries.
- When adjusting for the confounding effects of previous injury and age, there was a 33% increase in hamstring strain injury rate with every one-point increase in S-MAS across a six-month time-period.
- S-MAS scores above 5.5 had a sensitivity of 78.6% and specificity of 65.4% for new hamstring injuries.

How this study might affect research, practice or policy:

- The time-efficient nature of the S-MAS means this method can be integrated into regular in-season screening practices to evaluate sprint kinematics as part of performance assessments, injury screening and rehabilitation.
- Screening sprint mechanics within rehabilitation and injury prevention may be beneficial considering their association to new hamstring injuries, although the modification of prevention programs based on the S-MAS requires further study.

- Given the multifactorial nature of injury development, sprint mechanics should be assessed within holistic screening programs alongside other factors such as physical qualities, individual characteristics and training loads.

Sprint Running Mechanics are associated with Hamstring Strain Injury: a 6-month prospective cohort study of 126 Elite Male Footballers

ABSTRACT

Objective: To investigate the association between sprint running biomechanics and sprint-related hamstring strain injury (HSI) in elite male football players.

Methods: This prospective cohort study recruited 126 professional male football players from eight clubs in the English football league, who were followed across a 6-month period. Maximal velocity sprint running videos (240fps) were collected from five teams during pre-season (June to August) and three teams during the in-season period (October to March), and subsequently assessed using the Sprint Mechanics Assessment Score (S-MAS) by a single, blinded assessor. Sprint-related HSI within the previous 12 months and any new MRI confirmed sprint-related HSI were reported by club medical staff. Incidence rate ratios were calculated using a Poison regression model to determine the association between S-MAS and new sprint-related HSIs.

Results: There were 23 players with a previous sprint-related HSI and 17 new HSIs during the follow up period, with 14 sprint-related injuries. S-MAS values were significantly greater amongst players with a previous HSI (median difference (MD): 1, p=0.007, 95%CI: 0 to 3) and those sustaining a new sprint-related HSI (MD: 2, p=0.006, 95%CI: 1 to 3) compared to uninjured players. Adjusting for age and previous injury found a significant association between the S-MAS and prospective sprint-related HSIs, with an adjusted incidence rate ratio of 1.33 (95%CI: 1.01 to 1.76) for each one-point increase in S-MAS.

Conclusion: This is the first study to identify an association between sprint running kinematics and prospective sprint-related HSI in elite male football players. Sprint running mechanics assessed using the S-MAS were associated with both past and future HSIs with a 33% increase in the risk of a new HSI with every one-point increase in S-MAS. Given the association to injury, evaluating sprint mechanics within rehabilitation and injury prevention may be warranted.

INTRODUCTION

Over the past two decades, hamstring strain injury (HSI) rates in professional football have continued to rise: accounting for 12% of all injuries in the 2001/02 English football season, increasing to 24% in the 2021/22 season (1). This corresponds with a 10 percentage point increase in the proportion of all injury absence days due to HSI (1), which can have significant financial and performance implications for professional football teams (2). Consequently, there is a need to identify potential factors that can be targeted within injury prevention practices.

Several risk factors for HSI have been identified within existing literature, including previous hamstring injury (3), age (3), eccentric hamstring muscle strength (4), muscle fascicle length (3, 5), and sudden increases in sprint running exposure (6). As sprint running is considered the primary mechanism for HSI (1, 7), the role of biomechanics in injury development has been widely debated (8). Conditioning coaches, physiotherapists (9, 10) and expert opinion articles frequently recommend modifying sprint mechanics within injury prevention and rehabilitation programmes (8, 11-14); however, the available prospective evidence to support the association between sprint mechanics and HSI remains inconclusive.

Biomechanical factors are thought to influence HSI by altering the mechanical stress and/or strain applied to the hamstrings (15). While kinetic factors have been linked to HSI (16, 17), the majority of existing literature has focused upon sprint kinematics. Kinematic features such as increased anterior pelvic tilt (18), thoracic side flexion during swing (18, 19), along with altered neuromuscular activity of trunk and pelvis musculature (20, 21) have been observed in individuals sustaining future HSIs. However, these studies are frequently limited by small sample sizes and a reliance upon three-dimensional motion capture (3DMoCap) technology. Whilst considered the gold standard for biomechanical assessments, 3DMoCap is difficult to implement in most team-sport settings due to the high equipment cost, time-consuming nature of assessments and the need for dedicated laboratory space. Consequently, this limits the practical ability to screen athletes as part of injury risk mitigation and rehabilitation processes.

