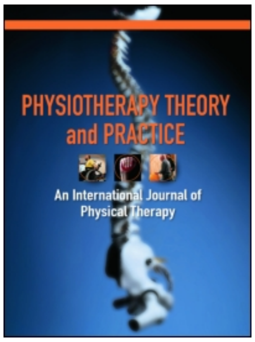

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Previous and current injury and not training and competition factors were associated with future injury prevalence across a season in adolescent elite athletes

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ABSTRACT

Introduction: Understanding the factors associated with different injury prevalence profiles in young athletes is needed for the design of tailored injury prevention programs.

Objectives: To explore the factors associated with different levels of injury prevalence in adolescent elite athletes.

Methods: A total of 389 adolescent elite athletes (age range 15–19 years), participating in 16 different sports, were monitored repeatedly over 52 weeks using the Oslo Sports Trauma Research Center Overuse Injury Questionnaire. The athletes were grouped in three injury categories: (1) "Low injury"; (2) "Medium injury"; and (3) "High injury," based on the proportion of times the athletes reported substantial injury over the season.

Results: Logistic and multinomial regression identified substantial injury the first week (odds ratio (OR) 53.9, 95% confidence interval (CI) 7.1–407.7), and an interaction between sex and previous injury (OR 3.9, 95% CI 1.1–12.4) as significant factors that increased the odds of belonging in the High injury compared to the Low injury group. A female athlete with a previous injury the last 12 months had a higher probability of belonging in the High injury group compared to a male athlete.No significant ($p > .05$) difference in training, sleep, or competition exposure was found across the injury category.

Conclusion: Current substantial injury and previous injury were strongly associated with the most injured athletes. Coaches and medical team should consider limiting the injured athlete competition exposure.

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Athletic injury; youth athletes; performance

Introduction

During the last decade, an increased professionalization of youth competition has taken place (DiFiori et al., 2014), pushing youth sports closer to the sports of adults in terms of competitiveness. Consequently, elite sports for young athletes are associated with high training volume, training intensity, and high amount of participation in competitions, all in an attempt to develop young athletes into potential top athletes (von Rosen et al., 2018a). This emphasis on success at such an early stage is likely to increase the risk for musculoskeletal injuries and other unhealthy events such as drop-outs, social isolation, overdependence, or burnouts (DiFiori et al., 2014; Malina, 2010). In addition, sports injuries could greatly burden a young athlete and stress physical and psychosocial functioning, as well as affect performance (Maffulli, Baxter-Jones, and Grieve, 2005; von Rosen et al., 2018b). Unfortunately, a limited number of prospective long-term studies on injury surveillance in adolescent elite athletes are available, making injury prevention difficult in these athletes due to lack of epidemiological data (van Mechelen, Hlobil, and Kemper, 1992).

In contrast to adult elite athletes, injuries and associated risk factors for injuries in adolescent elite athletes are less studied. The existing prospective injury surveillance studies have shown a high injury incidence (Jacobsson et al., 2013; Kirialanis, Malliou, Beneka, and Giannakopoulos, 2003; Kolt and Kirkby, 1999; Le Gall, Carling, and Reilly, 2008; Le Gall et al., 2006; Price, Hawkins, Hulse, and Hodson, 2004; Westin, Alricsson, and Werner, 2012) as well as high injury prevalence (Jacobsson et al., 2012; von Rosen, Heijne, and Frohm, 2016). The injury incidence has varied between 1.4 and 6.4/1000 hours of training and up to 22.4/1000 hours of competition, probably related to use of different injury definitions and data collection methods (Clarsen, Myklebust, and Bahr, 2013).

Identifying risk factors is a crucial step in injury prevention (van Mechelen, Hlobil, and Kemper, 1992). Apart from within football, there are limited studies in the scientific literature on injury risk and risk factors in adolescent elite athletes. The etiology of sports injuries is multifactorial, involving both internal and external

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risk factors (Bahr and Krosshaug, 2005). By considering multiple risk factors and interactions in one model, the unique contribution to injury risk of a specific factor can be established (Meeuwisse, 1994).

