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Influence of the Weekly and Match-play Load on Muscle Injury in Professional Football Players

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ABSTRACT

The aim of this investigation was to examine the impact of the weekly training load and the match running patterns prior to a muscle injury as potential risk factors of muscle injury in professional football players. Forty male professional football players participated in the investigation. Running distances at different intensities 5 min and 15 min prior to the injury were compared to the same time-points in official matches of the same player with no injury events. Furthermore, the cumulative cummulative session rating of perceived exertion (sRPE) and training load of the week prior to the injury were compared to a control week (mean value of training weeks without injury). Nineteen players suffered 31 non-contact muscle injuries during matches. The distance covered at 21–24 km/h ($p < 0.001$; effect size (ES) = 0.62) and at > 24 km/h ($p = 0.004$; ES = 0.51) over the 5-min period prior to the injury was greater than in matches without injury. The cumulative sRPE ($p = 0.014$; ES = 1.33) and training volume ($p = 0.002$; ES = 2.45) in the week prior to the injury was higher than in a control week. The current data suggest that the combination of a training week with a high load and a short period of high intensity running during the match might increase the risk of muscle injury in professional footballers.

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Introduction

Football (soccer) requires players to perform repeated high intensity actions such as sudden accelerations, decelerations, sprints, changes of direction, jumps and landings interspersed with recovery periods of lower exercise intensity [1]. Due to the high physical demands of football and its characteristic movement patterns, lower limb muscle injuries occur frequently [2, 3]. In professional football players, muscle injuries represent 31 % of total injuries with about 0.6 muscle injuries per player each season [2]. Interestingly, the incidence of muscle injuries might be increasing at a rate of

2.3 % per year [3]. Most of the muscle injuries are located at the thigh, with a particularly high incidence in the hamstring muscle [4]. Although the severity of muscle injuries is lower than in other types of injuries such as the ones located in the ligaments [5], muscle injuries cause an important loss of time from competitions for the players who suffer them and eventually have a significant impact on team performance [2, 6, 7].

Previous studies have investigated the effectiveness of different preventive programmes (e. g., multicomponent training protocols and prevention strategies aimed at increasing muscle elasticity and strength) with the aim of decreasing muscle injuries in football players [8]. However, there is no clear consensus about the most effective prevention programmes to reduce muscle injury incidence [9], perhaps due to the high variability in the physical demands imposed during training and competition that lead to a muscle injury [10, 11]. In fact, it has been suggested that one of the best strategies to prevent injuries is by monitoring match-play exposure and training load, particularly in professional football players [10].

It has been found that a greater running distance during several weeks when compared to the players' seasonal average increases the risk of non-contact soft tissue injuries [12]. Furthermore, non-contact injury risk increases when a high number of accelerations has accumulated over a 3-week period [13]. The exposure to a higher than habitual external load during training might affect all types of injuries [5]. It should be highlighted that match-play has been consistently associated with a several-fold greater rating of muscle injuries compared to training [2, 14]. In this regard, match play-derived loads typically represent the most demanding session of the week in professional football [15], especially for starters competing twice per week [16]. This suggests that the external load imposed by the match play may be the most prone scenario to develop muscle injuries, especially during the phases of the season with a congested fixture. In fact, it has recently been found that the volume of sprinting during competitive football match-play has a harmful association with muscle injury occurrence [17] while low recovery periods among sprint actions might also be a risk factor for muscle injury [18].