The Sprint Mechanics Assessment Score (S-MAS) is a 12-item qualitative movement screening tool developed for the in-field assessment of kinematic features associated with HSI (22). The score uses slow-motion video analysis to evaluate the overall movement quality of an individual's sprint running mechanics; with higher scores indicating sub-optimal movement patterns. Although its validity against 3DMoCap has not yet been established, the S-MAS has demonstrated good inter- and intra-tester reliability (Intraclass Correlation Coefficients (ICC) of 0.799 and 0.828 respectively) (22). The practical nature of this assessment tool means that it could potentially be integrated into clinical practice to identify individuals who demonstrate biomechanical patterns associated with HSI. However, the association between the S-MAS and HSI is not yet known.

The aim of this study was to investigate the association between sprint running kinematics, using the S-MAS, and both retrospective and prospective HSI in elite male football players.

METHODS

Study design

This prospective cohort study was conducted between June 2022 and March 2024 with clubs followed over a 6-month period following initial enrolment. Methodological reporting was completed in accordance with the STROBE checklist (23). Ethical approval was received from the University of Salford ethics committee (Reference: 5583), and all participants provided written informed consent prior to participation.

Participants

Outfield players at professional football clubs across various leagues within the English Football League system were eligible for participation within this study. To be included, participants were required to be medically cleared for full training and match play at the start of the study and provide written informed consent. Participants were excluded if they were under the age of 18 or returning from surgery within the previous six months. Goalkeepers were excluded due to their limited exposure to sprint running. Football clubs within the professional network of the authors were invited to participate in this study. Nine clubs agreed with one excluded as players did not meet the age criteria.

Data from one club collected in the first round of data collection were used within a power calculation to estimate sample size required for a dichotomous outcome (24) (G*Power, 3.1): 100 participants were needed to achieve a 90% power at type 1 error (two-sided α) of 5%, based on an injury prevalence of 22% in the pilot data and an enrolment ratio of 1:4 (injured: uninjured).

Sprint Running Data Collection

Sprint running data were collected during two 35 metre maximal effort sprints from all participants. Data from five teams were collected during the pre-season period (June to August) and three teams in-season (October to March). Participants first completed a 15–20-minute warm-up led by the club’s sports science team, followed by sub-maximal sprint runs at 80% and 90% of maximum effort. Two maximum effort 35-metre sprint running trials were then recorded using a slow-motion camera sampling at 240fps (iPhone 13 pro, Apple). All running trials were completed on synthetic artificial field-turf or grass football pitches, with participants wearing their own sport-specific footwear. Witty Photocell timing gates (Micrograte, USA) were positioned between 25–30 metre to monitor maximal running speed. The camera was positioned on a tripod 0.8m high and 7m perpendicular to the capture volume (Figure 1). Two sprint trials were collected to ensure a clear video was obtained of the right and left limb respectively.

S-MAS Scoring

Sprint running trials were assessed against the S-MAS by a single blinded assessor (biomechanist with 10 years experience). The S-MAS is a 12-item composite score, evaluating movement patterns across the gait cycle against specific criteria (22) (supplementary file 1). Videos were viewed using computer software Kinovea (version 0.9.5) allowing footage to be played in slow motion and paused at appropriate points of the gait cycle. Using a dichotomous scoring system, players are scored one point for the presence, and zero points for the absence of each of the 12 kinematic features. Scores are summed to produce a total rating of overall movement quality, with scores of zero indicating optimal mechanics and 12 for sub-optimal. The S-MAS has been shown to have good inter-tester (ICC: 0.799, 95%CI: 0.642 to 0.892) and intra-tester reliability (ICC: 0.828, 95%CI: 0.688 to 0.908), with a standard error of measurement of one point (22).

Hamstring Injury Reporting

HSIs were included in both the retrospective and prospective data analysis providing they were non-contact and sustained during sprinting in either training or match-play.

