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The Relationship Between Acute: Chronic Workload Ratio of High-Speed Running and Hamstring Injuries in Professional Footballers

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ABSTRACT

Hamstring strain injuries are common within professional footballers with high-speed running (HSR) being known to increase the likelihood of sustaining a hamstring injury. This study aimed to assess the acute: chronic workload ratio (ACWR) of HSR that preceded hamstring injuries in professional footballers. Global positioning system (GPS)-derived HSR distances and weekly ACWR were obtained from 18 footballers from one English Football League (EFL) club during the 2018-2019 season. Hamstring injuries were documented by the club's medical team and the ACWR data of the four weeks preceding each hamstring injury were analysed. The mean ACWR of injured players was calculated for the season along with the ACWR of the squad. Ten hamstring injuries were recorded in total, across eight of the 18 players (44%). The most common site of injury was the medial part of the hamstring (70%). At the time of injury the mean ACWR for injured players was 0.90, while the squad mean ACWR for the season was 1.04. In conclusion, this study evidenced a high prevalence of non-contact hamstring injuries over a competitive season within an EFL club. The majority of hamstring injuries occurred when the mean ACWR was below the squad mean ACWR for the season. The loading pattern of 'moderate to high' followed by 'low to moderate' ACWR was commonly observed in the four weeks prior to injury.

Keywords: Professional football, high-speed running, hamstring injury, GPS

INTRODUCTION

High speed running (HSR) is an integral part of all outfield positions in football (Malone et al., 2017) and has become an important key performance indicator, as it influences decisive moments in games (Arjol-Serrano et al., 2021, Barnes et al., 2014). In the modern era, footballers have a requirement to perform greater distances of HSR within games (Arjol-Serrano et al., 2021). However, HSR has been shown to contribute to hamstring injuries which is the most common time loss injury in football (Ekstrand et al., 2016). On average, professional footballers sustain two injuries per season, which causes them to miss approximately 37 days in a season (Ekstrand et al., 2011). Hamstring injuries have increased by approximately 4% each year since 2001 in men's professional football (Ekstrand et al., 2016) and sprinting is the most common action contributing to hamstring injuries (Opar et al., 2015). When

sprinting, hamstring injuries are commonly caused by excessive muscle strain during the eccentric contraction of the late swing phase of the running gait cycle (Danielsson et al., 2020). Malone et al. (2017) described the relationship between HSR and hamstring injuries as "U-shaped" as the risk of injury is increased when players are under or over exposed to HSR.

Acute: chronic workload ratio (ACWR) is frequently used to quantify spikes in training load to identify players at a higher risk of injury (Barnes et al., 2014). ACWR is typically calculated over a four week period and quantifies the acute workload (one week) versus the chronic workload (four weeks) (Bowen et al., 2020). Research has shown that the rapid increase or decrease in training load, and not the high or low workload of training itself, increases the likelihood of injury (Rogalski et al., 2013). Low load has been identified when the ACWR falls below 0.8 and high load when the ACWR exceeds 1.3 (Gabbett, 2016). An ACWR within the 'optimal range' (0.8-1.3) signifies small to moderate fluctuations in workload, whilst an ACWR above the optimal range signifies a large spike in workload. Bowen et al. (2020) found that the risk of injury was 5-7 times greater when the ACWR spiked very high or dipped very low. However, HSR and sprint distance failed to demonstrate similar findings. This concurs with the findings of Ehrmann et al. (2016) who found that footballers performed higher meterage per minute in the weeks leading up to their injury in comparison to their seasonal averages but did not find the same for HSR. Although it has been shown that running at higher speeds heightens the risk of injury (Ekstrand et al., 2016), there is contrasting evidence around ACWR of HSR and the relationship with hamstring injuries in professional football. The "optimal" chronic dose of HSR has yet to be quantified and is likely to be influenced by several variables, including the age of player, playing position and stage of the season (Hasan et al., 2021). There appears to be a paradox whereby exposing players to HSR provides robustness for players, although spikes in HSR increase the likelihood of obtaining a hamstring injury (Malone et al., 2017).

This study aimed to assess the weekly ACWR of HSR that precede hamstring injuries in EFL footballers. The HSR load during the four weeks leading up to each hamstring injury was assessed to investigate whether trends existed between HSR and injury.

METHODS

Participants

HSR and hamstring injury data were collected from male footballers (n = 18) from one English Football League (EFL) club during the 2018-2019 season. The club played within the fourth tier of the English football league system. All participants were full-time professional footballers (age: 23.2 ± 3.6 years, height: 179.0 ± 6.4 cm, weight: 81.4 ± 6.7 kg). Only outfield players were included in the study as goalkeepers did not have global positioning system (GPS) data and all participants were kept anonymous throughout the study.