While external load is important in understanding the likelihood of injury, internal load, defined as player's physiological or psychological response to an external training or competition load [19], can be also considered as a useful assessment to aid in the prediction of injury in football. To this regard, previous studies have shown a positive relationship between the internal load, measured using the session rating of perceived exertion (sRPE), and the likelihood of injury in football players [11]. Although sRPE is a subjective tool used by practitioners to calculate the internal workload, a previous investigation have shown a strong link between sRPE values and the risk of suffering an injury in professional football [20]. In addition, the acute:chronic workload ratio, that compares the load of a particular training week to that of previous weeks, is one of the most applicable measurements for identifying injury risk in athletes [21]. Additionally, a previous investigation [22] has shown that the cumulative loads during 3 and 4-week periods were significantly associated with non-contact injury incidence. However, training-load prognostic factors are sometimes interpreted causal variables to develop injury, which can lead to inappropriate recommendations [23]. To date, there is no evidence supporting the effectiveness of the manipulation of training-load prognostic factors to reduce injury risk, and the manipulation in the load to modify the acute:chronic workload ratio should be used with caution to reduce the likelihood of injury. Lastly, other less well investigated training load variables such as monotony and strain have been associated with negative impacts on athletes' training adaptations [24] and increased injury incidence [24, 25]. However, to date, it is unknown which of these variables best reflect the influence of the training load on the likelihood of injury. To the best of the authors' knowledge, no previous research has analysed the relationship between training load and the match physical efforts preceding a muscle injury. Therefore, the aim of this study was to examine the impact of the weekly internal and external load and the match running patterns prior to a muscle injury as potential risk factors for muscle injury in professional football players.

Materials and Methods

Participants

Forty outfield professional football players volunteered to participate in this prospective observational study. The participants were recruited from two professional teams playing in the First-Division Spanish football league during one season (2013–2014). Players had been training an average of 13.0 ± 2.2 h/week across the full season, including all football training activities conducted in their clubs and all football competitions (habitually, once per week). As part of their training activities, participants usually performed 5 days of field training that included physical conditioning exercises, small-sided games, skill-based routines, and tactical exercises. In addition, players performed a strength-based training program with free-weights that normally entailed one session per week. In the study sample, 19 (age, 28.5 ± 2.8 years; body mass, 74.6 ± 4.6 kg; height, 178 ± 5.3 cm) suffered a total of 31 non-contact lower limb muscle injuries during the league matches. Thus, the results of the present investigation are those obtained from this pool of 19 players (n = 4 defenders, n = 7 midfielders, n = 8 attackers). Before the start of this investigation, written informed consent was obtained from all participants and the procedures were approved by the institutional Ethics Review Committee (code: DPC.VMP.01.18). The current investigation meets the ethical standards of the International Journal of Sports Medicine [26].

Injury data collection

Muscle injuries sustained during competitive matches were diagnosed and documented by the team's physician. Only muscle injuries sustained from starters were recorded for this investigation. All muscle injuries were diagnosed, classified and recorded following the classification system developed by Fuller et al. in 2006 [27]. Specifically, the team's physician recorded the type (contact or non-contact), location, and minute when the injured occurred during the match. The team's physician also collected information (i. e., video analysis of the match and personal interview with the player) to objectively determine the specific movement/action that leaded to the injury. Regarding injury severity, it was defined as the as the total number of days lost from normal training/competition, starting from the day after the injury until the day of return of full

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participation. The following classification was used to categorize injury severity: slight injury, 0 days; minimal injury, 1–3 days; mild injury, 4–7 days; moderate injury, 8–28 days; severe injury, > 28 days. Injury burden was calculated as the number days lost from training/competition per team and per season. A recurrent injury was recorded when an injury of the same type and at the same location occurred after the player had returned to full participation. Only non-contact lower limb muscle injuries were used for this investigation.

Data collection of running patterns during match play

All competitive matches were played on a natural grass surface with pitch dimensions of ~100 × 70 m. Running patterns during the matches were obtained from the multicamera tracking system Mediacoach. Mediacoach has been used by Spanish football teams to evaluate physical performance indicators in competition [28] and it has been recently validated against GPS data [29]. Physical performance data of the players who sustained an injury were obtained 15 min and 5 min prior to the injury. These data were compared with normative values for the same player in matches without injury by mimicking the duration of the periods and the minutes analysed (i. e., control). The normative values for the control situation were obtained by averaging running patterns in the ten matches prior to the injury, considering only those matches where the player had participated in the match from the beginning to the end. The total distance covered and the running distance at > 21.0-to-24.0 km/h, and at > 24.0 km/h were used for analysis. We selected these running speeds because we wanted to investigate running actions performed at high intensity, as these speed thresholds haven used previously to define high intensity running and sprinting in professional football [30–31].

