


# Overuse injuries in the knee, back and hip of top elite female alpine skiers during the off-season preparation period: prevalence, severity and their association with traumatic preinjuries and training load

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## ABSTRACT

**Objectives** To investigate knee, back and hip overuse injuries in top female elite alpine skiers during the off-season preparation, which has so far received little attention, and to assess their relationship with traumatic preinjuries and overall training load.

**Methods** A cohort of 26 females of the Swiss Alpine Ski Team were prospectively surveyed by the use of the Oslo Sports Trauma Research Centre questionnaire. Along with the surveys also total training loads were monitored. Data on preinjuries were assessed retrospectively by baseline questionnaires and were verified by team medical records.

**Results** 57.7% of the female skiers suffered from at least one severe traumatic knee injury during their preceding career. The average 2-weekly prevalence of overuse injuries was highest for the knee, followed by the back and hip. Technique specialists (major giant slalom and slalom) were more prone to back overuse injuries than speed specialists (major super-G and downhill). The occurrence of knee overuse complaints was directly associated to previous severe traumatic knee injuries and athletes' total training hours.

**Conclusion** In top female elite alpine skiers, knee, back and hip overuse injuries are relatively frequent. Moreover, discipline preferences, previous traumatic injuries and the overall training load may play an important role for their manifestation.

## INTRODUCTION

Competitive alpine skiing is known to expose athletes at high risks of injury.<sup>1–7</sup> While in recent years, traumatic injuries have received increasing attention, only little is known about overuse injuries.<sup>8</sup> The few studies dealing with overuse injuries, however, revealed remarkably high rates, particularly during the off-season preparation period (ie, summer training).<sup>9–11</sup> This period starts with the first joint on-snow team training beginning of

## What are the new findings

- ▶ Top female elite alpine skiers suffer from a remarkably high number of knee-related, back-related and hip-related overuse complaints during the off-season preparation period, in which intensive physical conditioning combined with extensive amounts of ski training are typical.
- ▶ Namely, discipline preferences, previous traumatic injuries and the overall training load may play an important role for the manifestation of such injuries.
- ▶ Particularly striking is the high number of severe pre-injuries of the knee that have been reported; many of them already occurred at very young ages.

## How it might impact on clinical practice in the near future

- ▶ Beside the prevention of traumatic injuries, in alpine ski racing, a special preventive focus should also be laid on overuse problems.
- ▶ Both from a traumatic and overuse injury perspective, preventing the first severe traumatic knee injuries in the career of youth competitive alpine skiers should be of highest priority.

July on the glaciers and ends with the qualification runs in the forefront of the World Cup season opening beginning of October. During that time, intensive physical conditioning combined with extensive amounts of on-snow training are typical (approximately 10–14 training sessions for a total of 14–21 hour per week with major emphasis on aerobic capacity (intervals), maximal/explosive strength training and volume-orientated ski training),<sup>12</sup> and skiers' risk for overuse injuries is the highest of the entire year.<sup>11</sup>

The anatomical regions particularly prone to overuse injuries in skiers are the knee, the hip and the back.<sup>9–11</sup> For such patterns, an accumulation of heavy mechanical loads on the musculoskeletal system during intense/extensive training periods, such as during the aforementioned off-season preparation period, may play an important role. So far lacking, however, is knowledge about the association of overuse injuries and the total training hours, as an estimator of the accumulated overall load caused by off-snow and on-snow training. Similarly, little is known on whether athletes are more susceptible to subsequent long-term complaints if previous traumatic injuries have occurred. In this context, female skiers are of particular interest, because they suffer from a relatively high number of traumatic knee injuries.<sup>13 14</sup> It was hypothesised that, in female elite skiers, knee complaints are associated with previous traumatic knee injuries and the overall training load.

Therefore, the aims of the current study were: (1) to prospectively investigate the prevalence and severity of knee-related, back-related and hip-related overuse injuries in top female elite alpine skiers during the off-season preparation period and (2) to assess the relationship of knee complaints with traumatic preinjuries and the total training hours.

## METHODS

### Study design, setting and participants

All female athletes of the Swiss Alpine Ski-Team (National, A, B and C squads) were asked to participate in a prospective 14 weeks cohort study during the off-season preparation period (beginning of July until beginning of October). Athletes were included if fully participating in the official team trainings. Three athletes performed their preseason preparation training individually, and therefore, were excluded. Out of the 26 participating athletes, 15 were specialised in the technique disciplines (slalom and giant-slalom) and 11 in the speed disciplines (super-G and downhill). Their age and anthropometrics are presented in [table 1](#).