Several risk factors for injuries in youth elite sports have been suggested (DiFiori et al., 2014), where the most conclusive risk factor is a previous injury (Brooks, Fuller, Kemp, and Reddin, 2005; Hjelm, Werner, and Renstrom, 2012; Jacobsson et al., 2013). A previous injury has been found to increase the risk of a subsequent injury, possibly related to inadequate rehabilitation or to a specific injury risk behavior or trait associated with the previously injured athlete (Hagglund, Walden, and Ekstrand, 2006; Murphy, Connolly, and Beynnon, 2003). Sex differences regarding injury type and injury location have been found, where female athletes have a higher risk for knee injuries in general, including serious knee injuries such as anterior cruciate ligament injury, compared to male athletes (Richardson, Clarsen, Verhagen, and Stubbe, 2017; Swenson et al., 2013). Still, identifying risk factors for young athletes based on injury surveillance data for a complete season is uncommon, but a necessity for providing an appropriate picture of injury risk in a wider perspective (Bahr, 2009; van Mechelen, Hlobil, and Kemper, 1992). Due to different length of study period, injury definitions, and data collection methods, several uncertainties exist regarding injury risk in young athletes. Understanding the factors associated with different injury prevalence profiles would be helpful when designing tailored prevention programs and to identify high injury risk groups. The primary aim of this study was, therefore, to explore factors associated with different levels of injury prevalence in adolescent elite athletes.

Methods

This study is part of the KASIP-study (Karolinska Athlete Screening Injury Prevention), aiming to understand injury occurrence and associated risk factors in Swedish adolescent elite athletes based on a prospective cohort design, and is approved by the Regional Ethical Committee in Sweden (No: 2011/749–31/3).

Recruitment process and participants

Recruitment of participants was performed in September–December 2013 and 2014 and has previously been described in detail (von Rosen et al., 2017). The heads of all National Federations in Sweden with national sports high schools were invited to participate in the KASIP-study. This resulted in acceptance from the National Federation of Skiing, Orienteering, Handball, Track and Field, Water ski, Canoe, Rowing, Wrestling, Bowling, Triathlon, Golf, Cycling, and American football.

In all, 732 adolescent elite athletes (age range 15–19) from 16 different sports and 24 National Sports High Schools were invited to participate. All athletes are considered to be elite athletes since they are participating in national teams, national junior cups, and studying on sports high schools where only athletes with the highest ranking of their age are eligible. The schools were visited by one of the authors to inform the coaches and the athletes about the purpose of the study.

A total of 680 athletes (92.9%) responded to the invitation. Written consent was obtained from all athletes. The Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire and questions about performed training and sleep were e-mailed to the athletes for a period of 52 weeks. The athletes monitored during the first year received the questionnaire weekly and the athletes monitored during the second year received the questionnaire bi-weekly. Changing the questionnaire distribution the second year was decided upon in order to improve the response rate of the athletes. If no response had been registered, a reminder e-mail was sent four days later. During the first week of the study, all athletes were also asked to fill out an online background questionnaire about personal data including the history of previous injury the last year and access to medical personnel. The software Questback online survey (Questback V. 9.9, Questback AS, Oslo, Norway) was used for data collection.

In this study, all athletes only contributed to data for either the first or the second year. This was decided upon to limit the follow-up time to 1 year for all athletes. To be included in data analysis, athletes needed to report at least 33% (year 1, $n = 17$; year 2, $n = 9$) of all questionnaires. The rationale for this was to have a constant report of injury data throughout the season. Consequently, 291 athletes were excluded (year 1 = 156, year 2 = 135) and 389 adolescent elite athletes (female = 188, male = 201, year 1 = 225, year 2 = 164) were included, representing 53% of the initial selection of athletes. The excluded athletes did not differ from the cohort under investigation, regarding sex, history of previous injury, and injury at study start ($p > .05$). All athletes were grouped in tertiles based on the proportion of times the athletes reported injury leading to moderate or severe reductions in training volume, or moderate or severe reduction in performance, or complete inability to participate in sports (i.e., substantial injury according to the OSTRC Overuse Injury Questionnaire) over the season. The three groups, making up the injury category, are named: (1) “Low injury” ($n = 129$); (2) “Medium injury” ($n = 125$); and (3) “High injury” ($n = 135$).