Data collection of internal training load

The team's physical coach collected the RPE and the exercise time on an individual basis in each training session and match to calculate sRPE. RPE was assessed by using a 1-to-10-point scale and participants were informed that 0-point was equivalent to how they feel when sitting in a chair and 10-point was equivalent to how you they feel at the end of very intense exercise activity [32]. Week-long cumulative internal training load was calculated for each player by summing all sRPE scores recorded for the week (including the competition). Training monotony was obtained each training week as the mean training load of the last seven days divided by the standard deviation of the training load of these last seven days [24]. The training strain was calculated as the weekly monotony (7 days) multiplied by the absolute training load, in minutes, of the last 7 days [24]. As in the running patterns during match play, data on these variables in a week that ended with an injury during the competitive match were compared with a "control week" that included an average of the values for the same player obtained in the weeks without injury. The normative values for the control week were obtained by averaging training load, sRPE, monotony and strain in the ten weeks prior to the injury.

Statistical analysis

The distribution of raw data sets was carried out using the Shapiro-Wilk test and demonstrated that all variables had a normal distribution ($p > 0.050$). Paired-sample t-tests were performed to compare differences in the variables obtained in a match with injury vs. control matches. A $p < 0.050$ value was used to determine statistically significant differences. When a statistical difference was found, effect size (ES) was calculated by using Cohen's *d* units, and interpreted according to the following ranges: < 0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; 2.0–4.0, very large and; > 4.0, extremely large [33]. The odds ratio (OR) and 95 % confidence interval (CI) was calculated for variables with a statistically significant difference. Data are presented as frequencies for qualitative variables and as mean ± SD for quantitative variables. All statistics were performed using the SPSS software (version 22.0; IBM, Chicago, IL, USA).

Results

Taken into account the whole group of participants, there was an injury incidence of 0.03 lower limb muscle injuries per 1000 h of play (equivalent to 0.41 muscle injuries per match). The hamstring muscle represented the most common location (25.8 %), followed by the adductor longus (19.3 %), rectus femoris (19.3 %), sartorius (16.1 %), gastrocnemius and soleus (16.1 %) and gluteal (3.4 %). Most of the injuries occurred during an explosive action such as an acceleration of a few meters with a feeling of fatigue (74.9 %) while the rest happened during a sprint > 20 m (9.6 %), during a football action that required a muscle stretching (6.4 %), during an action related to kicking the ball (6.4 %) or in a change of direction (2.7 %). Regarding severity, 32.4 % of the injuries were catalogued as minimal, 29.0 % moderate, 16.1 % slight, 16.1 % as mild and only 6.4 % as severe. The mean time of recovery for these muscle injuries was 9 ± 9 days (median value = 9 days, range from 2 to 37 days). This represented an injury burden of 140 days lost per team and per season. Twenty-two point five per cent of the injuries were recurrent injuries while the remaining were new. Most of the injuries occurred during the last phase of the competitive league (round 30-to-38; ▶ **Fig. 1a**) and most of them were reported in the last 15 min of the match (▶ **Fig. 1b**).