Procedures

GPS technology was used to collect HSR data from all training sessions and competitive matches. The GPS units (Minimax S4 and Optimeye S5, Catapult Sports, Melbourne, Australia) were placed in bespoke vests between the scapulae of the players. Each GPS unit sampled at 10 Hz and the accelerometers sampled at 100 Hz. The use of 10 Hz GPS has shown to be more accurate for measuring HSR when compared to 5 Hz GPS units (Jaspers et al., 2018). Players completed four training sessions per week in general (Monday, Tuesday, Thursday, Friday) and played matches on the weekend (usually Saturday). Several weeks consisted of two games, one of which was completed in the early part of the week (e.g. Tuesday or Wednesday), and the second was completed on the weekend. Players who were not in the match-day squad often completed a training session on the day of the game to compensate for the missed workload.

Raw data files were downloaded by the clubs' sports scientist after each training session and match using the GPS software (Catapult Sprint, 5.1.7, Melbourne, Australia). Catapult GPS software has been shown to produce highly valid data for all locomotor variables analysed when comparing real time data collection and post session download data collection (r = .98–1.00) (Barrett, 2017). For sessions where data was unavailable for a player because of a player not having GPS data, not wearing a GPS unit, not completing the full training session, the data was excluded from the data set. GPS data was also used when players were involved in international games and reported back to the clubs' sports scientist, who added the data to the players' raw data file.

DATA ANALYSIS

High Speed Running

HSR was classified as the cumulated distance running at a speed >5.5 m/s (Abt & Lovell, 2009). Running at a speed above 5.5 m/s is commonly used as the threshold for HSR distance as it allows comparison across a squad regardless of fitness levels (Sweeting et al., 2017). However, it must be noted that individualised speed categories can also be used to provide a more accurate reading of a player's HSR distance (Abt & Lovell., 2009).
Weekly HSR ACWR of the week prior to injury was calculated for each player. This was calculated by exporting weekly HSR data for each player into a Microsoft Excel File. The weekly HSR distance was divided by the average HSR distance of the sum of the current week and the three weeks prior to calculate the weekly HSR ACWR.

$$\text{Weekly HSR ACWR:} \quad \frac{\text{Week 4}}{\text{Week 1} + \text{Week 2} + \text{Week 3} + \text{Week 4}}$$

The ACWR has been critiqued for exponentially magnifying the acute load as the acute term is present on both sides of the ratio (Impellizzeri et al, 2021). However, use of the ratio in the present study was deemed appropriate for the analysis, as in indication of weekly patterns of increase or decrease in acute weekly load. The weekly HSR ACWR was classified into discrete ranges as previously categorised by Bowen et al. (2020): very low <0.09, low 0.10-0.54, low to moderate 0.55-1.08, moderate to high 1.09-1.62, high 1.63-2.16, very high >2.17.

Hamstring Injuries

Hamstring injuries were classified as injuries to the hamstring muscle that caused any absence from training. All injury data was recorded by the clubs' physiotherapist. Hamstring injuries were described by the site of occurrence on the lower limb and the mechanism in which the player acquired the injury (e.g. 'contact' or 'non-contact'). Hamstring injuries were categorised as 'minimal' (1-3 days of football activity missed), 'mild' (4–7 days of football activity missed), 'moderate' (1–4 weeks of football activity missed) and 'severe' (4+ weeks of football activity missed) (Fuller et al., 2006). This is different to commonly used medical grading (I, II, III) (Ekstrand et al., 2013), where the average time loss for grade I hamstring injuries is 17 ± 10 days (Ekstrand et al., 2012). The clubs medical staff decided to sub-divide acute injuries this into 'minimal', 'mild' and 'moderate' to provide in-house classification and reference on observed injuries. When a hamstring injury was identified, the previous four weeks of HSR data was examined within Microsoft Excel to investigate ACWR of HSR. This process is identical to Duhig et al. (2016), who inspected the four weeks prior to the injury to assess the cause of injury. The mean ACWR over the season was calculated for the whole squad of players.

RESULTS

Injury Incidence

For the duration of the study, 10 hamstring injuries were recorded with eight of the 18 players (44%) suffering at least one hamstring related injury, two players had reoccurring injuries (Table 1). The most common site of injury was the medial part of the hamstring (70%) and all were 'non-contact' injuries. Regarding injury severity, two minimal, four mild and four moderate hamstring injuries were reported. More hamstring injuries (60%) occurred in the second half of the season (e.g. in 2019).

Hamstring injuries and high-speed running

All but one (player 7) of the hamstring injuries occurred when the weekly ACWR of HSR was in the 'optimal' ACWR range (0.8-1.3). At the time of injury, the mean ACWR of injured players was 0.90 ± 0.13. Mean ACWR over the whole season for the squad was 1.04 ± 0.05. Mean ACWR over the season was similar for players who suffered an injury (n = 8; 1.03 ± 0.05) versus those who stayed injury free (n = 10; 1.05 ± 0.06). Most injuries (80%) occurred when ACWR was below the squad average for the season. Although the weekly ACWR of HSR differed for each player leading up injury, all injured players except one (player 11) had a similar four week workload pattern leading up to injury. This workload pattern featured week(s) of 'moderate to high load' followed by week(s) of 'low to moderate' load prior to injury occurrence.

