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Harmful association of sprinting with muscle injury occurrence in professional soccer match-play: a two-season, league wide exploratory investigation from the Qatar Stars League

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Abstract

Objective: To investigate the impact of physical efforts performed in the period preceding activity as a potential risk factor of muscle injury during match-play within a sample of professional soccer players.

Design: Observational cohort study.

Methods: Match load (running [>14.4-19.8 km/h], high-speed running [>19.8 km/h to 25.2 km/h], sprinting [> 25.2 km/], leading and explosive sprint type) averaged in 1-minute and 5-minute periods prior to an event or non event for 29 professional outfield soccer players. Conditional logistic and Poisson regression models estimated the risk of injury for a 2 within-subject standard deviation in match load or 1-action increment in the number of sprinting activities, respectively. Associations were deemed beneficial or harmful based on non-overlap of the 95% confidence intervals against thresholds of 0.90 and 1.11, respectively.

Results: An increment in sprinting distance [+ 2-SDs = 11 meters] covered over a 1-minute period (odds ratio [OR]: 1.22, 95%CI, 1.12 to 1.33) increased the odds of muscle injury.

Conclusions: Our study provides novel exploratory evidence that the volume of sprinting during competitive soccer match-play has a harmful association with muscle injury occurrence.

Introduction

In elite soccer, lower injury incidence and higher match availability is positively associated with points gained per league match.[1] Strategies focused on enhancing playing availability are therefore fundamental to the work of players' support teams; routine modifications in training load help prepare players for the demands of competition as well as for reducing susceptibility to non-functional over-reaching, injury, and illness.[2] Increasingly, attention has focused on the influence of training load as a modifiable injury risk factor. Players can be at increased injury risk when exposed to high (i.e. "spikes") absolute (1-3 week) training loads, large week-to-week changes in load,[2] and greater training times spent above 85% of maximal heart rate.[3] Paradoxically, players are better able to tolerate higher loads and high-intensity activities with reduced injury risk following exposure to appropriate chronic (e.g. 3-4 week) training loads prior to performing these high-intensity activities.[4] Thus, completion of high-intensity activity as part of correctly prescribed training load, culminating in enhanced aerobic fitness may serve to reduce the injury risk associated with high-intensity activity.[4]

While useful for understanding associations between training load and injury risk, the aforementioned studies did not isolate match loads which represent the highest load experienced by players during the microcycle. Predictably, overall injury incidence is greater in matches (27.5 injuries per 1000 h) than in training (4.1 injuries per 1000 h),[5] with muscle injury incidence also greater during matches than training and influenced by fixture congestion.[6] Of further relevance to help our understanding of soccer match injuries and in turn the support provided to players, is that precise descriptions of the inciting event are needed to help understand injury cause.[7] In the context of soccer match-play, increases in critical incidents and injury risk observed during the early and latter stages of match-play were postulated to reflect both the higher exercise intensities when players are fresh and lower intensities when players experience fatigue, although player activity was not recorded.[8] In other studies, movement intensities were recorded subjectively but no comprehensive data were provided on running characteristics (e.g., speed) preceding injury.[9, 10] Using match data recorded via a computerised motion-analysis system, high-speed running and recovery between high-speed bouts was generally higher and lower in the 5-minute period immediately preceding injury, respectively.[11] However, this investigation did not examine the association between physical match load and injury occurrence. Therefore, further research on the role of prior activity on match injury occurrence is needed.[11] Using motion analysis data derived from an entire professional soccer league and adopting a novel design analysis approach to provide realistic associations,[12] we aimed to examine the influence of players' physical efforts during 1-minute and 5-minute periods immediately preceding a muscle injury sustained during match-play.

Methods

Study participants were 29 outfield professional soccer players competing in the Qatar Stars League (2013-2014 and 2014-2015). Muscle injuries sustained during 276 competitive matches were diagnosed and documented by the team's physician. Performance data were collected as a condition of employment in which player performance is routinely measured during match-play.[13] The Aspire Zone Research Committee and the Anti-Doping Laboratory Institutional Review Board, Qatar (protocol number: E2017000252) granted ethics approval.

The methodologies and definitions of injury used in the present study closely follow those of a previous consensus statement.[14] Information including the type, location, and diagnosis of injury, alongside the occasion (training/match) and minute of the injury were recorded by the team physician on a injury card. Descriptive information on the final action at the time the injury was sustained and whether contact had occurred between players was recorded. Each match injury incident was cross-referenced to determine whether the match had been recorded and analysed by the multiple-camera player tracking system (Prozone®, Leeds, England) used by the clubs to evaluate physical performance in competition as described previously.[15] This system has previously been shown to be a valid and reliable system for measuring match activity in soccer.[15] Where information from the system was available, physical performance data were used to measure the players' efforts over 1-minute and 5-minute periods leading up to the injury.