For the retrospective analysis, players self-reported any hamstring injury within the previous 12 months, the affected limb (left, right, bilateral), and injury mechanism (sprint running, tackle, kicking, stretch, other), which were subsequently confirmed by club medical staff.

For the prospective analysis, clubs were followed over a 6-month period, reporting monthly occurrence of any new HSIs. Prospective injuries were diagnosed by club medical staff and radiologically confirmed via magnetic resonance imaging (MRI). Club staff reported details including: injury mechanism, situation (training or game-play), affected limb, muscle injured (biceps femoris, semitendinosus, semimembranosus), and the grade of each HSI classified using the British Athletics Muscle Injury Classification System (BAMIC) (25). At the end of the six-month follow up period clubs were contacted to discuss if any of the players sustained any severe time-loss injury that was not a HSI, defined as an injury resulting in absence from training and games for more than 28 days, or repeated bouts (two or more) of moderate injuries ranging between eight and 28 days, based on published injury severity ratings (26). These players were subsequently excluded from the uninjured group in the final prospective analysis. This exclusion criteria aimed to remove participants with reduced training exposure due to the potential confounding affect this may have on both sustaining and not sustaining a future HSI.

Equality, Diversity, and Inclusion

Our author group is comprised of individuals of diverse genders, ethnic groups and professional backgrounds including both male and female authors, senior and early career researchers. Professional backgrounds include a physiotherapist, sports scientist, statistician, and a strength and conditioning coach. While the study focused on a male population, efforts were made to recruit female clubs of a similar level. However, challenges such as refusal to participate, lack of response, and limited access to medical and MRI facilities for HSI verification limited participation.

Patient and Public Involvement

Patient and public involvement occurred throughout the design and delivery of this research. Specifically, practitioners working in football were involved in establishing the research priority and question with feedback and consultation sought to develop and refine the outcome measures used and research methodology.

Statistical Analysis

Statistical analysis were performed in Stata (release 13, College Station, TX: StataCorp LLC) with figures created in JASP (version 0.18.1, University of Amsterdam), aligning with the CHAMP statement (27). Data normality was assessed using the Shapiro-Wilk test and Q-Q plots, and homogeneity of variance assessed using Levene's test. Differences between participant characteristics for uninjured and injured groups were determined using independent t-tests (normally distributed variables) and Mann-Whitney-U tests (non-normally distributed variables) in both retrospective and prospective analysis.

For the retrospective analysis, differences in S-MAS values were compared between uninjured players (PREV-UNINJ) and players with a sprint-related HSI in the previous 12 months (PREV-INJ) using Mann-Whitney-U tests. In the prospective analysis, new MRI confirmed sprint-related HSIs were considered the primary outcome with S-MAS the independent variable. Participants who sustained a new sprint-related HSI were included in the injured group (PROSP-INJ) with Mann-Whitney-U tests used to compare S-MAS values between this group and those who remained uninjured throughout the 6-month follow up period (PROSP-UNINJ). S-MAS scores for injured players were taken from the video positioned on the same side of the injured limb, and compared to a randomly selected limb of uninjured players using a random cell selector function in Microsoft Excel.

Effect sizes were calculated with Hedges' g and interpreted as 0.2 small, 0.5 medium and 0.8 large (28). Kruskal-Wallis test with post-hoc Dunn's correction was used to compare S-MAS values between sub-groups of players with a first-time sprint-related HSI, previous sprint-related HSI and uninjured players.

In the prospective analysis, the continuous S-MAS variable was entered into a Poisson regression model as a predictor variable for new sprint-related HSIs (outcome variable) (29). Age and previous hamstring injury were included in an adjusted model as potential confounders based on a prior systematic review identifying these variables as having the strongest association to prospective HSI (3). Poisson regression model was selected to estimate adjusted incidence rate ratios for sprint-related HSIs over the 6-month follow up period, as it is well suited for modelling the incidence of discrete events within a fixed time frame.

Receiver operator characteristic (ROC) curves were used to determine a cut-off threshold for the S-MAS, defined as the value yielding the best combined sensitivity and specificity (30). This categorical variable was entered into a separate Poisson regression model to determine the association between S-MAS as a categorical variable and prospective sprint-related HSI.

