Journal of Athletic Training 2018;53(3):262–270
doi: 10.4085/1062-6050-251-16

www.natajournals.org

High Injury Burden in Elite Adolescent Athletes: A 52-Week Prospective Study

Philip von Rosen, PhD*; Annette Heijne, PhD*; Anna Frohm, PhD*; Cecilia Fridén, PhD*; Anders Kottorp, PhD†

*Division of Physiotherapy and †Division of Occupational Therapy, Department of Neurobiology, Care Sciences, and Society (NVS), Karolinska Institutet, Huddinge, Sweden

Context: Our understanding of the injury burden in elite adolescent athletes in most sports is limited or unknown because of the lack of prospective, long-term injury studies.

Objective: To describe injury patterns in terms of type, location, prevalence and incidence, recurrence, and severity grade; time to first injury; and prevalence of illness in elite adolescent athletes and to compare differences in injury data by sex and sport type.

Design: Cohort study.

Setting: Fifteen national sports high schools in Sweden.

Patients or Other Participants: Participants were 284 elite adolescent athletes (boys = 147, girls = 137; median age = 17 years; 25th–75th percentile range = 16–18 years) competing at a high national level for their age in athletics (track and field), cross-country skiing, downhill skiing, freestyle skiing, handball, orienteering, or ski orienteering.

Main Outcome Measure(s): All athletes were monitored weekly over 52 weeks, using a validated online questionnaire to identify injury type, location, prevalence or incidence, and severity grade; time to first injury; and prevalence of illness.

Results: Among all athletes, 57.4% reported at least 1 new injury, whereas the 1-year injury prevalence was 91.6%. The overall injury incidence was 4.1/1000 hours of exposure to sport, and every week, on average, 3 of 10 (30.8%) elite adolescent athletes reported being injured. Of all injuries from which athletes recovered, 22.2% (n = 35) resulted in absence from normal training for at least 2 months. Female athletes reported higher ($P < .05$) average weekly injury prevalence and substantial injury prevalence (injuries leading to a moderate or severe reduction in sport performance or participation or time loss) than male athletes.

Conclusions: A considerable number of elite adolescent athletes were injured weekly, resulting in serious consequences for sport participation, training, or performance (or a combination of these). Appropriately designed interventions to prevent knee and foot injuries will target both the greatest number of injuries and the injuries with the most serious consequences in elite adolescent athletes.

Key Words: youths, injury epidemiology, injury surveillance

Key Points

- The high prevalences of average weekly injuries and substantial injuries, along with the fact that 20% of injuries resulted in at least 2 months of lost training time, indicated that both injury risk and injury severity were significant concerns in elite adolescent athletes.
- Female athletes reported a greater prevalence of injuries and substantial injuries than male athletes.
- The injury burden was highest in handball players.
- Appropriately designed interventions to prevent knee and foot injuries will address both the majority of injuries and the specific injuries with the most serious consequences in elite adolescent athletes.

An increase in the competitive nature of youth sports (ages 6–18 years) has led to a professionalization of pediatric and adolescent sport participation that resembles that in collegiate and professional athletes.[1,2] This emphasis on success at such an early stage is likely to increase the risk of injuries, especially in *elite athletes*,[3] defined as athletes competing at a high national level for their age group. Sport injuries could greatly burden young athletes, stress physical and psychosocial functioning, and affect performance. In contrast to injuries in elite adult athletes, injuries in elite adolescent athletes have been studied less frequently. Identifying injury patterns and high-risk sports in this age group is therefore warranted.[4]

Few long-term prospective injury reports on elite adolescent athletes have been conducted,[4,5] except in alpine skiing,[6] athletics,[7] football,[8–10] gymnastics,[11,12] and orienteering.[13] The reported injury incidence in elite adolescent athletes varies from 1.7 to 18.0/1000 hours of training and up to 22.4/1000 hours of competition versus 6.3/1000 hours of competitions and training sessions for college-aged competitive athletes.[14] Multisport observation can help researchers understand injury profiles across a variety of sport types; in addition, differences in injury type or location can be identified. This information would be of great value when designing tailored prevention programs and prioritizing preventive actions for high-risk groups.[4,15,16]

Our objective was to identify the injury burden in a cohort of elite adolescent athletes in multiple sports by following these athletes weekly during 1 calendar year, using validated, self-reported questionnaires in line with recommendations by Bahr[17] and Clarsen et al.[18] Specifi-

