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Original Article

Two-peak seasonal pattern of injury occurrence among elite u-15 football players

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Abstract
Aim: This study aimed to examine intra-seasonal variation in monthly injury incidence, muscle injuries, and injury characteristics across six consecutive competitive seasons in an elite U15 football academy. Particular emphasis was placed on identifying high-risk periods during the training year using exposure-adjusted injury incidence to provide practical recommendations for injury prevention and training periodization. Methods: Injury data were retrospectively collected over six consecutive competitive seasons from elite U15 football players. Overall injuries, muscle injuries, and injury characteristics were recorded according to standardized injury surveillance procedures. Monthly injury frequencies were calculated descriptively, while exposure-adjusted injury incidence was analysed using incidence rate ratios (IRR) with 95% confidence intervals and Poisson regression with a log link function. Differences in the monthly distribution of traumatic and overuse injuries were assessed using the Wilcoxon matched-pairs signed-rank test. Statistical analyses were performed using TIBCO Statistica 14.1.0 and MedCalc software, with the significance level set at $p < 0.05$. Results: A total of 337 injuries were recorded during the observation period, of which 130 (38.6%) were classified as muscle injuries. Injury occurrence varied considerably throughout the season, with the highest overall injury frequencies observed in September (n = 46), October (n = 48), and February (n = 42). Muscle injuries demonstrated a comparable temporal pattern, peaking in September (n = 22) and April (n = 17). Incidence rate ratios revealed significantly greater injury risk in August (IRR = 1.79), September (IRR = 2.14), October (IRR = 2.33), and February (IRR = 2.18), whereas December exhibited the lowest injury risk (IRR = 0.10; $p < 0.001$). No significant differences were observed between the monthly distributions of traumatic and overuse injuries ($p = 0.31$). Conclusions: Injury occurrence in elite U15 football players demonstrates clear seasonal variation, with distinct high-risk periods immediately following the preseason and again during the second half of the competitive season. These findings emphasise the importance of exposure-based injury surveillance and support the implementation of targeted load management, structured strength and conditioning programmes, and injury-prevention strategies during periods of elevated injury risk.
Keywords: youth football; injury epidemiology; seasonal variation; injury incidence; muscle injuries; injury prevention

Introduction

High-intensity actions such as changes of direction, braking, sprinting, and tackles, performed frequently during football matches, contribute to the substantial injury burden observed in the sport (Carling, Le Gall, & Dupont, 2012). Injuries negatively affect team performance as well as players' health and wellbeing (Hägglund et al., 2013). In youth football, the consequences may be particularly important because injury-related time loss can disrupt long-term athletic development, reduce participation during important developmental periods, and potentially interfere with the acquisition of physical qualities during key "windows of trainability" (Materne et al., 2021). Furthermore, being separated from teammates and normal football activities may impose an additional psychological burden on young players (Merkel, 2013). These consequences emphasize the importance of primary injury prevention and, consequently, the identification of periods during which injury risk may be elevated (Frisch, Croisier, Urhausen, Seil, & Theisen, 2009; Jones et al., 2019).

Injury occurrence in football is not constant throughout the training year. Previous research in team sports has identified temporal fluctuations in injury rates, with increased injury occurrence during the early competitive period and at later stages of the season (Hawkins & Fuller, 1999; Orchard, 2002). One potential explanation is a carry-over effect from preceding training phases, whereby high preseason training loads followed by increased competitive demands may result in accumulated fatigue and repetitive tissue stress (Coppalle et al., 2019; Ekstrand, Spreco, Windt, & Khan, 2020; Leventer, Eek, & Lames, 2019). In addition, abrupt increases in training load following periods of reduced activity may further increase injury risk,

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particularly for non-contact soft-tissue injuries (Hulin et al., 2014; Read, Oliver, De Ste Croix, Myer, & Lloyd, 2018). Consequently, identifying specific periods of increased injury occurrence may provide practitioners with an opportunity to anticipate changes in injury risk and adjust training load, recovery, and physical preparation accordingly.

