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ORIGINAL RESEARCH

INJURY PATTERNS IN ADOLESCENT ELITE ENDURANCE ATHLETES PARTICIPATING IN RUNNING, ORIENTEERING, AND CROSS-COUNTRY SKIING

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ABSTRACT

Background: Prospective injury registration studies, monitoring adolescent elite athletes, are sparse in running, orienteering and cross-country skiing, yet essential for developing prevention programs.

Purpose: The aims of this study were to describe the injury prevalence/incidence, severity grade, injury location, risk factors and the prevalence of illness in running (RU), orienteering (OR) and cross-country skiing athletes (CR).

Study Design: Prospective cohort study.

Methods: One hundred fifty adolescent elite athletes (age range 16-19), participating in orienteering (25 females, 20 males), running (13 females, 18 males), cross-country skiing (38 females, 36 males), from 12 National Sports High Schools in Sweden, were prospectively followed over one calendar year using a reliable and validated web-based questionnaire.

Results: The main finding was that the average weekly injury prevalence was higher during the pre-season compared to the competitive season in all three sports. RU reported the significantly ($p < 0.05$) highest average weekly injury prevalence (32.4%) and substantial injury prevalence (17.0%), compared to OR (26.0, 8.2%) and CR (21.1%, 8.9%). Most injuries occurred in the lower extremity (RU 94.4%; OR 91.9%; CR 49.9%) and foot and knee injuries had the highest severity grade in all three sports. History of serious injury ($p = 0.002$, OR 4.0, 95% CI 1.6-9.7) and current injury at study start ($p = 0.004$, OR 4.0, 95% CI 1.5-11.2) were identified as the strongest risk factors for substantial injury. Younger athletes aged 16 ($p = 0.019$, OR 2.6, 95% CI 1.2-5.8) and 17 ($p = 0.045$, OR 2.4, 95% CI 1.0-5.9), had a significantly higher injury risk for substantial injury compared to older athletes aged 18-19.

Conclusion: Practitioners should be aware of the increased injury risk during pre-season and in younger athletes. By focus on prevention of foot and knee injuries, the injuries with the highest severity grade will be targeted in adolescent elite athletes participating in running, orienteering and cross-country skiing.

Level of evidence: 2b

Key words: athletics, elite sports, injury burden, youth

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INTRODUCTION

The training sessions in endurance sports are often of long duration involving repetitive movements, likely contributing to the high risk of overuse injuries.[1-3] By identifying the injury incidence and prevalence as well as associated risk factors and injury mechanisms in sports, effective injury prevention programs can be designed, aiming to reduce the risk for injuries and unhealthy behaviors. Despite the value of injury surveillance studies, few reports have included youth athletes and especially adolescent elite athletes.[4] The knowledge of the injury incidence and prevalence in this age group (age 13-19) is limited and in most sports unknown. This study focuses on exploring injury patterns in adolescent elite athletes participating in running, orienteering, and cross-country skiing.

Although running, orienteering, and cross-country skiing have a long history, few prospective studies on injury occurrence are available in the scientific literature. Instead, most reports are point prevalence studies based on data collected during competitions and championships.[5-9] Such data is not representative of an entire season, covering both preseason and competition periods.

Long-term prospective reports in running are sparse, especially following young running athletes (RU) over an entire season. Rauh et al.[10] monitored high school cross-country runners over a 15-year period and found an overall injury rate of 13.1/1000 training sessions/competitions. Most running injuries occur in the lower extremity[11] and the incidence of severe injuries, such as stress fractures, have been found to be high.[12] In a one-year prospective study by Jacobsson et al,[13] following track & field athletes, including middle- and long-distance runners, more than 50% of all injuries were severe in nature resulting in at least three weeks absence from normal training. Different risk factors for a running injury have been implicated, such as a high training volume, history of previous injury as well as a higher overall injury risk in female runners compared to male runners.[2,11,14,15] Still, these studies are mainly based on adult runners.

In cross-country skiing the athletes complete races over courses of varying lengths using mainly two type of skiing styles, classic or skate. Cross-country skiing athletes (CR) are traditionally considered as having low-risk for severe injuries.[16, 17] However, low back pain has been proposed as a severe injury in this group of athletes,[17-19] whereas other reports have shown the injury severity to be higher in the lower extremity, including knee and anterior thigh injuries.[2, 16] Few reports have monitored CR prospectively over a complete season. In a retrospective study, Ristolainen et al.[2] identified the overall injury incidence rate to 2.1/1000 hours of exposure in elite cross-country skiing athletes aged 15-35 years.