**Table 1** Participants' age, anthropometrics and total training hours per week

	Overall (n=26)	Technique Specialists (n=15)	Speed Specialists (n=11)
Age (years)	20.91±2.67	21.32±2.64	20.61±2.75
Height (m)	1.69±0.06	1.69±0.08	1.69±0.04
Weight (kg)	65.7±5.7	67.0±5.5	64.7±5.8
Body mass index (kg/m <sup>2</sup> )	23.0±1.5	23.6±1.2	22.6±1.5
Total training hours (hour/ week)	19.4±5.0	20.0±6.1	18.6±2.9

Data are expressed as mean±SD. There were no significant group differences based on unpaired sample t-tests ( $p < 0.05$ ).

## Data collection

The data collection based on two types of questionnaires, that were manually filled out by the participating female skiers during their physiotherapy sessions. In case of any understanding problems or reporting uncertainties, their team physiotherapist was available to assist.

### Baseline questionnaire

A baseline questionnaire included free-text questions on athletes' currently relevant pain, pre-injuries and previous surgeries. The correctness and completeness of the self-reported data on preinjuries were verified by consulting the team medical records. Preinjuries were classified as severe, when having resulted in an absence from training and/or competition of >28 days.<sup>15</sup>

### Prospective questionnaires

For the prospective data collection, the Oslo Sports Trauma Research Centre (OSTRC) questionnaire on overuse injuries was used.<sup>16</sup> The specific questions tailored to the anatomical area of interest (ie, the knee, back and hip) can be retrieved/equally derived from the supplementary material of Clarsen *et al.*<sup>16</sup> Along with the 2-weekly self-reported OSTRC questionnaire data, also all traumatic injuries (ie, injuries resulting from a specific, identifiable event<sup>15</sup>), were queried by an additional free-text question. Moreover, based on their personal training diary, athletes were asked to indicate their accumulated training hours (off-snow and on-snow training) since filling in the last biweekly questionnaire.

## Data evaluation and measure calculations

### Injury definition and classification

An overuse injury was defined as any physical complaint caused by repeated microtrauma without a link to a single, clearly identifiable event.<sup>15 16</sup> A reported overuse problem was rated substantial if it led to moderate or severe reduction in sports performance or participation, or time loss (ie, option 3, 4, 5 in either question 2 or 3 of the OSTRC questionnaire).<sup>16</sup>

### Measure calculations

All OSTRC questionnaire measures were calculated in full accordance to Clarsen *et al.*<sup>16</sup> However, due to a 2-weekly survey frequency, the average 2-weekly prevalence and the average 2-weekly severity score were reported. The cumulative severity score was calculated for every injury that has been reported repeatedly by summing the severity scores from each single questionnaire. Symptoms' duration was defined as the weeks a certain overuse injury was reported. Athletes' average total training hours per week were calculated based on their biweekly self-reported accumulated training hours.

### Statistical analysis

Participants' age, anthropometrics and total training hours were expressed as mean±SD. Corresponding differences between technique and speed specialists were analysed using unpaired sample t-tests ( $p < 0.05$ ). Baseline

data on currently relevant pain, preinjuries and previous surgeries was reported as the percentage proportion of the athletes affected. OSTRC-based prevalence data were expressed as mean values with 95% CI in parenthesis. Duration and severity score data were expressed as median with the 25%–75% IQR in parenthesis. Corresponding differences between technique and speed specialists were analysed by Mann Whitney U tests ( $p < 0.05$ ); differences between knee-related, back-related and hip-related overuse injuries were assessed using Kruskal-Wallis H tests ( $p < 0.05$ ). The associations of previous traumatic injuries and total training hours with overuse complaints were analysed using binary logistic regression models and correlation analyses ( $p > 0.05$ ), respectively. Due to a slight departure from normality, analyses including total training hours were either backed-up by bias corrected accelerated bootstrapping with 10'000 samples or were analysed by non-parametric tests.

## RESULTS

### Participant characteristics and response rate

There were no significant differences in age, anthropometrics and total training hours between the technique and speed specialists at  $p < 0.05$  (table 1). The overall response rate to the questionnaires was 99.5%.

### Pain, preinjuries and previous surgeries at baseline

At the beginning of the study, 11.5% of the female skiers reported to suffer from acute knee pain, 3.9% from acute back pain. No acute hip pain was reported. As much as 57.7% of the female skiers had sustained one or more severe traumatic knee injuries during their previous career; 30.8% underwent an orthopaedic knee surgery (including an anterior cruciate ligament (ACL) reconstruction) previously. Two of the 26 female skiers reported former (however not acute) back pain episodes (7.7%). Both had a disc herniation, one of them already underwent a decompression surgery. None of the skiers reported previous hip problems or hip surgeries.