Despite the practical importance of seasonal injury variation, football-specific evidence comparing different phases of the training year remains relatively limited (Bahr, Clarsen, & Ekstrand, 2018). However, a few available studies focused solely to youth football academies, and reported the injury spikes in September, with August, January and March also contributing significantly to increased injury risk (Deehan, Bell, & McCaskie, 2007; Jones et al., 2019; Le Gall et al., 2006; Price, Hawkins, Hulse, & Hodson, 2004; Read, Oliver, et al., 2018). Deehan et al. investigated the U9-U18 players from FC Newcastle and found stable inter-seasonal injury patterns, with evidently a higher number of injuries in September and March (Deehan et al., 2007). Similarly, an audit of 608 injuries from six English professional academies also denoted September as the month with the highest injury occurrence, most likely due to the accumulation of fatigue following intensive training and the start of the competitive season (Read, Oliver, et al., 2018). Notably, January was also identified as a high-risk month for injuries, resulting from inappropriate loading upon training resumption (Price et al., 2004). Among other factors, injury risk appears to be significantly influenced by acute spikes in workload, as rapid escalations in training load can increase the likelihood of sustaining a non-contact soft tissue injury (Read, Oliver, et al., 2018). Lowest injury incidence has consistently been displayed in May and June, plausibly as a consequence of competitions usually being finalized mid to late May or early June. Considering all the available evidence, an „inverse U“ shape in injury rates was established during the youth football season, with incidence culminating during early in-season, falling low during late in-season, and peaking again in the spring part of the season (Hawkins & Fuller, 1999).

The temporal distribution of muscle injuries is of particular interest because muscle injuries represent a substantial proportion of injuries in both adult and youth football, accounting for approximately 37% and 45% of all injuries, respectively (Ekstrand, Hägglund, & Waldén, 2011a; Renshaw & Goodwin, 2016). In professional football, intra-seasonal analyses have demonstrated a two-peak pattern in muscle injury incidence, with increases occurring toward the end of both the first and second parts of the season (Leventer et al., 2019). Such patterns may be associated with cumulative training and match loads, fatigue, and insufficient recovery (Ekstrand, 2008; Rahnama, Reilly, & Lees, 2002; Reilly, Drust, & Clarke, 2008). Muscle injuries may also be particularly sensitive to rapid increases in external load, especially when training demands exceed the level to which the athlete has previously adapted (Gabbett, 2016). Therefore, monitoring muscle injury occurrence throughout the season may provide additional information for the planning of strength and conditioning programmes, high-speed running exposure, and recovery strategies.

This issue may be particularly relevant during adolescence, as U15 players commonly approach or progress through peak height velocity (PHV), accompanied by substantial morphological and physical changes that may temporarily challenge musculoskeletal adaptation to increasing football-specific loads (Bult, Barendrecht, & Tak, 2018). Accordingly, injury prevention in this population should emphasize progressive development of physical robustness through appropriately prescribed strength, power, and conditioning programmes (Moran et al., 2017). Moreover, although limited evidence suggests a higher proportion of overuse injuries, such as tendinopathies, during preseason and a greater tendency toward traumatic injuries during the competitive period, it remains unclear whether these injury types follow distinct monthly patterns (Ergun, Denerel, Mehmet, & Ertat, 2013; Le Gall et al., 2006). However, previous studies have largely relied on descriptive injury counts or broad seasonal comparisons, whereas evidence based on exposure-adjusted monthly incidence across multiple consecutive seasons remains scarce, particularly in players around peak height velocity. Therefore, this study aimed to examine intra-seasonal variation in the monthly incidence of overall and muscle injuries, as well as injury type and mechanism, across six consecutive competitive seasons in an elite U15 football academy. We hypothesised that injury incidence would be highest during the early competitive period, particularly in September, and again during the second half of the season. To our knowledge, no previous study has examined exposure-adjusted monthly injury incidence patterns across multiple consecutive seasons exclusively in elite U15 academy football players. Identifying periods of increased injury occurrence may provide practitioners with practical information for anticipating changes in injury burden and optimizing year-round training periodization, load management, physical preparation, and recovery strategies.

