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Previous injury, sex and well-being are associated with injury profiles in 422 adolescent elite athletes of age 15–16 years: a 20-week longitudinal study

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ABSTRACT

Background Adolescent elite athletes have a high injury risk and many risk factors for injury have been suggested. However, there is a lack of prospective studies in adolescent elite athletes of age 15–16 years.

Aim The aim of the study was to prospectively explore risk factors associated with different injury prevalence profiles in adolescent elite athletes.

Methods Substantial injury was monitored in adolescent elite athletes (n=422) using the validated Oslo Sports Trauma Research Center Questionnaire over 20 weeks. Athletes were categorised in tertiles based on injury prevalence.

Results The median substantial injury prevalence for all athletes was 10% (IQR 0%–20%). Compared with the 'no injury' group, previous injury (p<0.001, OR 3.91) and well-being (p<0.001, OR 0.93) were associated with the 'high injury' group, and previous injury (p=0.006, OR 1.96) and being a female athlete (p=0.002, OR 2.08) with the 'low injury' group. A female athlete with a previous injury and low perceived well-being (25th percentile) had a 48% risk (95% CI 36% to 59%) of belonging to the 'high injury' group, compared with 7% (95% CI 4% to 12%) for a male athlete with no previous injury and high well-being (75th percentile).

Conclusion Medical personnel should be aware of the high injury risk and risk factors for injury in adolescent elite athletes, and closely monitor the rehabilitation post-injury as a previous injury is such a strong risk factor for a new injury.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Although few prospective injury registration studies are available, adolescent elite athletes have in general a high injury risk and many risk factors for injury have been suggested.

WHAT THIS STUDY ADDS

⇒ A female athlete with a previous injury and low perceived well-being had the highest risk of belonging in the most injured group.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Medical personnel should be aware of the high injury risk and associated risk factors for injury in adolescent elite athletes, and closely monitor the rehabilitation process as a previous injury is such a strong risk factor for a new injury.

BACKGROUND

Elite sports for young athletes are associated with high training volume, training intensity and high amount of participation in competitions, in an attempt to develop young athletes into potential top athletes. However, the high levels of exposure to sports in young athletes are likely to increase the risk of musculoskeletal injuries.[1 2] Besides, adolescent athletes are in a period characterised by rapid physical growth, in which biological, cognitive and psychosocial processes are maturing. Therefore, participation in elite sports during adolescence, when the athlete goes through several rapid body changes, likely increases the risk of injury further.[1 3 4]

An elite athlete is defined as an individual who competes in his or her sport at a high national or international level. In adolescent elite athletes, the injury incidence has varied between 1.4 and 6.4/1000 hours of training and up to 22.4/1000 hours of competition.[5–7] Even if injury risk is sports specific, the majority of injuries in adolescent elite athletes seem to occur in the lower extremities, such as the foot and knee regions, often involving the apophyses.[6–8] In contrast to adult elite athletes, a limited number of prospective long-term studies on injury surveillance in adolescent elite athletes are available, making strategies for injury prevention difficult to develop due to a lack of epidemiological data.[9] In addition, few studies are available in young adolescent athletes (age 13–16 years), in a period of life when sports specialisation becomes more and more common.[1 10]

Identifying risk factors is a crucial step in injury prevention[9] and the aetiology of sports injuries is suggested to be multifactorial.

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Table 1 Descriptive data by all athletes and injury group membership

	All athletes (n=422)	No injury (n=199)	Low injury (n=132)	High injury (n=91)
Female, n (%)	196 (47)	74 (37)	73 (55)	49 (54)
BMI*, mean (SD)	58.5 (21.1)	57.7 (21.7)	57.6 (21.2)	61.7 (19.2)
Individual exercise programme, n (%)	283 (67)	132 (66)	87 (66)	64 (71)
Previous injury†, n (%)	162 (39)	56 (28)	54 (41)	52 (58)
Previous illness†, n (%)	46 (11)	14 (7)	15 (11)	17 (19)
Medical personnel, n (%)	272 (65)	115 (58)	90 (69)	67 (74)
Training volume, mean (SD)	10.7 (4.1)	11.1 (4.3)	10.6 (3.9)	10.2 (4.0)
Well-being, mean (SD)	72.8 (13.5)	76.5 (12.2)	73.3 (13.6)	63.9 (12.2)
Age sports specialisation, mean (SD)	12.4 (1.8)	12.4 (1.8)	12.6 (1.7)	12.0 (1.9)
Injury prevalence, median % (IQR)	10 (0–20)	0 (0)	11 (10–20)	44 (33–67)

*BMI-for-age percentile (adjusted for age and sex).
†Sustained injury or illness within the last 12 months that has affected or completely hindered training for a continuous period of at least 3 weeks.
BMI, body mass index.

