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The prevalence and severity of health problems in youth elite sports: a 6-month prospective cohort study of 320 athletes

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Abstract

Little is known regarding the overall health of youth elite athletes. Our aim was to describe the prevalence and severity of health problems in a cohort of youth elite athletes representing a variety of endurance, team and technical sports.

Elite sport athletes (N=260, 16.2 yrs) from different Sport Academy High Schools in Norway, and a group of their teammates (N=60, 16.4 yrs) attending regular high schools, were included in the study. The Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems was used to self report injuries and illnesses for 26 weeks.

At any given time, an average of 43% [95% CI: 37-49%] of the elite sport athletes had some form of health problem and 25% [20-31%] had substantial health problems. The prevalence of health problems was similar between the elite team sport athletes versus their teammates, except for substantial injuries (22% [16-30%] vs. 10% [5-20%]). Endurance sport athletes reported more illnesses (23% [15-35%]) than technical and team sport athletes (10% [5-20%] and 8% [4-14%]). In contrast, technical and team sport athletes reported more injuries (36% [95% CI: 25-48] and 37% [95% CI 29-45]) compared to endurance sport athletes (15% [8-25%]). The total impact of health problems was roughly split in thirds between overuse injuries (37%), acute injuries (34%) and illnesses (30%).

This is the first prospective study to present self-reported injury and illness data in a large heterogeneous group of youth elite athletes, documenting a substantial impact of both injuries and illnesses on the health of this population.

Key words:

Overuse injuries; illness; epidemiology; injury prevention; sport academy high school; adolescents; sporting injuries; sub-elite athletes

Introduction

The health advantages of youth sports participation are well recognized. However, a relevant question is whether the health benefits of youth sport at an elite level are outweighed by the risk for injury and their potential long-term sequelae. Early single-sport specialization, early talent identification, overscheduling and increasing training loads at an early age represent potential risk factors for injury or illness, possibly related to a short-term focus on performance [1, 2].

In recent years, there has been an increased focus on health monitoring and mapping of injuries affecting elite athletes [3-5]. Health surveillance programs have been established during major international competitions at the senior level [4, 6-12], and the value of monitoring elite athletes' health outside of major competitions has become increasingly recognized [13-15]. Unfortunately, this is not yet the case for the next-generation athletes, where the prevention of injury and illness has received less attention, in particular in out-of-competition periods [3]. Previous studies tend to be small or most often specifically related to only one sport and until recently, most reports do not take the voice of the youth athlete into account [16-24]. The International Olympic Committee has recently published a consensus-statement on this issue in an effort to promote a more unified and evidence-informed approach towards the medical care of youth elite athletes [25, 26].

Monitoring the overall health of elite athletes over extended periods of time outside of major competitions is the first step in the care pathway, for both adult and adolescent athletes [13, 15]. In this study, we used a recently developed method, useful for evaluating a wide array of health problems in a cohort representing multiple sports [13, 15], focusing on the young athlete's own experience of their health, and how it influences on their training, participation and performance over time. Our aim was to describe the prevalence and severity of health problems in a cohort of young elite athletes representing a variety of endurance, team and technical sports, a group of their sub-elite teammates, as well as 16-year old adolescents not participating in competitive sports.

Methods

Participants and recruitment

This cohort study involved 15- and 16-year old boys and girls, enrolled in specialized Sport Academy High Schools in Norway (elite athlete group). A large proportion of these students are members of regional and national representative teams, and they all compete for sports clubs not affiliated with their sports high schools. All first year students in three selected Sport Academy High Schools in Norway were invited to join the study, 82% accepted to participate (Figure 1). Thirty different sport disciplines were represented and categorized into three major categories (endurance, technical and team sports) in accordance with a previous study on health problems in a heterogeneous group of athletes (Table 1) [15]. We also invited a sample of teammates, playing on the same teams as the elite team sport athletes, but attending regular high schools and a convenience sample of non-athletes attending regular high school. The teammates were mostly at a slightly lower athletic level compared to the Sport Academy High School students, and thus considered a sub-elite group. In the sub-elite group, 133 athletes were invited to participate, but 27 of them attended other Sport Academy High Schools than the three we selected and could not be included. Of the 106 eligible athletes in the teammate group, 60 were included (56%). In the non-athlete group, 53 students were invited and 21 accepted to participate (Figure 1). Ninety-three percent of the teammates and 97% of the elite athletes completed the 26-week study. The non-athlete group was excluded from the study because of low compliance.