Materials and Methods

Study design

This prospective cohort study carried out injury surveillance of the elite Croatian U15 football players from one Academy during 6 competitive seasons. The investigation started in September 2016 and lasted until the end of the 2021/2022 season, including the COVID-19 period. Injured players were diagnosed by the medical department, with injury data immediately shared among all involved through the club's injury database. Informed consent was gathered from the parents/legal guardians of all injured athletes, considering that U15 players are minors. This study was performed in accordance with the Declaration of Helsinki and was approved by the Ethics

Committee of the Faculty of Kinesiology with approval number xyxyxy (approval number hidden for review purposes).

Participants

A total of 337 injuries, of which some 130 were muscle injuries, were analysed during the study. Injuries were classified according to the Consensus statement for injury surveillance in football (Fuller et al., 2006). Injury was defined as „*any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities*“. All players from the U15 group, including goalkeepers, were enrolled in the study. In this academy, players followed a structured training schedule that included five on-field training sessions per week (with an average duration of 85 minutes), supplemented with at least one weekly strength-training session. In addition, athletes participated in a minimum of one competitive match per week, with occasional mid-week cup games. During the observed period, the U15 category averaged 45 games per season.

Variables

Several injury-related variables were collected and analysed to examine seasonal and monthly patterns in injury occurrence. All time-loss injuries sustained during training or match play were recorded and aggregated to describe the overall injury burden across seasons and months. These data were used to assess the overall temporal trend in injury occurrence. Muscle-related time-loss injuries were extracted as a separate category to analyse the specific trend and distribution of muscle injuries across the observational period. Additionally, all injuries were classified according to the competitive season and the calendar month in which they occurred. This allowed for the examination of seasonal variation and potential monthly clustering of injuries. Further, to compare the mechanism of occurrence, injuries were classified into traumatic or overuse sub-groups. Lastly, monthly incidence rates were calculated by dividing the total annual injury incidence by the number of months during which players had regular training exposure. To ensure accuracy, exposure adjustments were made for months with reduced or irregular training loads. For example, December and January were counted as half-exposure months due to reduced training schedules during the winter break. Also, for the pandemic-affected season, training exposure from March to August was excluded, as no organised training or matches took place during this period.

Statistics

Injury occurrence was analysed using both descriptive and inferential statistical procedures. Injury incidence rates were calculated as the number of injuries divided by the corresponding exposure, expressed as injuries per 1,000 hours of football participation. To compare injury incidence across the six competitive seasons, Incidence Rate Ratios (IRR) with corresponding 95% confidence intervals were computed. IRR values were generated using MedCalc (MedCalc Software Ltd., Ostend, Belgium). Monthly injury incidence was modelled using a generalized linear model with a Poisson distribution and a log link function. Monthly exposure was included as an offset variable, allowing comparisons of exposure-adjusted injury incidence across months. The Wilcoxon matched pairs test was used to compare the monthly variation in traumatic and overuse injuries. Effect size (r) was calculated according to Cohen's recommendations and interpreted as small (0.10), moderate (0.30), or large (0.50). Statistical analyses were performed using TIBCO Statistica version 14.1.0 (TIBCO Software Inc., 2023). Statistical significance was set at $p < 0.05$ for all tests.

Results

A total of 337 injuries were recorded across the six competitive seasons, of which 130 (38.6%) were classified as muscle injuries. Overall injury occurrence demonstrated marked monthly variation, with the highest frequencies observed in October (48 injuries), September (46), and February (42) (Table 1).