### Prevalence of knee-related, back-related and hip-related overuse injuries

The average 2-weekly prevalence was highest for the knee, followed by the back and the hip (table 2). With respect to back overuse injuries, skiers specialised in technical disciplines were more frequently affected than skiers specialised in speed disciplines. No such difference was found for knee or hip overuse injuries ( $p < 0.05$ ).

### Number, average duration and severity of knee-related, back-related and hip-related overuse injuries

The overall number of reported overuse incidents, the duration of symptoms of an overuse problem and the associated severity scores are shown in table 3. There were no significant differences at  $p < 0.05$ .

### Association of previous traumatic knee injuries and training load with recurrent knee complaints

There were significant associations of previous severe traumatic knee injuries and total training hours with the current occurrence of knee overuse complaints (table 4). No such associations were found for the back or the hip at  $p < 0.05$ . A Spearman's rank correlation analysis revealed total training hours to be related to the cumulative severity score of knee overuse injuries ( $r = 0.536$ ,  $p = 0.005$ ,  $n = 26$ ).

## DISCUSSION

### Alarmingly high number of severe traumatic knee pre-injuries

Especially striking is the high number of severe preinjuries of the knee that have been reported by the female elite competitive alpine skiers. On the one hand, this coincides with previous studies reporting the knee to be the most frequently injured body part.<sup>5 9 14 17–19</sup> On the other hand, the fact that more than 30% of the female skiers already underwent an ACL surgery is, in view of their young average age (20.9±2.67 years), nevertheless impressive.

**Table 2** Average 2-weekly prevalence of all and substantial knee-related, back-related and hip-related overuse injuries

	Overall (n=26)	Technique Specialists (n=15)	Speed Specialists (n=11)
<b>Knee</b>			
All (%)	28.7 (24.9 to 32.5)	30.6 (25.9 to 35.4)	26.0 (18.9 to 33.1)
Substantial (%)	4.4 (1.9 to 7.0)	3.8 (1.2 to 6.4)	5.2 (1.6 to 8.9)
<b>Back</b>			
All (%)	20.5 (16.0 to 25.0)	29.8 (25.5 to 34.0)	7.9 (1.7 to 14.1)
Substantial (%)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)
<b>Hip</b>			
All (%)	10.5 (8.4 to 12.6)	12.5 (9.0 to 15.9)	7.8 (5.2 to 10.3)
Substantial (%)	2.7 (0.6 to 4.9)	1.0 (-0.9 to 2.8)	5.2 (1.6 to 8.8)

Data are expressed as mean values with 95% CI in parenthesis. Overuse injuries were defined as substantial if they led to moderate or severe reduction in sports performance or participation, or time loss (ie, option 3, 4, 5 in either question 2 or 3 of the OSTRC questionnaire).<sup>16</sup> OSTRC, Oslo Sports Trauma Research Centre.

**Table 3** Number and severity of knee, back and hip overuse injuries

	Overall (n=26)	Technique Specialists (n=15)	Speed Specialists (n=11)
<b>Knee</b>			
No of Incidents (n)	52	32	20
Duration (weeks)	10 (3–12)	10 (3–12)	10 (3–12)
Average Two-Weekly Severity Score (-)	23 (16–29)	20 (16–27)	28 (23–32)
Cumulative Severity Score (-)	98 (31–168)	106 (20–155)	92 (43–189)
<b>Back</b>			
No of Incidents (n)	37	31	6
Duration (weeks)	6 (2–10)	8 (3–13)	4 (2–6)
Average Two-Weekly Severity Score (-)	21 (16–22)	19 (16–23)	22 (15–22)
Cumulative Severity Score (-)	66 (22–114)	81 (23–122)	30 (22–66)
<b>Hip</b>			
No of Incidents (n)	19	13	6
Duration (weeks)	4 (2–10)	4 (2–9)	6 (4–8)
Average Two-Weekly Severity Score (-)	27 (22–37)	25 (15–27)	44 (40–47)
Cumulative Severity Score (-)	40 (28–107)	40 (25–79)	144 (91–198)

Data are expressed as median with the 25%–75% IQR in parenthesis. There were no significant differences between (1) the technique and speed specialists based on Mann Whitney U tests ( $p < 0.05$ ), and (2) knee, back and hip overuse injuries based on Kruskal-Wallis H tests ( $p < 0.05$ ).

