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# *The Association between Early Specialization and Performance Level with Injury and Illness Risk in Youth Elite Athletes*

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## Abstract

A trend is observed towards more specialized training and selection into talent programs at an early age for youth athletes. Little is known how this might influence the risk of illness and injury. The aim of the study was to assess whether, in a group of youth elite athletes, those specializing early or performing best were at increased risk of incurring injury or illness after entering a specialized Sport Academy High School program. We enrolled 259 16-year old elite athletes. They completed a baseline web-based questionnaire covering their age at specialization, single- versus multi-sport involvement during the previous 2 years and current performance level (rated by themselves and their coach). Subsequently, the Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems was used to self-report injuries and illnesses weekly for 26 weeks from October to May. In this specialized Sport Academy High School program, 39% of the athletes reported early specialization (at 12 years or younger). However, early specialization did not increase the risk of injury or illness during the 26 weeks, nor did being a single-sport athlete the previous two years increase this risk. The best performing athletes at the time of enrollment were not at greater risk of becoming injured or ill during the 26 weeks. In conclusion, in a group of youth elite athletes entering a specialized Sport Academy High School program neither early single-sport specialization nor performance level appears to represent risk factors for injury or illness after enrollment.



## Key words:

Single-sport specialization; Performance level; Talent; Overuse injury; Acute injury; Illness; Adolescent; Sport academy

## Introduction

Nearly twenty years ago, the American Academy of Pediatrics [1] pointed out the potential risks of high-intensity training and sports specialization at a young age, related to high physical, physiological and psychological demands. In 2013, the American Medical Society for Sports Medicine developed these recommendations into a position statement on overuse injury and burnout in youth sports, advising that specialization in a single sport should be discouraged before adolescence [2, 3]. There is no universally accepted terminology regarding what is considered adolescents, but the World Health Organization defines it as young people between the ages of 10 and 19 years while youths can include the 15- to 24-year age group [4]. More recently, a consensus statement by the American Orthopedic Society of Sports Medicine recommend closely monitoring for signs of overuse injury, burnout and overtraining in young athletes who practice intense training for more than 16 h per week or more hours per week than their age [5, 6]. However, although recent reports claim that specialized training in young athletes increases the risk of serious overuse injury [2, 6-8], there are no prospective studies examining this relationship or the relationship between early single-sport specialization and acute injuries, illnesses or psychological stress and burnout [9, 10].

Despite great concerns expressed from the medical community, there is a trend towards more training, more specialized training and early selection into talent programs at an ever earlier age [5, 6, 11-13]. A growing number of coaches and parents believe that the best way to produce superior young athletes is to have them play only one sport from a young age [14, 15]. Of particular interest is the transition from a regular club-based program to a specialized Sport Academy High School program, typically leading to a steep increase in training load, often doubling their training load over a short period and having to relate to multiple coaches both at school and in their club-based environment. Additionally, the most gifted young athletes among those selected for talent programs, may be tempted by the opportunity to attend multiple practices and multiple levels of competition, as they are often selected for both regional and national representative teams. These are all factors that may put the best performing youth athletes at greater risk of injury or illness [14, 16].

In a recent paper, we documented that there was a substantial impact of both injuries and illnesses on the health of 16-year old elite athletes after enrollment into intensive,

specialized Sport Academy High School programs [17]. The aim of the current study was to examine whether among these, the early-specialized or best-performing athletes were at increased risk of injury or illness after enrollment.

## Methods

### Study Design

This study was based on data from a prospective cohort study involving youth elite athletes enrolled in three specialized Sport Academy High Schools in Norway [17]. Baseline data, including retrospective information on early specialization and performance level, were collected in August 2014, and the athletes reported their weekly injury and illness status prospectively for 26 weeks from October until May 2015, when supplemental interviews were done to complete the injury/illness recording. 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).