Before initiating the study, we held meetings with the management of the schools to engage their support and to improve the chances of implementation of future recommendations based on our findings. Through school meetings, verbal and written information was given to the students and their parents about the purpose of the study, the importance of athlete commitment and the procedures of the study. The same information was given to the teammates and their coaches during training sessions and by telephone. Parents of teammates were not present at these meetings.

The study was approved by the Norwegian Data Inspectorate (No. 38888) and reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics (2014/902/REK Sør-Øst). Informed consent was obtained from the athletes and from the parents of those under 18 yrs.

Data collection procedures

The study consisted of two main parts: 1) A prospective cohort study conducted from August 1st 2014 through May 31st 2015 and 2) Supplemental interviews at the end of the study period (May/June 2015). Within two weeks of inclusion in the study (August-October 2014), all participants completed a web-based questionnaire which collected information on their anthropometrics, medical and sporting history, previous competition and training loads and performance level. The baseline questionnaire also included the Oslo Sports Trauma Research Center questionnaire on health problems (OSTRC questionnaire; [13, 15]) covering the previous week.

Prospective data collection

A smartphone application (Spartanova N.V., Gent, Belgium) was installed and used by the participants for weekly submission of the OSTRC questionnaire, training and competition hours and days of time-loss from training and/or competition. The questionnaire was distributed to participants every Sunday from October 30th 2014 until May 3rd 2015 (26 weeks). Reminders were sent to non-responders after 2, 4 and 6 days, both automatically through the application and manually through SMS by the principal investigator. During the registration period, we had regular contact with athletes, the school boards and all principal coaches.

Supplemental interviews

To supplement missing data from the prospective weekly registration and verify the accuracy of the prospective data, we conducted interviews at the end of the study period (May/June 2015). We interviewed all available participants still included in the study. All athletes brought their training diaries to the interview, we used all available prospective health data and we registered all major competitions in the interview form beforehand. One OSTRC questionnaire was completed for every health problem registered during the 26-week period, with the questionnaire responses applied to the entire duration of the

problem. Most interviews were conducted in person at school or during a training session, in some cases by telephone.

During the athlete interviews, prospectively reported data were reviewed and quality controlled, and missing data were supplemented using interview data.

OSTRC questionnaire on health problems; Registration of injury, illness, time loss, training and competition hours

The OSTRC questionnaire consisted of four graded key questions about sport participation, training volume, performance and health problems experienced during the previous 7 days (Clarsen et al. 2014). Health problems were defined as all injuries and illnesses, regardless of severity and consequences. We did not specify that injuries had to be sports-related. We also specified that sadness, depression, anxiety and feeling troubled could be registered as an illness. The responses to each of the four questions were allocated a numerical value from 0 to 25, were 0 represented no problems and 25 represented the maximum level for each question. The four response values were summed in order to calculate a severity score from 0 to 100 for each health problem. In sum, the OSTRC questionnaire records the consequences of the athlete`s health problems during the last week, as well as to what extent they had experienced symptoms. If the lowest score on each of the four key questions was recorded (no health problems or symptoms reported), the questionnaire was complete for that week. However, if any health problems were reported, athletes were asked to define whether the problem was an injury or an illness. In the case of an injury, they were asked to classify it as an acute injury (sudden event after for instance falling or a tackle) or an overuse injury (no particular injury situation) and thereafter to record the anatomical location of the injury. If illnesses were reported, athletes were asked to select the main symptoms they had experienced during the past week [13]. Multiple predefined symptoms could be registered. For both injuries and illnesses, they reported the number of whole days of time loss to training or competition the past week (defined as total inability to train or compete). In cases of multiple health problems during the same week, the questionnaire repeated itself up to four times. Participants were instructed to report all health problems every week, regardless of whether or not the problem had been registered the previous week. The total number of training and competition hours per week (0-25 hours) was added to the validated OSTRC questionnaire and recorded during the period.

Data collection and classification

If an athlete reported the same health problem for more than 4-6 weeks, the principal investigator contacted the participant by telephone (call or SMS), to evaluate the extent of the health problem and suggest that further medical treatment was sought. If necessary, further follow-up by a physician or a physiotherapist at the Norwegian Olympic Training Center or with the school nurse was organized.

All participants and their parents could contact the principal investigator for medical advice through SMS or telephone calls at any time during the study.

In December 2014, we offered a small financial incentive (30€ gift card) to all participants that had reported every week since October.