RESULTS

Population

A total of 126 professional male football players agreed to participate from eight clubs in the English Football League; including three Premier League (first team n = 9, academy n = 22), one Championship (n = 24), two League 1 (n = 22), one League 2 (n = 25), and one National League (n = 24) club. Figure 2 illustrates participant flow throughout the study. In the retrospective analysis, 118 players were included with 23 players in the PREV-INJ group (height: 180.4cm, mass: 79.5kg) and 95 in the PREV-UNINJ group (height: 182.6cm, mass: 78.4kg). For the prospective cohort analysis, 118 participants were followed across a six-month period, seven were lost to follow up (5.9%) with 16 (13.5%) players excluded from the uninjured group due to sustaining a severe time loss injury or repeated bouts (two or more) of moderate injuries or illness which were not HSIs. 17 new HSIs occurred across the follow up period, 14 of which were sprint related. The three non-sprint related HSIs were excluded from the final analysis, leaving a total of 92 participants with 14 participants in the PROSP-INJ group (height: 182.1cm, mass: 79.1kg) and 78 in the PROSP-UNINJ group (height: 181.9cm, mass: 78.1kg).

Retrospective Analysis

Of the 118 participants included no significant differences were found for age, mass, height or maximal running speed between the PREV-INJ group (n = 23) and the PREV-UNINJ group (n = 95) (Table 1). Significant, trivial to large differences were observed between groups for the S-MAS (p=0.007, *Hedges' g* = 0.17 to 1.1), with median score of five in the PREV-UNINJ and six in the PREV-INJ group.

*Table 1:Mean (standard deviation) for normally distributed variables; Median (interquartile range) for non-normally distributed variables; T-test for normally distributed variables; Mann-Whitney-U test for non-normally distributed variables. 95% confidence intervals (CI) were calculated using the Hodges-Lehmann estimates. *Statistical significance at p<.05, †Denotes non-normally distributed variables, assessed using Mann-Whitney-U test.*

Variable	**Total (n=118)**	**PREV-INJ (n=23)**	**PREV-UNINJ (n=95)**	**Between group difference (95% CI)**	**p-value**
Age (years)†	21 (19, 25)	20 (19, 25)	21 (18, 25)	1 (-1 to 2)	0.474
Mass (kg)	78.8 (7.7)	79.5 (5.9)	78.4 (8.0)	-1.1 (-4.8 to 2.6)	0.556
Height (cm)	182.2 (6.0)	180.4 (6.4)	182.6 (5.8)	2.2 (-0.5 to 5.0)	0.109
Maximal running speed (m/s)†	8.9 (8.3, 9.3)	8.8 (8.3, 9.4)	8.9 (8.3, 9.3)	0 (-0.4 to 0.4)	0.984
S-MAS†	5 (2, 7)	6 (6, 7)	5 (2, 7)	1 (0 to 3)	0.007*

Prospective Analysis

Table 2 provides details on the frequency, mechanism and grade of all 17 HSIs sustained during the follow up period. 92 players were included in the final analysis with significant, small to large differences were observed between PROSP-UNINJ (n = 78) and PROSP-INJ (n = 14) groups for the S-MAS (p=0.006, *g* = 0.22 to 1.37) (Figure 3), with a median S-MAS of four in the PROSP-UNINJ compared to six in the PROSP-INJ group. Comparisons between players with a first-time sprint-related HSI (n = 8) compared to PROSP-UNINJ revealed a statistically significant difference of three S-MAS points (median: 7 vs. 4, p=0.017) (Figure 4).

The continuous S-MAS variable was significantly associated with a higher rate of new sprint-related HSIs, with an incidence rate ratio of 1.38 (95%CI: 1.06 to 1.79; p=0.017). After adjusting for age and previous HSI, the incidence rate ratio remained significant at 1.33 (95% CI: 1.01 to 1.76; p=0.044). Indicating that each one-point increase in S-MAS corresponded to a 33% increase in the risk of developing a new sprint-related HSI during the follow up period.