### Participants

Inclusion criteria for the study [17] were all first-year students enrolled in three selected specialized Sport Academy High Schools in Norway 2014/-15. To attend these schools, athletes must demonstrate excellent skills in their sport, compete at a high level and pass multiple admission tests. There were no exclusion criteria. Verbal and written information was given to all 316 first-year students ($11^{th}$ grade, age 15 or 16 yrs) and their parents at the beginning of the school year about the purpose of the study. Of these, 259 accepted to participate. A large proportion of the participants were members of regional (76%) or national (37%) representative teams and competed at the national or international level [17]. Thirty different sport disciplines (both summer and winter sports from both individual and team sports) were represented and grouped into three major categories (endurance (n=69), technical (n=62) and team sports (n= 128)) [17]. Further details of the flow of participants and characteristics of the study population have been reported previously [17]. Written consent was obtained from all participants and their parents.

## Baseline Data Collection

Within two weeks after inclusion, participants completed a web-based questionnaire with information on their anthropometrics, medical history, motivation for training (numeric scale, 1=very, very low to 7=very, very high), sport category, age when the athlete defined one sport as being more important than other sports (sport specialization) and self-evaluated performance level. The questionnaire was completed during school hours, without any assistance by parents. They were also asked to report participation in other sports during each of the past 6 years ($5^{th}$ through $10^{th}$ grade). We related the different sport disciplines to the different school grades and gave them multiple-choice alternatives to choose from in order not to miss important sports. They also reported how many hours on average they had participated in training and competition during each of the past 12 months.

## Risk factor classification

*Early specialization*. We defined sport specialization as the time when the athlete defined one sport as being more important than other sports and asked the athletes: "At what age did you decide to focus on your sport?" classified into seven categories: ≤10 yrs, 11 yrs, 12 yrs, 13 yrs, 14 yrs, 15 yrs or 16 yrs. For the analyses, we dichotomized their response as early (≤12 yrs) or late specialization (>12 yrs) [5, 12, 13, 18-22].

*Single-sport and multi-sport athletes*. To assess previous and current involvement in different sports we listed the 18 most common sports in Norway as well as an open category asking the athletes to describe their involvement in each of these during the past 6 yrs (excluding in physical education class). For the analyses, we classified athletes having participated in more than their main sport during the past 2 years (9th and/or 10th grade) as multi-sport athletes.

*Self-evaluated performance level.* At baseline, all athletes were asked the following question: "In your opinion, how do you rate your own performance level compared to other same-age athletes in your sport in Norway?" classified into six categories: Top 1%, top 5%, top 10 %, top 25%, top 50% and below 50%. For the analyses, we dichotomized their responses into above or below top 10%.

*Coach-evaluated performance level*. Their coaches were asked to rate athletic performance at the beginning of the school year based on the following question: "Compared to the average of the athletes in your training group, how do you rate this athlete's current performance level?" classified into quartiles from the top 25% to the lowest 25%. For the analyses, we dichotomized the coach evaluation into above or below the top 50%.

## Definition of injury and illness

Health problems were defined as all injuries and illnesses, regardless of severity and consequences.

Health problems were classified as an injury if affecting the musculoskeletal system, as well as concussions [23], 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 [24]. Injuries were further categorized into acute and overuse as reported by the athlete. A definition of acute (linked to a specific injury event, such as falling or being tackled) vs. overuse (those that could not be linked to a single clearly identifiable event) was shown each time the athlete opened the app for their weekly health report [25]. The instructions also emphasized that sadness, depression, anxiety and feeling troubled should be registered as an illness. If an illness were reported, athletes were asked to select the main symptoms they had experienced during the past week [23]. Illnesses were coded according to organ system affected [24].

Substantial health problems were defined as problems leading to moderate or severe reductions in training volume or performance, or complete time loss from sport.