Health problems were classified as an injury if affecting the musculoskeletal system or concussions [13] and as an illness if affecting other organ systems such as respiratory, gastrointestinal, cardiac, dermatological and psychological systems, as well as unspecified or generalized symptoms such as fever, dizziness or fatigue. Injuries were further categorized into acute and overuse as reported by the athlete. An acute injury were defined as one which onset could be linked to a specific injury event, such as falling or being tackled, whereas overuse injuries were those that could not be linked to a single clearly identifiable event [27]. Illnesses were coded according to organ system affected [15].

Prevalence, severity and relative impact of injury and illness

To calculate the prevalence of any and substantial health problems, we followed the methodology of Clarsen et al. [13]. Prevalence measures were calculated by dividing the number of athletes reporting any health problem by the number of questionnaire respondents for each week of the study. We calculated prevalence numbers for illness and injury (acute and overuse) and for sub groups of athletes (technical athletes, endurance athletes, team sport athletes, teammates, males and females) for all health problems as well as for substantial health problems within these same categories. Substantial health problems were defined as those problems leading to moderate or severe reduction in training volume or performance, or complete time loss from sport. All prevalence measures are presented as proportions with 95% confidence interval [95% CI], averaged over the study weeks. We excluded data from the first two weeks of the prospective study (week 43

and 44), in accordance with previous recommendations [13] and also because we did not collect information from these weeks in the retrospective study.

Each week, we calculated a severity score from 0-100 for each of each health problem based on athletes' responses to the four key weekly questions [13]. At the end of the study, the cumulative severity score of each case was calculated by summing the score for every week it was reported. The average severity score was calculated for each case by dividing the cumulative score with the number of weeks that the health problem was reported.

In the case of injuries, where the same diagnosis was interspersed with periods of apparent recovery, the retrospective interview data were used as a backup check, to determine whether the problem should be considered as exacerbations of an unresolved problem or a recurrence of a fully recovered problem (re-injury/new injury) in accordance with the definitions by Fuller et al. [27]. Illnesses were treated in the same fashion, with repeated conditions in the near longitudinal period (close proximity) treated as a single case for the purpose of severity and duration analysis [13].

To assess the relative impact from illnesses and injuries (acute and overuse) to the athletes` health, we summed the cumulative severity scores for these different types of health problems and the proportions of the three were determined.

Statistical analysis

The sample size was based on previous studies by Clarsen et al. [13, 15]. With 80% power and 5% significance level ($\alpha = 0.05$) the estimated number of main participants (n=300) and subgroups (n=50 to n=100) exceeded the previous power calculation for these studies, and were considered sufficient in this study as well, using the same methodology.

Our study design allowed for four different sets of group comparisons. We explored the differences between athletes and non-athletes (baseline prevalence only), elite team sport athletes and their teammates, endurance sport athletes vs technical sport athletes vs team sport athletes as well as between gender.

Potential group differences in baseline data were tested with t-tests for continuous variables and Pearson chi-squared (or Fisher mid-P) tests for dichotomous variables.

Differences in demographic variables between sporting groups were assessed using t-tests for continuous variables and chi-square tests for categorical variables. To assess differences in prevalence of all health problems and substantial health problems between sporting groups, we used chi-square tests. We considered modeling changes over time; however, crude data analyses revealed only minor and inconsequential changes over time, and because our interest was limited to group averages over the entire period, we only analyzed summary measures of prevalence, not individual weekly prevalence. In addition, the inclusion of retrospective data into the prospective data decreased the precision of weekly estimates, which contributed to our decision to analyze summary prevalence measures.

In order to assess differences between groups in the duration and severity of health problems, we used Mann Whitney U-tests due to data skewness regarding both duration and cumulative severity data.

Results

Participants

Baseline characteristics are shown in table 2. In the elite sport athlete population, the majority were boys (68%), while the gender split was more even among teammates (48% boys). Age was similar between all athlete groups, while boys were taller ($p<0.001$) and had greater body mass ($p<0.001$) than girls.

Sports history at baseline

Table 3 describes the sports background of all athletes by sports group and gender. Most athletes started playing their sport at an early age (team sports earlier than endurance sports and technical sports, $p<0.001$) and the majority had decided to specialize in their sport by the age of 14 yrs. About 60% of all team sport athletes reported that during the previous two years, they did not play any other sports. In contrast, 76% of the endurance sport athletes played at least one other sport ($p<0.001$).

Most of the athletes reported a high weekly training and competition load the year before the baseline registration, for the elite team sport athletes higher than their teammates ($p=0.049$). The total weekly training and competition load was 11-15 h for 47% of the elite sport athletes, while 25% reported training ≥16 h.