ROC curves indicated S-MAS values of 5.5 produced the highest combined sensitivity (78.6%) and specificity of (65.4%) with an area under the curve of 0.732. Therefore, players were categorised into groups with a score of ≥6 or with scores of ≤5 to calculate incidence rate ratios for S-MAS as a categorical variable. The incidence rate ratio for a new sprint-related HSI associated with the categorical S-MAS variable was non-significant (p=0.065, IRR 2.8, 95%CI: 0.94 to 8.35).

Table 2: Hamstring injury details for all injuries including player position, injury location, grade, injury scenario and the mechanisms of injury. CD = central defence, CM = central midfield, FB = full back, FW = forward. BFSH = biceps femoris short head, LHBF = long head biceps femoris, ST = semitendinosus.

Injury Number	Player Position	Injury Location	BAMIC Grade	Injury Scenario	Mechanism of Injury
1	CM	LHBF	3c	Training	Sprint
2	FW	LHBF	2c	Training	Sprint
3	CM	BFSH	2b	Game	Sprint
4	CM	LHBF	3c	Game	Sprint
5	FB	ST	2b	Training	Sprint
6	CD	LHBF	2c	Game	Sprint
7	FB	LHBF	2b	Training	Sprint
8	CM	LHBF	3b	Game	Sprint
9	FW	LHBF	2b	Game	Stretch/ Kick
10	FW	LHBF	1b	Game	Sprint
11	CM	LHBF	1b	Game	Deceleration
12	CM	LHBF	4c	Game	Sprint
13	CM	LHBF	2c	Game	Sprint
14	CM	LHBF	2b	Game	Tackle
15	CD	ST	2b	Training	Sprint
16	FW	LHBF	1b	Game	Sprint
17	CM	LHBF	2b	Training	Sprint

*Table 3: Mean (standard deviation) for normally distributed variables; Median (interquartile range) for non-normally distributed variables. T-test for normally distributed variables; Mann-Whitney-U test for non-normally distributed variables. 95%CI were calculated using the Hodges-Lehmann estimates. *Statistical significance at p<.05, †Denotes non-normally distributed variables, assessed using Mann-Whitney-U test.*

Variable	Total (n=92)	PROSP-INJ (n=14)	PROSP-UNINJ (n=78)	Between group difference (95% CI)	p-value
Age (years)†	20 (18, 25)	21 (20, 25)	20 (18, 24)	1 (-1 to 3)	0.211

Mass (kg)	78.2 (7.4)	79.1 (7.1)	78.1 (7.5)	-1.0 (-5.3 to 3.3)	0.643
Height (cm)	182.0 (5.6)	182.1 (6.1)	181.9 (5.6)	-0.2 (-3.5 to 3.1)	0.893
Maximal running speed (m/s)†	8.9 (8.3, 9.3)	8.4 (7.1, 9.1)	8.9 (8.6, 9.4)	-0.5 (-1.5 to 0.1)	0.120
S-MAS†	5 (3, 6)	6 (6, 7)	4 (2, 6)	2 (1 to 3)	0.006*

DISCUSSION

Main Findings

The main findings of the present study confirm that sub-optimal running kinematics, indicated by higher S-MAS values, which reflect lower sprinting movement quality, are associated with both past and future sprint-related HSI occurrence in elite male footballers (Figure 3). When adjusting for the potential confounding effects of previous HSI and age, incidence rate ratios indicate that for every one-point increase in S-MAS there was a significant 33% increase in sprint-related HSI rate across a six-month time-period, with values of 5.5 yielding a sensitivity of 78.6% and specificity of 65.4%.

Sprint Running Mechanics and HSIs

Mechanistically, HSIs are attributed to the interaction between applied mechanical strain and hamstring strain capacity, with running mechanics considered one factor influencing applied mechanical strain (15, 31). While modelling and cadaver studies support the theoretical link between mechanical features and hamstring strain (32-34), limited prospective studies have investigated their association to injury (3).

Of the available evidence, several kinematic, kinetic, and neuromuscular features have been linked to HSI development. These include lower maximal horizontal force production (16, 17), reduced trunk and gluteal muscle activity during swing (20), increased gluteus medius activity during stance (21), as well as increased anterior pelvic tilt (18) and thoracic side flexion during swing (18, 19). Our findings of greater S-MAS amongst prospectively injured individuals add to the existing evidence, further supporting the association between sprint running kinematics and HSI.