To investigate the effects of physical efforts prior to injury, distances covered in the following activity categories were measured over the 1-minute and 5-minute period preceding the time of injury: walking (<7.2 km/h), jogging (>7.2-14.4 km/h), running (>14.4-19.8 km/h), high-speed running distance (>19.8 km/h to 25.2 km/h), and sprinting distance (> 25.2 km/h).[15] Further analysis of sprint activity (> 25.2 km/h) included the total number of leading and explosive sprints undertaken. An explosive sprint (i.e., rapid acceleration), was defined as the attainment of sprint speed from either walking, jogging or running with time spent in the high-speed running category less than 0.5 seconds.[16] A leading sprint (i.e., gradual acceleration), was defined as the attainment of sprint speed from either walking, jogging or running with time spent in the high-speed running category for a minimum of 0.5 seconds.[16] To determine whether performance over these 1-minute and 5-minute periods influenced muscle injury occurrence, data across the completed matches were used in an attempt to establish a normative physical performance profile for each player.[11] For this profile, the total high-intensity distance (>14.4 km/h) covered was calculated for entire games. For example, to calculate the distance covered over a 5-minute period, the total high-intensity distance covered was divided by the match duration expressed in minutes and then multiplied by 5. This figure was considered to be the player's habitual match-play high-intensity activity level over a 5-minute period. The physical performance data used for the normative profile were based on information during the same season in which injury occurred. The normative profile was subsequently compared to physical efforts over the 5-minute period prior to injury. The characteristics of physical efforts undertaken during the final 5-seconds preceding each injury occurance were also investigated. Where the exact time of injury was not discernible from video observation, the injury was not included in the analysis (N=4).

Distances were averaged into 1-minute and 5-minute periods for the three primary exposures (running distance, high-speed running distance and sprint distance). These data were stratified into (i) the 1-minute and 5-minute time periods immediately preceding an in-match muscle injury, (ii) the 1-minute and 5-minute periods for the same players as in (i) but for all other within-match time periods (those periods that did not immediately precede the injury), and (iii) normative data of 1-minute and 5-minute data bins where an injury did not occur.

Conditional fixed-effects logistic regression analyses estimated the odds of muscle injury occurrence (0, no; 1, yes) based on the comparison of players' pre-injury match load data versus normative data in which an injury did not occur using the *survival* package. This procedure is conceptually different from the conventional logistic regression modelling, whereby the calculation of the conditional likelihood involved the analysis of load data with player identity as a cluster factor in the model to account for the within-subject association between the examined observations.[17] The association between distances covered at running, high-speed running, or sprint intensities with injury occurrence was examined for the first event only. Odds ratios (OR) to determine the association between physical match load and muscle injury occurrence were derived for a 2-within-player SD increment in each primary exposure variable, representing the effect of a typically high versus a typically low value of the exposure.[18] A within-player SD of the exposure was calculated as the square root of the residual mean square.[19] Separate conditional Poisson regression models estimated rate ratios (RR) describing the association of a 1-action increment in leading and explosive sprint activities, entered as primary exposure variables in the model, and muscle injury occurrence.[20] In the absence of an established anchor to inform on the smallest meaningful association between physical match load and muscle injury, thresholds of 0.90 and 1.11 represented beneficial and harmful associations, respectively.[18] Retrospective design analyses assessed Type M error rates and, corrected the point estimates and respective sampling uncertainty for the observed effects.[21] This approach provides an objective quantification of the Type M error indicating the degree of overestimation of an observed effect estimate relative to the magnitude of the true underlying population effect given the data.[21] Corrected ORs were obtained by dividing the logarithm of the estimated OR by the respective magnitude of exaggeration or Type M error relative to a targeted increase or reduction in the odds of muscle injury of $\ln OR = \pm |0.105360515657826|$. Associations were deemed beneficial or harmful based on non-overlap of the respective 95% confidence intervals for the estimated ratio statistic with the aforementioned thresholds (i.e., 0.90 and 1.11). Overlap of the confidence interval with these thresholds represented a trivial association. Outcome statistics are reported as point estimates and 95% confidence intervals (CI). Statistical analyses were performed using R (version 3.6.1, R Foundation for Statistical Computing, Vienna, Austria).