The athletes also reported participation at a high performance level; 37% of the elite sport athletes reported international participation (junior or senior national team) compared to 12% of the teammates (p<0.001). Also, almost half (44 %) of the elite sport athletes rated their performance as top 5% nationally, compared to 17% among teammates (p< 0.001).

Prevalence of injury and illness at baseline

At baseline, more than 60% of all athletes in all groups reported having a current health problem (p=0.32 between groups) (table 4). Substantial health problems were reported by 24% of the elite athletes and adolescent controls and 30% of the teammates. There was no difference between sports groups (p=0.29) or between genders (p=0.94) (table 4).

Response to the weekly questionnaires

Prospectively, the response rate was 66% on average through all weeks for the elite sport athletes and 50% for the teammates. We interviewed 99% (n=251) of the elite sport athletes and 55% (n=31) of the teammates still included in the study. Thereafter, prospectively reported data were supplemented using interview data. This process resulted in a response rate of 99.4 % from the elite sport athletes (adjusted for withdrawals (n=5) during the period). The prospective data accounted for 66% and the supplemental interview data for 34% of the total registrations. For the teammates the new total response rate was 82%, adjusted for withdrawals (n=4), 61 % prospective data and 39 % supplemental interview data.

Prevalence of injury and illness symptoms throughout the year

As shown in table 5, the average weekly prevalence of all health problems was 43% [95% CI: 37% to 49%] among elite sport athletes, with a prevalence of substantial health problems of 25% [95% CI: 20% to 31%]. The differences between prospectively collected data and interview data were minimal for all health problems (44% [95% CI: 37% to 52%] vs. 40% [95% CI: 31% to 51%]) and for substantial health problems (23% [95% CI: 17% to 30%] vs. 28% [CI: 20% to 38%]). The maximum number of registered health problems per athlete per week was three. Health problems were more common among girls than boys (p=0.034), while no significant gender difference was detected for substantial health problems (p=0.08) (table 5).

Endurance sport athletes reported a higher prevalence of illnesses compared to technical (p=0.035) and team sport athletes (p=0.002). In contrast, these groups reported a higher prevalence of injuries than did endurance sport athletes (p=0.006 and p=0.001 vs. technical and teams sports respectively). The prevalence of overuse problems did not differ between sports groups (p=0.47).

There were no significant differences in the prevalence of health problems in general between the two groups of team sport athletes (elite team sport athletes vs teammates: all health problems p=0.264, substantial health problems p=0.261). However, we found a significant difference in the prevalence of substantial injuries between the elite team sport athletes and their teammates (p=0.049).

Duration and severity of health problems

A total of 912 unique health problems were reported by 489 elite sport athletes over the course of the study (table 6). Of these, 48% were illnesses 26% were overuse injuries and 25% were acute injuries. Illnesses represented the highest median weekly severity score. However, as illnesses were generally of shorter duration than injuries (Table 6), they only represented 30% of the total impact of all health problems, compared to 37% for overuse injuries (p=0.001 vs. illnesses) and 34% for acute injuries (p=0.007 vs. illnesses, p=0.54 vs overuse injuries). Illnesses represented the highest median weekly severity score, but also had the shortest duration (table 6). Overuse injuries had the longest duration but the lowest median weekly severity score. Acute injuries had a higher weekly severity score than overuse injuries, but were of shorter duration. Comparing all team sport athletes, the teammates report acute injuries with shorter duration and lower cumulative severity score than the elite team sport athletes (p=0.005 and p=0.003, respectively) (table 6).

Discussion

This is the first prospective study of injuries and illnesses in young elite athletes representing a variety of endurance, team and technical sports. We found that 43% of athletes reported a health problem any given time, with 25% of all young elite athletes reporting a substantial health problem. Furthermore, although patterns differed somewhat between sports groups, the total impact of health problems was evenly distributed between overuse injuries (37%), acute injuries (34%) and illnesses (30%).

The vast majority of previous epidemiological studies of injuries and illnesses among elite athletes have used a time-loss injury/illness definition. This has been shown to lead to an underreporting of overuse injuries in particular, which often do not lead to time loss from sports [13, 28, 29]. We used an "all health complaints" definition and a questionnaire intended to capture all sport-related injuries and illnesses, enabling us to estimate the true impact of all health problems regardless of the amount of time lost. However, as a consequence of differing definitions, direct comparison between our study and many previous studies is difficult.

