

Prospective cohort study identifying risk factors for sports injuries in adolescent athletes: the Healthy Injury-Free Adolescent Athletes (HIFAA) study

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ABSTRACT

A high incidence of injuries has been reported in young athletes. Several factors have been associated with athletes' sports injuries. However, scientific evidence is lacking, particularly for adolescent athletes. Hence, the Healthy Injury-Free Adolescent Athletes (HIFAA) was designed to evaluate sports injuries and examine associations with risk factors related to physical load and mental health. Secondary aims are to evaluate differences between sex, age, high school year and sports and examine injuries and the athletic situation 5 to 10 years after graduation. Adolescent athletes aged 15–19 years enrolled in high school and competing in sports to reach a national or international level of sports will be included. At inclusion, athletes will sign an informed consent form and fill out a baseline questionnaire addressing potential risk factors (eg, sports, training and competing health and injuries, and psychosocial status). Athletes will then prospectively be monitored weekly regarding injuries, physical (training/match/competing, perceived exertion) and psychological (fatigue, sleep, mental stress, recovery) load until graduation. A shortened version of the baseline questionnaire will be filled out every year, and a follow-up questionnaire regarding injuries, sporting situations and mental health will be filled out 5–10 years after graduation.

Injuries are frequent among adolescent athletes, with consequences ranging from shorter interruptions in sports performance to mental health problems and early termination of sports. A reduction of these injuries is warranted. This study will provide a detailed understanding of risk factors, a prerequisite to introducing appropriate preventive measures.

INTRODUCTION

Sports injuries among adolescents are a common phenomenon. Studies on young athletes have shown a high incidence of injuries,^{1–5} and it is one of the most common reasons for seeking healthcare among adolescents.⁶ Sports injuries may lead to short-term and long-term consequences, ranging from smaller obstructions/interruptions in sports

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Sports injuries among adolescents are a prevalent and concerning issue, with significant implications for the health, well-being and athletic development of young athletes. The aetiology of these injuries is multifactorial, involving sport-related and training-related factors such as training volume and load, rapid increases in training intensity, imbalances between training and recovery and diet. Despite the common occurrence of these injuries, there is a significant gap in the literature due to a lack of large, prospective, long-term studies that comprehensively examine the diverse range of risk factors contributing to sports injuries in this population.

WHAT THIS STUDY ADDS

⇒ The Healthy Injury-Free Adolescent Athletes (HIFAA) study addresses this gap by prospectively evaluating sports injuries and exploring the associations among adolescent athletes' various risk factors, including physical and psychosocial load and mental health. This study's unique approach allows for a holistic understanding of the incidence, aetiology and injury mechanisms, which is crucial for developing effective prevention strategies. Additionally, by investigating differences across sex, age, school year and sport as well as examining injury patterns and athletic outcomes 5–10 years postgraduation, the HIFAA study provides a valuable longitudinal perspective on the long-term impact of these factors.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings from the HIFAA study will have significant scientific and clinical relevance, offering critical insights that can inform targeted interventions to reduce injury risk, enhance athlete health and optimise training protocols for adolescents. Ultimately, this study aims to promote a safer sporting environment for young athletes, fostering their long-term athletic participation and success.

performance to early termination of sports careers.⁷ Furthermore, sports injuries are also correlated with mental health problems, such

as cognitive and emotional reactions, including a sense of exclusion, loneliness and loss of identity, influencing the athlete's well-being.^{8,9}

The cause of sports injuries is multifactorial. Sport-related and training-related factors, such as training volume and load,^{10,11} rapid increase in training load (duration, frequency, intensity),^{10,12} imbalance between training load and recovery,^{10,13} and early sport specialisation¹⁴ have been associated with increased risk of injury. Biological factors such as previous injury,^{3,15,16} age^{3,17} and sex¹⁶ have been suggested as further risk factors. Finally, the discussion regarding psychosocial factors has grown, and factors such as self-reported well-being and stress have been shown to have a large impact on the risk of injuries.^{8,18} Moreover, negative life events stress^{8,9} and sleep¹² have also been associated with a higher risk of injuries. Some of these risk factors are furthermore bidirectional—for example, an injured athlete has decreased well-being.^{19,20}