Orienteering athletes (OR) must run through tough terrain and at the same time making route choices, in order to complete the course as fast as possible. Both prospective[3,8] as well as cross-sectional studies[6,9] have identified injuries to most often occur in the lower extremity. Von Rosen et al.[3] followed 64 adolescent elite OR over 26 weeks and the incidence rate was 18 injuries/1000 hours of training with an average weekly prevalence of 18% for severe injuries. The high incidence rate is likely influenced by the injury definition of including all kinds of physical complaints. No difference between injured male and female athletes was found. The incidence of injuries seems to be higher in OR[3] compared to CR and TR.[2,16] However, different injury definitions and surveillance periods have been used, making study comparisons difficult.

In summary, prospective reports monitoring adolescent elite athletes over a complete season are sparse in orienteering, running and cross-country skiing, yet essential for development of injury prevention programs. The aims of this study were to describe the injury prevalence/incidence, severity grade, injury location, risk factors and the prevalence of illness in RU, OR and CR.

METHODS

Data collection

The National Federations of Orienteering, Track & Field, and Skiing were invited to a physical information meeting about the KASIP-study (Karolinska Athlete Screening Injury Prevention). After the meeting, the three National Federations of Sports agreed to participate and twelve Swedish National

Sports High Schools were invited to participate. One of the authors visited each school to inform the athletes and their coaches about the purpose of the study and the voluntary nature of participation. By definition, all adolescent athletes studying at National High Sports Schools are elite athletes because their sport performance results were of such a standard that allowed entry. To attend these schools athletes need to be among the top in terms of ranking in their age group for respective sporting events on national level. A running athlete was defined as an athlete participating in 800-10 000 meter events.

A total of 224 athletes (age range 16-19) were then invited by e-mail and 189 athletes (84.4%) responded to the invitation. Written consent was obtained from all athletes. A questionnaire

was e-mailed to all athletes weekly over one calendar year, consecutively starting between September and December 2013, using the software; Questback online survey (Questback V. 9.9, Questback AS, Oslo, Norway). Athletes that did not respond to the questionnaire received an e-mail reminder four days later. An online background questionnaire was also distributed to the athletes during the first week of the study.

In order to provide a valid picture of the injury burden over a complete season, keep a constant response rate and avoid a biased result based on occasional responders during the first five weeks, in line with Clarsen et al.,[20] a total of 39 athletes were excluded from the analysis (n = 6 due to missing background data, n = 33 due to less than 10% response rate) (Figure 1). The excluded athletes were equally distributed among the three sports (p = 0.368). The final cohort therefore consisted of 150 adolescent elite athletes (female = 74, male = 76), median 17 years (range 16-19) and included 67.0% of the initial selection of athletes (Figure 1). This study is approved by the Regional Ethical Committee in Sweden (No: X).

Questionnaires

The weekly distributed questionnaire was based on the reliable and validated version of the OSTRC (*Oslo Sports Trauma Research Centre*) Overuse Injury Questionnaire,[21] previously used in multiple sports studies,[3, 16, 20] as well as questions about new injuries used by Jacobsson et al.[13] in a track & field surveillance study. OSTRC Overuse Injury Questionnaire quantifies injury consequences on sports participation, performance, training and pain based on four questions with alternative responses.[21] It assesses injuries effect on participation (four alternative responses from "full participation" to "cannot participate"), reduction in training volume (five alternative responses from "no reduction" to "cannot participate"), reduced sporting performance (five alternative responses from "no effect" to "cannot participate") and experience of pain (four alternative