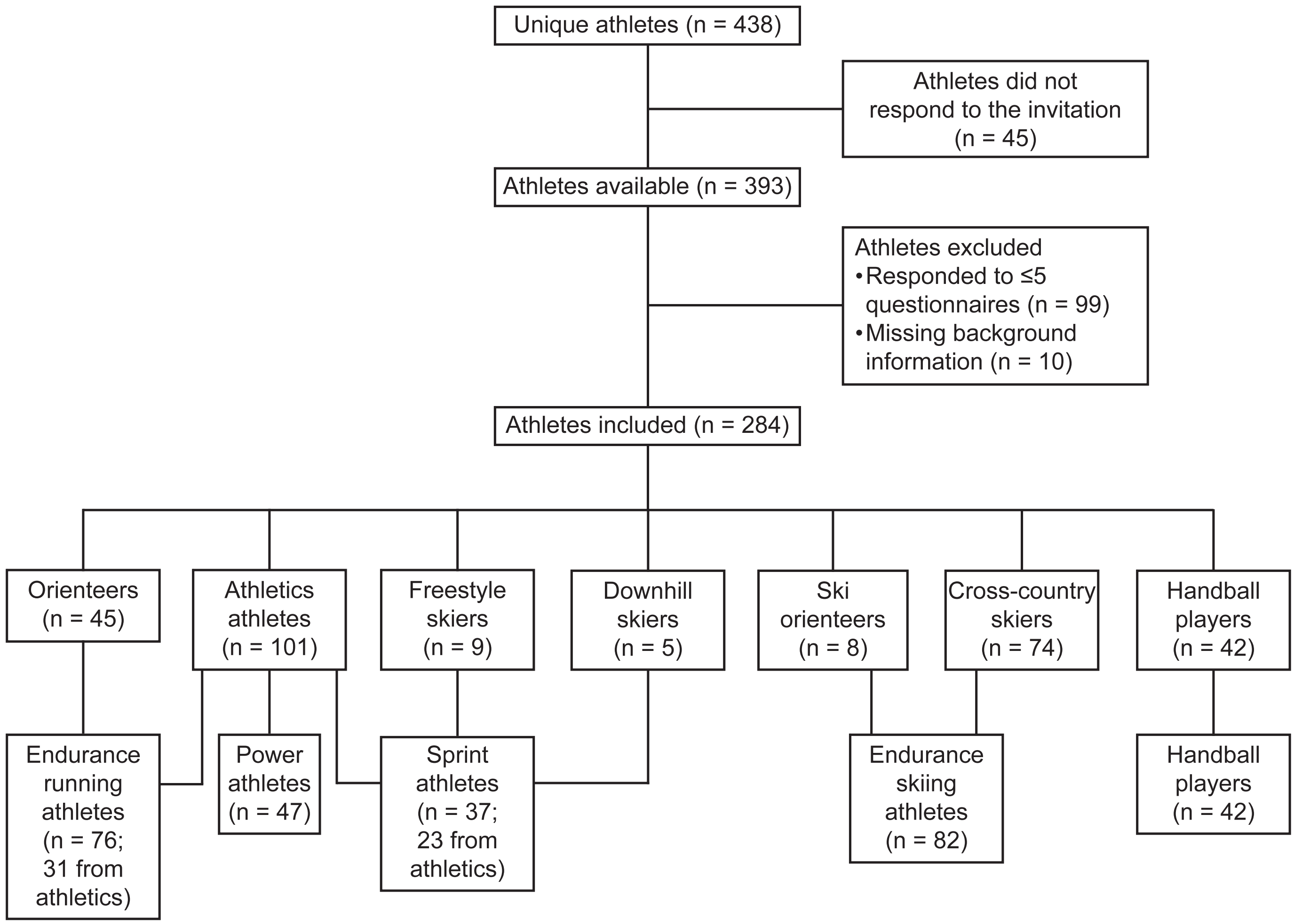

Figure 1. Flowchart of participant enrollment.

cally, our aims were to (1) describe the injury patterns in terms of injury type, location, prevalence or incidence, recurrence, and severity grade; time to first injury; and prevalence of illness, and (2) compare differences in injury data by sex and sport type.

METHODS

This study is part of the Karolinska Athlete Screening Injury Prevention study, which aims to understand injury occurrences and associated risk factors in Swedish elite adolescent athletes and was approved by the Regional Ethical Committee in Sweden (2011/749-31/3). A prospective cohort design was used to explore the injury burden.

Data Collection

The national federations for handball, orienteering (which requires athletes to run through rough terrain while making route choices to complete the course as quickly as possible), skiing, and track and field were contacted and gave oral permission for us to conduct the study. In all, we included athletes in 7 sports (athletics [track and field], cross-country skiing, downhill skiing, freestyle skiing, handball, orienteering, and ski orienteering) from 15 high schools in the study. The cohort consisted of 438 elite adolescent athletes (median age = 17 years; range = 15–19 years). These athletes were considered *elite* because they participated on national teams or in national junior cups, which included athletes with the highest rankings for their age group. Each school was visited by one of the authors, and the coaches and athletes were orally informed of the purpose of the study and the voluntary nature of participation.

All 438 athletes were invited by e-mail to participate, and 393 athletes (89.7%) responded to the invitation. Written consent was obtained from all athletes. A questionnaire was e-mailed to all athletes weekly, starting between September 2013 and March 2014 and ending 52 weeks later. If no response was registered in a week, a reminder e-mail was sent 4 days later. If there was still no response, the athlete was contacted again the next week as usual and asked to respond regarding the missed week. All athletes were also asked to fill out an online background questionnaire during the first week of the study. The Questback online survey software (version 9.9; Questback AS, Oslo, Norway) was used for data collection.

A total of 109 athletes were excluded due to insufficient data (n = 10 due to missing background data, n = 99 due to less than 10% response rate, ie, ≤5 surveys completed over the study period), consistent with recommendations by Clarsen et al[19] (Figure 1). Of the excluded athletes, the majority responded only to the background request or the

Table 1. Operational Injury and Illness Definitions

Injury or Illness	Operational Definition
Injury	Any self-reported physical complaint resulting in difficulties participating in normal training or competition, reduced training volume, pain, or reduced performance in sport related to an injury
Substantial injury	Any self-reported physical complaint resulting in a moderate or severe reduction in training volume, a moderate or severe reduction in performance, or the complete inability to participate in sports related to an injury
Recurrent injury	An injury in the same body site as the previous injury within the last year
Illness	A self-reported health problem other than the musculoskeletal system, such as cold or influenza, resulting in reduced training volume or difficulty participating in normal training or competition

first or second weekly questionnaire and then stopped participating, even though we sent reminders. The excluded athletes did not differ from the cohort under investigation in terms of sex or sport participation ($P > .05$). Therefore, the final cohort consisted of 284 elite adolescent athletes (girls = 147, boys = 137), representing 64.8% of the initial athletes.

Questionnaire

The weekly questionnaire contained the validated and translated version of the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire[20] as well as questions used by Jacobsson et al[7] in an athletic surveillance study. It consisted of 3 parts: (1) questions about training variables and prevalence of injuries and illnesses based on items used by Clarsen et al,[18] (2) questions about any new injury occurrence as described by Jacobsson et al,[7] and (3) questions about the return to sport after an injury as described by Jacobsson et al.[7] The OSTRC Overuse Injury Questionnaire measures injury consequences for sport participation, training, pain, and performance based on 4 questions. It assesses how injuries affect participation (4 possible responses ranging from *full participation* to *cannot participate*), a possible reduction in training volume (5 responses ranging from *no reduction* to *cannot participate*), a possible reduction in sport performance (5 responses ranging from *no effect* to *cannot participate*), and pain (4 responses ranging from *no pain* to *severe pain*). Completion of the questionnaire took approximately 5 minutes and an additional 2 to 3 minutes if part 2 or 3 was current.

