ORIGINAL ARTICLE

Anterior cruciate ligament tear during the menstrual cycle in female recreational skiers

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KEYWORDS
ACL; Injury risk; Menstrual cycle; Female skiers

Summary

\textbf{Introduction:} Women run a 4-8-fold greater risk of anterior cruciate ligament (ACL) tear than men, and especially during the pre-ovulation stage of their cycle. The main study objective was to describe the distribution of ACL lesions according to menstrual cycle in a large population of female recreational skiers.

\textbf{Materials and methods:} A prospective study was conducted during the 2010–11 ski season on women sustaining ACL tear during skiing. Patients filled out a questionnaire during consultation with the mountain physician, including date of last menstrual period (LMP) and contraceptive method. Fifty-seven of the 229 patients with diagnosed ACL tear were excluded from analysis, 41 being post-menopausal (mean age, 47 ± 9 years), and 16 having irregular cycles or LMP > 30 days. One hundred and seventy-two patients (mean age, 34 ± 8.7 years) were thus included.

\textbf{Results:} Fifty-eight women (33.72%) were in follicular phase, 63 (36.63%) in ovulatory phase and 51 (29.65%) in luteal phase; difference with respect to the theoretic distribution regardless of menstrual phase was highly significant: $\chi^2 = 48.32; P = 0.00001$. Fifty-three of the 172 women (30.8%) were taking oral contraceptives. ACL tear was 2.4-fold more frequent in pre-ovulatory than post-ovulatory phase, whether in women using oral or other contraceptives: 85/119 (71.4%) vs. 36/53 (67.9%); $P = 0.64$.

\textbf{Conclusion:} ACL tear risk in skiing in women is not constant over the menstrual cycle, being 2.4–fold more frequent in pre-ovulatory (folicular and ovulatory) than post-ovulatory phase (luteal). Oral contraception seems not to exert any protective effect.

\textbf{Level of evidence:} Level IV. Retrospective cohort study.

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\textsuperscript{1} Identifying anterior cruciate ligament (ACL) risk factors [1] enables adapted prevention strategies to be drawn up [2]. Risk is 4-to-8-fold higher in women than men [3] at
equivalent sports levels [4]. The sex predominance varies depending on the sport [5]: 2.77 in soccer, 4 in combat sports and 5 in handball; in skiing, whether recreational or competitive, it is 3 [6,7]. Pujo[. et al. [8], however, in an epidemiological study of French competitive skiers over a 25-year period, reported a 28.2% risk of at least 1 ACL lesion in women and 27.2% in men, with a total incidence of 5.7 per 100 ski seasons. Anatomic, neuromuscular, genetic and hormonal factors may account for these sex-ratios [9,10]. The hormonal theory is based on several reports of elevated ACL tear rates in pre- compared to post-ovulatory phase [3,11,12], doubtless partly implicating elevated circulating estrogens and reduced progesterone levels. A recent study [13] also reported a 3-fold elevation of relaxin, a myorela-
tant polypeptide hormone synthesized by the corpus luteum, in sportswomen presenting ACL lesion as compared to controls, and that the risk of ACL tear was multiplied by four when relaxin levels exceeded 6 pg/mL.

According to Möller and Hammar [14], oral contraceptives, by stabilizing female hormone levels over the menstrual cycle, exert a protective effect on the ACL, although other teams failed to confirm this [15,16].

Most of these studies, however, concerned small patient samples. The present study had as principal objective to describe the distribution of ACL tear over the menstrual cycle in a large population of female recreational skiers. The secondary objective was to investigate the use of oral contraceptives in the study population.

Material and methods

A prospective study was conducted during the 2010–11 winter season in eight medical surgeries in Alpine ski resorts, including 12 physicians of the Médecins de Montagne (“Mountain Doctors”) association. Included subjects were female recreational skiers with clinically diagnosed ACL tear (with suggested trauma mechanism, immediate functional impotence, hemarthrosis, positive Lachman test and knee laxity) sustained in a skiing accident, and with a regular menstrual cycle of 26–30 days and a 4–7 day men-
strual period. All patients had been examined by one of the physicians within 24h of trauma. The study design was observational and non-interventional.