Being both a student and an athlete can be challenging. When starting high school, the athlete adolescents are exposed to several risk factors. Many athletes decide to apply for National Sports High Schools with the opportunity to combine education with their sport. For certain sports, attending such schools is even a prerequisite to reaching the elite level.²¹ Sweden has a national system for high-performance sports and high school studies in terms of National Elite Sports Gymnasiums (RIG) and Nationally Approved Sports Programs (NIU). Young athletes typically move away from home when admitted to these schools, resulting in a cascade of changes related to social support and responsibility, as well as a larger educational burden and increased pressure on themselves, often with a doubling in training due to heightened competitiveness. Hence, facing both physical and psychological stress factors is well known, increasing the risk of injuries.¹

Sports injuries have further been associated with major costs to the healthcare systems.²² With regard to the negative consequences associated with injuries, developing preventive programmes should be a priority. Identifying risk factors and determining how these factors are associated are important steps towards decreasing the risk of injuries. Although many risk factors have been presented in the literature, few have consistent findings. Most knowledge is limited to isolated risk factors, adult athletes, single sports and specific injuries. Due to the multifactorial nature of injuries, a more comprehensive analysis including a combination of sport-related, training-related and psychosocial factors is warranted. Furthermore, factors modifiable and prospectively associated with injuries are more useful, as they provide interventions usable by clinicians in prevention programmes.

There is a lack of large, prospective, long-term studies examining several risk factors for adolescent sports injuries. Without knowledge about incidence, aetiology and injury mechanism, it is impossible to prevent injuries effectively. The primary aim of the Healthy Injury-Free

Adolescent Athletes (HIFAA) study is to prospectively evaluate sports injuries and examine associations to risk factors according to physical and psychosocial load and mental health among adolescent athletes. The objectives are to evaluate how these variables differ between sex, age, high school year and sports and examine injuries and the athletic situation 5–10 years after graduation.

METHODS

This is a prospective cohort study designed according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (STROBE) with extension for Sports Injury and Illness Surveillance (STROBE-SIIS),²³ a consensus statement on how to report such data recommended by the International Olympic Committee.²³

Participants

Adolescent men and women aged 15–19 years, participating in sports and attending either national sports high schools (NIU or RIG) or regular high schools, are eligible to participate. Inclusion criteria will be: (1) attending high school, (2) competing in their sport and aiming to reach a national or international level of sports. All types of sports will be included.

Exclusion criteria will be athletes practising sports at a recreational level. Participants who drop out of school or finish their sports career will be excluded from further data collection from their next semester. However, they will be included in the total analyses. Athletes who meet the inclusion criteria will be invited to participate in the project by oral and written information. Schools and athletes deciding to participate will receive more detailed information.

An internal pilot study has been performed to test the implementation of the questionnaires related to the project. The pilot showed satisfying results regarding feasibility and validity (unpublished data).

Data collection

All athletes will be followed prospectively from the time point of inclusion until they graduate from high school (1–4 years). Traditionally, high school in Sweden is 3 years; however, for some national sports high schools (eg, Alpine schools), the duration is 4 years. The reason for 4 years is a prolonged high school to achieve the academic requirements. The athletes will answer a baseline questionnaire at the time of recruitment and, after that, a weekly questionnaire. They will fill out a shorter version of the baseline questionnaire at the beginning of each new school year.

All data collection will be completed by a web application (app) through the athlete's smartphone, whereby all athletes will receive a personal text message weekly with the questionnaire link. If there is no response, a reminder text message will be sent out the next day. The app will be distributed by the researcher responsible for the project, together with the company developing the app. The athletes can track their results through the app,

that is, after completing the weekly questionnaire. They receive a chart of, for example, their sleeping, stress and perceived exertion pattern.