Defining Sport Types

Based on sport characteristics and physiological demands (anaerobic, aerobic, power, athletes with a mix of these qualities) and the approach of Clarsen et al,[21] we grouped the participating athletes into 5 types of sports: sprint athletes (downhill skiers, freestyle skiers, sprint athletics athletes), power athletes (jumpers, throwers, and athletes competing in combined athletic events), endurance running athletes (orienteers and middle- and long-distance runners), endurance skiing athletes (cross-country skiers, ski orienteers), and handball players (Figure 1). Sprint athletes (n = 37) have high anaerobic demands and compete in events lasting less than 2 minutes, power athletes (n = 47) have high power demands, endurance running athletes (n = 76) and endurance skiing athletes (n = 82) have high aerobic demands, and handball players (n = 42) participate in team sports.

Operational Definitions

All injury data were self-reported, and the athletes were asked to report as an *injury* any physical complaint that affected participation in normal training or competition or led to reduced training volume, pain, or reduced performance in sport.[18] A *substantial injury* was defined as an injury leading to a moderate or severe reduction in training volume, a moderate or severe reduction in performance, or the complete inability to participate in sport.[20] If an athlete reported a new injury, this injury was categorized as a *recurrent* or *nonrecurrent* injury depending on whether the injury affected the same body site as the previous injury within the previous year. Definitions of injury and illness are presented in Table 1.

Statistical Analysis

Descriptive statistics for continuous variables were presented as means ± standard deviations (SDs) for non–normally distributed data or for ordinal data as medians with 25th–75th percentiles (p25–p75). Descriptive statistics for categorical data were presented as frequencies with proportions (%). The response rate for the population was determined by dividing the number of responding athletes each week by the total number of athletes who responded. Prevalence measures were calculated for all injury variables and illnesses by dividing the number of athletes reporting any form of injury or illness by the number of questionnaire respondents. Over the study period, the 1-year injury prevalence and 1-year substantial injury prevalence were calculated by dividing the number of athletes reporting injuries and substantial injuries, respectively, by the total number of athletes. The incidence rate of injuries was determined by summing all new injuries per 1000 hours of exposure to sports. The 1-year injury incidence was calculated as the proportion of athletes reporting new injuries over the 52 weeks. For each body site, the injury incidence was determined by dividing the number of new unique injuries to an anatomic area by the total number of new unique injuries. The proportional injury incidence was calculated as the proportion of athletes who reported new injuries divided by the total number of respondents for that week. The proportional injury incidence, response rate, and all prevalence measures except the 1-year prevalence measures were presented as weekly averages. Therefore, both the 1-year prevalence measures and the average weekly injury prevalence measures are provided in this article.

We determined a cumulative severity score by allocating a numeric value from 0 to 25 to the response to each of the 4 questions in the OSTRC Overuse Injury Questionnaire,

Table 2. **Demographic Values for All Athletes and for Sex and Sport Type**

Characteristic	All Athletes (N = 284)	Sex: Female (n = 147)	Sex: Male (n = 137)	Sport Type: Sprint (n = 37)	Sport Type: Power (n = 47)	Sport Type: Endurance Running (n = 76)	Sport Type: Endurance Skiing (n = 82)	Sport Type: Handball (n = 42)
Age, y (median [25th–75th percentiles])	17 (16–18)	17 (16–18)	17 (16–18)	17 (17–18)	17 (16–18)	17 (17–18)	17 (16–18)	17 (16–18)
Sex, n (female/male)	147/137	147/NA	NA/137	16/21	29/18	38/38	42/40	22/20
Body mass index, mean ± SD	21.6 ± 2.2	21.2 ± 2.1	22.0 ± 2.2	21.2 ± 1.7	22.1 ± 2.4	20.1 ± 1.8	21.9 ± 1.7	23.4 ± 2.0
Training volume, h/wk[a] (mean ± SD)	9.0 ± 4.6	8.6 ± 4.5	9.4 ± 4.7	9.0 ± 6.3	8.8 ± 3.4	7.3 ± 3.3	9.9 ± 5.2	10.1 ± 4.0
Competition, h/wk (mean ± SD)	1.1 ± 1.1	1.1 ± 1.0	1.2 ± 1.2	0.6 ± 1.0	1.1 ± 0.8	1.2 ± 1.0	0.8 ± 0.8	1.9 ± 1.4
No. of training sessions/wk[b]	7–8	5–6	7–8	7–8	5–6	5–6	7–8	7–8
Injured at start of study, % (n)	31.0 (88)	36.1 (53)	25.5 (35)	27.0 (10)	42.6 (20)	35.5 (27)	13.4 (11)	47.6 (20)
History of injury,[c] % (n)	36.3 (103)	40.8 (60)	31.4 (43)	43.2 (16)	44.7 (21)	38.2 (29)	20.7 (17)	47.6 (20)

Abbreviation: NA, not applicable.

[a] Sum of training and competition time, including warm-ups and cool-downs.

[b] Median of categorical data.

[c] Sustained injury during the previous year that affected or completely hindered training for a continuous period of at least 3 weeks.

based on the approach in Clarsen et al.[18] The scores for the 4 answers were then summed. Consequently, a score of 0 represented *no injury* and 100, the *highest severity grade*. An average severity score was then calculated for each anatomic area for all athletes and for sex and sport type. See Clarsen et al[18] for additional information.

Mann-Whitney *U* tests and Kruskal-Wallis nonparametric analysis of variance were applied to analyze differences in injury prevalences and incidences between sex and sport type, respectively. Differences in injury onset and recurrent injuries were assessed for sex and sport types by applying the χ^2 test. Descriptive statistics were used to illustrate differences regarding injury locations and the severity grades of injuries. Time to first injury was evaluated using the Kaplan-Meier method and the log-rank test to identify differences among subgroups with regard to sex and sport types. The athletes with existing injuries at the start of the study (n = 88) were left censored (ie, data were not included) until 1 week after 4 weeks of reporting a severity score of zero (ie, uninjured) in all body sites. This resulted in an additional 53 athletes being included in the analysis. We chose a cutoff value of 4 weeks based on clinical reasoning. A cutoff value that is too low may be associated with a high reinjury risk because the athlete might not be fully recovered at inclusion. Throughout calculations, the significance level was set to $P < .05$. In addition, 95% confidence intervals (CIs) were computed for rates and prevalence values. All analyses were performed using SPSS for Windows (version 22.0; IBM Corp, Armonk, NY) and Microsoft Excel (version 2013; Microsoft Corp, Redmond, WA).

RESULTS

Response Rate and Demographics

During the 52-week study, the average weekly response rate was 60.0% (95% CI = 57.4%, 62.6%). At the start of the study, 31.0% (n = 88) of the athletes were injured; the highest proportion (47.6%, n = 20) were handball players (Table 2).