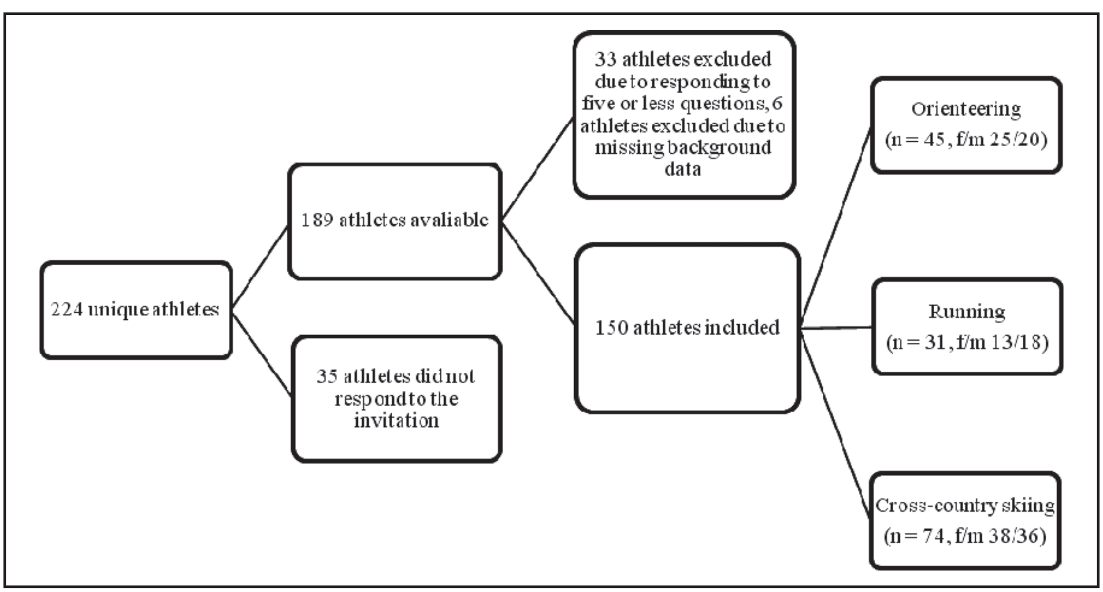

Figure 1. *Flowchart of participant enrollment. f = female; m = male.*

responses from ”no pain” to ”severe pain”). In addition, athletes were asked to report all performed training and competition time in hours/week. The completion of the questionnaire took approximately five minutes.

Operational definitions

All injury data were self-reported and the athletes were asked to report an injury as any physical complaint that affected participation in normal training or competition, led to reduced training volume, experience of pain or reduced performance in sports.[21] A substantial injury was defined as an injury leading to moderate or severe reductions in training volume, or moderate or severe reduction in performance, or complete inability to participate in sports.[21] A new injury was categorized as a recurrent or a non-recurrent injury, based on if the injury occurred in the same body site as the previous injury within the last year. Illness was defined as a self-reported health problem other than the musculoskeletal system, such as cold, influenza etc., resulting in reduced training volume or difficulties participating in normal training or competition.

A complete season refers to the time athletes were followed, including both pre-season and competitive season. Based on occurrence of main competitions, the competitive season for CR was defined as started from beginning of November to end of March, for OR as beginning of May to end of September and for RU as beginning of May to middle of September. This resulted in follow up periods for running, orienteering, cross-country skiing of 20/32, 27/25, 23/29 weeks for pre-season/competitive season, respectively.

STATISTICAL METHODS

Descriptive statistics for continuous variables are presented as mean and standard deviation (SD), for non-normally distributed or ordinal data as median with 25th–75th percentiles (p25–p75), and as frequency and proportion (%) for categorical data. The response rate, prevalence and incidence measures of injury were determined and ninety-five percent confidence intervals (95% CI) were computed for these measures.

Prevalence of injury, injury consequences and illness was calculated by dividing the number of athletes reporting injury, illness or injury consequences, by the number of respondents for each week. The average weekly injury prevalence, substantial injury prevalence, injury consequences prevalence and illnesses prevalence over one calendar year, were determined. The incidence rate of injuries was estimated by summing all new injuries per 1000 hours of exposure to sports. The injury incidence was determined by taking the proportion of athletes reporting a new injury for each week. The average value was used. The average response rate was calculated by dividing the number of respondents with the total number of athletes for each week and taken the average number of these values. The prevalence of injury was determined for the pre-season and competitive season.