A questionnaire drawn up by the authors (Supplementary material, Annex 1) was filled in, comprising three blocks of questions, concerning the circumstances of the accident, the patient’s sports level and her menstrual cycle (notably date of last menstrual period: LMP) and use of oral contra-
ceptives

The main assessment criterion was the menstrual cycle phase at trauma as assessed on interview: 1—9 day follicu-
lar phase, ovulation at 10–14 days and luteal phase of 15–30 days after LMP. Like in other studies, the ovula-
tory phase was counted systematically, including in patients under oral contraception. For purposes of comparison with other studies, results were also presented in two phases: pre-ovulatory (follicular and ovulatory) and post-ovulatory (luteal). Secondary assessment criteria were type of contra-
ception and use of oral contraceptives (yes/no).

Patients

Two hundred and twenty-nine ACL tears were diagnosed. Fifty-seven patients were excluded from analysis: 41 post-
menopausal, of mean age 47 ± 9 years; and 16 with irregular cycle or LMP > 30 days. The series thus comprised 172 patients with a mean age of 34 ± 8.7 years. 91/172 (52.9%) were skiing for their first time, 69 (40.1%) skied once a year and 12 (7%) at least twice a year. The mean number of years skiing for the regular (at least once a year) skiers was 16.2 ± 11.2. The accidents mainly occurred on blue-graded slopes at medium speed (Table 1) and most patients had not removed their skis. Knee torsion was the most frequent mechanism.

Statistical analysis

The null hypothesis was that risk of ACL tear was independent of day in the menstrual cycle (theoretic distribution). Given the sample size, the χ² test was used to compare theoretic and observed numbers. The expected ACL tear rate was calculated by dividing the number of days in a given phase by the number of days in a normal cycle; theoretic num-
bers were then calculated by multiplying the total number of patients by the expected tear rate per phase. At a signif-
icance threshold of 0.05, the χ² threshold with two degrees of freedom was 5.99.

Results

Fifty-eight of the 172 patients (33.72%) were in follicular, 63 (36.63%) in ovulatory and 51 (29.65%) in luteal phase (Fig. 1). The difference with respect to the theoretic distribution was strongly significant: χ² = 48.32, P = 0.00001. ACL tear was 2.4-fold more likely in pre- (follicular and ovulatory) than post-ovulatory phase (70.3% vs. 29.7%) (Table 2).

Eight patients (4.6%) had definitive contraception: seven tube ligatures and one Essure coil. Temporary methods were: abstinence (+ non-response), 75 (43.6%); oral contraceptives, 53 (30.8%); IUD, 28 (16.3%); condom, six (3.5%); or ring, two (1.2%). Oral contraceptives comprised: single-phase mini-dose combined oestro-progestative, 30 (56.7%); three-phase mini-dose combined oestro-progestative, six (11.3%); transdermal oestro-progestative, one (1.9%); micro-dose progestative, six (11.3%); estro-antiandrogen, four (7.5%); non-response, six (11.3%).

ACL tears were more frequent in pre-ovulatory phase, whether in patients using oral contraceptives or another contraceptive method: 85/119 (71.4%) vs. 36/53 (67.9%), P = 0.64.

Discussion

The present study of a large population of female recre-
ational skiers found a significant correlation between menstrual cycle phase and ACL tear, which was more frequent in the follicular or ovulatory than luteal phase. Also, almost 31% of the ACL tear victims were taking oral contra-
ceptives, mainly mini-dose combined oestro-progestatives. This ovulation-linked increased risk of ACL tear was...
Table 1  Ski accident circumstances for the 172 patients.

<table>
<thead>
<tr>
<th>Trauma mechanism (more than one response possible)</th>
<th>Type of slope</th>
<th>Speed</th>
<th>Skis removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsion or rotation of knee 129 (75%)</td>
<td>Green 27 (15.7%)</td>
<td>Zero 15 (8.7%)</td>
<td>Yes 37 (21.5%)</td>
</tr>
<tr>
<td>Lateral fall 51 (29.6%)</td>
<td>Blue 69 (40.1%)</td>
<td>Slow 52 (30.2%)</td>
<td>No 135 (78.5%)</td>
</tr>
<tr>
<td>Forward fall 44 (25.6%)</td>
<td>Red 64 (37.2%)</td>
<td>Medium 81 (47.1%)</td>
<td></td>
</tr>
<tr>
<td>Backward fall 18 (10.5%)</td>
<td>Black 6 (3.5%)</td>
<td>Fast 22 (12.8%)</td>
<td></td>
</tr>
<tr>
<td>Other 1a (6.6%)</td>
<td>NRb 6 (3.5%)</td>
<td>NRb 2 (1.2%)</td>
<td></td>
</tr>
</tbody>
</table>

a  Collision from behind.
b  No response.