Association between S-MAS and Prospective HSIs

A novel aspect of the current study is the use of the S-MAS, which is a composite score evaluating the overall quality of sprint running mechanics via 2D analysis (22). This methodology contrasts prior studies that have predominantly focused on associations between singular biomechanical parameters and HSI using 3DMoCap (18, 19). The composite nature of the score aims to reflect the collective contribution of multiple mechanical features influencing the stress and strain applied to the hamstrings, which may not otherwise be accounted for when focusing on isolated biomechanical parameters (15). This is similar in approach to methods such as the Cutting Movement Assessment Score (35) and Landing Error Scoring System used for screening in anterior cruciate ligament injuries (36, 37) and aims to shift practitioner focus away from singular variables which in isolation may be insufficient to explain injury development.

When adjusting for age and previous HSI we found a 33% increase in the risk of sprint-related HSI for every one-point increase in S-MAS. This finding suggests that sprint running mechanics, as assessed using the S-MAS, represent a factor associated with future sprint-related HSI and supports the use of the composite nature of the score; with values of 5.5 or above considered the optimal cut off for determining those with "sub-optimal" mechanics. However, it is important to interpret this finding within the context of wider factors associated with HSI, particularly when considering the relatively low sensitivity (78.6%) and specificity (65.4%) of the S-MAS as an independent variable. While sprint running mechanics can influence the applied mechanical strain, physical and morphological factors including eccentric hamstring strength (4, 38) and muscle fascicle length (5) are also associated with the development of future HSIs. These factors influence the capacity of the muscle to tolerate applied strain and might thus act as effect-measure modifiers in the relationship between sprint mechanics and HSI. Therefore, in both a research and clinical context, it is important that sprint mechanics are not considered in isolation, but instead within a multifactorial context for HSI.

Rehabilitation Considerations

The current findings further suggest that sprint running mechanics are perhaps inadequately addressed during rehabilitation as players with a previous sprint-related HSI were found to have greater S-MAS compared to uninjured players in the retrospective analysis. Considering higher S-MAS values were also associated with prospective injury development, it highlights a potential need to consider sprint mechanics within rehabilitation and injury prevention processes to mitigate potential risk of injury and/or reinjury. This is perhaps more pertinent when acknowledging that previous injury can lead to ongoing physical and/or structural deficits, reducing the ability of the hamstrings to withstand strain induced from sub-optimal running mechanics.

Limitations

Importantly, we were unable to monitor individual training and game load demands that may have influenced exposure, or lack of exposure to potential injury-inciting events. To mitigate this risk, we excluded players from the uninjured group if they had sustained repeated moderate or severe time loss injuries that were not HSIs (e.g. ACL injures). The rationale for this was that these players would have significantly reduced participation in sprint running, limiting their exposure to the mechanisms associated with HSI. As such, it was felt including them within the uninjured group could confound the results, as their reduced exposure to sprint running would lower their likelihood of sustaining a HSI. However, this exclusion may have inadvertently removed players who, despite having optimal sprint technique, remain susceptible to injury. This is particularly relevant for faster athletes, where the mechanical demands imposed on the hamstrings place them at the upper limits of their physical capacity (39), increasing the risk of injury despite optimised running technique.

A further limitation of this study is that the power analysis was conducted using data that were also included in the final analysis. This approach was utilised to maximise participant numbers and ensure sufficient injury incidence rates. However, it is important to acknowledge that this introduces a post-hoc element to the power analysis, which may inflate the precision of effect size estimates. That said, the effects of using internal data for sample size calculations in binary data are generally minimal (40). To further address this, we have provided 95% confidence intervals to aid interpretation of the variability in the observed effect sizes and offer a more accurate representation of the results.

Despite demonstrating good intra- and inter-rater reliability (22), it is important to note that the S-MAS has not yet been validated against 3DMoCap. Furthermore, in the current study, the rater was an experienced biomechanist and as such it remains unknown whether these results are generalizable to scores by less experienced users.