Table I Total and mean values of overall and muscle injuries

Month	**Overall injuries**		**Muscle injuries**	
	Total (n)	Mean/season	Total (n)	Mean/season
July	16	2.7	6	1.0
August	31	5.2	9	1.5
September	46	7.7	22	3.7
October	48	8.0	16	2.7
November	29	4.8	12	2.0
December	2	0.3	1	0.2
January	23	3.8	5	0.8
February	42	7.0	15	2.5
March	36	6.0	13	2.2
April	29	4.8	17	2.8
May	33	5.5	14	2.3
June	2	0.3	0	0.0
	337	-	130	-

Muscle injuries followed a similar temporal pattern, peaking in September (22 injuries) and April (17 injuries) (Figure 1). Average monthly frequencies confirmed these findings, with the highest mean number of muscle injuries recorded in September (3.7 per season) and April (2.8 per season), whereas June demonstrated negligible injury occurrence.

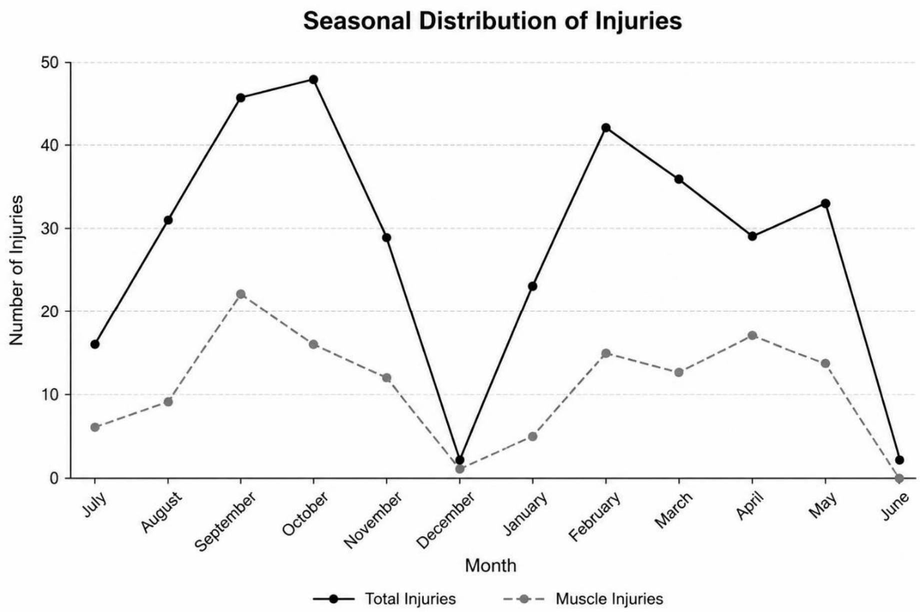

Figure I Monthly distribution of overall and muscle injuries

Seasonal comparisons using incidence rate ratios (IRRs) identified the 2016–17 season as having the highest injury risk (IRR = 1.84, 95% CI: 1.28–2.63, p = 0.0009), whereas the 2019–20 COVID-19 season demonstrated the lowest injury incidence (IRR = 0.67, 95% CI: 0.44–1.02, p = 0.062) (Table 2).

Table II Incidence rate ratio (IRR) by seasons (season 21–22 set as a reference year)

	IRR	**95% CI**	**p – value**
Season 16–17	**1.84**	1.28 – 2.63	**0.0009**
Season 17–18	0.96	0.65 – 1.42	0.836
Season 18–19	1.06	0.72 – 1.56	0.771
Season 19–20	0.67	0.44 – 1.02	0.062
Season 20–21	0.83	0.55 – 1.24	0.352

Monthly IRR analysis revealed significantly greater injury risk in August (IRR = 1.79, 95% CI: 1.03–3.09, p = 0.037), September (IRR = 2.14, 95% CI: 1.26–3.65, p = 0.005), October (IRR = 2.33, 95% CI: 1.38–3.94, p = 0.002), and February (IRR = 2.18, 95% CI: 1.28–3.70, p = 0.004), while December exhibited the lowest injury risk (IRR = 0.10, 95% CI: 0.03–0.39, p < 0.001) (Table 3, Figure 2). Notably, Poisson regression yielded findings consistent with the IRR analysis; therefore, only the IRR estimates are presented for clarity.