Apart from within football, there are limited studies in the scientific literature on injury risk factors. The most conclusive risk factor for a new injury is a previous injury.[11–13] This has been suggested to be explained by inadequate rehabilitation or by a specific injury risk behaviour or trait associated with the previously injured athlete.[14 15] However, several other risk factors have also been highlighted such as sex, training exposure and psychosocial factors.[16 17]

Due to the use of different injury definitions and data collection methods, several uncertainties exist regarding injury risk in young athletes. Understanding factors associated with different injury prevalence profiles is important for developing injury prevention programmes and identifying athletes with the highest injury risk. Therefore, the primary aim of this study was to explore risk factors associated with different injury prevalence profiles in adolescent elite athletes of age 15–16 years. We hypothesised that a previous injury could distinguish the three groups.

METHOD

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.

Recruitment process and participants

Recruitment of participants was performed in March–May 2019. The heads of all National Federations in Sweden with sports high schools were invited to participate in the KASIP Study. This resulted in acceptance from the National Federation of Bandy, Basketball, Canoe, Curling, Football, Gymnastics, Ice Hockey, Orienteering, Sailing, Skiing, Swimming, Tennis and Volleyball.

Approximately 700 adolescent elite athletes (age range 15–16 years) who had applied to start studying at a sports high school were considered eligible and therefore invited. A total of 489 athletes (70%) accepted the invitation, representing the sports bandy (n=2), basketball (n=11), canoe (n=3), cross-country skiing (n=51), curling (n=4), downhill skiing (n=21), football (n=185), gymnastics (n=19), ice hockey (n=74), orienteering (n=26), sailing (n=6), ski cross (n=4), swimming (n=44), tennis (n=16) and volleyball (n=23).

Written consent was obtained from all athletes. The Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire[18] was sent to the athletes using text messages, including 10 weeks before and 10 weeks after

Table 2 Multinomial regression analysis for injury group membership

	Low injury versus no injury*			High injury versus no injury†		
Model	OR (95% CI)	SE	P value	OR (95% CI)	SE	P value
Female athlete	2.08 (1.30 to 3.32)	0.24	0.002	1.52 (0.85 to 2.70)	0.29	0.157
Previous injury‡	1.96 (1.21 to 3.15)	0.24	0.006	3.91 (2.21 to 6.90)	0.29	<0.001
Well-being	0.99 (0.97 to 1.004)	0.01	0.121	0.93 (0.91 to 0.95)	0.01	<0.001

*Intercept 1.14.
†Intercept 3.34.
‡Sustained injury within the last 12 months that has affected or completely hindered training for a continuous period of at least 3 weeks.

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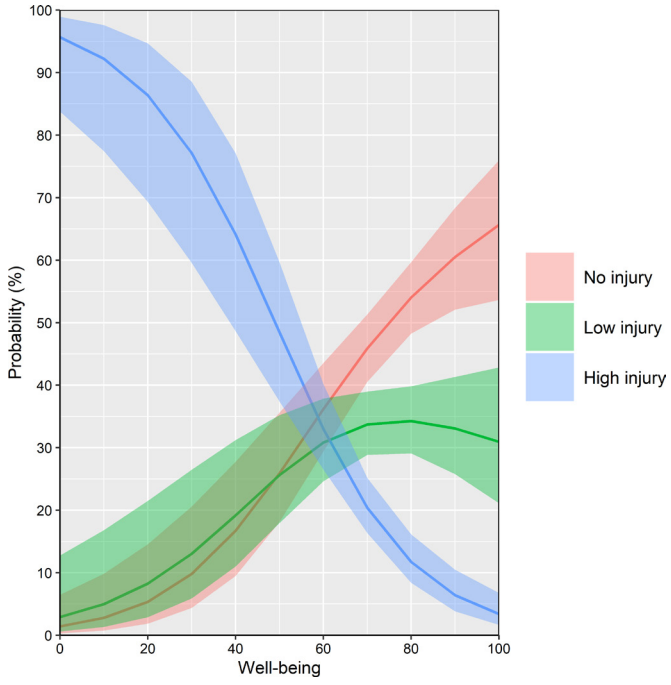