Incidence and Prevalence of Injury and Illness

Injury incidence was equally distributed over the 52 weeks, and 326 new unique injuries were identified (Figure 2). The injury incidence rate was 4.1/1000 hours of total

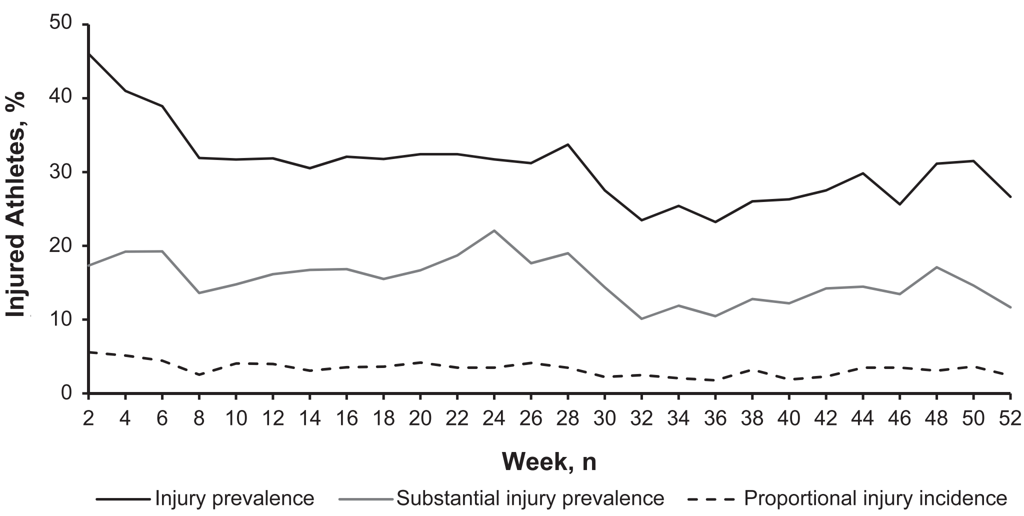

Figure 2. Injury prevalence (proportion of injured athletes), substantial injury prevalence (proportion of athletes with substantial injury), and proportional injury incidence (proportion of new injuries) biweekly over 52 weeks.

Table 3. Injury Incidence Rate, Average Weekly Injury Incidence, and Prevalence of Injury and Illness for All Athletes and by Sex and Sport Type

		Sex		Sport Type				
	All Athletes (N = 284)	Female (n = 147)	Male (n = 137)	Sprint (n = 37)	Power (n = 47)	Endurance Running (n = 76)	Endurance Skiing (n = 82)	Handball (n = 42)
Injury incidence rate/1000 h of exposure to sport (95% confidence interval)	4.1 (3.7, 4.5)	4.1 (3.5, 4.7)	4.0 (3.4, 4.6)	3.7 (2.7, 4.7)	4.6 (3.4, 5.8)	5.3 (4.3, 6.3)	2.7 (2.1, 3.3)	4.7 (3.5, 5.9)
Weekly average, % (95% confidence interval)								
Proportional injury incidence	3.3 (3.1, 3.5)	3.2 (2.9, 3.5)	3.5 (3.2, 3.8)	3.0 (2.5, 3.5)	3.6 (3.1, 4.1)	2.0 (1.7, 2.3)	2.4 (2.0, 2.8)	4.1 (3.5, 4.7)
Injury prevalence	30.8 (30.0, 31.6)	35.6 (34.7, 36.5)	25.4 (24.6, 26.2)	32.6 (31.1, 34.1)	34.7 (33.1, 36.3)	19.4 (18.3, 20.5)	21.4 (20.4, 22.4)	47.2 (45.7, 48.7)
Substantial injury prevalence	15.4 (15.0, 15.8)	17.5 (17.0, 18.0)	13.0 (12.5, 13.5)	20.1 (18.9, 21.3)	17.6 (16.7, 18.5)	9.9 (9.3, 10.5)	8.8 (8.2, 9.4)	28.6 (27.6, 29.6)
Prevalence of difficulties participating in normal training or competition due to injury	19.9 (19.3, 20.5)	22.9 (22.3, 23.5)	16.4 (15.8, 17.0)	26.1 (24.9, 27.3)	23.9 (22.6, 25.2)	13.4 (12.5, 14.3)	10.8 (10.1, 11.5)	33.8 (32.5, 35.1)
Prevalence of reduced training volume due to injury	15.9 (15.4, 16.4)	18.1 (17.5, 18.7)	13.4 (12.9, 13.9)	21.8 (20.6, 23.0)	21.3 (20.4, 22.2)	11.8 (11.1, 12.5)	6.6 (6.0, 7.2)	27.7 (26.7, 28.7)
Prevalence of affected performance due to injury	19.0 (18.4, 19.6)	22.5 (21.8, 23.2)	14.9 (14.3, 15.5)	23.0 (21.8, 24.2)	23.7 (22.5, 24.9)	13.3 (12.4, 14.2)	11.4 (10.7, 12.1)	34.3 (33.0, 35.6)
Prevalence of pain due to injury	25.1 (24.4, 25.8)	29.6 (28.6, 30.6)	19.9 (19.2, 20.6)	25.0 (23.4, 26.4)	28.5 (27.1, 29.9)	16.0 (15.0, 17.0)	18.2 (17.3, 19.4)	36.3 (34.8, 37.8)
Prevalence of illness	12.1 (11.6, 12.6)	12.4 (11.7, 13.1)	11.9 (11.3, 12.5)	7.7 (6.9, 8.5)	8.3 (7.4, 9.2)	14.6 (13.7, 15.5)	15.4 (14.4, 16.4)	5.9 (5.3, 6.5)

training volume (Table 3) and the 1-year injury incidence was 57.5% (n = 163). Over the study period, the 1-year injury prevalence and 1-year substantial injury prevalence were 91.6% (n = 260) and 72.2% (n = 205), respectively. On average, the weekly injury prevalence was 30.8% and the weekly substantial injury prevalence was 15.4% (Table 3).