Finally, players included in this study were from multiple different leagues and were not all monitored over the same period of the football season. Some were followed from pre-season to mid-season, and others over the latter half of the season. Consequently, injury risk may have varied between leagues and throughout the season due to non-mechanical factors such as changes in training load, match exposure, fatigue, and physical conditioning practices (13). These fluctuations may have influenced both the exposure to, and the capacity to withstand injury inciting events, which were not fully accounted for in the study design.

Therefore, future work should consider monitoring sprint running mechanics as part of multifactorial prospective designs, accounting for exposure and the time-varying confounding effect of additional variables such as eccentric hamstring strength and muscle architecture. The results from this study are also limited to male football populations, whether the S-MAS is associated with injury in female footballers, or other team sports requires further exploration.

Clinical Implications

The association between S-MAS scores and future HSI suggests there may be benefit in utilising the S-MAS in the screening and evaluation of sprint running mechanics. Several authors recommend assessing and addressing running mechanics as part of holistic hamstring injury prevention and rehabilitation strategies (8, 11, 13). However, there has previously been a lack of methods available for practitioners to assess running mechanics in practice, with methods restricted to 3DMoCap which is not feasible to use in team sport settings. In contrast, the S-MAS is a quick and reliable method with parameters easily visible using slow-motion video footage (Figure 5). Therefore, the S-MAS can be used in applied settings to evaluate, inform, and individualise training approaches based on sprint running mechanics.

Recent research highlights that targeted interventions can successfully modify sprint running mechanics (41, 42). Specifically, Mendiguchia et al (42) demonstrated a multimodal programme including technique training was effective in modifying mechanical features and improving sprint performance. Therefore, current methods can aid practitioners in the injury risk screening process, identifying individuals who may demonstrate “sub-optimal” movement patterns for which interventions can be targeted towards. However, whether interventions targeted towards sprint running mechanics can be successfully transferred to game-situations and reduce HSI rates remains unknown and represents a logical next step in research.

CONCLUSION

This is the first study to investigate the association between sprint running mechanics and prospective sprint-related HSI in elite male English Football. Sprint running mechanics, assessed using the S-MAS, were found to be associated with both past and future sprint-related HSI development. When accounting for age and previous hamstring injury there was a 33% increase in injury incidence risk for every one-point increase in S-MAS. The practical nature of the S-MAS means that methods used within this study can be integrated into clinical practice aiding practitioners with the screening of individuals who demonstrate mechanical patterns associated with HSI. However, practitioners should be aware that there are likely interactions with additional factors influencing both applied mechanical strain and strain capacity. Therefore, sprint running mechanics should be considered as part of multifactorial, holistic injury screening and risk mitigation practices.

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Figure Legends

Figure 1: Diagram showing the camera set-up and the perspective view from the camera of the running capture volume.

Figure 2: Flow diagram depicting participant flow through the study

Figure 3: Raincloud plot illustrating the distribution of S-MAS values amongst prospectively injured participants (PROSP-INJ) and uninjured (PROSP-UNINJ). Raw data points depict individual scores, a density estimate depicts the distribution of data and boxplots depict the median (solid central line), interquartile range (upper and lower box) and upper and lower limit of the interquartile range (whiskers). Data points outside of the whiskers represent outliers.

Figure 4: Raincloud plot illustrating the distribution of S-MAS values amongst subgroups within the prospective cohort. Previous injury includes data for individuals sustaining a new injury who had an injury in the previous 12 months, First Time Injury are those sustaining a new hamstring injury. Raw data points depict individual scores, a density estimate depicts the distribution of data and boxplots depict the median (solid central line), interquartile range (upper and lower box) and upper and lower limit of the interquartile range (whiskers). Data points outside of the whiskers represent outliers.

Figure 5: Illustrative example of S-MAS scoring for an injured player (A) and uninjured player (B). Using S-MAS criteria player A would score a total of 7 points out of 12 with 1 point awarded for each of the following criteria: trailing leg extension, lumbo-pelvic rotation, thigh separation at late swing, thigh separation at touch-down, shin angle and foot v centre of mass position at touch-down and vertical collapse at midstance. Player B would score 0 out of 12 points. MVP = maximal vertical projection.