Table 1. Injury details and ACWR loading pattern of HSR

Player	Date of injury	Injury site	Injury severity	Weekly HSR ACWR of week prior to injury	Weekly HSR ACWR loading pattern prior to injury*
Player 3	05/01/19	Proximal	Moderate	0.91	2 weeks of low to moderate load, 1 week of moderate to high load, 1 week low to moderate load
Player 4	21/08/18 18/02/19	Medial Medial	Minimal Minimal	1.08 0.96	3 weeks of moderate to high load, 1 week of low to moderate load 1 week of moderate to high load, 3 weeks of low to moderate load
Player 6	03/09/18	Medial	Moderate	0.87	2 weeks of low to moderate load, 1 week of moderate to high load, 1 week of low to moderate load
Player 7	08/03/19	Proximal	Moderate	0.67	1 week of low to moderate, 2 weeks of moderate to high load, 1 week of low to moderate load
Player 8	18/03/19	Medial	Mild	1.04	1 week of low to moderate load, 1 week of moderate to high load, 2 weeks of low to moderate load
Player 11	03/11/18	Medial	Moderate	0.84	1 week of moderate to high load, 2 weeks of low load, 1 week of low to moderate load,
Player 14	12/01/19	Proximal	Mild	0.80	1 week of low to moderate load, 1 week of moderate to high load, 2 weeks of low to moderate load
Player 18	01/09/18 05/01/19	Medial Medial	Mild Mild	0.98 0.87	2 weeks of low to moderate load, 1 week of moderate to high load, 1 week of low to moderate load 2 weeks of moderate to high load, 2 weeks of low to moderate load
Mean ± SD				0.90 ± 0.13	

*Most recent weekly load prior to injury specified last within four week description

DISCUSSION

To our knowledge, this is the first study to explore the ACWR of HSR and relationship with hamstring injuries in professional English Football League footballers. Eight of 18 players (44%) experienced a non-contact hamstring injury during the season, which is a high rate when compared to previous cohorts of professional footballers (16%; Fousekis et al., 2011; 17-26%; Ekstrand et al., 2016). A common four week loading pattern preceded most hamstring injuries. The large majority (90%) of hamstring injuries had a pattern of 'moderate to high' followed by 'low to moderate' weekly ACWR loading prior to occurrence. In addition, the mean ACWR at the week prior to injury was 0.90, which was somewhat lower than the squad mean ACWR season (1.04). Therefore, any observed spikes in ACWR during the season were not associated with injury occurrence. These findings resonate with Bowen et al. (2017) who reported that spikes in HSR didn't cause injury in professional footballers and Ehrmann et al. (2016) who reported high HSR distances were not correlated with hamstring injuries in professional footballers. More hamstring injuries (60%) were reported in the second half of each season in this study, where accumulative fatigue was a potential factor (Mallo & Dellal, 2012). Malone et al. (2017) reported that an ACWR of 1.00-1.25 is protective for professional footballers and higher levels of intermittent aerobic capacity offer protection when players are exposed to rapid spikes in workload. In consideration of this, the squad mean ACWR was within this range (1.04) while 80% of injuries occurred when players went

below a weekly ACWR of 1.00.

The physical demands elicited upon footballers during matches differ significantly dependent upon playing position (Domene, 2013). A full-time professional footballer's schedule can be congested at certain stages of the season and players are often required to play two games per week (Dupont et al., 2010) with as little as three days recovery (Nédélec et al., 2015). Duhig et al. (2016) recommended slightly reducing the volume of HSR every four weeks to help protect against hamstring injuries and this method could also be applied in advance of busy fixture schedules. Buckthorpe et al. (2019) also recommended applying a 'deload week' every three or four weeks to allow players to recover and prepare for future training. Although this notion does somewhat contradict our findings from, where 9 out of 10 injuries occurred when load was reduced from 'moderate to high' to 'low to moderate' within the four weeks prior to injury. Hamstring injuries can be influenced by numerous factors and a larger sample size would have allowed more meaningful results to be drawn from this study (Ehrmann et al., 2016). With modern trends showing that football is becoming more intermittent with greater emphasis placed on HSR, it is important to develop HSR qualities in footballers to help enhance robustness and reduce the likelihood of hamstring injuries (Buckthorpe et al., 2019). Future avenues of research could include the relationship between hamstring injuries, positions, and match outcome.

In conclusion, this study evidenced a high prevalence of non-contact hamstring injuries (8 of 18 players) over a competitive season within an EFL professional football club. The large majority of hamstring injuries occurred when the mean ACWR at the week prior to injury was below the squad mean ACWR for the season. The pattern of 'moderate to high' followed by 'low to moderate' ACWR was the most common weekly loading pattern in the four weeks prior to injury occurrence.

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