Results

A complete overview of the number and type of muscle injuries examined in the study is illustrated in Figure 1. Twenty injuries occurred in the second half of which eight events during the final 15 minutes.

Analysis of the 1-minute data periods revealed a harmful association only between sprinting distance and muscle injury (Figure 2a). Type M error rates for the observed point estimates for running (7.20), high-speed running (6.29), and sprinting distances (3.65) indicated the original injury odds to be overestimated by approximately 4-to-7 times. Conditional Poisson regression analyses revealed a trivial association between a 1-action increment in the number of leading (RR = 1.16; 95%CI, 1.06 to 1.26) and explosive (RR = 1.09; 95%CI, 1.00 to 1.19) sprints undertaken by a player 1-minute prior to the event.

For the analysis of the 5-minute data periods, running, high-speed running, and sprinting distance were all trivially associated with muscle injury occurrence (Figure 2b). The corresponding Type M error rates were 8.57, 8.87, and 7.10 suggesting the original injury effects to be exaggerated by approximately 7-to-8 times. A 1-action increment in the number of leading (RR = 1.01; 95%CI, 0.92 to 1.10) or explosive (RR = 0.99; 95%CI, 0.91 to 1.08) sprints undertaken by a player 5-minute prior to an injury resulted in trivial associations. Additional sensitivity analyses comparing the 1-minute or 5-minute periods immediately preceding an in-match muscle injury with the 1-minute and 5-minute periods within the same match time periods or the available normative data in which an injury did not occur revealed our results to be unaffected.

Discussion

Competition load is deemed a critical element contributing to greater muscle injury risk,[2] yet our understanding of the activity preceding injury during professional soccer match-play is not well understood. Therefore, we investigated the influence of player match physical activity during time periods immediately prior to muscle injury. Of the match load variables commonly investigated, we found only match sprinting to be harmfully associated with muscle injury occurrence in professional soccer players.

Match injuries have previously been reported to be preceded by players moving at relatively moderate speeds during the prior 5-minute period.[11] In the present study though, the associations between a 2 within-subject SD increment in sprinting, high-speed running or running distances and muscle injury were all trivial. However, when using the 1-minute period prior to injury, a typically high increment sprinting distance had a harmful association. As short sprints (≤10 m) represent the dominant type of sprint activity during elite soccer match-play,[15] the risk associated with the increment in pre-injury 1-minute sprinting distance is likely equivalent to 1-2 sprints. Taken together, while the use of 5-minute periods is a widely adopted match analysis criterion,[22] our findings highlight the importance of quantifying and examining physical match loads in shorter time periods.

In the context of load-injury research, our study provides novel applied and methodological insights. First, the present investigation advances current knowledge regarding pre-injury running activities. An early study examining players' exposure to injury risk reported contesting possession as a determining factor for experiencing injury,[8] yet subsequent work showed most injuries occurred during breakdown attacks and tackling duels.[10] However, no exact detail about pre-injury running activities was provided.[10] More recently, Carling et al.,[11] reported that eight of ten final running actions immediately preceding injury involved a high-intensity running effort. In the present study the same analysis was not possible due to the nature of the data available. Therefore, it remains to be determined whether the activity immediately prior or the cumulative (i.e., 1-minute) activity serves as the likely risk factor in these instances. Second, the design analyses revealed studies in this field were conducted with inadequate sample sizes and incorrect statistical analyses. Furthermore, when using advances in methodological procedures established on pseudo-R^2 statistics[23] and informed by existing studies[6] a minimum sample size of 369 players would be needed in our 1-minute sprinting distance model (Cox-Snell pseudo-$R^2 = 0.362$). Taken together, in this field of research, the use of design analysis demonstrated how associations from small-scale studies are anticipated to be exaggerated in future similar investigations of equal size leading to erroneous and misleading conclusions.[12, 24]

Published investigations on load and injury have also failed to demonstrate how any estimated association could inform the player management and training process meaningfully in applied terms.[25] In practice, the presence of any association indicating the higher the load, the higher the in-match injury risk would suggest coaches and practitioners pay particular attention to prepare players adequately to cope with the demands characterising soccer match-play. In general, physical demands are assumed to be greater in competition than during training.[2] Accordingly, repeated-sprint training has the potential to elicit clear beneficial effect for the development of speed, explosive leg power, and high-intensity running performance.[26] Therefore, adoption of training strategies impacting on physical determinants of soccer performance, with a particular reference to a player's ability to repeat and tolerate very high-intensity efforts during match-play, would appear relevant to the context of our study.[26]