A severity score was determined, by allocating a numerical value from 0 to 25 to the responses in the four questions in the OSTRC Overuse Injury Questionnaire.[21] The four questions were then summed. Consequently, a score of 0 represents no injury and 100 the highest level of severity. To demonstrate the relative impact of injuries in each body site the severity grade was calculated by summing athletes' severity scores over one calendar year for each body site and dividing the sum with the total number of respondents. The severity grade can be described as a measure of the consequences of injuries on sports participation, training, performance and pain, adjusted for different group sizes and response rates in each sport. Please see Clarsen et al.[21] for additional information about the calculation of severity grade. The injury risk for substantial injury in the three sports overall were calculated using the Pearson's chi-square test. The risk factors included were sport types, sex, age, history of serious injury, injury at study start, number of rest days/week and number of training sessions/week. Number of rest days/week and number of training sessions/week were dichotomized at the 50% percentile, i.e. ≥3 rest days/week, ≥7 training sessions/week. Odds ratios were calculated for each risk factor. Throughout calculations, the significance level was set to $P < .05$. All analyses were performed using the SPSS software for Windows, version 22.0 (SPSS, Evanston, IL) and Microsoft Excel software (Excel 2013; Microsoft Corp, Redmond, WA).

RESULTS

Demographics and response rate

In average, the orienteering athletes (OR) had a training volume of 7.1 (SD 3.0), running athletes (RU) 8.3 (SD 3.6) and cross-country skiers (CR) 9.8 (SD 4.7) hours per week. At the start of the study, 33.3% (n = 15) of the OR and 35.5% (n = 11) of the RU were injured, compared to 10.8% (n = 8) of the CR. In CR, 20.3% (n = 15) reported to have sustained a serious injury the previous year that partly or completely hindered training for at least three weeks, compared to 37.8% (n = 17) and 41.9% (n = 13) in OR and RU, respectively.

Injury incidence and prevalence of injury and illness

OR had a significantly ($p < 0.05$) higher injury incidence rate (5.7 injuries/1000 hours exposure to sports, 95% CI 4.2-7.1) compared to CR (2.5 injuries/1000 hours exposure to sports, 95% CI 1.8-3.1) (Table 1). The prevalence of injury was significantly ($p < 0.05$) higher during the pre-season compared to the competitive season in each sport (Figure 2). The average weekly injury prevalence, average weekly substantial injury prevalence were significantly ($p < 0.05$) higher in RU, than for OR and CR. Male RU had a significantly ($p < 0.05$) higher average weekly injury prevalence (39.3%) and substantial injury prevalence (23.2%) compared to female RU (21.9%; 8.2%), whereas in CR, female athletes had a significantly ($p < 0.05$) higher average weekly injury prevalence (26.6%) and substantial injury prevalence (11.1%), compared to male athletes (14.1%; 5.9%). The prevalence of illness was equally distributed in each sport (range 14.0-15.0%) and no significant ($p < 0.05$) difference between sexes was found within sports. The most common illnesses in all three sports were cold and flu.

Injury location

The majority of injuries occurred in the lower extremity, however, the proportion varied in each sport. In OR, 91.9% (n = 56) were located in the lower extremity, mainly the foot (39.3%, n = 24), knee (23.0%, n = 14) and the lower leg (13.1%, n = 8). In RU, 94.4% (n = 34) of all injuries were located in the lower extremity, 2.8% (n = 1) in the lower back and 2.8% (n = 1) in the shoulder. In CR, 49.9% (n = 29) of all injuries were located in the lower extremity, 15.5% (n = 9) in the lower back, 12.1% (n = 7) in the shoulder and 8.6% (n = 5) in the hand.

Injury risk and severity grade

A total of 155 unique new injuries were identified, including 41 recurrent injuries (26.5%). History of serious injury ($p = 0.002$, OR 4.0) and current injury at study start ($p = 0.004$, OR 4.0) were identified as the strongest risk factors for substantial injury

Table 1. *Demographics of orienteering, running and cross-country skiing athletes.*

	Orienteering (n=45)	Running (n=31)	Cross-country skiing (n=74)
Sex (female/male %)	55.6/44.4	41.9/58.1	51.4/48.6
Age*	17 (16-19)	17 (16-18)	17 (16-19)
BMI†	20.8 (1.8)	19.3 (1.5)	21.8 (1.6)
Training volume hours/week†	7.1 (3.0)	8.3 (3.6)	9.8 (4.7)
Competition weeks/season†	16.7 (8.2)	9.1 (7.0)	21.1 (8.9)
Competition hours/week†	1.5 (0.9)	0.3 (0.4)	0.7 (0.8)
Number training sessions/week‡	4-7	4-7	4-7
Injured§ (%)	33.3	35.5	10.8
History of serious injury** (%)	37.8	41.9	20.3
Response rate 52-weeks††	62.6 (57.3-68.0)	66.7 (63.4.0-70.1)	62.7 (57.8-67.6)