Injury prevalence and substantial injury prevalence fluctuated over the study period; injury prevalence decreased during the first 8 weeks (from 46.0% to 31.9%). Compared with male athletes, female athletes reported a higher average weekly injury prevalence (35.6% versus 25.4%; $P < .001$) and substantial injury prevalence (17.5% versus 13.0%; $P < .001$). Handball players had the greatest average weekly injury prevalence (47.2%; 95% CI = 45.7%, 48.7%; $P < .001$) and substantial injury prevalence (28.6%; 95% CI = 27.6%, 29.6%; $P < .001$).

Type of Injury

More injuries were sustained during training (76.7%, n = 250) compared with competition (23.3%, n = 76; $P < .001$). The injury incidence rate was higher during competition than during training (23.8/1000 hours of competition, 95% CI = 18.5, 29.1 versus 2.8 injuries/1000 hours of training volume, 95% CI = 2.4, 3.2; $P < .05$). Of all injuries sustained during training, 43.2% (n = 108) occurred during endurance training, 19.7% (n = 49) during technique training, 11.7% (n = 29) during strength training, and 10.2% (n = 25) during warm-ups or at the end of a training session. Significantly more injuries had gradual onsets (59.5%, n = 194) than sudden onsets (40.5%, n = 132; $P < .001$). No differences in injury onset were demonstrated for sex ($P = .263$) or sport type ($P = .683$). Of all injuries, 36.9% (n = 120) were recurrent. No differences for recurrent injuries were identified for sex ($P = .404$) or sport type ($P = .353$).

Number of Injuries

Among all athletes over the 52 weeks, 121 (42.6%) reported no new injury, 80 (28.2%) reported 1 new injury, and 83 (29.8%) reported 2 or more new injuries. No sex difference was noted for athletes who reported no new injuries or 1 or more new injuries ($P = .418$). Similarly, no difference occurred between athletes who reported fewer than 2 new injuries and athletes who reported 2 or more new injuries ($P = .802$). A lower proportion of handball players (23.8%, n = 10) reported no new injuries compared with endurance skiing athletes (57.3%, n = 47) and sprint athletes (54.1%, n = 20; $P < .001$). No difference for sport type was observed for athletes reporting 2 or more new injuries ($P = .381$).

Injury Locations and Severity Grades

The majority of injuries affected the *lower extremity* (69.0%, n = 225), defined as all body parts from the hip to the toes. The highest injury incidence was in the foot (24.5%, n = 80), followed by the knee (15.6%, n = 51) and lower back (11.7%, n = 38; Table 4).

Of the total number of injuries, athletes recovered from 48.4% (n = 158) during the study period, meaning that they could participate fully in sport, had no reduction in training

Table 4. New Injuries per Injury Location for All Athletes and by Sex and Sport Type

	All Athletes	Sex		Sport Type				
		Female	Male	Sprint	Power	Endurance Running	Endurance Skiing	Handball
No. of injuries	326	168	158	31	60	103	68	64
Location, n (%)[a]								
Head/face	6 (1.8)	6 (3.6)	0	2 (6.5)	0	2 (1.9)	0	2 (3.1)
Cervical spine	4 (1.2)	3 (1.8)	1 (0.6)	1 (3.2)	1 (1.7)	1 (1.0)	0	1 (1.6)
Shoulder	22 (6.7)	7 (4.2)	15 (9.5)	0	5 (8.3)	0	9 (13.2)	8 (12.5)
Upper arm	1 (0.3)	0	1 (0.6)	0	0	0	1 (1.5)	0
Elbow	8 (2.5)	4 (2.4)	4 (2.5)	0	2 (3.3)	0	2 (2.9)	4 (6.3)
Hand	10 (3.1)	9 (5.4)	1 (0.6)	0	2 (3.3)	0	6 (8.8)	2 (3.1)
Finger	5 (1.5)	3 (1.8)	2 (1.3)	0	1 (1.7)	1 (1.0)	1 (1.5)	1 (1.6)
Chest	1 (0.3)	0	1 (0.6)	0	0	0	1 (1.5)	0
Thoracic spine	9 (2.8)	6 (3.6)	3 (1.9)	0	3 (5.0)	2 (1.9)	4 (5.9)	0
Lower back	38 (11.7)	22 (13.1)	16 (10.1)	4 (12.9)	15 (25.0)	3 (2.9)	11 (16.2)	5 (7.8)
Hip	20 (6.1)	6 (3.6)	14 (8.9)	2 (6.5)	3 (5.0)	6 (5.8)	5 (7.4)	4 (6.3)
Thigh	32 (9.8)	14 (8.3)	18 (11.4)	10 (32.3)	3 (5.0)	8 (7.8)	2 (2.9)	9 (14.1)
Knee	51 (15.6)	24 (14.3)	27 (17.1)	3 (9.7)	6 (10.0)	20 (19.4)	11 (16.2)	11 (17.2)
Lower leg	34 (10.4)	15 (8.9)	19 (12.0)	4 (12.9)	1 (1.7)	19 (18.4)	2 (2.9)	8 (12.5)
Foot	80 (24.5)	46 (27.4)	34 (21.5)	4 (12.9)	18 (30.0)	38 (36.9)	12 (17.6)	8 (12.5)
Toes	9 (2.8)	6 (3.6)	3 (1.9)	1 (3.2)	1 (1.7)	6 (5.8)	1 (1.5)	0
Internal organ	1 (0.3)	1 (0.6)	0	0	0	0	0	1 (1.6)

[a] Percentages were rounded.

volume or performance, and had no pain related to the previous injury. The athletes with the remaining injuries were either not fully recovered during the study or lost to follow-up (n = 168). Of the reportedly recovered injuries, 22.2% (n = 35) resulted in absence from normal training for at least 2 months, and of those, 10.8% (n = 17) resulted in absence for more than 6 months. The knee injuries had the greatest severity grade for all athletes (3.76 ± 27.1), female athletes (4.26 ± 28.7), and handball players (12.86 ± 25.8; Figure 3).