Table III Incidence rate ratio (IRR) by months (June set as a reference month)

	IRR	**95% CI**	**p – value**
July	0.81	0.43 – 1.54	0.525
August	**1.79**	1.03 – 3.09	0.037
September	**2.14**	1.26 – 3.65	0.005
October	**2.33**	1.38 – 3.94	0.002
November	1.65	0.95 – 2.87	0.076
December	**0.1**	0.03 – 0.39	<0.001
January	1.18	0.66 – 2.13	0.578
February	**2.18**	1.28 – 3.70	0.004
March	1.69	0.97 – 2.93	0.063
April	1.26	0.70 – 2.25	0.44
May	1.54	0.88 – 2.70	0.129

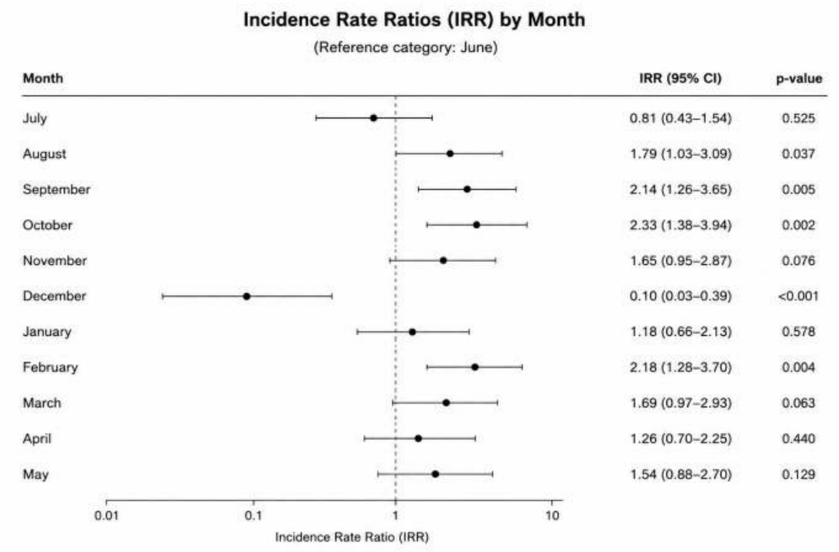

Figure II Forrest plot of monthly IRRs

A Wilcoxon matched-pairs signed-rank test was conducted to compare the monthly frequency of traumatic and overuse injuries aggregated across six competitive seasons. The analysis revealed no statistically significant difference between the two injury types ($T = 26.0$, $Z = 1.02$, $p = 0.31$). The corresponding effect size was small to moderate (r = 0.29), indicating only a weak tendency for monthly counts of traumatic and overuse injuries to differ (Table 4).

Table IV Wilcoxon matched-pairs comparison of monthly traumatic and overuse injury frequencies

Comparison	**T**	**Z**	**p-value**	**Effect size (r)**
Traumatic vs. overuse injuries	26.0	1.02	0.31	0.29

Discussion

This study examined seasonal and monthly fluctuations in injury incidence over six competitive seasons, revealing pronounced temporal variations in both overall and muscle-related injuries. Across the observed period, 337 injuries were documented, of which 130 (38.6%) were muscle injuries. Injury occurrence was not evenly distributed throughout the year, and several months consistently emerged as periods of heightened injury burden, aligning closely with the existing literature in youth and elite soccer populations.

Intra-seasonal variation in injury incidence

One of the most prominent findings was the clear clustering of injuries early in the competitive part of the season. September (46 injuries) and October (48) demonstrated the highest overall injury counts, with February (42) marking a secondary peak. Muscle injuries followed a similar temporal pattern, with the highest frequencies also occurring in September (22 injuries) and, interestingly, in April (17). Consistent with our findings, previous research reported a marked peak in September across six English professional academies (U11–U18), which was attributed to accumulated fatigue from preseason conditioning alongside the commencement of competitive fixtures (Read, Oliver, et al., 2018). Similarly, a group of French investigators found September to have the highest monthly incidence (9.7/1000h) in U14–U16 players, with June as the period of minimal injury occurrence, precisely matching our off-season findings (Le Gall et al., 2006). Moreover, the obvious early-season spike is further supported by Price et al., who observed increased injury rates immediately after preseason phases due to elevated training volume and insufficient adaptation time (Price et al., 2004).