Questionnaires

The different questionnaires have been developed meticulously to confirm both validity and reliability. Initially, a reference group constructed the questionnaires after reviewing the literature based on the aim of the study and to suit the target population. All questionnaires have been developed by the researchers responsible for the project based on studies evaluating similar subjects such as injuries and physical and psychosocial load. The questions were then reformulated better to suit the target population and purpose of the project. To increase the content and construct validity, the first draft of the questionnaires was sent to the research group, which consisted of medical doctors and physiotherapists experienced in sports medicine, mental health and working with adolescents. After revisions, updated questionnaires were developed. A pilot study was conducted to validate the method and questionnaires. The questionnaires were pretested by young athletes (the target population) to ensure the feasibility and validity of the method and questionnaires. Based on the results from this pilot study, the questionnaires were once again revised before the final draft was confirmed.

Baseline questionnaire

The baseline questionnaire addresses potential risk factors contributing to sports injuries, demographics and general health status. The athletes are assessed in different areas, including sport, training and competing: sport discipline, training and match/competing exposure, playing position, junior/senior class, other sports participation, age of sport specialisation, changes in training/competing habits and current level of sport; *health*: injuries, illness, medication, sleep habits and diet habits; psychosocial: changes in living conditions (ie, moving away from home), club-transfer, change of coaches and mental health. A short version of the Warwick Edinburgh Mental Well-being Scale (SWEMWBS)²⁴ is included to assess mental health and well-being. The SWEMWBS consists of seven statements, each answered on a Likert scale, summarised and converted into metric scores. The SWEMWBS has been translated and validated into Swedish.²⁴ It is an established score previously used to measure mental health in the National Public Health Survey—Health on Equal Terms by the Public Health Agency of Sweden.

Weekly questionnaire

The weekly questionnaire includes an injury and pain report, the session rate of perceived exertion (session-RPE) for total physical load and a 'Wellness score' for physiological load. The injury and pain report include pain grading using the Numeric Rating Scale, a modified version of the Oslo Sports Trauma Research

Center Questionnaire on health problems (OSTRC-H),²⁵ pain drawing and injury mechanism (acute with/without contact, gradual during practice or outside practice). The OSTRC-H has been translated and validated into Swedish for adolescents and used in several previous studies.^{4 10}

It has been shown that a total physical load index (combining external load (training and competing hours) and internal load (self-reported intensity)) is associated with injury risk in athletes.^{2 10} Therefore, the total physical load will be analysed using the session RPE. Session-RPE records training and competing hours in relation to perceived exertion, estimated on the Borg Scale, and is the most commonly used measure for this purpose.¹⁰

The psychological load will be analysed using a 'Wellness-score'. A recent systematic review concluded that subjective measures were more sensitive than objective measures when examining acute and chronic changes in the athlete's psychological load.²⁶ A 'Wellness score' is the most frequently used measure to investigate this in a sports population. Hence, the athletes will answer questions regarding fatigue, sleep, mental stress and recovery on a five-graded Likert scale.²⁶

Yearly questionnaire

A shortened and modified version of the baseline questionnaire will be filled out at the beginning of every new school year (years 2, 3 and 4). The modification involves deleting some demographic questions. In contrast, questions regarding finishing high school and/or their sports career are added as well as reasons for finishing school and/or their sports careers. Questions regarding sports, training and competing, health (injuries, illness, sleep, diet) and psychosocial areas (living and club transfer, mental health and SWEMWBS) are also included.

Five-year follow-up questionnaire

A follow-up questionnaire will be distributed to the included athletes approximately 5 years after graduation. This questionnaire contains the Tegner activity scale, SWEMWBS,²⁴ and questions partly derived from the Swedish Sports Confederation report *The Roads to the National Team*²¹ regarding sport, career and injuries. Examples of questions are current age, the age when starting an elite sports career, whether the athlete is still pursuing an elite sports career, what goals the athlete has for their elite sports career, whether the athlete is at the desired level of sport, and if not, the reason for this, the number of injuries with complete or partial absence from sports for at least 3 months, and the nature of these injuries and if applicable, reasons for not pursuing an elite sports career.