*Median (range)
†Mean (SD)
‡Median of categorical data
§Current injury at study start
**Sustained an injury during the prior year, that resulted in partly or completely hindered training for a continuous period of at least three weeks
††Mean (%, 95% CI)

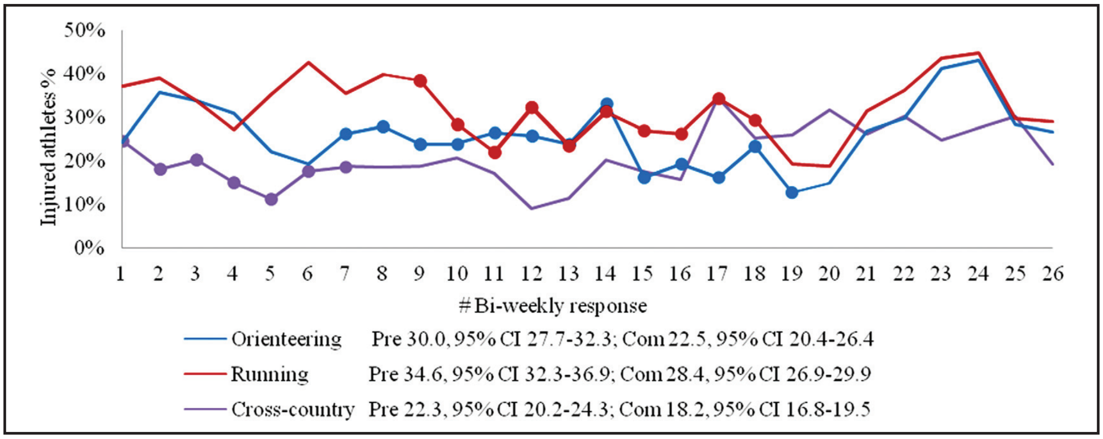

Figure 2. *The prevalence of injury showed bi-weekly over the 52 week study period (● indicate the competitive season for each sport) with the average injury prevalence for the pre-season (Pre) and competitive season (Com).*

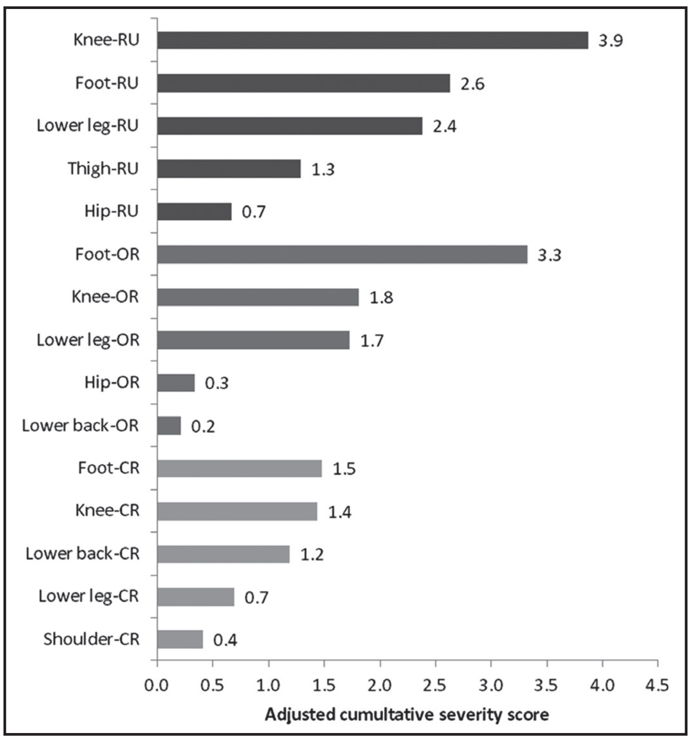

Figure 3. *Relative impact of injuries by sport (RU = running athletes; OR = orienteering athletes; CR = cross-country skiing athletes). Shown as top five highest relative impact per body site for each sport.*

(Table 4). Younger athletes of age 16 ($p = 0.019$, OR 2.6) and 17 ($p = 0.045$, OR 2.4) had a significantly higher injury risk for substantial injury compared to older athletes of age 18-19. The injuries that caused the highest severity grade were mainly located in the foot and the knee region in all the three sports (Figure 2).