Questionnaire and operational definitions

The questionnaire contained the validated and translated version of the OSTRC (Overuse Injury Questionnaire (Clarsen, Myklebust, and Bahr, 2013; Ekman et al., 2015) as well as questions about training volume (hours/ week), training intensity, number of days of competitions, average sleep volume per day, and injury recovery (Jacobsson et al., 2013). In this study, only the OSTRC Overuse Injury Questionnaire and questions about training and sleep were used. The OSTRC Overuse Injury Questionnaire measures injury consequences on sports participation, performance, training, and pain based on four questions with alternative responses. The OSTRC Overuse Injury Questionnaire assesses injuries' effect on (1) sports participation (four responses ranging from "full participation" to "cannot participate"); (2) reduction in training volume (five responses ranging from "no reduction" to "cannot participate"); (3) reduced sporting performance (five responses ranging from "no effect" to "cannot participate"); and (4) experience of pain (four responses ranging from "no pain" to "severe pain"). Thereby, both overuse and acute injuries based on self-reported data can be identified. The completion of the questionnaire took approximately 5 min and additionally 2–3 min if part 2 or 3 was current. The average response rate across the season was 72% for the included athletes. In this study, an injury was defined as a substantial injury leading to moderate or severe reductions in training volume, or moderate or severe reduction in performance, or complete inability to participate in sports based on responses to items of the OSTRC Overuse Injury Questionnaire (Clarsen, Myklebust, and Bahr, 2013).

Data analysis

Descriptive statistics for continuous variables are presented as mean and standard deviation (SD) and for categorical data as frequency with proportion (%). The effect size for injury, sleep, and training data across injury category was computed using Hedges' *g* calculation. A cumulative severity score was determined, by allocating a numerical value from 0 to 25 to the alternative responses in the four questions in the OSTRC Overuse Injury Questionnaire (Clarsen, Myklebust, and Bahr, 2013). The scores from the four questions were then summed. Consequently, a score of 0 represents no injury and 100 the highest level of a severity grade. An average severity score was then calculated for each anatomical area across the injury category (Clarsen, Myklebust, and Bahr, 2013).

A multinomial regression was used to model the injury category with Low injury group as reference. Predictors were nominal variables (i.e., sex, previous injury the last 12 months, medical access, and substantial injury at study start) and continuous variables (i.e., average sleep volume, training intensity, training volume, and number of days of competitions). Incomplete information regarding the predictor substantial injury at study start was apparent since no athlete reported substantial injury the first week in the Low injury group compared to 14% (n = 16) and 37% (n = 50) in the Medium and High injury group, respectively. This variable was, therefore, excluded in the multinomial regression model. The predictors were simultaneously entered in the model to assess the impact of all variables in the same model. The interaction was tested by sex and other predictors and included in the final model if significant ($p < .05$). The final model was adjusted by age.

To theoretically estimate an overall effect of substantial injury at study start, the cutoff value for the Low injury group was arbitrary changed (substantial injury <3%), and consequently, five more athletes were included in the Low injury group, resulting in that one athlete in the new Low injury group had a substantial injury at study start. The new injury category was then modeled in a logistic regression model with High injury as the outcome of the dependent variable and Low injury as reference, including the same predictors as in the multinomial regression model.

The final regression models were assessed for goodness of fit (Hosmer–Lemeshow test); linearity of the logit and influence diagnostics (Cook's distances, DFBeta values); and multicollinearity (Variance inflation factors (VIF) and Tolerance values). All assumptions and models diagnostics were determined to be satisfactory (Cook's distances <1; DFBeta values <1; VIF < 1.1; and Tolerance <1) except for the assumption of linearity, where the variable number of days of competitions did not hold the assumption and was consequently excluded from the regression analyses. Throughout calculations, the significance level was set to $p < .05$, and 95% confidence intervals (95% CI) were calculated. All statistical analyses were performed in SPSS (V.24, IBM Corporation, New York, USA).

Results

The average substantial injury prevalence for all athletes was 16.0% (SD 21.8). Of all athletes, 29.3% (n = 109) reported previous injury the last 12 months and 17.0% (n = 66) reported injury at study start. A similar distribution of sex and athletes that had access to medical personnel was found across the injury category (Supplementary file). However, a higher proportion of the High injury group reported previous injury the last 12 months (n = 56, 41%) and injury at study start (n = 50, 37%) compared to the Low injury group (previous injury, n = 21 (17%); injury at study start, n = 0).

Across the season, the High injury group reported higher substantial injury prevalence compared to the Low injury group with a very large Hedges'g effect size (2.3) (Table 1). Of the four sports with the highest number of participants, the High injury group consisted of about half of all athletes from athletics (47%, n = 53) and handball (58%, n = 25), in contrast to a smaller proportion of athletes from orienteering (15%, n = 8) and cross-country skiing (19%, n = 14). Across injury category, the severity score differed for injuries in the foot, lower leg, knee, hip, lower back, and shoulder (average difference of 2.3–8.1 points between High and Low injury groups), in contrast to the remaining body regions (Figure 1).