In the week prior to the injury, there were no differences in training load monotony (2.3 ± 1.3 vs. 2.2 ± 0.3 A.U., $p = 0.472$; ES = 0.48) nor in strain (▶ **Fig. 2**, mean difference (Δ) = 751 ± 291 A.U., $p = 0.261$; ES = 0.93) with a control week. However, the training load time was higher in the week prior to the injury when compared to a control week (▶ **Fig. 2**, Δ = 505 ± 584 min, $p = 0.002$; ES = 2.45). Likewise, the cumulative sRPE value in the week prior to the injury was higher than in the control week (▶ **Fig. 2**, Δ = 379 ± 620 A.U., $p = 0.014$; ES = 1.33). The sRPE at the end of the match was similar on the day of injury to that of the control match (622 ± 153 vs. 628 ± 107 A.U., $p = 0.955$; ES = –0.05).

During the competitive matches, there were no differences in total running distance ($p = 0.412$), in distance covered at 21–24 km/h ($p = 0.126$), nor in the distance covered at > 24 km/h ($p = 0.565$) in the 15 min of match play prior to the injury when compared to the same 15-min period in the control matches (▶ **Fig. 3**). However, the distance covered at 21–24 km/h (Δ = 11.0 ± 14.9 m,

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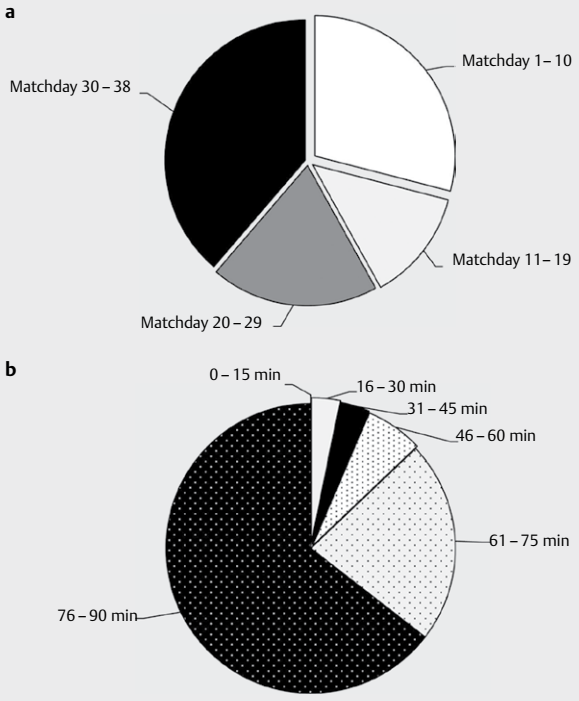
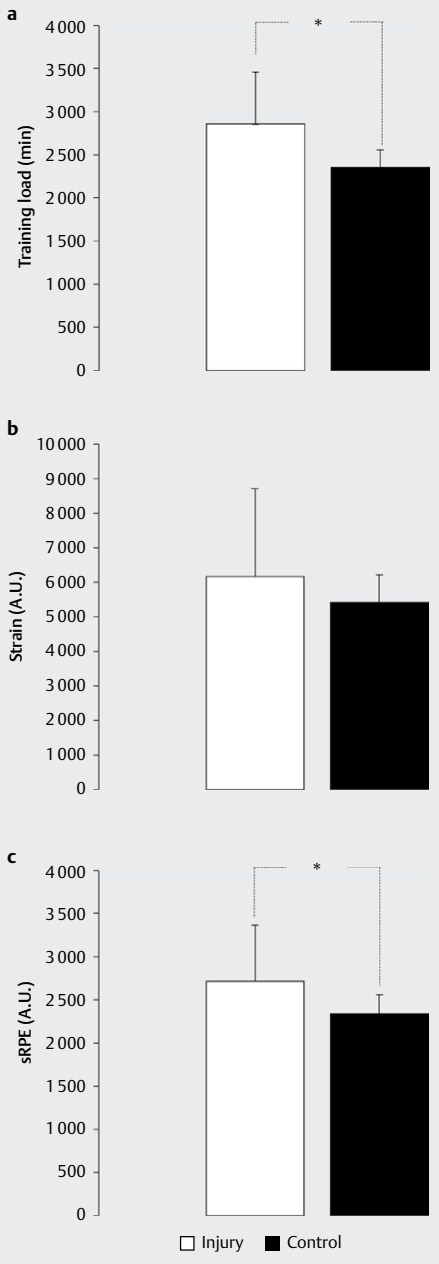


▶ **Fig. 1** Match day (**a**) and minute (**b**) at which non-contact muscle injury occurred during competition.