Sample size

The sample size is calculated using the formula recommended by Riley *et al*²⁷ (calculator accessible via <https://riskcalc.org/samplesize/clinical-prediction-models-with-a-time-to-event-outcome>). This formula gives a sample size

of 370 participants, with 15 candidate predictor parameters, an approximate 95% CI for the overall outcome proportion, a margin of error (δ) ≤ 0.05 and an overall event rate in the population of interest of 33% (0.33) based on the pilot study results (injury incidence of 33%, unpublished material).

Statistical methods

Each year, a compilation of data will be executed. The HIFAA study will include a large number of research questions. Hence, different statistical analyses will be executed. The study will partly be a descriptive study, where injury frequency, type and grade of injuries, physical and psychological load and well-being, including the SWEMWBS, will be analysed and described with numbers, percentages, means and SD for the entire group as well as stratified by sex, age and type of sport. A generalised linear model will be used to investigate differences in the prevalence of injuries between sex, age and type of sport and will be presented as a prevalence ratio with a corresponding 95% CI and incidence as number of injuries/1000 exposure hours. Using linear and logistic mixed model regression analyses, the risk of reporting injuries will be explored based on, for example, the wellness score or physical load from the previous week. Predicting current mental health and wellness will also be explored using linear mixed model regression analyses, including injury as an independent variable. ORs will be presented with a 95% CI. The plan is to use mixed models to investigate changes over time (repeated measures). Furthermore, the Cox regression analyses will also be performed to investigate potential risk factors for the first reported injury, with consideration taken into potential confounders. Based on the Cox regression models, the hazard rate ratio (HRR) will be presented with a corresponding 95% CI. Kaplan-Meier curves will be constructed to plot injury risk for covariates of gender and those with a significant HRR. As mentioned above, the HIFAA study includes many research questions, and the exact statistical method that will be used will, therefore, depend on the specific research question. A p value of <0.05 will be considered as statistically significant.

Time plan

Athletes will be recruited from the beginning of 2023 and then continuously until we reach over 370 athletes. The athletes will be invited to participate once they start high school, followed once weekly throughout high school and then again 5 years after graduation.

Ethics approval and consent to participate

This study was approved by the Regional Ethical Review Authority in Sweden, with diary number 2021-05496-01. All included athletes will receive oral and written information regarding the study. They will also give their written informed consent at the time of recruitment. The individual answers and results in the app are strictly confidential and will not be shared with, for example, coaches

or teachers. Hence, it will not influence the athletes' chances of making teams or competitions.

The study will be executed according to the Helsinki Declaration and reported in accordance with the STROBE-SIIS.

Availability of data and materials

The datasets analysed during this project will not be publicly available. However, it will be available from the authors on reasonable request.

DISCUSSION

The main purpose of the HIFAA project is to report on physical and psychological risk factors for sports injuries among adolescents.

Injuries are frequently reported in adolescent athletes¹⁻⁴ and may lead to short- and long-term consequences ranging from shorter interruptions in sports performance to mental health problems and early termination of sports.^{7,9} Not only do sports injuries affect the well-being of the individual, but there is also a risk of negative long-term consequences with early sports termination. It has further been associated with major costs to healthcare systems.²² With regard to the negative consequences, a reduction in injuries and physical problems is highly warranted. The results from the HIFAA project will, therefore, contribute to more knowledge about physical and psychological risk factors in elite adolescent athletes, which will be important for injury management and future injury prevention, including early career-ending in different sports.

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Contributors JA initiated the study. JA and IL conceived the study protocol and all authors (IL, SRA, MS, AB, JS) contributed to the development of the study protocol. IL and JS share the main responsibility for the project. All authors approved the final manuscript. IL is the guarantor.

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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 Consent obtained directly from patients.

Ethics approval This study involves human participants and was approved by Regional Ethical Review Authority in Sweden, with diary number 2021-05496-01. Participants gave informed consent to participate in the study before taking part.

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Data availability statement No data are available.

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