Our study is not without its limitations. Given the underlying nature of our research question, our study analyses might not have accounted for potentially relevant unmeasured intrinsic and extrinsic factors of injury risk. Specifically, with a larger sample size, inclusion of other independent predictors could have potentially mitigated the extent of the main effects of the selected primary exposures in a multivariable-adjusted model. For example, even though players' in-match load distances for non-event outcome were treated as control data in our investigation, a lack of information about training load over the examined period might represent a limitation. Likewise, as observed in other team-sport contexts, cumulative match involvement could have been deemed an additional variable relevant to our study.[27] The analysis of in-match loads expressed in terms of distances covered in predefined speed zones may also represent another limitation of our study. In practical terms, the use of arbitrary speed thresholds likely fails to provide coaches and sports scientists with an accurate quantification of the relative physical demands during a soccer match.[28] As our data were collected across an entire professional league, individualisation of speeds zones was not, however, logistically possible. Also, information regarding prior clinical history to the selected observational period for players involved in this study were not available. Finally, it is necessary to point out that ratio outcome statistics substantiating information about odds or hazards of event provide clinicians and practitioners with estimates regarding the average effect describing the probability of clinical outcome, but this may not necessarily translate to meaningful impact in the real-world. We, therefore, maintain that caution is necessary to generalise our findings to other populations of professional soccer players or to consider the estimated odds of injury as real effects since our results provided small-scale empirical evidence which ultimately rendered the present investigation exploratory in nature.

Conclusions

Our study provides novel evidence that the volume of sprinting during competitive soccer match-play has a harmful association with muscle injury occurrence. Therefore, we recommend careful attention be paid to preparing players to sustain and repeat sprint type activity during match-play. Collectively, our findings provide an important contribution that may be valuable to inform decisions of coaches and practitioners relating to the optimal player management throughout a season.

Practical implications

- The volume of match sprinting activity is a risk factor of muscle injury occurrence in elite soccer players.
- There is greater sensitivity in quantifying the relationship between physical performance and assessing injury risk using shorter (e.g., 1-minute) time periods than those traditionally used (e.g., 5-minute).
- Our exploratory findings place emphasis on the physical preparation of players to withstand high isolated and repeated sprint activities during competitive match-play.

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Figures

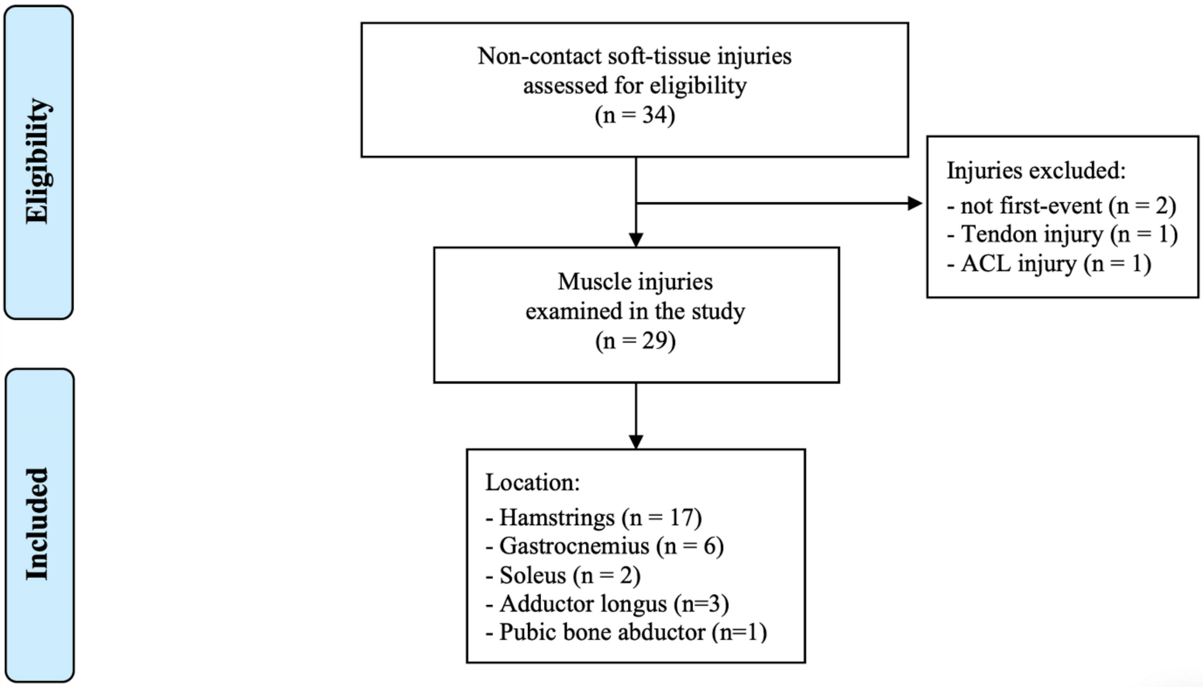

Figure 1. Flowchart illustrating the number and type of muscle injury examined in the study.