In our study, the prevalence of health problems (45%) was higher than that observed in the only two prior studies using the same methodology. Clarsen et al. [15] reporting a 36% prevalence and Pluim et al. [30] reporting 21%. However, an important difference between these three studies is the participant profiles: Clarsen et al. monitored adult Olympic athletes, while Pluim et al. followed younger (11-14 year old) elite tennis players.

Our study design allowed for four sets of group comparisons: i) athletes vs non-athletes (baseline prevalence only), ii) elite team sport athletes attending sports schools vs teammates (sub-elite athletes) from the same clubs not attending sport school programs, iii) endurance sports vs technical sports vs team sports, and iv) males vs females.

First, as many as 76% of the non-athletes (both genders) reported having health problems of some sort at baseline, compared to 60% of the young elite athletes (females 61% and males 59%). Although a one-/first-time response to the OSTRC questionnaire should be interpreted with caution [13], these data suggest that adolescents experience frequent health problems from time to time, regardless if they play sports or not. In a recent Norwegian National health report among 16-yr olds, 22% of the girls and 8% of the boys reported daily physical complaints during the past month [31].

Second, the prevalence of health problems was surprisingly similar between the elite team sport athletes attending sports schools, who on most days trained twice a day, versus sub-elite teammates from the same clubs not attending sports schools, who normally did not have training in the morning. One exception was that substantial injuries were more common in the elite team sport athlete group (22%) than among teammates (10%), although not at baseline (24% vs. 30%). Previous studies show that young players with high

levels of athletic skills (elite team sport athletes) are at greater risk of sustaining injuries than their less skilled teammates [32-34]. Higher training volumes, performance level and a high competition load among the talented or more mature team sport athletes may exacerbate injury risk [21, 33, 35]. In contrast, the elite team sport athletes seemed to report less illnesses (8%) compared to their teammates (14%), but this difference was not significant (p=0.23).

Third, sports group had an impact on the prevalence of injury and illness. In-competition surveillance studies have documented that different sporting groups report different patterns of injury and illness [36-39]. In the present study, endurance athletes had a higher illness prevalence, but a lower injury prevalence compared to technical and team sport athletes. The high illness prevalence among endurance athletes in our study (23%) was similar to that reported in a small prospective, Swedish study, on young elite orienteers (20%) using the same methodology [40]. In contrast, adult elite endurance athletes reported a somewhat lower illness prevalence (16%) [15].

Surprisingly, although the majority of injuries affecting endurance athletes were related to overuse, athletes in team and technical sports tended to report more overuse injuries than endurance athletes (20% and 17% vs. 12%), although this difference was not significant. It should be noted that about half of all injuries reported in team sports and technical sports were overuse injuries. The incidence of injury among elite youth athletes has been reported to be greater in technical and team sports compared to endurance athletes [36, 37, 39]. A two times higher injury risk has been reported in team sports compared to individual sports among young athletes attending sport schools [41, 42]. However, in contrast to our data, these studies, which were based on a traditional time-loss definition, showed that the vast majority of injuries reported were acute, not related to overuse.

Finally, females reported a significantly greater prevalence of health problems during the school year (52%) than males (39%). A difference in illness incidence by gender has been reported in previous studies [8, 12, 36, 37, 43, 44]. A greater risk of injuries among females compared to males was also shown in athletics [45] and snowboard cross [38], but this is not a consistent finding in the literature [36, 37, 46].

One novel finding in our study was that at any given time, not only acute injuries, but also overuse injuries and illnesses constituted a substantial impact on the health of young elite athletes. In contrast, using a time-loss definition, previous studies have reported mainly acute injuries; illnesses as well as overuse injuries have been neglected [15, 28]. Recent editorials emphasize a need for more evidence about overuse injuries in young elite athletes [33, 47-49]. According to Bahr [33], overuse injuries probably constitute a substantial problem among adolescent elite athletes. This view is supported by all the three studies on young elite athletes done using our methodology to date [30, 40].

Illnesses are also increasingly being included in surveillance studies during major youth championships [36-38]. In out-of-competition periods, evidence is still scarce. Our findings strongly suggest that at any given time, symptoms of illness have substantial impact on health, training and performance. This was also suggested in a recent IOC consensus statement on load in sport and risk of illness [50].

Methodological considerations

The current method depends on comprehensive athlete responses [15], and missing data constitute a challenge. The app-based questionnaires were meant to be easy to use and readily accessible at all times, but poor Wi-Fi coverage at times, generated low participation rates, as did holiday periods (Christmas, Easter) and multiple software upgrades. Therefore we chose to use supplemental interview data to fill in the gaps. This obviously introduces the limitation of recall bias.