DISCUSSION

This is one of the first prospective cohort studies presenting and comparing injury data in endurance sports of adolescent elite athletes, collected over one calendar year. The main finding was that the average weekly injury prevalence was higher during the pre-season compared to the competitive season. Three risk factors were identified; having a history of serious injury, having an injury at the start of the study, and being 16-17 years old as compared to the 18-19 year old athletes. Most injuries as well as the injuries with the highest severity grade occurred in the lower extremity, mainly the foot and the knee, which calls for prevention programs targeting these regions.

The findings support the concept that a previous or current injury could increase the risk of a severe injury,[22,23] in adolescent elite athletes participating in endurance sports. In contrast to Ristolainen et al.,[24] number of rest days or number of training sessions per week did not affect the injury risk. This may be due to different study-designs (prospective vs. retrospective) or sample characteristics, such as including adult athletes in Ristolainen et al. That younger athletes had a higher injury risk than older athletes in endurance sports may be related to the increased pressure, competiveness, or training load occurring during the first years in National Sports High Schools. Although injury risk has been found to be high during competition in track & field event[5,25,26] or orienteering,[9] the injury risk was found to be higher during pre-season compared to the

Table 2. *The injury incidence rate, the average weekly injury incidence and injury prevalence data and illness presented for all athletes and by sex in each sports (95% CI in parentheses).*

	Orienteering			Running			Cross-country skiing		
	All n=45	Female n=25	Male n=20	All n=31	Female n=13	Male n=18	All n=74	Female n=36	Male n=38
Injury incidence rate per 1000 h exposure to sports	5.7 (4.2-7.1)	6.6 (4.5-8.8)	4.6 (2.8-6.4)	4.0 (2.7-5.3)	2.9 (1.1-4.8)	4.6 (2.9-6.4)	2.5 (1.8-3.1)	2.2 (1.4-3.0)	2.9 (1.9-3.9)
Injury incidence (%)	3.8 (2.6-4.9)	4.1 (2.4-5.8)	3.2 (2.0-4.4)	3.2 (2.3-4.2)	2.2 (0.7-3.8)	3.9 (2.6-5.3)	2.2 (1.5-2.8)	1.7 (1.0-2.4)	2.7 (1.5-3.9)
Prevalence of injury (%)	26.0 (23.4-28.6)	31.7 (28.6-34.8)	18.9 (15.3-22.5)	32.4 (30.3-34.5)	21.9 (18.3-25.5)	39.3 (36.7-41.9)	21.1 (19.1-23.2)	26.6 (24.1-29.0)	14.1 (11.5-16.7)
Prevalence of substantial injury (%)	8.2 (6.5-10.0)	8.2 (5.9-10.4)	8.2 (6.0-10.4)	17.0 (15.2-18.8)	8.2 (5.7-10.7)	23.2 (20.7-25.6)	8.9 (7.7-10.1)	11.1 (9.4-12.7)	5.9 (4.6-7.3)
Prevalence illness (%)	15.0 (12.8-17.2)	14.7 (11.7-17.8)	14.9 (11.4-18.3)	14.0 (11.2-16.9)	16.3 (12.1-20.4)	12.2 (9.1-15.2)	14.6 (12.9-16.4)	12.8 (10.8-14.8)	16.8 (14.4-19.3)

Injury was defined as any physical complaint resulting in reduced training volume, experience of pain, difficulties participating in normal training or competition, or reduced performance in sports.
Substantial injury was defined as any physical complaint resulting in moderate or severe reductions in training volume, or moderate or severe reduction in performance, or complete inability to participate in sports.
Illness was defined as a self-reported health problem other than the musculoskeletal system, such as cold, influenza etc., resulting in reduced training volume or difficulties participating in normal training or competition.