Figure 1 Probability for injury group membership across perceived well-being. Athletes were grouped in tertiles based on the proportion of times the athletes reported injury and a multinomial regression analysis was used to estimate probability for injury group, adjusted for sex, previous injury and perceived well-being. Lighter colours depict 95% CIs.

the athlete had started to study at a sports high school. The athletes received the questionnaire biweekly. If no response had been registered, a reminder email was sent 4 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 an injury. The software Questback online survey (Questback V.9.9, Questback, Oslo, Norway) was used for data collection.

Questionnaire and injury definition

The questionnaire contained the validated and translated version of the OSTRC (Overuse Injury Questionnaire)[18 19] as well as questions about training volume (hours/week), training intensity, number of days of competitions, average training intensity (0–10 scale) and perceived well-being (0–100 scale). 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'). The completion of the questionnaire took approximately 3 min. In this study, injury was defined as a substantial injury leading to moderate or severe reductions in training volume, moderate or severe reduction in performance, or complete inability to participate in sports based on responses to items of the OSTRC Overuse Injury Questionnaire. The average response rate across the season was 86% for the included athletes.

Data processing

To be included in data analysis, athletes needed to report at least 50% (n=5) of all questionnaires. The rationale for this was to have a constant report of injury data throughout the study period. This resulted in 67 excluded athletes. All athletes were grouped in tertiles based on the proportion of times the athletes reported substantial injury. This approach resulted in slightly unbalanced groups since several athletes reported no injury. The three groups, making up the injury category, are named: (1) 'no injury' (n=199); (2) 'low injury' (n=132) and (3) 'high injury' (n=91).

Data analysis

Descriptive statistics are provided as mean and SD or median and IQR for continuous data and as frequency with proportion (%) for categorical data. A multinomial regression was used to model the injury category with 'no injury' as a reference. Possible independent variables were categorical variables (ie, sex, previous injury in the last 12 months, previous illness in the last 12 months, access to medical personnel, following an individual exercise programme, age when deciding one sport as being more important than other sports (referred to as sports specialisation)) and continuous variables (ie, body mass index-for-age percentile (adjusted for age and sex), training volume, training intensity, well-being) measured at baseline. All independent variables associated with the dependent variable at $p<0.20$, in univariate regression analyses, were included in a backward multinomial regression. Independent variables were then removed 'one by one' based on information criteria such as Akaike information criterion and Bayesian information criterion values, and the final model was chosen based on these values.

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 and tolerance values). Throughout calculations, the significance level was set to $p<0.05$, and 95% CIs were calculated. All analyses were conducted using the R statistical system V.3.5.2 (R Foundation for Statistical Computing, Vienna, Austria, 2021).

RESULTS

The median substantial injury prevalence for all athletes was 10% (IQR 0%–20%). Of all athletes (n=422), 33% (n=162) reported a previous injury within the last 12 months. Most athletes had access to medical personnel