## Prospective Recording of Injury and Illness

The Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems [24] was used to self-report injuries, illnesses and training load weekly through a smartphone application (Spartanova N.V., Gent, Belgium). The OSTRC questionnaire records the consequences of any health problems the athlete may have experienced during the past week. It consists of four graded questions about sport participation, training volume, performance and health problems experienced [23, 24]. Each question is allocated a numerical value from 0 to 25, where 0 represent no problems and 25 the maximum level for each question. The four response values are summed, resulting in a severity score from 0 to

100 for each health problem reported. If the lowest score on each of the four key questions is recorded (no health problems or symptoms reported), the questionnaire is complete for that week. However, if any health problem is reported, the athletes are asked to define the problem as an injury or an illness. In case there are multiple health problems during the same week, the questionnaire repeat itself up to four times. Participants are instructed to report all health problems every week, regardless of whether or not the problem has been registered the previous week.

## Supplemental Interviews

At the end of the study period, we conducted supplemental interviews with all available participants still included in the study. All athletes brought their training diaries to the interview. We used all available prospective OSTRC questionnaire data recorded, and we registered all major competitions in the interview form beforehand. Interviews were conducted in person at school or during a training session, in 7 cases by telephone. During the athlete interviews, the data recorded prospectively using the smartphone app were reviewed and quality controlled, and missing data were supplemented using interview data. One OSTRC questionnaire was completed for every health problem registered during the 26-week period. Details about the injury and illness registration and the data collection procedures have been reported previously [17].

## Outcomes

For every athlete, we calculated the number of all and substantial health problems during the 26-week period. The cumulative severity score of injuries and illnesses was calculated by summing the score for every week the health problem was reported, as previously described in detail [17].

## Statistical methods

All data were analyzed using SPSS for Windows (version 24). The number of all and substantial health problems, illnesses, acute and overuse injuries, as well as their cumulative severity scores, were the main outcomes for the risk factor analyses. For each of the eight main outcomes, we generated four separate linear regression models, one for each candidate risk factor: 1) Early specialization, 2) Single-sport athlete previous 2 yrs, 3) Self-evaluated performance level above top 10%, and 4) Coach-evaluated performance level

above top 50%. Crude linear regression analyses were made for all risk factors. We adjusted all models for the same set of factors, potentially influencing the number of health problems: sex, sport category and baseline training load. Other risk factor variables (prospective training load, training motivation, main sport) were examined in separate univariable analyses and those with a p-value of <0.2 were investigated further in a multiple regression model.

We explored the differences in outcome measures (number of health problems and cumulative severity score) for all the four different risk factors. All four binary independent variables were included in unadjusted univariable linear regression models. Adjusted multiple regression models were based on clinical practice and literature review. Based on the unadjusted models, adjusted multiple linear regression analyses were also constructed for all candidate variables with a p-level <0.2. Results are reported as the mean with 95% confidence intervals. Significance was accepted at a p-level <0.05.

## Results

We included 259 athletes in the study. Six athletes were lost to follow-up [17].The response rate was 66% on average through all weeks for the prospective data collection. We interviewed all but two of the elite sport athletes still included in the study, supplementing the prospectively reported data. This process resulted in a final response rate of 99.4%.

### Early sport specialization, single-sport athletes and risk of injury and illness

Early specialization was reported by 39% of the athletes (n=102), but only 23% (n=57) of the athletes reported both early sport specialization and practicing a single sport (Table 1). The cohort was roughly split in halves between single- (48%) and multi-sport (52%) athletes the previous two years. We could not detect any association between being a single- or multi-sport athlete and the risk of injury (Table 2). In contrast, early sport specialization was associated with an increased risk of acute injuries, but this association was modified by sex, sport category and training load at baseline, and no longer significant after adjustment for these factors (Table 2).