### High prevalence of overuse-related injuries during the off-season preparation period

Overall, our data further highlight the remarkably frequent occurrence of overuse injuries in alpine skiers during the off-season preparation period, and the necessity to record injuries during the entire year to avoid a significant underestimation of the actual injury extent.<sup>9</sup> During this particular period, intensive physical conditioning combined with extensive amounts of on-snow training are typical.<sup>12</sup> In contrast, during the competition period, training intensities are much lower (physical preservation training) and skiing is more quality than quantity orientated (only 2–3 runs a day).<sup>12</sup> Accordingly, it seems plausible that the overall load on the musculoskeletal system is higher during off-season preparation and that this could explain why the overuse injury risk during this period is the highest of the entire year.<sup>11</sup>

### Technique specialists are more prone to back overuse injuries than speed specialists

Despite being plausible, a discipline specificity of overuse injuries has not been demonstrated previously. One explanation

approach for back overuse injuries being more frequent in technique specialists (as found in this study) is the markedly different loading patterns compared with those of speed disciplines, with higher and more pronounced ground reaction force peaks.<sup>20,21</sup> Another explanation might be the distinct discipline differences with respect to the training contents, with more quickness and power-orientated physical conditioning, and more turn repetitions in the training of technique specialists.<sup>12</sup>

### Previous severe traumatic knee injuries and training load play an important role for recurrent knee complaints

Traumatic injuries are likely to result in permanent damage to the knee, as already shown for youth team sports.<sup>22</sup> Moreover, ACL injuries are known to be an important risk factor for the development of knee osteoarthritis.<sup>23,24</sup> It can, therefore, be assumed that reducing traumatic knee injuries may also reduce subsequent knee overuse complaints.

Likewise, the observed association between training loads and knee overuse complaints is entirely plausible, since

**Table 4** Binary logistic regression analysing the association of previous traumatic knee injuries and total training load with current knee overuse injuries

	Dependent variable	Predictor	B	e <sup>B</sup>	SE <sub>B</sub>	P value*
<b>Model 1:</b> $\chi^2=8.215$ , $p=0.004$ , $R^2_{\text{Nagelkerke}}=0.361$ , Cohen $f=0.75$ , $n=26$	Current knee overuse injury (yes; no)	Previous severe traumatic knee injury (yes; no)	2.516*	12.375	0.976	0.010**
<b>Model 2:</b> $\chi^2=6.033$ , $p=0.014$ , $R^2_{\text{Nagelkerke}}=0.276$ , Cohen $f=0.62$ , $n=26$	Current knee overuse injury (yes; no)	Total training hours	0.023 (0.006 to 0.093)†	1.023	0.376	0.034*

\*Level of significance:  $p < 0.05$ , \*\* $p < 0.01$ .

†Data are expressed as regression coefficients B and the lower and upper bias corrected accelerated bootstrapping-based CIs with 10 000 samples in brackets.

more training hours means higher accumulated mechanical load on the joint.<sup>25</sup> However, the questions that remain are as to which training content particularly increases the risk for those complaints (ie, on-snow training or off-snow training), and what role a rapid increase in training volume plays in competitive alpine skiers. To this end, a systematic training load monitoring may provide further insights and approaches to prevention, for example in terms of better load dosage.

### Study limitations

First, the prospective data collection relied on 2-week survey intervals and self-reported health problems, which bears the risk of suffering from a recall bias and/or reporting bias. Second, the applied methodology did not allow to derive exact diagnoses on the complaints reported. For such purpose, additional clinical examinations and imaging would have been necessary. Third, the observation was restricted to 14 weeks (ie, an entire off-season preparation period) and one national team only. An extended follow-up or larger international cohort might have pictured potential seasonal and national variations in overuse injury prevalence and severity better.

### CONCLUSION

During the off-season preparation period, overuse complaints of the knee, the hip and the back were relatively frequent among female elite competitive alpine skiers. Effective prevention measures for back overuse injuries should be tailored to athletes' alpine discipline preferences. With regard to knee overuse injuries, the current study emphasises the important role of traumatic preinjuries and the overall training load for their manifestation and prevention.

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**Competing interests** None declared.

**Patient consent for publication** Not required.

**Ethics approval** This study was approved by the ethics committee of the Department of Sport Science and Kinesiology at the University of Salzburg (EC\_NR. 2010\_03), and was carried out in accordance with the Declaration of Helsinki.

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