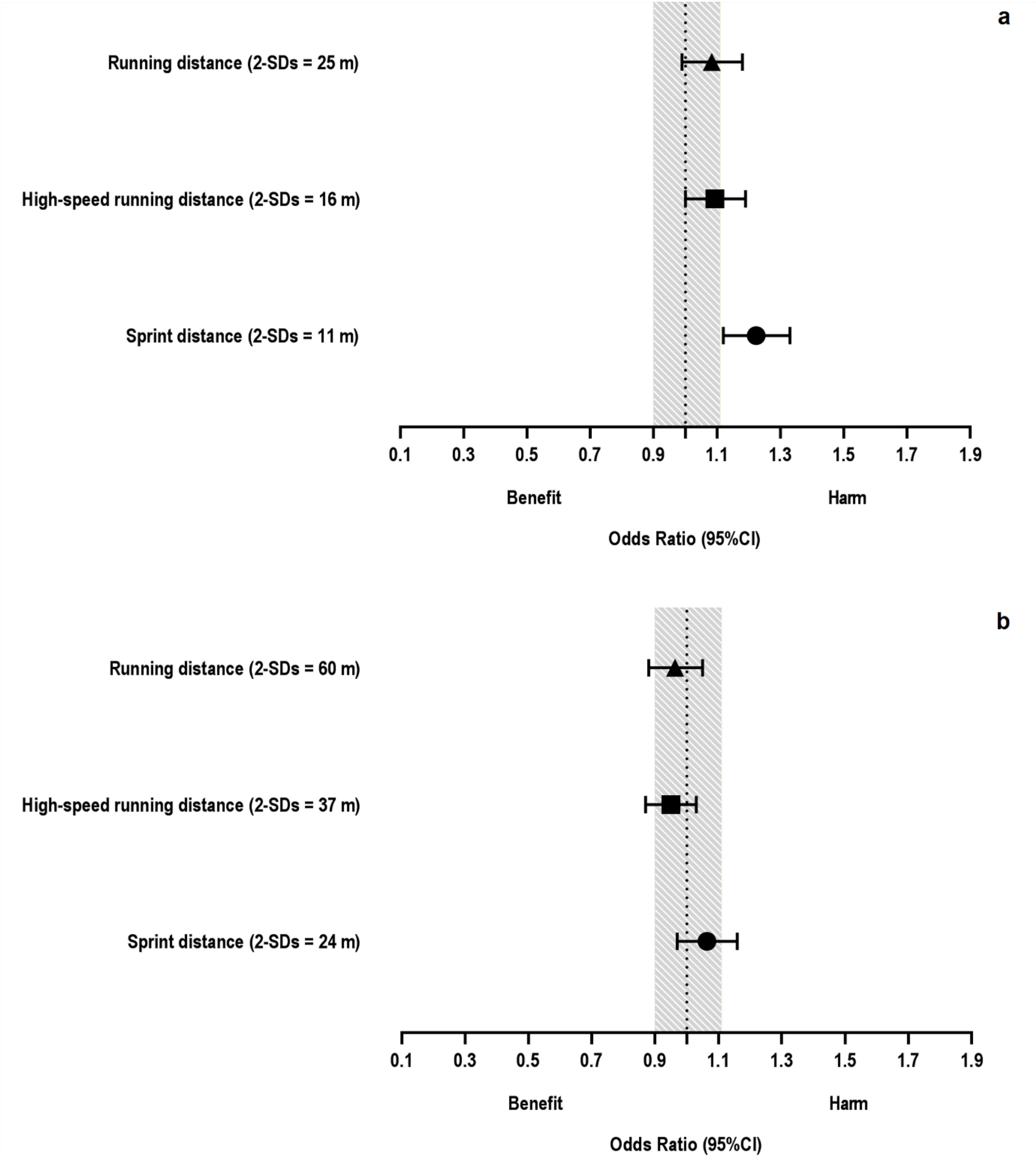

Figure 2. Outcome statistics for the association between 1-minute match load (a), 5-minute match load (b), and muscle injury occurrence. The grey shaded area identifies the bounds for a small reduction (OR =0.9) or increase (OR = 1.11) in the risk of injury, respectively.