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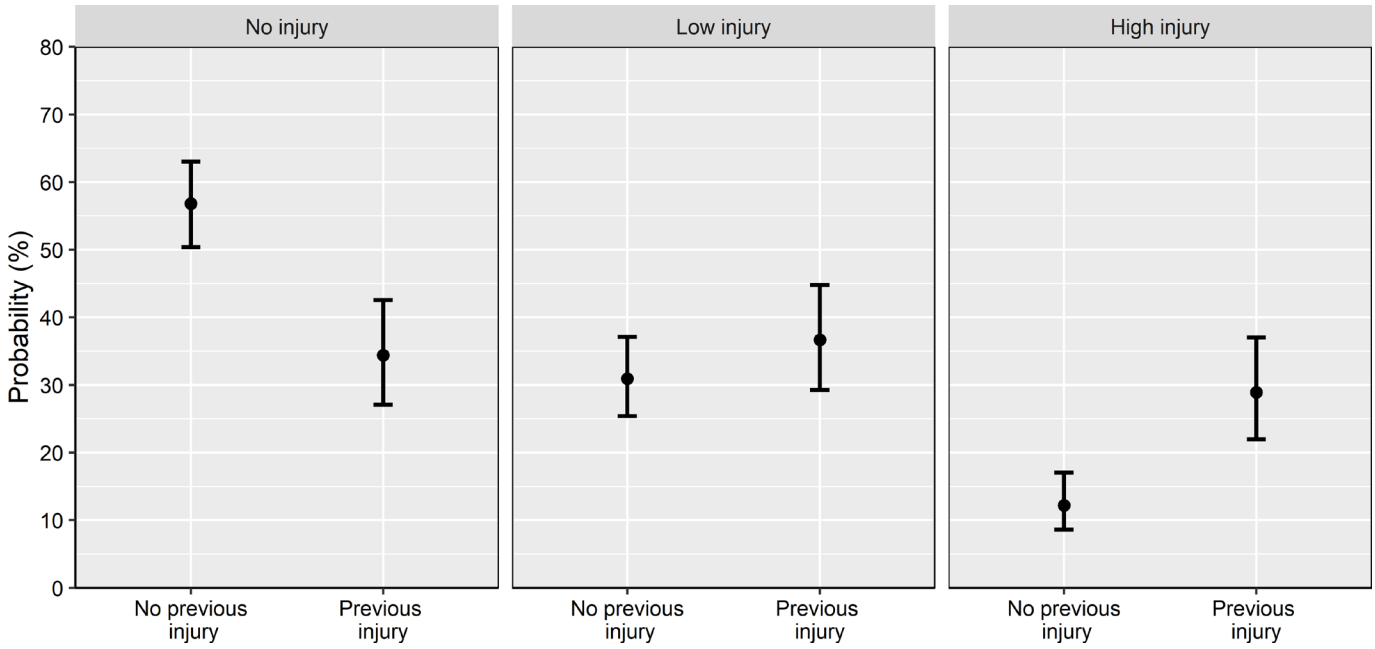

Figure 2 Probability for injury group membership by previous injury sustained within the last 12 months that has affected or completely hindered training for a continuous period of at least 3 weeks. Athletes were grouped in tertiles based on the proportion of times the athletes reported injury and a multinomial regression analysis was used to estimate probability for injury group, adjusted for sex, previous injury and perceived well-being. Tails indicate 95% CI.

(65%) and were following an individual exercise programme (67%) (table 1).

The median substantial injury prevalence for the 'high injury' and 'low injury' group was 44% (IQR 33%–67%) and 11% (IQR 10%–20%), respectively. Compared with the 'no injury' group, the 'high injury' groups reported significantly ($p<0.05$) lower perceived well-being (63.9 vs 76.5) and higher frequency of a previous injury within the last 12 months (58% vs 28%). Compared with the 'no injury' group, the 'low injury' group had a significantly ($p<0.05$) higher frequency of athletes with a previous injury within the last 12 months (41% vs 28%) and a higher proportion of female athletes (55% vs 37%) (table 2).

Based on a multinomial regression analysis, the probability of belonging to the 'high injury' group increased with lower perceived well-being (figure 1). An athlete with no previous injury had a 12% probability of belonging to the 'high injury' group (95% CI 9% to 17%), compared with a 29% for an athlete with a previous injury (95% CI 22% to 37%) (figure 2). In the 'no injury' group, a previous injury was associated with a 34% probability of belonging to that group (95% CI 27% to 43%), whereas having no previous injury was associated with a 57% probability (95% CI 50% to 63%). A female athlete had a 42% probability of belonging to the 'low injury' group (95% CI 35% to 49%), compared with a 28% probability for a male athlete (95% CI 22% to 35%) (figure 3). Combining these risk factors showed that a female athlete with a previous injury and low perceived well-being (25th percentile) had a 48% risk (95% CI 36% to 59%) of belonging to the 'high injury' group, compared with 7% (95% CI 4% to 12%) for a male athlete with no previous injury and high well-being (75th percentile).