### Performance level and risk of injury and illness

When comparing themselves to all same-age athletes in the country in their sport, 66% of the athletes enrolled in the study (n=171) rated their own performance within the top 10% in the country. Ninety percent (n=234) of the athletes rated their performance within the top 25% and only 2% (n=5) below 50% compared to other same-age athletes in their sport in Norway. The coaches rated 46% (n=96) of the athletes as top 50% compared to their classmates at baseline (Table 2). The coaches failed to evaluate 19% (n=49) of the athletes, of whom 75% rated themselves as top 10% in the country. For 36% (n=75) of the athletes, there was a match between the highest self-rating (top 10% in the country) and coach-rating (top 50% in cohort). Crude analyses of the relationship between performance level and the number of health problems (injuries and illnesses) revealed no greater risk of getting injured or ill if categorized in the top performance athlete groups (Table 2). The 75 athletes (36%) categorized as being in the best performance group by both the athletes themselves and their coaches were also not at greater risk of injury or illness (p=0.46). An exception was an increased risk of overuse injuries in the self-evaluated top 10% performance group when adjusting for sport category, sex and baseline training load.

### Cumulative severity score, early single-sport specialization and performance level

We tested differences in cumulative severity scores for overuse injuries, acute injuries and illnesses associated with early or single-sport specialization, and performance level. Univariable (P=0.06 to 0.85) and multiple (P=0.09 to 0.96) linear regression analyses showed that the cumulative severity score did not differ significantly between the binary categories of early or single-sport specialization or performance level (data not shown).

## Discussion

Even though early sport specialization was associated with an increased risk of acute injuries, our data suggest that early or single-sport specialization cannot be considered risk factors for health problems among youth elite athletes after enrollment into an intensive sport academy program. Also, an increased risk of overuse injuries in the self-evaluated top 10% performance group was evident, but as an overall finding the best performing athletes in the program were not at greater risk of becoming injured or ill.

## No increased risk of injury in early specialized athletes

Some of the specific results from our study need to be addressed. First, crude data indicated that early sport specialization was associated with an increased risk of acute (substantial) injuries. However, in a previous study we reported a significantly higher prevalence of acute injuries among team and technical athletes compared to endurance athletes [17]. Both team and technical athletes tended to specialize earlier and were more likely to practice a single sport than endurance athletes. So after we adjusted for sport category, this association was no longer significant.

Second, we did not detect an increased risk of overuse injuries between early- and late-specializing athletes and no association between the more severe injuries (i.e. cumulative severity score) and early specialization. This is in contrast to the findings of Jayanthi et al, who found the highly specialized athletes to be at a higher risk of incurring more serious overuse injuries. Methodological differences may explain this discrepancy, as discussed below. Additionally, in the same study by Jayanthi et al [2], the initiation age of specialization (early versus late) was not associated with an increased risk of injuries. This is similar to our findings, that early specialization was not associated with an increased injury risk.

## Lack of consensus regarding early sport specialization

There is only a handful previous reports on early single-sport specialization and injury risk, and a lack of consensus of what should be considered a highly specialized youth athlete makes direct comparisons across studies difficult.

Some studies have reported an increased injury-risk [2, 7, 26]. Jayanthi et al reported that during a 4 week summer tournament, junior tennis players specializing in tennis only were about 6 times more likely to suffer a time-loss injury compared to multi-sport athletes [7]. Hall and co-workers observed a 1.5-4 fold greater risk of developing anterior knee pain (patellofemoral pain, Osgood-Schlatter disease and patellar tendinopathy) among 13-14 year old female single sport-specialized athletes in basketball, volleyball and soccer in a retrospective study [26]. And finally, an independent risk of injury and serious injury in young athletes who specialize in a single sport was demonstrated in a clinical case-control study comparing injured athletes aged 7-18 years from a sports medicine clinic to non-injured peers [2].

Compared to our study, these studies differ in both definitions used, design and methods [2, 7, 9, 26]. The term specialization was defined either by single-sport participation [7, 26] or by degree of specialization (low, moderate, high) [2].The studies were either of a very short duration (only 4 weeks during a summer tournament season) [7], retrospective [26] or case-control based [2]. Additionally, recall bias is a limitation in the retrospective study, as well as a possible selection bias in the case control study, where the more specialized youth athletes may have been more likely to seek help from sports medicine specialists when injured, possibly overestimating the risk of injury in this group.