The multinomial regression analysis, with the Low injury group as reference, showed no significant ($p > .05$) difference in average training volume, training intensity, or sleep volume across injury category (Table 2). Instead, a significant ($p = .039$) interaction was found between sex and previous injury (odds ratio (OR) 3.9), demonstrating that a female athlete with a previous injury the last 12 months had a probability of 67% of belonging in the High injury group compared to the Low injury group. The same value for a male athlete was 37%.

A logistic regression was then conducted to handle incomplete separation regarding substantial injury where the dependent variable was High injury group with Low injury group as reference. Including the same predictors as in the multinomial regression analysis with the addition of substantial injury at study start showed that reporting substantial injury the first week significantly ($p < .001$) increased the odds by 54 times (95% CI 7.1–407.7) of belonging in the High injury group. Overall, a significant ($p < .05$) higher proportion of the High injury group reported substantial injury at each time point compared to the other two groups. Consequently, injury data differed across the injury category at an early stage of the study (Figure 2).

Discussion

Our results provide supporting evidence that substantial injury at study start and previous injury the last 12 months have a clear association with future injury in adolescent elite athletes. In addition, the three injury groups showed clear differences in injury data across all time points of the season, illustrating that the average athlete in each group differed significantly at an early stage of the study. We could also demonstrate that females with a previous injury had a higher risk of belonging in the High injury group as opposed to a male athlete with a previous injury.

Returning to sports while injured

In this study, the average training or competition exposure did not differ across injury groups. For instance, even the athletes with more than a third of all times points with substantial injury were involved in a similar amount of training or competition exposure as athletes with less or no substantial injury. This questions if the coaches or medical teams are aware of athletes' injury occurrence or competition behavior and recognize the problem with returning to sports too soon following injury (Hamilton, Meeuwisse, Emery, and Shrier, 2011). It further questions if the rehabilitation for the athletes in the High injury group was adequate. Even if it is common for elite athletes to continue to train and compete despite pain (Bahr, 2009; Clarsen, Myklebust, and Bahr, 2013; von Rosen et al., 2018b), the consequences of such behavior are less known for future sports participation. One challenge for the medical teams is to provide adequate long-term rehabilitation care and make appropriate return-to-play decisions (Ardern et al., 2016; Shultz et al., 2013). We also found that the absolute and greatest difference in severity grade across injury category was related to injuries located in the foot, lower leg, knee, lower back, and shoulder. In order to equal injury occurrence across injury category based on our findings, medical teams will have to focus on the treatment of injuries in these body regions.

Table 1. Injury, sleep, and training data across injury category, presented with mean values (SD) over 52 weeks.

	High injury (n = 135)	Medium injury (n = 125)	Low injury (n = 129)	Hedges' g High injury vs. Medium injury	Hedges' g High injury vs. Low injury
Substantial injury prevalence	38.7 (23.3)	7.6 (3.3)	0 (1.0)	1.8	2.3
Training intensity	5.8 (1.8)	5.8 (1.7)	5.9 (1.7)	0	0.1
Training volume hours/week	8.8 (3.1)	8.9 (3.6)	9.6 (3.6)	0	0.2
Days competitions/week	1.2 (0.5)	1.4 (0.5)	1.4 (0.4)	0.3	0.3
Sleep volume hours/week	7.8 (1.2)	7.9 (0.6)	7.9 (0.6)	0.1	0.2

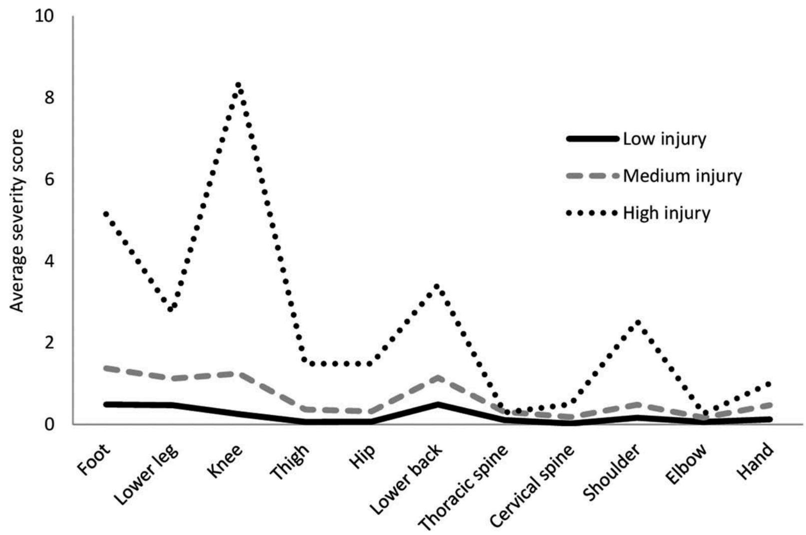

Figure 1. The average severity group displayed for different body regions, across injury category.