Declining response rates from athletes with long-term injuries as well as long-term healthy athletes is another factor to consider. This phenomenon was also described by Pluim et al. [30]. However, to complete missing data, to verify all health problems reported and to remove problems that may have been registered by mistake, we conducted interviews of all athletes within a few weeks after the end of the study period. Still, recall bias and underreporting of health problems is a possibility. In order to minimize this, we took advantage of the available prospective data sets, the training diaries and competition schedules during the interviews. We calculated both data sets separately and found minimal differences. In this way, each data set served as a "control" for the other and no systematic bias in either direction is anticipated. Nevertheless, a lower than expected response rate

and subsequent inclusion of retrospective interview data into the prospective data, decreased the precision of weekly estimates and limited which statistical analyses we could use.

Another limitation of the study is that injury/illness surveillance could affect awareness among athletes and parents. Previous studies applying this method have reported a slight reduction in the prevalence of overuse injuries and illnesses over time [15]. In contrast, our data show a stable prevalence of substantial health problems during the 26-week study course.

Some health-related problems may be expected when participating in high-level sports. The "all health complaints" definition covers most health issues, and even minor and transient cases like muscle soreness and unspecific symptoms of illness (e.g. light headache or tiredness) are likely to be registered [13]. This is a source of systematic bias, overestimating the true prevalence of sports-related health problems. Nevertheless, this is why we also used the "substantial problem" definition, which filters out the least consequential problems and may provide a better estimate of the impact of injuries and illnesses on the health of the young athletes.

Perspectives

Nearly half of the young elite athletes reported symptoms from injury or illness at any given time, and one in four experienced health problems with a substantial negative impact on training and performance.

Our data suggest that the prevention focus should not only be on acute injuries, but also on overuse injuries and illnesses among young athletes. Giving special attention to development and training techniques, rather than emphasizing competition and winning, may minimize or mitigate injuries. Superior athletic skills enable many of these young athletes to participate on a number of different teams and with older athletes, often having to relate to several different coaches. To this end, encouraging increased collaboration between coaches, promoting load management through individualized training programs and long-term personal goal setting seems reasonable.

In order to minimize illnesses, basic preventive measures like hygiene education and frequent hand washing with soap and running water has proven effective among adult elite athletes [51]. The same preventive measures are relevant for youth elite athletes. An additional focus on how to prevent specific infectious diseases such as mononucleosis seems relevant. Adolescent-adapted education, with an overall focus on eating, sleeping and other lifestyle factors (e.g. managing stress and other non-sporting loads), is a key step.

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Tables

Table 1. Different sport disciplines in the Sport Academy High School group, categorized into three major categories. Values represent the number of athletes in each sport.

Endurance sports (n=69)	Technical sports (n=62)	Team sports (n=129)
Athletics (3)	Athletics (4)	Basketball (9)
Biathlon (17)	Alpine skiing (10)	Floorball (7)
Cross-/Cycling (11)	Badminton (2)	Handball (38)
Cross-country skiing (18)	Climbing (3)	Ice hockey (31)
Nordic combined (3)	Fencing (1)	Soccer (40)
Orienteering (4)	Freeski (8)	Volleyball (4)
Paddling (3)	Golf (3)	
Swimming (10)	Gymnastics (3)	
	Luge (4)	
	Martial arts (6)	
	Motocross (3)	
	Sailing (4)	
	Skeleton (1)	
	Ski jumping (6)	
	Snowboard (2)	
	Tennis (2)	

Table 2. Baseline characteristics of the participants.

	Endurance sports (n=69)		Technical sports (n=62)		Team sports (n=129)		Team sport teammates (n=60)	
	Males	Females	Males	Females	Males	Females	Males	Females
Gender, n (%)	46 (67%)	23 (33%)	43 (69%)	19 (31%)	89 (69%)	40 (31%)	29 (48%)	31 (52%)
Age (yrs), mean (SD)	16.2 (0.3)	16.1 (0.3)	16.2 (0.3)	16.2 (0.4)	16.2 (0.3)	16.2 (0.3)	16.6 (0.9)	16.2 (1.6)
Height (cm), mean (SD)	179 (6.9)	168 (4.9)	178 (6.7)	165 (6.7)	180 (6.7)	170 (6.7)	180 (5.5)	170 (5.6)
Body mass (kg), mean (SD)	67 (8.4)	59 (7.9)	67 (8.8)	57 (7.9)	72 (8.6)	61 (7.3)	71 (9.3)	60 (7.8)

Table 3. Sports history at baseline. Data are shown as numbers with percentages.

