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Examination of the external and internal load indicators' association with overuse injuries in professional soccer players

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ABSTRACT

Objectives: Research in professional soccer focusing on the relevance of external and internal load indicators for injury prevention is scarce. This study examined the relationship between load indicators and overuse injuries.
Design: Prospective cohort study.
Methods: Data were collected from 35 professional male soccer players over two seasons. Following load indicators were examined: total distance covered (TD), distance covered at high speed (THSR; >20 km h^{-1}), number of accelerations (ACC_{eff}; >1 m s^{-2}), number of decelerations (DEC_{eff}; <−1 m s^{-2}), and rating of perceived exertion (RPE) multiplied by duration. Cumulative 1-, 2-, 3-, 4-weekly loads and acute:chronic workload ratios (ACWR) were calculated and split into low, medium and high groups. Only overuse injuries were included in the analysis to focus on their specific relationship with the load indicators. Generalized estimating equations were applied to analyse the relationship between load indicators and overuse injuries in the subsequent week.
Results: In total, 64 overuse injuries were registered. For cumulative loads, results indicated an increased injury risk for higher 2- to 4-weekly loads as indicated by TD, DEC_{eff}, and RPE multiplied by duration. For ACWR, a high ratio for THSR (>1.18) resulted in a higher injury risk. In contrast, a lower injury risk was found when comparing medium ratios for ACC_{eff} (0.87–1.12), DEC_{eff} (0.86–1.12), and RPE x duration (0.85–1.12) to low ratios.
Conclusions: Findings demonstrate that mainly external load indicators are associated with increased or decreased injury risk. The monitoring of various load indicators is recommended for injury prevention in professional soccer.

1. Introduction

Professional soccer players sustain on average 2.0 injuries per season, which cause them to miss 37 days in a 300-day season on average.[1] Training and match load are considered to be strongly associated with injuries, however, these loads were not included in previous injury aetiology models.[2] Following the updated injury aetiology model, training and match load contribute together with intrinsic and extrinsic risk factors to the multifactorial and dynamic aetiology of injury.[2] Not only excessive loading and insufficient recovery, but also underpreparedness may increase injury risk by exposing players to large relative changes, or spikes, in load during periods with higher training and match loads.[3] These spikes can be identified using the acute:chronic workload ratio (ACWR).[4] Therefore, training and match load monitoring is considered essential to optimize load management and to minimize injury risk.[4]

Training and match load are generally quantified in terms of external and internal loads.[5] The external load refers to all player's locomotor movements and can be measured using electronic tracking systems such as global positioning systems (GPS) and accelerometers. The external load is quantified in terms of distance, velocity and accelerations.[4] The internal load refers to the physiological response of players to external load and can be determined using heart rate (HR) and ratings of perceived exertion (RPE).[4] The relationship with overuse injury for both external and

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internal load indicators has been examined in various elite team sports such as Australian football, cricket, rugby league,[4] and also in youth soccer.[6] In professional soccer, however, little evidence exists with respect to the load indicators that may be related to injury.[7]

For internal load, one study investigated the relationship between RPE multiplied by duration and injury risk.[8] One study found a relationship between HR and overuse injuries, in particular a positive correlation between muscular strains and training intensity measured by average HR.[9] Aforementioned studies focusing on internal load already stated the need to consider GPS data (i.e., external load indicators) to examine the relationship between injuries and external load indicators, especially in terms of high-intensive activities such as high-speed running, accelerations and decelerations.[8,9]

To date, one study in professional soccer found a relationship between non-contact soft tissue injuries and a higher distance covered per minute in the weeks before injury, in comparison with the players' season average values.[10] Additionally, lower average values for an external load indicator based on triaxial accelerometry, when compared to players' season average, were found in the weeks before injury.[10] No relationship was found for injury risk and distance covered at high speed.[10] High-speed running is related to non-contact soft tissue injuries in other team sports.[11–13] However, one limitation of the study by Ehrmann et al.[10] is the use of 5 Hz GPS units. This sampling frequency exhibited limitations in terms of accuracy and reliability when applied for measuring high-intensity efforts.[14] These limitations may have impacted on the results for high-speed running variables.[10] Additionally, accelerations and decelerations were not examined by the authors due to the 5 Hz sampling frequency limitations.[10]

In professional soccer, these high-intensive activities are considered important to monitor.[15] Interestingly, accelerations, decelerations and RPE multiplied by duration have not been studied yet for their relationship with overuse injury risk.[7] Assessment of this relationship may provide evidence for their implementation and succeeding predictive research to optimize load management strategies in professional soccer.[16] Therefore, the aim of the present study was to examine different external and internal load indicators in relation to overuse injuries.