▶ **Fig. 2** Training load (**a**), strain (**b**) and session rating of perceived exertion (sRPE; **c**) in the week prior to suffering a non-contact muscle injury compared to the same period of control training. (*) Injury different from control at $p < 0.05$.

$p < 0.001$; ES = 0.62) and the distance covered at > 24 km/h (Δ = 6.8 ± 11.8 m $p = 0.004$; ES = 0.51) in the 5 min of match play prior to the injury was higher than in the same period of the control matches (▶ **Fig. 3**). The OR for an injury was 2.29 (95 % CI = 0.80 to 6.50, $p = 0.133$) for those players who ran > 13.8 m at 21–24 km/h in a 5-min period and 3.50 (95 % CI = 1.20 to 10.2, $p = 0.021$) for those players who ran > 13.1 m at > 24 km/h in a 5-min period.

Discussion

The aim of this study was to examine the impact of the weekly internal and external load and the match running patterns prior to a muscle injury as potential risk factors for muscle injury in professional football players. The rationale for this investigation was based on previous studies suggesting that a competitive match is a scenario that may increase the likelihood of lower limb non-contact muscle injuries [2, 14]. As a main finding, the current investigation indicates that the convergence of a training week with a high training volume and sRPE values, together with a 5-min period of high intensity running during a match, were present before the development of a lower limb muscle injury. Interestingly, three out of four injuries reported in this investigation occurred during a short acceleration while participants reported fatigue before this event. In addition, two out of three injuries occurred during the last 15 min of the match. This may indicate that both chronic and acute fatigue play key roles for the development of muscle injuries during competitive matches. As a whole, the current investigation suggests that training weeks with a high load together with short periods of high intensity running during the match might be factors that increase the risk of muscle injury in professional footballers, especially in the final minutes of the match. In this respect, the control of acute and chronic workload may aid in the prevention of muscle-type injuries developed during a football match. However, these prognostic factors should not be interpreted as factors with a causal effect on injury, as these factors may concur without the existence of a muscle injury.

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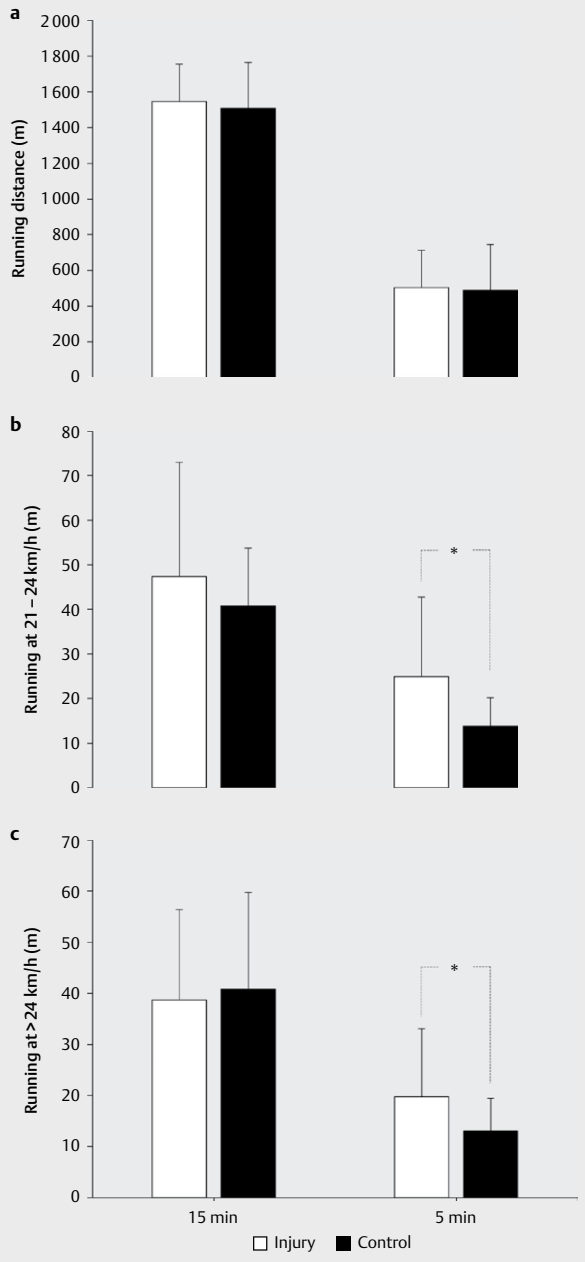