Table 3. *Number of injuries (%) per sport.*

	Orienteering n=61	Running n=36	Cross-country skiing n=58
Overall injury data			
Injury (female/male %)	61 (60.7/39.3)	36 (27.8/72.2)	58 (48.2/51.8)
Injury type			
Recurrent injury	16 (26.2)	11 (30.6)	14 (24.1)
Non-recurrent injury	45 (73.8)	25 (69.4)	44 (75.9)
Injury situation			
Training	49 (80.3)	33 (91.6)	47 (71.0)
Competition	12 (19.7)	3 (8.3)	11 (19.0)
Injury location (n female/male athletes)			
Head/face	1 (1/-)	-	-
Cervical spine	-	1 (1/-)	-
Shoulder	-	-	7 (1/6)
Upper arm	-	-	1 (-/1)
Elbow	-	-	2 (-/2)
Hand	-	-	5 (5/-)
Finger	1 (-/1)	-	1 (1/-)
Chest	-	-	1 (-/1)
Thoracic spine	1 (1/-)	-	3 (2/1)
Lower back	2 (1/1)	1 (-/1)	9 (5/4)
Hip	4 (2/2)	2 (-/2)	5 (2/3)
Thigh	2 (2/-)	5 (1/4)	1 (1/-)
Knee	14 (8/6)	6 (1/5)	8 (3/5)
Lower leg	8 (4/4)	8 (3/5)	2 (2/-)
Foot	24 (16/8)	12 (4/8)	12 (5/7)
Toes	4 (2/2)	1 (-/1)	1 (1/-)

Table 4. *Overall risk for substantial injury, showed with odds ratio (OR) and corresponding 95% confidence interval (95% CI).*

Risk factor	p value	OR (95% CI)
Sex (female)	0.772	1.1 (0.6-2.2)
Current injury at study start	0.004	4.0 (1.5-11.2)
History of serious injury*	0.002	4.0 (1.6-9.7)
≥ 3 rest days/week	0.250	0.7 (0.3-1.4)
≥ 7 training sessions/week	0.336	0.7 (0.4-1.4)
Age		
18-19 years		Reference
17 years	0.045	2.4 (1.0-5.9)
16 years	0.019	2.6 (1.2-5.8)
Sports		
Cross-country skiing		Reference
Running	0.079	2.3 (0.9-6.1)
Orienteering	0.301	1.5 (0.7-3.3)

*Sustained an injury during the last year, that resulted in partly or completely hindered training for a continuous period of at least three weeks.

competitive season in all three endurance sports and markedly higher during pre-season in orienteering. This finding supports the results from Rauh et al.,[14] showing that runners had a higher injury risk during pre-season, possibly explained by the long training sessions or high training volume endured during pre-season in endurance sports.[24] The training variation may be less pronounced during pre-season, compared to the competitive season. Although the three sports included have similar characteristics with athletes undertaking high training loads, there were clear differences in injury patterns in terms of injury and substantial injury prevalence, discussed below.

Since, running is part of the umbrella term track & field, many authors have previously reported longitudinal injury data for track & field athletes overall, instead of per athletic event category. This makes it hard to compare the data to the cohort of runners. However, the existing studies have shown that runners, at least during competitions, may have a higher injury risk compared to other disciplines of track & field.[5,25,26] In line with a systematic review of long-distance runners by van Gent et al.,[11] most injuries occurred in the lower extremity, which were also the region with the highest injury severity grade. No significant sex differences of injury incidence in RU was found, in line with Bennell & Crossley[12] and Alonso et al.,[26] but contrary to Alonso et al.[5, 25] and Jacobsson et al.[13,27] The use of different injury definitions, study designs and study period may explain the diversity between studies. For example, in Alonso et al.[5] athletes were only followed over specific championships, whereas in Bennell & Crossley[12] and Jacobsson et al.,[13] athletes were closely monitored during one year. However, there was a significant difference in the average injury prevalence and substantial prevalence, illustrating a higher injury burden in male RU compared to female RU.

Only two reports, using relatively small samples, have followed OR prospectively.[3,8] Linde[8] monitored OR monthly, whereas in von Rosen et al.,[3] OR were weekly monitored during 26 weeks. In line with these two reports, the majority of injuries in elite OR occurred in the lower extremity, mainly the foot, lower leg and the knee. A similar distribution of injury locations identified in this report, has been found in middle- and long-distance runners,[10,14] illustrating comparable injury patterns in athletes of running and orienteering. High training volume on uneven surfaces has been proposed as an explanation to the high occurrence of injuries in the lower extremity.[28] Linde[8] found that most injuries were ankle sprains. In this study, foot and knee injuries caused the highest severity grade of all injuries. Female OR had a higher overall injury incidence rate (6.6 injuries/1000 hours exposure to sports) and injury prevalence (31.7%) compared to male athletes (4.6 injuries/1000 hours exposure to sports, 18.9%). In summary, the prevalence of injuries was high in OR, but not as high as in RU.