Season 2016–17 exhibited significantly higher injury incidence compared with the other seasons, while the COVID-19–affected 2019–20 season displayed the lowest incidence, likely reflecting disruptions to training load, competition schedules, and exposure time (Škomrlj et al., 2024). Although the reasons for the gradual annual decline in injury incidence cannot be confirmed, it is plausible that continuous improvements in training methodology, greater involvement of qualified strength and conditioning specialists, and enhanced collaboration between the medical and coaching staff contributed to this trend (Bowen, Gross, Gimpel, & Li, 2017; Ekstrand et al., 2025; Read, Jimenez, Oliver, & Lloyd, 2018). When examining risk at the monthly level, August, September, and October were consistently associated with elevated injury risk, as indicated by significantly increased IRRs. It is important to note that although higher training volumes in the preseason may help athletes achieve optimal fitness, they also substantially contribute to the well-documented increase in injury rates during this period (Ekstrand et al., 2020). Our findings suggest a secondary rise in injury incidence during February. This is highly consistent with trends reported in large-scale academy datasets, where January – February increases were attributed to reduced conditioning during mid-season breaks followed by rapid escalations in training load (Price et al., 2004; Read, Oliver, et al., 2018). This is in line with the broader sports science literature indicating that sudden spikes in acute workload significantly elevate injury risk (Hulin et al., 2014). Unsurprisingly, December stood out as the least risky, which is consistent with a general reduction in match load and the presence of scheduled breaks common to many competitive calendars (Deehan et al., 2007; Price et al., 2004; Read, Oliver, et al., 2018).

Intra-seasonal variation in muscle injury incidence

Muscle injuries accounted for 38.6% of all recorded injuries, highlighting their substantial contribution to the overall injury burden in elite youth football. Their seasonal distribution largely mirrored that of overall injuries, with the highest frequencies observed in September and a secondary peak in April. Besides the accumulation of fatigue following intensive preseason conditioning, muscle injuries may also result from sudden increases in training and match demands to which the musculotendinous system has not yet fully adapted (Read, Oliver, et al., 2018). Rapid spikes in workload have consistently been identified as important contributors to non-contact muscle injuries (Gabbett, 2016; Hulin et al., 2014). Furthermore, the start of competitive fixtures in September, characterized by greater exposure to sprinting, accelerations, decelerations and high-speed running, may further increase muscle injury susceptibility (Ekstrand, Hägglund, & Waldén, 2011b). It could also be speculated that the return to school following the summer break introduces additional psychological and lifestyle stressors, including altered sleep habits, reduced recovery time and academic demands, which may indirectly contribute to injury risk in this age group (Taylor, Chrismas, Dascombe, Chamari, & Fowler, 2016).

The second increase in muscle injuries observed in April may reflect the cumulative effects of prolonged mechanical loading and residual fatigue accumulated throughout the competitive season. Previous studies have similarly reported a biphasic pattern of muscle injury occurrence, with peaks during the latter stages of both competitive phases, suggesting a carry-over effect of repeated exposure to high training and match loads (Leventer et al., 2019). Collectively, these findings reinforce the importance of progressively developing lower-limb strength, muscle capacity and sprint exposure throughout the season, rather than focusing injury prevention strategies solely during the preseason (Darragi et al., 2024; Malone et al., 2018; Zouita et al., 2016).