DISCUSSION

Our main findings were that previous injury, sex and perceived well-being were associated with injury across 20 weeks in adolescent elite athletes. Higher perceived well-being increased the probability of belonging to the 'no injury' group, whereas low perceived well-being increased the likelihood of belonging to the 'high injury' group. We could also demonstrate that a female athlete with a previous injury had a much higher risk of belonging to the 'high injury' group as opposed to a male athlete with no previous injury.

Even if most of the athletes in this study had no injury or had few occasions with injury, the 'high injury' group, consisting of 21% of all athletes, were injured more than 40% of all reporting times. Consequently, even in young athletes, the injury risk is high.[6 20] Our results confirm previous findings that a previous injury is one of the strongest risk factors for a future injury,[21–23] both in youth and adult athletes. An athlete with a previous injury was twice as likely to belong to the 'high injury' group, compared with athletes without a previous injury. However, the mediation pathways between a previous and a future injury are not clear in this young population,[12 13 21 24 25] and both inadequate rehabilitation and injury risk behaviour or trait have been suggested as mediation factors. To explore this important knowledge gap, we need to monitor young athletes at lower ages and longer duration as almost half of all athletes have had a

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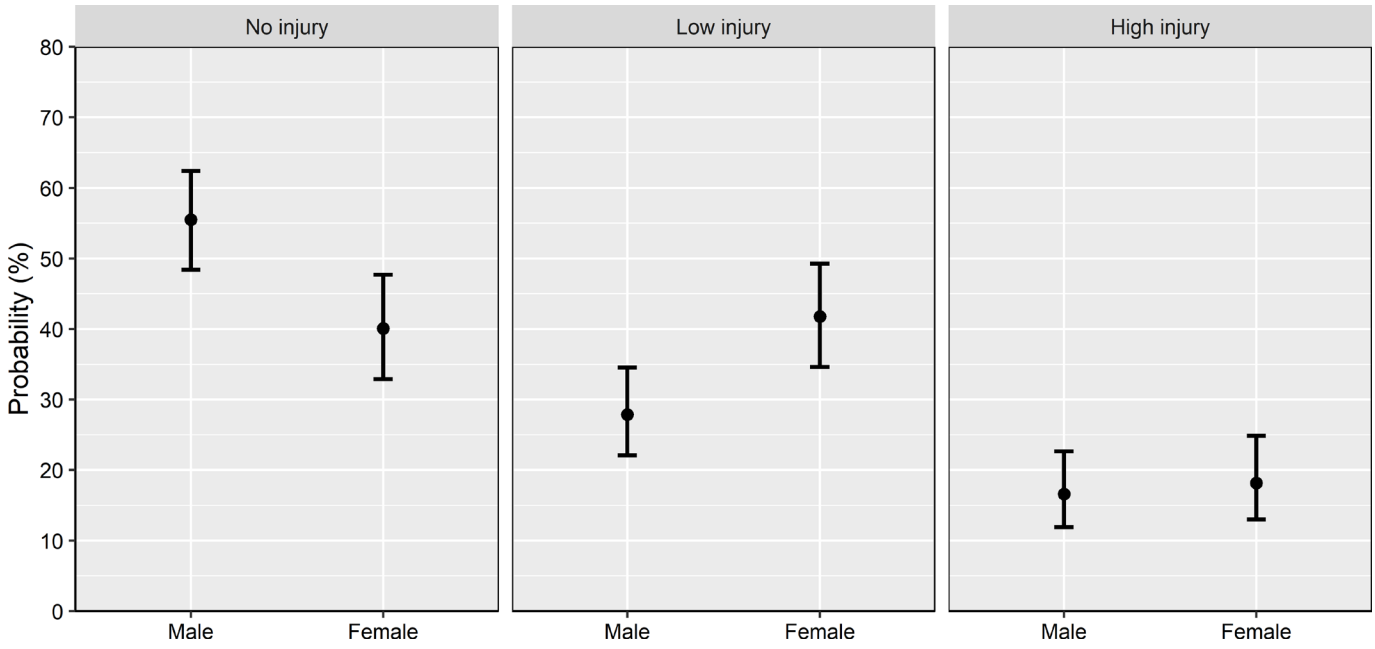

Figure 3 Probability for injury group membership by sex. Athletes were grouped in tertiles based on the proportion of times the athletes reported injury and a multinomial regression analysis was used to estimate probability for injury group, adjusted for sex, previous injury and perceived well-being. Tails indicate 95% CI.

previous injury within the last 12 months in this young population.