### Challenges regarding how to define early sport specialization

Age is a common injury risk factor among youth athletes [27, 28]. Therefore, it seems important to identify at which age sport specialization may be detrimental for the youth athlete, and at which point it might become beneficial [14]. Recent studies regarding sports specialization have focused mostly on the degree of specialization, rather than the age of specialization [2, 8, 26, 29-32]. Based on the literature [5, 18-20], we considered "early specialization" as specialization at 12 years or younger, and defined sport specialization as the time when the athletes considered one sport as being more important to them than other sports, and wanting to excel in this sport [11, 12, 20-22]. This did not include quitting other sports, practicing one sport solely, whether or not they had ever only participated in one single sport, or the timeframe within which the sport was practiced.

Another definition suggested is "year round intensive training in a single sport at the exclusion of other sports"[2, 6]. In accordance with this definition, a 3-point scale has been suggested to categorize the degree of specialization as low, moderate or high, depending on the fulfillment of one or more of these three criteria: 1. Year-round training (more than 8 months per year), 2. Choosing a single sport, and 3. Quitting all sports to focus on a single sport [2, 8]. However, there are some challenges that need to be recognized even if using this more graded definition of what constitutes being a "highly specialized" youth athlete. First, it does not define what is considered an early age for specialization, as previously discussed. Second, it does not consider performance level. Third, at least in Scandinavia, even recreational youth athletes participate for more than 8 months per year in one main sport.

In our study, we used both the age of sport specialization, as well as participation in other than their main sport during the past two years as measures of the degree of specialization. As illustrated in table 2, 48% were single-sport athletes and 39% had specialized early. Interestingly, only 23% reported both early sport specialization and practicing a single sport (Table 1). However, all athletes fulfilled at least two of three criteria on the 3-point scale (year-round training and choosing a main sport) and would be considered moderately specialized. Additionally, all single-sport athletes would be considered "highly specialized" (fulfilling all 3 criteria). Therefore, in our opinion this classification method is not either complete and of limited value, at least in our cohort.

### High performance level and risk of overuse injuries

To detect the best-performing athletes in this cohort, we asked both athletes and coaches to assess current performance level. Coaches were asked to compare with athletes in their own training group, athletes ranked themselves compared to same-age athletes in their sport in Norway. In our experience, most youth elite athletes have a good knowledge about their own performance level based on previous competitions, matches, talent camps, etc. In our experience, it comes as no surprise that 66% of these youths rank themselves in the top level, as admittance to the sport academy high schools is based on previous rankings, tests, results and information from their club coaches. We also know through personal correspondence with the schools that approximately two-thirds of their student-athletes are successful in taking a medal in their sport while enrolled at the Sport Academy High School.

Among the athletes who evaluated themselves as being among the top 10% in the country, we detected a 30% increased risk of overuse injuries. When the coaches selected the top 50% in the cohort, we did not detect any association between performance level and injury risk. An obvious limitation was that the coaches failed to evaluate nearly 20% of the athletes. However, as the distribution between sport categories ($p=0.10$) and gender ($p=0.13$) in this group was similar to the rest of the study population, a selection bias seems unlikely. Also, if we compared the subgroup of athletes who were rated in the top-performing categories by both themselves and their coaches (36% of the cohort), we detected no significant increase in overuse injury risk compared to the rest of the cohort.

We analyzed the combination of the highest performance level evaluated by both athlete and coach, but not all four risk factors together. As there was no consistent associations in univariate analyses with any of these factors, we would argue that it would be imprudent to go further with and report on more complex modelling of the data.

Most previous studies suggest an increased injury risk in higher performing youth athletes [33-38]. Johnson [35] showed that high-performing youth athletes, who are often early maturers, were more prone to injuries because of a higher training load, playing more matches and holding the more exposed positions. Studies from team sports such as football [37, 38], ice hockey [39] and volleyball [36] have all provided data documenting a greater injury-risk among youth elite players with high levels of tactical and technical skills. Few studies have reported a lack of association between injuries and high skills in youth athletes [33, 40].