Time to First Injury

The median time to first injury was 20 weeks (95% CI = 12.5, 27.5). Log-rank tests showed a statistically significant ($P < .001$) variation in the risk for injury among

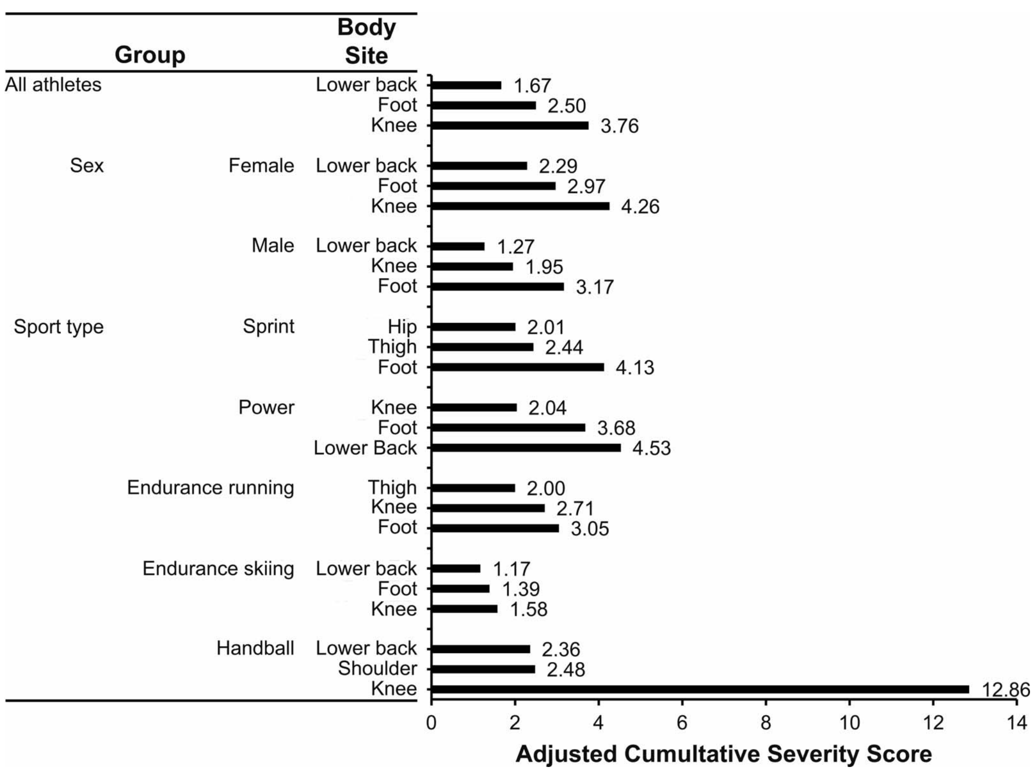

Figure 3. The severity grade of injuries by body sites for all athletes and by sex and sport type shown as the cumulative severity score, adjusted for number of respondents, for each group. The severity score (scale range, 0–100) measured the consequences of injuries on sport participation, training, pain, and performance, where 0 represented *no injury* and 100, the *highest severity grade*.

Table 5. Results of Log-Rank Tests for Time to First Injury

Characteristic	Log-Rank Test P Value	Median Time to First Injury, wk (95% Confidence Interval)
Sex	.34	
Male		20 (11.1, 28.9)
Female		20 (4.5, 35.5)
Sport type	<.001	
Sprint		19 (15.9, 22.1)
Power		20 (5.9, 34.1)
Endurance running		20 (10.6, 29.4)
Endurance skiing		41 (26.0, 56.0)
Handball		9 (6.4, 11.6)

sport types, with the shortest time to injury in handball players (9 weeks, 95% CI = 6.4, 11.6 weeks; Table 5, Figure 4). No differences were demonstrated between sexes ($P = .34$).

DISCUSSION

This is one of the first prospective cohort studies to follow a large number of elite adolescent athletes in multiple sports weekly during 1 calendar year. The main finding was the high average weekly injury prevalence; more than 3 of 10 elite adolescent athletes, on average, self-reporting being injured each week. Female athletes had a greater average weekly injury prevalence and substantial injury prevalence than male athletes. Handball players had the largest average weekly injury prevalence and substantial injury prevalence, proportional injury incidence, and severity grade of injuries.

The fact that more than every fifth injury (22.2%) in the recovered athletes resulted in absence from normal training for 2 months or more is worrying and probably leads to serious consequences in terms of sport performance and adverse health effects.[22,23] These are important reasons to prevent such injuries, not only from a sport performance perspective but also from a health perspective. In addition, by the end of the study, a large number of athletes had not recovered, which may suggest that the long-term consequences of injuries incurred during normal training may be underestimated. Comparing our results with those from other high school or collegiate athletes is difficult because authors have not reported the size of the main cohort, have studied different populations, have used different definitions of elite athletes, have used different data-collection methods, have reported different injury outcomes, and so on.[14,24,25] However, the overall data from prospective reports in this area showed that young athletes were at risk of severe injuries[7–9,12–14,25] and that in certain sports, they had even higher injury rates than adult athletes.[4]

Our results clearly showed that compared with athletes in other sports, handball players reported the highest injury burden for several injury outcomes. Handball players had a greater prevalence of injuries before entering the study and over the study period than athletes in other sports. These players were also participating in the only team and contact sport in our sample. In addition, the handball players had the largest training volume and highest number of hours of competition compared with the other sport types, which may explain the greater injury risk in this group of athletes.