2. Methods

Thirty-five professional male soccer players (mean ± SD age: 23.2 ± 3.7 years, weight: 77.5 ± 7.4 kg, height: 1.82 ± 0.06 m, body fat: 10.4 ± 1.9%) participated in this study. They were all players of the first team competing at the highest level in the Netherlands (Eredivisie). Goalkeepers were not included. Data were collected over two seasons (2014–2015 and 2015–2016), including preseason and in-season. Written informed consent was obtained according to the Helsinki declaration. The study was approved by the ethical committee of KU Leuven (file number: s57732).

External load was quantified individually during all field training sessions and matches using 10 Hz GPS technology (Minimax S4 and Optimeye S5, Catapult Sports, Melbourne, Australia). This sampling rate has proven a good validity and reliability for high intensive movement demands.[14] The data collection was completed following the guidelines for collecting and processing GPS data in sport.[17] The selected external load indicators were total distance covered (TD), distance covered at high speed (THSR; >20 $km\,h^{-1}$), the number of acceleration efforts >1 $m\,s^{-2}$ (ACC_{eff}) and deceleration efforts <–1 $m\,s^{-2}$ (DEC_{eff}). For a 10 Hz sampling rate, the accuracy of higher accelerations (>4 $m\,s^{-2}$) is compromised.[14] Therefore, we have chosen to detect total efforts >1 $m\,s^{-2}$ or <–1 $m\,s^{-2}$. The minimum effort duration to detect velocity was 0.6 s, and 0.4 s for acceleration with a smoothing filter of 0.2 s.[17,18]

Following each field training session and match, data was downloaded using the manufacturer's software (Catapult Sprint, 5.1.7), checked for irregularities (i.e., spikes in velocity data), satellite connection (≥8 satellites), and horizontal dilution of precision (<1.5), and then processed.[17] If data quality requirements were not met or player data were missing, values were estimated following Bowen et al.[6] For field training sessions, values were estimated for individual players using the average of players with a similar position that took part in the same training session (n = 193 of 6536; 3%). In addition, match data for season 2014–2015 were estimated due to FIFA restrictions regarding the use of GPS units in official matches. Therefore, match values were estimated by means of the player's average based upon measured data of friendly games and matches during season 2015–2016. Playing time was taken into account for all match value estimations.[6,10,13] For season 2015–2016, data was collected during all matches and only estimated if data quality requirements were not met (n = 121 of 873; 14%).[17] In total, the number of estimated external load data for field training sessions and matches was 870 of 8103 (11%).

Internal load was obtained for each individual following gym sessions, field training sessions and matches using RPE scores using the modified Borg CR-10 scale.[19] The RPE was administered approximately 30 min after the end of training sessions or matches to ensure that the perceived intensity would reflect the session as a whole.[19] All athletes were familiarized with the scale before the start of the study. The load in arbitrary units (AU) was derived for each player by multiplying RPE with training or match duration.

Injuries were diagnosed and recorded by members of the medical staff. The data collection procedures were in accordance with the consensus statement for soccer injury studies.[20] An injury classification system was embedded within a medical data management system to code each diagnosis by location, type, and mechanism of injury. All injuries during both seasons were recorded, but only time-loss overuse injuries that resulted in a player being unable to take a full part in soccer training or match play were included in the analyses.[20] An overuse injury is defined as an injury caused by repeated micro-trauma without a single, identifiable event responsible for the injury.[20] Injury incidence was calculated by dividing the number of injuries by exposure time and reported as rate per 1000 training and match hours.[20]

Data were categorized into weekly blocks from Monday until Sunday. Weeks in which players were away with national teams were excluded from further analyses (n = 177 of 1764; 10%). Cumulative 1-, 2-, 3-, 4-weekly loads were calculated as the sum of the daily load of the previous week(s).[21] The ACWR was calculated weekly by dividing the 1-week load of the most recent week by the 4-week rolling average weekly load.[22] These load variables were calculated for selected external and internal load indicators.

Data were analyzed using SPSS version 24 (IBM Corporation, New York, USA). Generalized estimating equations (GEE) were used to model the univariate association between each load variable and overuse injuries in the subsequent week.[23] The model was set for a binary distribution of the dependent variable (injury yes/no), logit link function, first-order autoregressive (AR1) working correlation structure, player as subject variable, weeks as within-subject variable and all load variables were modelled independently as predictor variable.

GEE was used for its ability to provide a population averaged effect from repeatedly measured data of multiple subjects. Data were first tested for normality and randomization of missing values. Load variables were sorted from lowest to highest and split into tertiles to divide the data in low, medium and high load groups. The lowest load group served then as reference group to compare injury risk with medium and high load group and allowed for non-