One potential explanation for our observations, and a limitation of our study, was that only 82% of all first year students participated. The missing 18% were abroad training or competing when the baseline questionnaire was distributed during school hours, and thus they could not be included in the study. This might have introduced a selection bias; the best performing athletes practicing summer sports were more likely to have been absent.

Another possible explanation was that athletes and coaches compared performance level between different groups; athletes to other same-age Norwegian athletes in their sport, coaches only between athletes in their training group. Also, in order to be selected for a Sport Academy High School, athletes must have attained a high skill level in their sport, resulting in a relatively homogenous cohort. Detecting an effect of performance level on injury risk, might therefore be difficult, as they all belonged to a highly skilled group.

## Methodological considerations

Prospective data collection depends on comprehensive athlete responses [23, 24], and missing data represent 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 could lead to recall bias [17]. We therefore compared between prospectively

collected data and interview data and found minimal differences. In this way, each data set served as a control for the other and no systematic bias in either direction could be seen, as documented previously [17].

Prospective data collection was carried out from October until the end of the school year (May), when the athletes started their exam period. In total, 28 weeks were registered. In line with the methodology of Clarsen et al [23, 24], data from the first two weeks of the study period were excluded. We do not know what the injury/illness risk was during the period from late August until data collection started in October. An increased training load and subsequent increased injury and illness risk after entering a specialized sport academy high school is possible. However, as our study covers most of the school year, we would argue that the observation period of 26 weeks is sufficient to be representative to quantify the injury/illness risk for the athletes enrolled in the study.

Another factor which might be considered a limitation of the study, is that athletes and coaches were asked to evaluate sport performance level by different cut offs and by comparing to different groups. The coaches were asked to rank the athletes in their training group in quartiles. This was successful, resulting in an even distribution between the quartiles, and 46% assessed as being above average and 54% below. For the athletes we chose more detailed categories, because we did not know what the distribution would be. But as the results showed, this ranking method allowed us to dichotomize the group into above or below the top 10% performers in their sport in Norway (66% above, 33% below).

Finally, youth athletes not enrolled in high performance sport academies were not included in the risk factor study. However, in a previous paper we showed that the prevalence of health problems was surprisingly similar between the best-performing elite team sport athletes attending sport academy high schools, versus their subelite teammates from the same clubs not attending sport academy high schools [17].

## Perspectives

This study shows that, even though youth elite athletes seem to be at a high risk of becoming injured or ill, early single-sport specialization and high performance level cannot be considered solitary risk factors. Thus, advocating participation in several sports or promoting specialization at an older age in order to reduce the risk of injury and illness is not

possible based on our findings. However, our concerns regarding youth elite athletes and overscheduling still seem relevant as almost half of the athletes in our cohort reported a health problem at any given time [17].

Finally, there is still a methodological challenge related to what is considered a highly specialized youth athlete. Future studies regarding the health of youth elite athletes and early sport specialization need to consider not only if they practice year-round training in a single sport. Performance level, sport category and age of single-sport specialization also need to be taken into account for these aspiring young athletes. There is an urgent need to care for young athletes by improving injury and illness prevention strategies.

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## Tables

*Table 1. Numbers (proportions %) of early specializing athletes categorized by performance level and single sport participation.*

| | | Early specialization (≤12 yrs) | |
|---|---|---|---|
| | n | Yes | No |
| Single-sport previous 2 yrs | 251* | 101 | 150 |
| - Yes | 121 | 57 (23%) | 64 (25%) |
| - No | 130 | 44 (18%) | 86 (34%) |
| Coach-evaluated performance level | 210* | 78 | 132 |
| - Top 50% | 96 | 42 (20%) | 54 (26%) |
| - Low 50% | 114 | 36 (17%) | 78 (37%) |
| Self-evaluated performance level | 259* | 102 | 157 |
| - Top 10% | 171 | 76 (29%) | 95 (37%) |
| - Below 10% | 88 | 26 (10%) | 62 (24%) |