Seasonal patterns of traumatic and overuse injuries

Finally, the comparison between traumatic and overuse injuries indicated no significant difference in their monthly distributions, suggesting that both categories follow similar temporal rhythms driven by shared determinants such as accumulated load, congested competitive schedules, and the transition from preseason to the competitive phase. The small-to-moderate effect size further supports the interpretation that any differences between these injury types are subtle rather than systematic. While our results showed a small, yet statistically insignificant trend toward a higher proportion of traumatic injuries across two-thirds of the training year, this tendency is weak and does not allow for firm conclusions. These findings are consistent with the Newcastle Academy study, which similarly reported parallel seasonal fluctuations in traumatic and overuse injuries (Deehan et al., 2007). Sharp increases occurring during the early competitive periods closely resemble the shape of the curve observed in our cohort. Conversely, circa-peak height velocity (PHV) French football players sustained the highest number of overuse disorders (i.e., tendinopathies) in August (Le Gall et al., 2006). In practical terms, this reinforces the need for developing player robustness through structured strength and power training, particularly in U15 boys who are typically around their PHV and undergoing substantial morphological changes that temporarily reduce tissue resilience (Moran et al., 2017). Equally, reinforcing fair play (e.g., adhering to the rules of game, respecting opponents, and minimizing unnecessary contacts) through systematic education may help mitigate the proportion of traumatic injuries that arise from contact situations.

Strengths and limitations

The main limitation of the study lies in the absence of key contextual factors such as biological maturity status, morphological differences, and external load characteristics, all of which are known to substantially influence injury risk in youth football. Consequently, these unmeasured variables may partially account for some of the temporal injury patterns observed. Furthermore, the generalizability of the findings is constrained by the fact that the sample consisted of a single age category from one elite football academy. Despite this, the multi-season, longitudinal nature of the dataset represents a notable strength, providing a robust foundation for identifying stable temporal trends in injury occurrence. Additionally, because monthly exposure time was systematically calculated, the resulting incidence and IRR estimates allow for a more accurate interpretation of monthly injury risk across the competitive calendar. Collectively, these findings offer meaningful and practical guidance for optimizing training load distribution and tailoring injury-prevention strategies in youth football environments.

Conclusion

This study demonstrated clear intra-seasonal variation in injury occurrence among elite U15 football players across six consecutive competitive seasons. Overall injury incidence was highest during the early competitive period, particularly in September and October, with a second increase observed in February. Muscle injuries showed a broadly comparable temporal pattern, with the highest frequencies observed in September and April, indicating that muscle injury prevention should also account for periods of increased seasonal load. In contrast, December consistently represented a period of markedly lower injury occurrence. No significant difference was found between the monthly distributions of traumatic and overuse injuries, suggesting that both injury categories may be influenced by common temporal factors such as changes in training and match exposure, accumulated fatigue, and transitions between different phases of the season.

From a practical perspective, these findings indicate that injury-prevention strategies should not be applied uniformly throughout the year, but should be adapted to the demands of specific periods of the competitive season. Particular attention should be given to the transition from preseason to competition and to the resumption of high-intensity training and competition during the second half of the season. Progressive load management, adequate recovery, and continuous monitoring of training and match exposure may help reduce abrupt changes in workload during these higher-risk periods. In addition, year-round development and maintenance of strength, power, speed, and aerobic capacity should be incorporated into the training process to enhance player robustness, particularly in U15 players undergoing substantial growth and maturation.

The findings also highlight the value of integrating injury surveillance with practical monitoring tools, such as session-RPE, wellness measures, external-load monitoring, and maturation assessment, to support individualized training decisions. Education regarding fair-play principles and appropriate technical behaviour in contact situations may further contribute to reducing preventable traumatic injuries. Overall, the present findings provide an exposure-adjusted, multi-season perspective on monthly injury patterns in elite U15 football and may assist coaches, strength and conditioning practitioners, and medical staff in planning more targeted and maturation-sensitive injury-prevention strategies. Future research should incorporate individual maturation status, internal and external load, match congestion, and positional demands to further clarify the mechanisms underlying temporal variations in injury risk.

Declaration of generative ai and ai-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT (OpenAI, San Francisco, CA, USA) in order to assist with language editing and improve the clarity and readability of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Conflict of interest

Authors declare no conflict of interest.

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