The average weekly injury prevalence and injury incidence was lower in CR compared to RU and OR. A low injury incidence in youth elite CR is in concordance with reports of adult elite CR.[17] Sex differences are limitedly reported in this sport and the few published studies have shown conflicting results. For instance, no sex differences regarding injury incidence rates occurred in World Cup CR,[17] whereas in one report neck pain was found to be more common in female compared to male CR.[18] In this report, female athletes reported a higher prevalence of injury (26.6%) and substantial injury (11.1%) compared to male athletes (14.1%, 5.9%). The difference between studies may be explained by different study-designs or definition of injury.

According to previous authors, low back pain is a common musculoskeletal disorder in CR.[18,29] In this report, the incidence as well as the severity grade of lower back injury was higher in CR compared to OR and RU. However, considering the incidence and the severity grade of foot injuries in CR, foot injuries should be the first priority, with low back pain a secondary priority, when designing prevention programs for this cohort.

With regard to illness, endurance athletes are believed to have an increased susceptibility to infections due to a high training load.[30] Even though the prevalence of illness is rarely reported in prospective reports, the incidence of illness has shown to increase during championships and during intense period of competitions.[31] In this report the prevalence of illness was equally distributed in CR (14.6%), RU (14.0%) and OR (15.0%), probably related to similar training and competition load in these three sports.

Interestingly, at the start of the study both a higher proportion of RU were injured and had a history of a severe injury compared to OR and CR. When analyzing the injury data on an individual level, the occurrence of injuries was not only associated with occurrence of new injuries but also related to injuries occurring prior to the start of the study. Of all athletes, 10% (n = 22) started the study reporting the same injury for at least ten of the first fifteen weeks. Directing action towards prevention of new injuries is a priority, but it may be as important to fully rehabilitate injured athletes and delay return to sports participation until that time. Health practitioners should therefore pay attention and treat early injury symptoms to prevent long-term injuries. In addition, preventive actions should be based on injury prevalence and severity as well as incidence. Finally, by focusing on foot and knee injuries in CR, OR and RU, the injuries with the highest incidence and most serious consequences will be targeted in these sports.

The strength of this study is the long study period, in which athletes with similar characteristics from three different sports were followed weekly over one calendar year including a complete season. The twelve schools included are located all over Sweden and include all available athletes in these three sports studying on National Sports High Schools. Therefore, the athletes could be defined as a homogeneous group, characterised by elite athletes competing at the highest national level of their age group. The questionnaire used is valid, reliable and has been repeatedly used in a sport context during recent years.[13,21] In addition, a broad spectrum of injury patterns was recorded, including injury incidence/prevalence, severity grade and injury risk factors. No attempt was made to classify injuries based on e.g. ICD-10, since correctly classified injuries require diagnosis by trained medical staff.[32]

It must also be recognized that this study has limitations. Following athletes during a complete year requires patience and persistence by the athletes. Due to the present respondent fatigue the prevalence and incidence data may be underestimated.[16] However, this phenomenon did not affect the results in terms of occurrence of substantial injuries, in concordance with previous reports.[3,21] Based on Clarsen et al.[20] athletes with a response rate of less than 10% were excluded. The analysis of the demographics of the excluded athletes showed no differences regarding sports participation compared to the main cohort. The response rate was in line with Clarsen at al.[20] and no significant difference was found between sports. The risk factor analysis was determined only for substantial injury, since this injury definition is leading to great consequences on sports participation, training and performance level. Further on, the risk factors were calculated for endurance athletes overall, since the power was too limited to detect sport specific risk factors.

CONCLUSION

This is one of the first prospective cohort studies comparing injury data, collected weekly over a complete season, in adolescent elite athletes participating in running, orienteering and cross-country skiing. The main finding was that the average weekly injury prevalence was higher during the pre-season compared to the competitive season in all three sports. RU had a higher average weekly injury prevalence and substantial injury prevalence compared to OR and CR. Athletes who had history of serious injury, who started the study with an injury or who were 16-17 years old were identified as having a higher risk of injury. Practitioners should be aware of increased injury risk during pre-season and focus on prevention of foot and knee injuries to target the severe injuries with greatest prevalence in these sports.

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