Table 2. Multinomial logistic regression analysis.

	High injury vs. Low injury[a]			Medium injury vs. Low injury[b]		
Mod2el	OR (95% CI)	Wald	*p*-Value	OR (95% CI)	Wald	*p*-Value
Previous injury[c]	0.6 (0.2–1.4)	1.591	0.207	0.5 (0.2–1.2)	2.316	0.128
Medical access	0.9 (0.5–1.6)	0.129	0.719	1.3 (0.8–2.3)	1.151	0.283
Sex-female	1.3 (0.7–2.4)	0.528	0.468	0.8 (0.5–1.5)	0.332	0.564
Sleep volume	0.8 (0.5–1.1)	1.993	0.158	0.9 (0.7–1.3)	0.112	0.738
Training intensity	1.0 (0.8–1.2)	0.011	0.916	1.0 (0.8–1.2)	0.031	0.860
Training volume	1.0 (0.9–1.0)	0.913	0.339	0.9 (0.9–1.0)	1.524	0.217
Interaction Sex × Previous injury	3.9 (1.1–12.4)	4.244	0.039	0.6 (0.2–2.2)	0.576	0.448

CI: confidence interval; OR: odds ratio.
[a]Intercept b = 3.9, adjusted for age category.
[b]Intercept b = 1.5, adjusted for age category.
[c]Sustained injury the last 12 months that has affected or completely hindered training for a continuous period of at least 3 weeks.

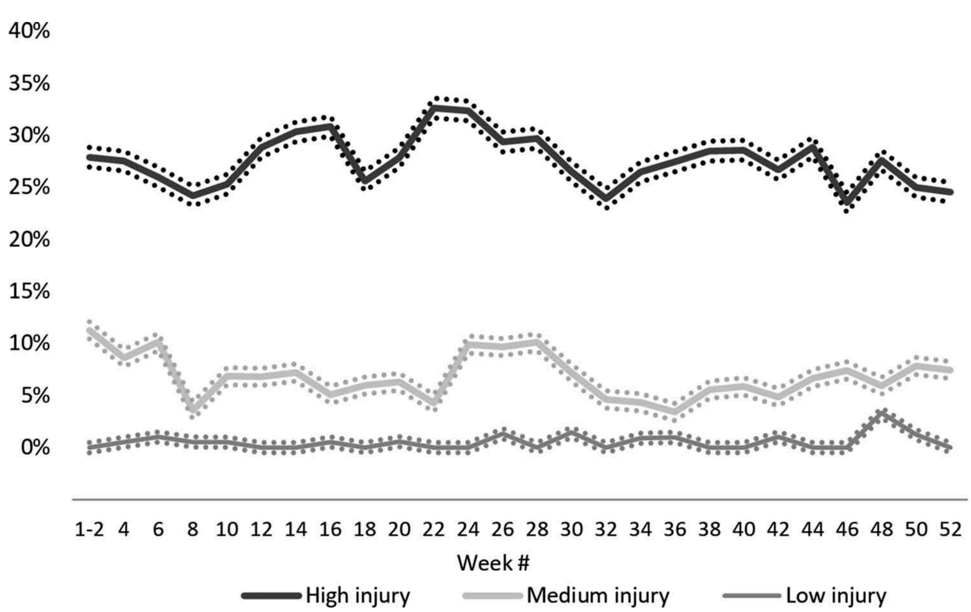

Figure 2. Substantial injury across injury category over 52 weeks with 95% CI depicted using dotted lines.

Already injured at study start

At the start of the study, more than a third of the athletes in the High injury group reported substantial injury and over 40% reported a previous injury. Even if this study included young elite athletes in age 15–19, the data suggest that already a high proportion of young elite athletes are injured. This raises the question if it is too late to monitor injury data in young elite athletes of age 15–19 in order to truly understand injury causes. We, therefore, suggest that injury data in young talented athletes are registered long before they enter a sport high school, to accurately understand the cause of injury. Since a previous injury is a strong risk factor for a new injury (Brooks, 2005; Emery, 2003; Engebretsen et al., 2010; Hjelm, Werner, and Renstrom, 2012; van der Worp et al., 2015), understanding the mediation pathways between previous and future injuries is warranted in this young population.