▶ **Fig. 3** Total running distance (**a**), running distance at 21–24 km/h (**b**) and running distance at > 24 km/h (**c**) in the 15 and 5 min prior to suffering a non-contact muscle injury compared to the same match-period of control matches. (*) Injury different from control at $p < 0.05$.

To our best knowledge, only one previous study has investigated the physical efforts leading to muscle injury (5 min and 1 min before) during match exposure [17]. In Gregson et al. investigation [17], the increment in sprinting distance covered over a 1-min period increased the odds of muscle injury during competitive soccer match play. The current investigation is innovative because it presents an analysis of the running patterns preceding the injury (up to 15 min) and interrelates these data with the training load of the week prior to the injury. Both investigations coincide in indicating that the volume of sprinting during competitive football match-play may have a harmful association with muscle injury occurrence, but the current investigation points toward the existence of a stressful week prior to the match as a contributing factor to increase the probability of injury. Additionally, the present data indicate that both chronic (league/training week) and acute fatigue (min of play/5-min period of high intensity) are potential risk factors for football muscle injuries [13], as a higher percentage of injuries were reported in the last 8 fixtures of the season and in the last 15 min of the match. From a practical perspective, it seems that both intrinsic and extrinsic risk factors converge to increase the likelihood of muscle strain or muscle tears during football competition. As the avoidance of high intensity actions at the end of the games is not a practical recommendation for professional football players, the most effective method for reducing the likelihood of muscle injury must be focused on controlling training loads during the season and monitoring players' perceived exertion in the days prior to a competitive match. These recommendations may be useful to avoid scenarios of excessive fatigue and unhabitual training load in professional football players, especially in the phases of the season with a congested calendar because they may lead to increased injury rates during competitive matches [34]. The use of individualized speed thresholds to monitor high intensity running and sprinting [16], together with the assessment of accelerations and decelerations [35] may also add value to monitoring player's external load during match play in a more personalized manner.

A deeper analysis of the physical efforts preceding the non-contact muscle injury reveal that there was a potential link between muscle injury and the distance covered at 21–24 km/h (OR = 2.29) and at > 24 km/h (OR = 3.50) in the 5 min prior to the injury. Our data confirm in part the findings of Gregson et al. [17] who identified a link between an increment in sprinting distance covered over a 1-min period with greater odds of muscle injury. In addition, 28 % of the muscle injuries in Gregson's study occurred during the last 15 min of the game, but there is no information about the match day in which the injuries occurred. Interestingly, Gregson et al. [17] did not find differences in the running patterns over the 5-min period prior to the injury with normative values, while this is the case of the current investigation. While the differences in physical and technical performance [31, 36] of the samples utilised (Qatar Stars League vs. Spanish First-Division League) might explain the discrepancies between these two investigations, it seems clear that accumulating a high volume of running at high and sprint intensity in the last phases of a match is a risk factor for muscle injuries. Further investigations should be aimed at determining the efficacy of sprint training in conditions of fatigue to reduce the likelihood of muscle injury.