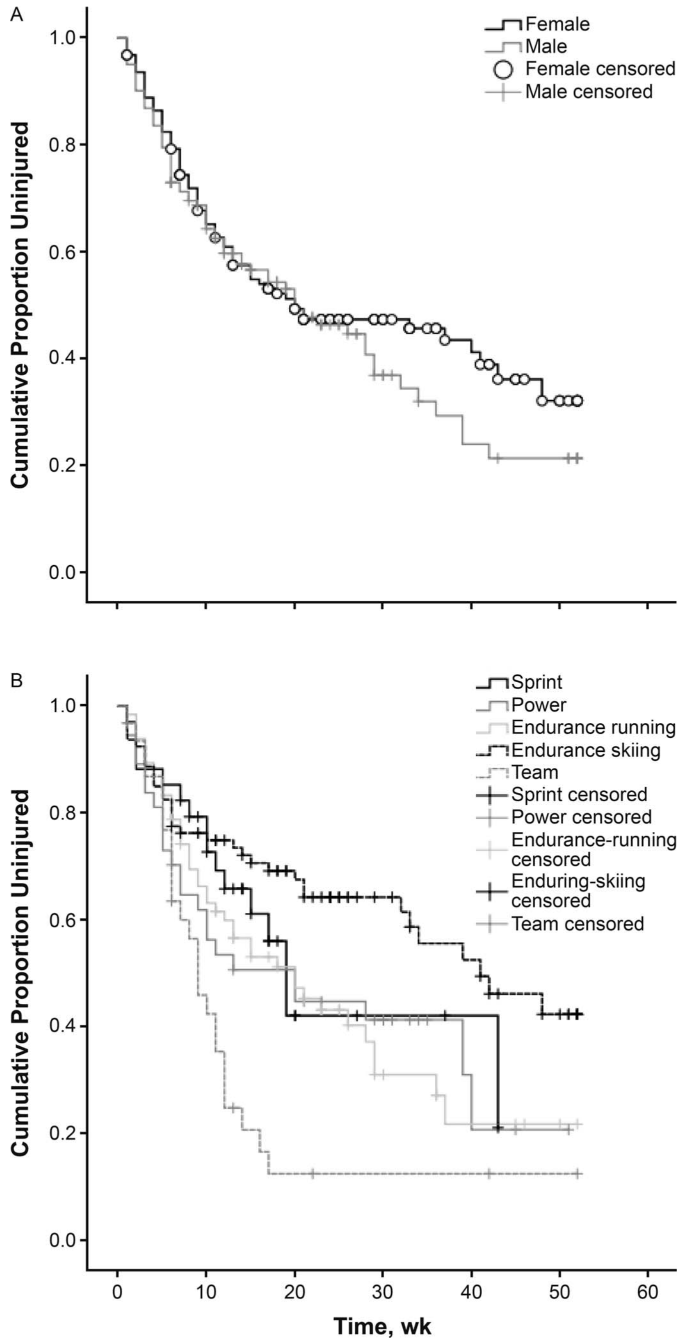

Figure 4. Kaplan-Meier curve for time to first injury during the study season displayed by A, sex, and, B, sport type.

Other surveillance reports[26,27] of adult handball players have shown a high injury incidence in competitions (14.3–23.5/1000 hours of competition). Consistent with these previous investigations, our findings highlight the severe injury burden in elite adolescent handball athletes. This result emphasizes the importance of designing and implementing targeted injury-prevention programs.

That female athletes reported a higher average weekly injury prevalence, higher substantial injury prevalence, and higher severity grade of injuries but no difference in proportional injury incidence compared with male athletes could be related to the fact that more female athletes were injured at the start of the study (36.1% versus 25.5%) and therefore more likely to continue to report prevalence of injury. A higher proportion of female athletes also had a history of an injury (within 1 year of entering the study). Addressing injuries in an early stage is likely to reduce injury severity and injury consequences.[28,29] However, the age at which the risk of injury increases in young athletes has not been fully determined.

More than 2 of 3 injuries affected the lower extremity, which is consistent with previous reports[7,9,26] of adolescent athletes. However, we followed athletes in a limited number of sports. In particular, athletes who were exposed to excessive forces on the lower extremity during sport activity were included, which may have influenced the large number of injuries to this region. The injuries causing the highest severity grade were also most evident in the lower extremity. Knee and foot injuries caused the greatest severity grade for all athletes, for male and female athletes, and for all sport types except power athletes. In power athletes, injuries to the lower back had the greatest severity grade, followed closely by foot and knee injuries. In agreement with numerous reports,[7,8,10,11,24,25] these findings clearly show that preventive targeted interventions focusing on knee and foot injuries would address most injuries and the predominant injuries with serious consequences in this sample of athletes. Yet before this can be attempted, future researchers should explore injury mechanisms in these anatomic areas.

We believe presenting data for both injury prevalence and incidence provides an important and more holistic view of injury data in a population. In our sample, 42.6% reported no new injury, whereas 8.4% reported no prevalence of injury throughout the 52 weeks. This difference clearly illustrates that results may be interpreted completely differently depending on the injury outcome. Athletes who began the study injured and reported symptoms related to previous injuries could explain the differences in the 2 measures. If we are aiming to identify unique injuries and establish a causal relationship between exposure and new injury, then injury incidence should be the first choice. However, the *prevalence* of injury, which represents the number of injured athletes in a given time interval, may also be useful from an injury-prevention perspective because injury incidence does not account for injuries that are present at the start of a study or the participation time affected by the injury. The 2 measures are relevant in exploring the injury burden from different perspectives. It is therefore recommended that health practitioners monitoring a group of athletes should base preventive actions not only on injury incidence but also on average injury prevalence.

The strengths of this study are the prospective nature and the large number of elite adolescent athletes followed weekly over 1 calendar year. We used a validated questionnaire previously used in sports surveillance[7,18] that is sensitive to capturing all kinds of physical complaints and used modern definitions of injury.[18] We are aware that some athletes, such as handball players and athletes participating in winter sports, entered this study while in their competition season and therefore may have had a different injury risk than athletes in the training and preparation phases. However, we followed all athletes during 1 year, which may limit this seasonal bias. The decrease in injury prevalence between weeks 26 and 32 (summer holiday) could perhaps be explained by less competition and training volume or a drop in the response rate during this period.

Our findings should also be viewed in light of potential limitations. Data collection was limited to 7 sports, with 3 sports contributing few athletes. This was because certain schools had only a small number of athletes available, whereas other schools contributed larger numbers of athletes. Dividing athletes into sport types was necessary for group analysis and for identifying injury risk groups based on sport characteristics. Athletics involves sports with highly variable characteristics and demands, so this was also a reason to allocate athletes by sport type.[7]

We aimed to include and follow all athletes at each school. However, not all athletes were interested in participating, which was probably reflected by the fact that several athletes chose not to continue the injury surveillance after the first or second week. In line with Clarsen et al,[19] we excluded athletes whose response rate was less than 10% given that we wanted to describe the injury burden over a complete season. The demographics of the excluded athletes showed no differences regarding sex or sport type compared with the main cohort. The response rate was lower than in studies by Jacobsson et al[7] and von Rosen et al[13] but comparable with Clarsen at al.[30] The response rate was not different by sex (male = 58%, female = 63%) but was lower in sprint athletes (49%) than in athletes in other sport types (58% to 62%). Based on Clarsen et al,[18] we believe the response rate underestimated the true average weekly injury prevalence in this sample. Still, the prevalence of substantial injuries was rather constant over the study period, which may indicate that the prevalence of severe injuries was accurate. The same is true for the proportional injury incidence, which also showed a relatively constant value. Despite these limitations, we present a comprehensive picture of the injury burden in several sport types, using modern injury definitions and data-collection methods, among a large number of elite adolescent athletes followed weekly for 52 weeks.