Figure 1  Anterior cruciate ligament tear according to day of menstrual cycle at accident.

previously reported in several sports [12,17]. Ruedl et al. [15] and Beynnon et al. [18] reported that 57% of female recreational skiers were in pre- vs. 43% in post-ovulatory phase. The present results found 70% of patients in pre-ovulatory or ovulatory phase, with a higher rate of ACL tear. Beynnon et al.’s case-control study [18] likewise reported a 3.2 odds-ratation between these two phases.

The 31% rate of ACL tear patients taking oral contraceptives is comparable to that reported by Agel et al. [16] for both cases (34.4%) and controls (35.5%); they found no correlation between oral contraception and ACL tear, whereas Möller and Hammar [14] reported a lower risk with oral contraception. The present study cannot shed light on this, as there was no “non-ACL-tear” group. Hormonal fluctuation may affect the passive and dynamic stability of the knee [12]. Zazulak et al.’s meta-analysis [19] and Park et al.’s studies [20,21] found increased ligament laxity in the pre-ovulatory period, with consequently increased load on the knee in adduction and external rotation in jumping [22]. Other studies reported no such difference [23–26]. Pollard et al. [24] measured knee laxity before and after physical exercise in 12 women during three menstrual phases and 12 men on three different days: laxity was systematically greater in women, but independent of estrogen level. This non-dependence on estrogen level was also reported by Karageanes et al. [25]. Eiling et al. [26] assessed lower-limb musculotendinous stiffness in 11 female athletes before and after warm-up at various menstrual phases on a protocol of

Table 2  Number of ACL tears per menstrual phase: observed and calculated values ($\chi^2$ test).

<table>
<thead>
<tr>
<th>Menstrual phase</th>
<th>Observed number (n = 172)</th>
<th>Observed frequency (%)</th>
<th>Calculated frequency (%)</th>
<th>Calculated number (n = 172)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follicular (1–9 days)</td>
<td>58</td>
<td>33.72 (58/172)</td>
<td>32.14 (9/28)</td>
<td>55.29</td>
</tr>
<tr>
<td>Ovulation (10–14 days)</td>
<td>63</td>
<td>36.63 (63/172)</td>
<td>17.86 (5/28)</td>
<td>30.71</td>
</tr>
<tr>
<td>Luteal (15–28 days)</td>
<td>51</td>
<td>29.65 (51/172)</td>
<td>50 (14/28)</td>
<td>86</td>
</tr>
</tbody>
</table>

ACL: anterior cruciate ligament. $\chi^2 = 48.32$. $P = 0.00001$. 

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two successive unilateral jumps: laxity did not significantly change according to menstrual phase, but stiffness was significantly lower in ovulatory than follicular phase or the first day of the menstrual period.

Most studies assessed only a single risk factor [27]. Ruedl et al. [28] used a self-administered questionnaire to compare female recreational skiers with ACL tear to a control group; multivariate logistic regression integrating known intrinsic and extrinsic risk factors identified the following independent factors: icy snow conditions (OR, 24.33), skiing during snowfall (OR, 16.63), use of traditional skis (OR, 10.49) and pre-ovulatory menstrual phase (OR, 2.59).

For the sake of homogeneity, the studies all concerned patients with normal menstrual cycles. This selection bias has prevented quantifying risk in patients with irregular or no menstrual cycle [29].

The present study has several limitations:

- the lack of a control group prevented analysis of ACL tear risk factors and incidence;
- assessment criteria were clinical — lesion type was not characterized on imaging;
- menstrual phase was estimated on interview rather than from hormone assay — although Wojtys et al. [11] reported an excellent correlation between the two.

Conclusion

The present findings confirm that the risk of ACL tear in women during skiing varies over the menstrual cycle, being 2.4-fold more frequent in pre-(follicular and ovulatory) than post-ovulatory phase. Female skiers should take special care during this period. Oral contraceptives do not seem to exert a protective effect.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.otsr.2013.02.005.

References

ACL injuries during menstrual cycle in female recreational skiers