Our results also showed that female athletes had an increased risk of being in the 'high injury' group, compared with male athletes. Recent reviews have shown that female athletes have a higher risk of ankle sprain, anterior cruciate ligament and concussion, compared with male athletes.[26 27] On the contrary, male athletes have been found to have a higher risk of groin injuries, compared with female athletes.[28] However, reporting sex-specific differences in injury epidemiology is often ignored by researchers, and the majority of studies often focus on including only one sex.[29] In addition, the use of different injury definitions and data collection methods complicates between-study comparisons.[18]

Previous research has identified several psychological factors associated with injury.[30] For instance, athletes sustaining negative life-event stress[31 32] and daily hassles[33 34] have been found to have a higher risk of injury. Our results also confirm previous research indicating an association between well-being and injury risk.[34 35] However, we now demonstrate this association in adolescent elite athletes, compared with adult athletes. As the mental status of adolescents has been highlighted in the recent years, it is important to explore this aspect more in depth. Coaches of young elite athletes should consider monitoring well-being and be aware of it as a risk factor for injury.

Sports specialisation has been stated to increase the risk of injury in young athletes,[36 37] yet few prospective studies are available. In line with findings from a prospective study on 16-year-old elite athletes,[38] we could not demonstrate that early sports specialisation is associated with injury. More importantly, early sports specialisation did not result in lower injury risk. Thus, sports specialisation did not prepare the athlete for elite sports in terms of reducing the overall injury risk. Methodological differences may explain the mixed findings of previous research. For instance, multiple definitions of sports specialisation are available, related to specialisation in a single sport or to the degree of performance level in a sport, which could potentially explain the diverse results in this field. In our case, we defined sports specialisation as the age when the athlete decided one sport as being more important than other sports, similar to Moseid *et al*.[38] In addition, recall bias is also likely to affect the mixed findings in this field. Therefore, monitoring athletes over a longer time when the athletes decide to specialise in a sport is warranted to more in detail understand the consequences of sport specialisation.

The strengths of this study are related to the prospective study design, following a high number of adolescent elite athletes in age 15–16 years. The sample consisted of athletes from over 30 National Sports High Schools, located all over Sweden, representing 15 different sports, and could be considered as a representative sample of adolescent elite athletes. To attend these schools, all athletes had to compete at the highest national level for their age group, making a homogeneous group of adolescent elite athletes. A reliable, valid questionnaire previously used in sports surveillance was also used. The findings of this study should also be viewed in light of potential limitations. Athletes were followed for 20 weeks and, due to sports representation, had different season schedules (eg, base training, pre-season, competitive seasons), which may have led to different injury risks

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across the study period. Training load was self-reported, and consequently, both overestimation and underestimation need to be considered. In addition, no risk factors in a classic epidemiological approach were identified,[39] as we 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. Since many athletes were injured at study start, this approach is beneficial but does not provide cause-relationship estimates.

Conclusion

Based on three completely different profiles of injury data, three factors were associated with the injury profiles. Well-being, sex and previous injury were associated with the injury profiles, whereas sports specialisation, having an individual exercise programme, access to medical personnel and average training exposure were not. A female athlete with a previous injury and low perceived well-being (25th percentile) had a 48% risk (95% CI 36% to 59%) of belonging to the 'high injury' group, compared with 7% (95% CI 4% to 12%) for a male athlete with no previous injury and high well-being (75th percentile). Medical personnel should be aware of the high injury risk and associated risk factors for injury in adolescent elite athletes, and closely monitor the rehabilitation process as a previous injury is such a strong risk factor for a new injury.

Contributors PvR was responsible for the conception of the study, collection of data and data analysis. PvR wrote the first draft of the paper, which was critically revised by LE and CF. All authors contributed to the interpretation of findings. PvR acted as the guarantor of the study. The final manuscript has been approved by all authors.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Obtained.

Ethics approval This study involves human participants and was approved by the Regional Ethical Committee in Sweden (no: 2011/749–31/3, 2019-01557). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data that support the findings of this study are available on reasonable request from the corresponding author.

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