Strong association between previous injury and future injury

Our findings are consistent with previous research demonstrating that previous or current injury constitutes a great injury risk for future injury (Arnason et al., 2004; Engebretsen et al., 2010; Fulton et al., 2014). These two variables had a remarkable strong effect on the odds of belonging in a specific injury category compared to other included variables. In our data, females with a previous injury had a greater injury risk compared to male athletes, and access to medical care did not alter injury risk. Therefore, we suggest that coaches and the medical team of young elite athletes should carefully decide on when the young athlete should return to sports following injury. A falsely taken return-to-play decision may result in that a large part of the season will be performed with injury, which may delay and have consequences for the future elite athlete career (von Rosen and Heijne, 2018). Besides, since a congested competition calendar is associated with an increased injury risk (Soligard et al., 2016), the effect on injury prevention by not letting the athlete return to competition too soon following injury needs to be tested. Since there are multiple factors influencing injury risk (e.g., genetic, psychologic, biomechanical, and nutritional) that were not controlled for in this study, future studies should investigate multiple factors, including previous or current injury, when exploring injury risk in adolescent elite athletes.

Methodological considerations

The strengths of this study are the prospective nature, following a high number of adolescent elite athletes over a complete season. The sample consisted of a wide geographical mix of adolescent elite athletes from 16 different sports and 24 National Sports High Schools, located all over Sweden. To attend these schools, all athletes have to compete at the highest national level for their age group. A reliable, validated questionnaire previously used in sports surveillance was also used, utilized a modern definition of injury.

The study's methodology has limitations, and the used inclusion criteria may represent a selection bias since the eligible athlete had to respond to every third questionnaire. This might have led to that the most motivated athletes were included. Although a subgroup analysis showed no difference regarding baseline injury data between the excluded and included athletes, we do not know for sure if these athletes differ in terms of prospective injury data. We excluded athletes with insufficient response rate to focus the results on athletes with a decent response rate. The response rate was on average 72%, and we did not consider the variation in response rate along the season, which affects the internal validity of the study. There exist no criteria for what constitutes a satisfactory response rate, and monitoring young athletes over 52 weeks using online questionnaires is challenging. Based on Clarsen, Myklebust, and Bahr (2013), we believe the response rate may have underestimated the true substantial injury prevalence.

The OSTRC Overuse Injury Questionnaire has been validated in both adolescents and adult athletes from a variety of sports (Clarsen, Myklebust, and Bahr, 2013) making it valid for the studied population. However, a higher number of questionnaires had to be responded in year 1 compared to year 2. Thus, different inclusion thresholds were used for different athletes. In addition, our analyses did not censor injured athletes at study start. Instead, all time points for each athlete were used to explore injury risk in a practical setting based on seasonal data. Thus, no risk factors in a classical epidemiological approach were identified (Meeuwisse, 1994); instead, the study was designed to identify the factors associated with different injury profiles. Since many athletes were injured at study start, this approach is beneficial but does not result in that cause-relationship estimates could be obtained. However, we controlled for exposure data across the injury category and found no great difference. Recall bias may be present, especially for the variable previous injury the last 12 months. Training exposure and sleep duration were self-reported, and consequently, both over- and underestimation has to be considered. However, most of the athletes included are used to estimate training volume and sleep, due to regular wear of GPS watches, smartphones, or keeping training diaries, suggesting that these estimates might be accurate. At the start of the inclusion, some athletes were in the competitive season, other in base training or pre-season, which may have led to different injury risks at study start related to variation in training or competition exposure. However, following the athletes during a complete season likely minimized this bias by allowing for all season components (i.e., base training, pre-season, and competitive season).

Conclusion

Our results provide supporting evidence that substantial injury at study start and previous injury the last 12 months are associated with future injury in adolescent elite athletes. In addition, the three injury groups showed clear differences in injury data across all time points of the season, illustrating that the average athlete in each group differed significantly at an early stage of the study. Concerning, no significant difference in training or competition exposure was found across injury category, suggesting that athletes with a high part of injury prevalence across a season participate in competitions to a similar degree as injury-free athletes or athletes with little injury prevalence. It is, therefore, suggested that coaches and medical team should consider limiting the injured athlete competition exposure.

Declaration of Interest

The authors declare no conflict of interest.

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