The current results showed that a disproportionate amount of muscle injuries occurred during the last phase of the competitive league. Altogether, the present findings suggest that players could be at greater risk of injury when performing a high amount of high intensity running and sprinting in the last 15 min of the match. These findings might be associated with the physical deconditioning of players and chronic fatigue developed by the continuance of training and competition across the football season [37]. As previously suggested, the reduction in physical performance in football

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players could be attributed to the physiological stress imposed during the competitive season [38] together with a reduction in the time allocated for muscle strength training [39]. Furthermore, fatigue is known to occur at the end of the game [40, 41] and congested fixture periods due to the depletion of muscle glycogen concentrations [42], and produces reductions in physical performance (e. g., muscle strength), ability to maintain high speed running [43], and acceleration/deceleration [44]. Thus, this cascade of physical changes in the last phase of the competitive league and in the last 15 min of the match could explain the high proportion of muscle injuries occurring in this particular scenario.

In accordance with previous findings [20], the players who sustained a muscle injury in our study showed a higher cumulative training load (+ 21.5 %) in the 7 days prior to the injury when compared to a control week. This was accompanied by an increase of 16.2 % in the cumulative sRPE suggesting that both internal and external strain were associated in the week prior to the injury. These data suggest that changes in training volume (in min) rather than changes in the exertion values reported by the players at the end of the training sessions (i. e., RPE) was the parameter that leaded to the high cumulative sRPE in the week prior to the injury. However, training load monotony and strain were similar in the week that led to the injury and in the control weeks [24]. As in previous investigations, the assessment of the change in the weekly load poorly predicted the risk of injury [45, 46] which suggests that the assessment of the changes in training load in isolation should not be used to predict non-contact injury. However, special attention should be paid during the competitive games to those players who report high sRPE values as the result of a week with a high unhabitual load.

The limitations of the study must be acknowledged to fully understand the outcomes of the investigation. Firstly, as the current study has been performed in a specific sample of male professional football players, these findings may not be extended to the amateur football or female football players. Secondly, only muscle injuries during competitive matches were investigated while muscle injuries during training might have also affected the results of the investigation. Also, information regarding the level of the opponent, match result and match location were not included in the current investigation while they may have a potential influence in the outcomes of the study. Third, we used total running distance and running distance at different speed thresholds to calculate the match load. However, the amount and intensity of the accelerations/decelerations performed by players are also crucial components to quantify the external load during a match [35]. Future investigations should investigate the association of in-game accelerations/decelerations and non-contact muscle injury in football. Finally, although the current results suggest an association between muscles injury and high intensity running in a fatigued situation, other factors such as previous structural damages, muscle weakness, muscle imbalances, poor range of motion or football-specific actions kicking, tackling or shooting may have also contributed to the development of the injury [47]. Unfortunately, we did not record this information, and this should be acknowledged as a limitation of this study.

Conclusion

In summary, the present findings suggest that the combination of an increased training load and player's perceived exertion for 1 week, along with higher than usual running activities at high intensity over a 5-min period in the last phases of the match, increased the odds of suffering a muscle injury. This information indicates that both accumulated fatigue and high intensity running in a fatigued situation might predispose players to suffering in-game muscle injuries. These outcomes underline the convenience of controlling training loads and players' perceived fatigue across the season for reducing the likelihood of muscle injury. It may be suitable that players with high weekly training/competition load or those with high values of self-reported exertion undergo a microcycle of recovery to reduce the odds of muscle injury. Additionally, professional football teams have now access to real-time data on players' match load, which can be used to make tactical decisions as deciding the timing of substitutions for players with higher than habitual loads during a competitive match. Finally, the control of these variables may aid in the prevention of muscle-type injuries in professional football, but they should not be interpreted as factors with a causal effect on injury.

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Conflict of interest

The authors declare that they have no conflict of interest derived from the outcomes of this study.

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