	Endurance sports (n=69)*		Technical sports (n=62)		Team sports (n=129)		Team sport teammates (n=60)	
	Males (n=46)*	Females (n=23)	Males (n=43)*	Females (n=19)	Males (n=89)*	Females (n=40)*	Males (n=29)*	Females (n=31)*
Age at primary sport debut								
≤8 yrs	17 (37%)	14 (61%)	27 (63%)	11 (58%)	77 (87%)	28 (70%)	19 (66%)	24 (77%)
9-12 yrs	20 (44%)	8 (35%)	13 (30%)	5 (26%)	11 (12%)	11 (28%)	9 (31%)	6 (19%)
13-15 yrs	8 (18%)	1 (4%)	3 (7%)	3 (16%)	1 (1%)	1 (3%)	0 (0%)	0 (0%)
Age at specialization**								
≤10 yrs	3 (7%)	0 (0%)	8 (19%)	2 (11%)	21 (24%)	5 (13%)	7 (24%)	5 (16%)
11-12 yrs	4 (9%)	7 (30%)	12 (28%)	6 (32%)	23 (26%)	11 (28%)	8 (28%)	8 (26%)
13-14 yrs	27 (59%)	6 (26%)	19 (44%)	8 (42%)	40 (45%)	16 (40%)	6 (21%)	14 (45%)
15-16 yrs	12 (26%)	10 (44%)	4 (9%)	3 (16%)	5 (6%)	8 (20%)	8 (28%)	4 (13%)
Playing other sports 2 previous years								
No other sport	8 (17%)	8 (35%)	18 (42%)	10 (53%)	59 (66%)	19 (48%)	14 (48%)	23 (74%)
1 other sport	10 (22%)	1 (4%)	5 (12%)	4 (21%)	10 (11%)	11 (28%)	6 (21%)	1 (3%)
2 other sports	12 (26%)	10 (44%)	8 (19%)	3 (16%)	8 (9%)	5 (13%)	5 (17%)	4 (13%)
≥3 other sports	15 (33%)	4 (17%)	11 (26%)	2 (11%)	9 (10%)	4 (10%)	4 (14%)	2 (6%)
Average training load previous year (h/wk)								
>20 h	3 (7%)	5 (22%)	1 (2%)	5 (26%)	2 (2%)	0 (0%)	2 (7%)	1 (3%)
16-20 h	6 (13%)	3 (13%)	11 (26%)	0 (0%)	26 (29%)	2 (5%)	3 (10%)	4 (13%)
11-15 h	30 (65%)	9 (39%)	21 (49%)	9 (48%)	36 (40%)	18 (45%)	15 (52%)	11 (36%)
6-10 h	5 (11%)	6 (26%)	9 (21%)	4 (21%)	22 (25%)	20 (50%)	8 (28%)	9 (29%)
0-5 h	2 (4%)	0 (0%)	1 (2%)	1 (5%)	3 (3%)	0 (0%)	1 (3%)	6 (19%)
Current competition level								
International	4 (9%)	8 (35%)	21 (49%)	13 (68%)	33 (37%)	17 (43%)	0 (0%)	7 (23%)
National level	40 (87%)	15 (65%)	33 (77%)	15 (79%)	66 (74%)	30 (75%)	10 (35%)	14 (45%)
Performance level								
Top 5%	21	10	24	13	40	7 (18%)	5 (17%)	5 (16%)

nationally	(46%)	(44%)	(56%)	(68%)	(45%)			

* Number of athletes at baseline ** At which age they decided to focus on their sport

Table 4. Baseline prevalence of all health problems and substantial health problems reported during the past 7 days, as well as for subcategories of illness and injury in each subgroup of athletes. Data are shown as the number and percentage of athletes reporting at least one (substantial) health problem.

	Elite Sport Athletes (n=260)						Team sport teammates (n=60)	Adolescent controls (n=21)
	All (n=260)	Males (n=178)	Females (n=82)	Endurance sports (n=69)	Technical sports (n=62)	Team sports (n=129)		
All health problems								
Total	155 (60%)	105 (59%)	50 (61%)	41 (59%)	33 (53%)	81 (63%)	37 (62%)	16 (76%)
Illness	49 (19%)	31 (17%)	18 (22%)	21 (30%)	11 (18%)	17 (13%)	12 (20%)	8 (38%)
Injury	106 (41%)	74 (42%)	32 (39%)	20 (29%)	22 (36%)	64 (50%)	25 (42%)	8 (38%)
Substantial health problems								
Total	61 (24%)	42 (24%)	19 (23%)	20 (29%)	10 (16%)	31 (24%)	18 (30%)	5 (24%)
Illness	14 (5%)	12 (7%)	2 (2%)	10 (15%)	1 (2%)	3 (2%)	3 (5%)	1 (5%)
Injury	47 (18%)	30 (17%)	17 (21%)	10 (15%)	9 (15%)	28 (22%)	15 (25%)	4 (19%)