*Numbers vary due to missing values

*Table 2. Relationship between the number of health problems (mean and 95% CI) and self- and coach-evaluated performance, being a single-sport athlete at entry and early specialization. Data are based on unadjusted univariable and multiple linear regression analyses adjusted for sport category, sex and baseline training load.*

| | Number of health problems (n)* | | Unadjusted | | Adjusted | |
|---|---|---|---|---|---|---|
| | Yes** | No** | P | B (95% CI) | P | B (95% CI) |
| *Self-evaluated top 10% performance level (n=259)** | n=171 | n=88 | | | | |
| All health problems | 3.5 (3.2,3.8) | 3.6 (3.2,4.0) | 0.86 | -0.05 (-0.56,0.46) | 0.91 | 0.03 (-0.49,0.55) |
| - Acute injuries | 0.8 (0.7,1.0) | 1.1 (0.8,1.3) | 0.08 | -0.24 (-0.52,0.03) | 0.09 | -0.24 (-0.51,0.04) |
| - Overuse injuries | 1.0 (0.9,1.2) | 0.8 (0.6,1.0) | 0.08 | 0.24 (-0.03,0.51) | 0.026 | 0.31 (0.04,0.59) |
| - Illness | 1.7 (1.5,1.9) | 1.8 (1.5,2.0) | 0.72 | -0.07 (-0.42,0.29) | 0.71 | -0.06 (-0.41,0.28) |
| Substantial health problems | 2.1 (1.9,2.4) | 2.2 (1.9,2.5) | 0.83 | -0.04 (-0.43,0.35) | 1.00 | 0.00 (-0.40,0.40) |
| - Substantial acute inuries | 0.5 (0.4,0.6) | 0.6 (0.5,0.8) | 0.25 | -0.12 (-0.33,0.09) | 0.23 | -0.13 (-0.33,0.08) |
| - Substantial overuse injuries | 0.5 (0.4,0.7) | 0.4 (0.3,0.6) | 0.23 | 0.12 (-0.08,0.32) | 0.13 | 0.16 (0.05,0.37) |
| - Substantial illness | 1.1 (0.9,1.3) | 1.1 (0.9,1.4) | 0.76 | -0.04 (-0.32,0.23) | 0.80 | -0.03 (-0.29,0.23) |
| *Coach-evaluated top 50% performance level (n=210)** | n=96 | n=114 | | | | |
| All health problems | 3.5 (3.1,3.9) | 3.2 (2.9,3.6) | 0.29 | 0.27 (-0.23,0.78) | 0.22 | 0.32 (-0.19,0.82) |
| - Acute injuries | 0.9 (0.7,1.1) | 0.8 (0.6,1.0) | 0.46 | 0.11 (-0.18,0.39) | 0.70 | 0.05 (-0.22,0.33) |
| - Overuse injuries | 1.0 (0.7,1.2) | 0.8 (0.7,1.0) | 0.37 | 0.13 (-0.15,0.40) | 0.28 | 0.15 (-0.12,0.42) |
| - Illness | 1.6 (1.4,1.9) | 1.6 (1.3,1.9) | 0.92 | 0.02 (-0.35,0.39) | 0.57 | 0.10 (-0.25,0.46) |
| Substantial health problems | 1.8 (1.6,2.1) | 2.0 (1.8,2.3) | 0.31 | -0.20 (-0.59,0.19) | 0.26 | -0.22 (-0.62,0.17) |
| - Substantial acute inuries | 0.5 (0.4,0.7) | 0.5 (0.4,0.6) | 0.77 | 0.03 (-0.18,0.25) | 0.78 | -0.03 (-0.24,0.18) |
| - Substantial overuse injuries | 0.4 (0.3,0.6) | 0.5 (0.3,0.6) | 0.73 | -0.04 (-0.24,0.17) | 0.73 | -0.04 (-0.24,0.17) |
| - Substantial illness | 0.9 (0.7,1.0) | 1.1 (0.9,1.3) | 0.16 | -0.20 (-0.47,0.08) | 0.24 | -0.16 (-0.42,0.11) |
| *Single-sport athlete previous 2 yrs (n=251)** | n=121 | n=130 | | | | |
| All health problems | 3.5 (3.1,3.8) | 3.7 (3.3,4.0) | 0.41 | -0.21 (-0.70,0.29) | 0.66 | -0.11 (-0.63,0.40) |
| - Acute injuries | 0.9 (0.8,1.1) | 0.8 (0.6,1.0) | 0.44 | 0.10 (-0.16,0.37) | 0.40 | -0.12 (-0.39,0.16) |
| - Overuse injuries | 0.9 (0.8,1.1) | 1.0 (0.8,1.2) | 0.79 | -0.04 (-0.30,0.23) | 0.68 | -0.06 (-0.34,0.22) |