CONCLUSION

This study contributes to the field of injury epidemiology as few long-term investigations have followed elite adolescent athletes over 1 calendar year, especially athletes in multiple sports. Our results showed that a considerable number of elite adolescent athletes were injured weekly, resulting in serious consequences regarding sport participation, training, or performance level. The fact that more than 20% of recovered injuries resulted in absence from normal training for 2 months or more is worrying. Female athletes did not report more new injuries but had a higher average weekly injury prevalence and substantial injury prevalence than male athletes. Of the included sports, handball had the highest injury burden both before and during the study. Our next step will be to explore risk factors and injury mechanisms in these athletes. Directing targeted interventions to prevent knee and foot injuries will reach the elite adolescent athletes with the most injuries and the injuries with the most serious consequences.

REFERENCES

1. DiFiori JP, Benjamin HJ, Brenner JS, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Br J Sports Med*. 2014;48(4): 287–288.
2. Williams C. Environmental factors affecting elite young athletes. *Med Sport Sci*. 2011;56:150–170.
3. Maffulli N, Baxter-Jones ADG, Grieve A. Long term sport involvement and sport injury rate in elite young athletes. *Arch Dis Child*. 2005;90(5):525–527.
4. Steffen K, Engebretsen L. More data needed on injury risk among young elite athletes. *Br J Sports Med*. 2010;44(7):485–489.
5. Rosa BB, Asperti AM, Helito CP, Demange MK, Fernandes TL, Hernandez AJ. Epidemiology of sports injuries on collegiate athletes at a single center. *Acta Ortop Bras*. 2014;22(6):321–324.
6. Westin M, Alricsson M, Werner S. Injury profile of competitive alpine skiers: a five year cohort study. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(6):1175–1181.
7. Jacobsson J, Timpka T, Kowalski J, et al. Injury patterns in Swedish elite athletics: annual incidence, injury types and risk factors. *Br J Sports Med*. 2013;47(15):941–952.
8. Le Gall F, Carling C, Reilly T, Vandewalle H, Church J, Rochcongar P. Incidence of injuries in elite French youth soccer players: a 10-season study. *Am J Sports Med*. 2006;34(6):928–938.
9. Le Gall F, Carling C, Reilly T. Injuries in young elite female soccer players: an 8-season prospective study. *Am J Sports Med*. 2008;36(2): 276–284.
10. Price RJ, Hawkins RD, Hulse MA, Hodson A. The Football Association medical research programme: an audit of injuries in academy youth football. *Br J Sports Med*. 2004;38(4):466–471.
11. Kirialanis P, Malliou P, Beneka A, Giannakopoulos K. Occurrence of acute lower limb injuries in artistic gymnasts in relation to event and exercise phase. *Br J Sports Med*. 2003;37(2):137–139.
12. Kolt GS, Kirkby RJ. Epidemiology of injury in elite and subelite female gymnasts: a comparison of retrospective and prospective findings. *Br J Sports Med*. 1999;33(5):312–318.
13. von Rosen P, Frohm A, Heijne A. Injuries and associated risk factors among adolescent elite orienteerers: a 26-week prospective registration study. *J Athl Train*. 2016;51(4):321–328.
14. Yang J, Tibbetts AS, Covassin T, Cheng G, Nayar S, Heiden E. Epidemiology of overuse and acute injuries among competitive collegiate athletes. *J Athl Train*. 2012;47(2):198–204.
15. Rauh MJ, Macera CA, Ji M, Wiksten DL. Subsequent injury patterns in girls' high school sports. *J Athl Train*. 2007;42(4):486–494.
16. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med*. 1992;14(2):82–99.
17. Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *Br J Sports Med*. 2009;43(13): 966–972.
18. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *Br J Sports Med*. 2013;47(8):495–502.
19. Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study. *Br J Sports Med*. 2014; 48(17):1327–1333.
20. Ekman E, Frohm A, Ek P, Hagberg J, Wirén C, Heijne A. Swedish translation and validation of a web-based questionnaire for registration of overuse problems. *Scand J Med Sci Sports*. 2015; 25(1):104–109.
21. Clarsen B, Rønsen O, Myklebust G, Flørenes TW, Bahr R. The Oslo Sports Trauma Research Center questionnaire on health problems: new approach to prospective monitoring of illness and injury in elite athletes. *Br J Sports Med*. 2014;48(9):754–760.
22. Caine DJ, Golightly YM. Osteoarthritis as an outcome of paediatric sport: an epidemiological perspective. *Br J Sports Med*. 2011;45(4): 298–303.
23. Finnoff JT. Preventive exercise in sports. *PM R*. 2012;4(11):862–866.
24. Fernandez WG, Yard EE, Comstock RD. Epidemiology of lower extremity injuries among U.S. high school athletes. *Acad Emerg Med*. 2007;14(7):641–645.
25. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42(2):311–319.
26. Møller M, Attermann J, Myklebust G, Wedderkopp N. Injury risk in Danish youth and senior elite handball using a new SMS text messages approach. *Br J Sports Med*. 2012;46(7):531–537.
27. Seil R, Rupp S, Tempelhof S, Kohn D. Sports injuries in team handball. A one-year prospective study of sixteen men's senior teams of a superior nonprofessional level. *Am J Sports Med*. 1998;26(5): 681–687.
28. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Epidemiology of injuries in English professional rugby union: part 1 match injuries. *Br J Sports Med*. 2005;39(10):757–766.
29. Kucera KL, Marshall SW, Kirkendall DT, Marchak PM, Garrett WE Jr. Injury history as a risk factor for incident injury in youth soccer. *Br J Sports Med*. 2005;39(7):462–466.
30. Clarsen B, Bahr R, Heymans MW, et al. The prevalence and impact of overuse injuries in five Norwegian sports: application of a new surveillance method. *Scand J Med Sci Sports*. 2015;25(3):323–330.

Address correspondence to Philip von Rosen, PhD, Division of Physiotherapy, Department of Neurobiology, Care Sciences, and Society (NVS), Karolinska Institutet, Alfred Nobels Allé 23, Huddinge, SE-141 83, Sweden. Address e-mail to philip42195@yahoo.com.