Table 5. Average weekly prevalence during the 6-month observation period of all health problems and substantial health problems reported, as well as for subcategories of illness and injury in each subgroup of athletes. Data are shown as the percentage of athletes reporting at least one (substantial) health problem, with 95% confidence intervals.

	Elite sport athletes (n=258)						Team sport teammates
	All (n=258)*	Males (n=177)	Females (n=81)*	Endurance sports (n=68)*	Technical sports (n=62)	Team sports (n=128)*	(n=60)
All health problems	43% (37,49)	39% (32,46)	53% (42,64)	38% (28,50)	45% (33,57)	45% (37,54)	37% (26,49)
Illness	12% (9,17)	11% (7,17)	16% (10,26)	23% (15,35)	10% (5,20)	8% (4,14)	14% (7,24)
Injury	31% (26,37)	28% (22,35)	37% (27,48)	15% (8,25)	36% (25,48)	37% (29,45)	23% (14,35)
- Acute injury	14% (12,20)	12% (8,17)	17% (11,27)	2% (0,8)	16% (9,27)	19% (13,26)	11% (6,22)
- Overuse injury	17% (13,22)	16% (11,22)	19% (12,28)	12% (6,22)	20% (11,31)	17% (12,25)	13% (7,24)
Substantial health problems	25% (20,31)	22% (17,29)	32% (23,43)	22% (14,33)	25% (17,38)	26% (19,34)	18% (11,30)
Illness	7% (4,11)	6% (4,11)	11% (6,20)	15% (8,25)	6% (3,15)	4% (2,9)	8% (4,18)
Injury	17% (13,22)	16% (11,22)	21% (14,31)	7% (3,16)	19% (11,31)	22% (16,30)	10% (5,20)
- Acute injury	10% (7,14)	9% (6,14)	12% (7,21)	1% (0,8)	11% (6,22)	14% (9,21)	6% (3,16)
- Overuse injury	8% (5,12)	7% (4,11)	9% (4,17)	6% (2,14)	8% (3,18)	9% (5,16)	4% (1,11)

*Indicates number of athletes at baseline

Table 6. Number of incidents (n), duration, average weekly severity score and cumulative severity score of illnesses, overuse injuries and acute injuries in median (interquartile range Q_1,Q_3).

	Elite sport athletes (n=258)						Team sport teammates (n=60)
	All (n=258)	Female (n=81)	Male (n=177)	Endurance (n=68)	Technical (n=62)	Team (n=128)	
Illness							
Number of incidents	441	165	276	175	87	179	90
Duration (weeks)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)
Average weekly severity score	46 (22,72)	50 (28,72)	44 (20,72)	51 (29,72)	37 (16,66)	46 (20,74)	40 (17,69)
Cumulative severity score	66 (29,110)	72 (37,128)	60 (28,100)	72 (37,140)	62 (27,113)	61 (28,100)	60 (20,103)
Overuse injury							
Number of incidents	241	89	152	53	65	123	42
Duration (weeks)	3 (1,8)	4 (1,9)	3 (1,8)	3 (1,8)	4 (1,8)	3 (1,9)	2 (1,6)
Average weekly severity score	28 (19,44)	28 (20,40)	28 (16,47)	29 (18,44)	26 (18,39)	28 (19,48)	26 (15,43)
Cumulative severity score	88 (28,293)	100 (34,354)	80 (22,237)	71 (28,276)	83 (25,297)	96 (28,301)	76 (27,161)
Acute injury							
Number of incidents	230	81	149	26	66	138	61
Duration (weeks)	2 (1,4)	2 (1,6)	2 (1,4)	1 (1,2)	2 (1,4)	2 (1,6)	1 (1,3)
Average weekly severity score	37 (23,58)	36 (22,55)	41 (25,60)	37 (22,48)	37 (22,54)	39 (26,60)	34 (20,59)
Cumulative severity score	74 (28,187)	60 (26,238)	86 (30,185)	46 (27,68)	79 (28,162)	90 (33,267)	53 (22,107)

Figures

Figure 1. Study flow chart showing the number of participants invited, included and analyzed.