| | | | | | | |
|---|---|---|---|---|---|---|
| - Illness | 1.6 (1.4,1.8) | 1.9 (1.6,2.2) | 0.08 | -0.31 (-0.65,0.04) | 0.85 | 0.03 (-0.31,0.37) |
| Substantial health problems | 2.2 (1.9,2.5) | 2.2 (1.9,2.4) | 0.75 | 0.06 (-0.32,0.44) | 0.56 | 0.12 (-0.28,0.52) |
| - Substantial acute inuries | 0.6 (0.5,0.8) | 0.5 (0.3,0.6) | 0.08 | 0.18 (-0.02,0.37) | 0.92 | -0.01 (-0.21,0.19) |
| - Substantial overuse injuries | 0.6 (0.4,0.7) | 0.5 (0.3,0.7) | 0.27 | 0.11 (-0.09,0.30) | 0.41 | 0.09 (-0.12,0.29) |
| - Substantial illness | 1.0 (0.8,1.2) | 1.2 (1.0,1.4) | 0.10 | -0.22 (-0.49,0.04) | 0.75 | 0.04 (-0.22,0.30) |
| *Early specialization (≤12 yrs) (n=259)** | n=102 | n=157 | | | | |
| All health problems | 3.5 (3.1,3.9) | 3.6 (3.3,3.9) | 0.79 | -0.07 (-0.56,0.43) | 0.92 | 0.03 (-0.50,0.55) |
| - Acute injuries | 1.1 (0.8,1.3) | 0.8 (0.6,0.9) | 0.045 | 0.27 (0.01,0.54) | 0.48 | 0.10 (-0.18,0.38) |
| - Overuse injuries | 0.8 (0.6,1.0) | 1.0 (0.9,1.2) | 0.11 | -0.21 (-0.47,0.05) | 0.10 | -0.23 (-0.51,0.05) |
| - Illness | 1.6 (1.4,1.9) | 1.8 (1.6,2.0) | 0.35 | -0.17 (-0.51,0.18) | 0.45 | 0.13 (-0.21,0.48) |
| Substantial health problems | 2.2 (1.8,2.5) | 2.2 (1.9,2.4) | 0.98 | 0.00 (-0.37,0.38) | 0.84 | 0.04 (-0.36,0.45) |
| - Substantial acute injuries | 0.7 (0.6,0.9) | 0.4 (0.3,0.6) | 0.004 | 0.30 (0.10,0.49) | 0.18 | 0.14 (-0.07,0.35) |
| - Substantial overuse injuries | 0.4 (0.3,0.6) | 0.6 (0.4,0.7) | 0.13 | -0.15 (-0.34,0.04) | 0.06 | -0.20 (-0.41,0.01) |
| - Substantial illness | 1.0 (0.8,1.2) | 1.2 (1.0,1.3) | 0.29 | -0.14 (-0.41,0.12) | 0.47 | 0.10 (-0.17,0.36) |

** Numbers may vary due to missing values*

*** Values are the number of athletes in each category (yes/no) for each exposure variable*