

A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball

Myklebust G, Mæhlum S, Holm I, Bahr R. A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. *Scand J Med Sci Sports* 1998; 8: 149–153. © Munksgaard, 1998

The purpose of this study was to examine gender differences in the incidence of anterior cruciate ligament (ACL) injuries in a population of high-level team handball players. We also wanted to examine injury mechanisms and possible risk factors for ACL injuries, including menstrual status. The study was done prospectively during the 1993–94, 1994–95, and 1995–96 seasons. We found 28 ACL injuries, 23 among women (incidence: 0.31 ± 0.06 inj./1000 h; $P < 0.001$ vs women; risk ratio: 5.0). Of the 28 injuries, 24 occurred during competition (0.91 ± 0.19 inj./1000 h; women: 1.60 ± 0.35 inj./1000 h; men: 0.23 ± 0.13 inj./1000 h; $P < 0.001$ vs. women; risk ratio: 7.0) and 4 during training (0.03 ± 0.02 inj./1000 h; $P < 0.001$ vs. competition; risk ratio: 29.9). Nearly all the injuries ($n=25$) occurred in non-contact situations when the players performed high-speed plant-and-cut movements which they were well accustomed to. A reliable menstrual history could be obtained in 17 of the 23 cases among females. Five of the injuries occurred in the menstrual phase, 2 in the follicular phase, 1 in the early luteal phase and 9 in the late luteal phase ($\chi^2_{3 \text{ d.f.}} = 13.2$; $P < 0.01$). The results suggest that there may be an increased risk of ACL injury during the week prior to or after the start of the menstrual period.

**G. Myklebust^{1,2}, S. Mæhlum^{2,3},
I. Holm⁴, R. Bahr³**

¹Norwegian Institute of Sports Medicine, ²National Sports Centre, ³Norwegian University of Sport and Physical Education, and ⁴National Hospital Orthopaedic Centre, Oslo, Norway

Key words: ACL injury; etiology; European team handball; menstrual status

Grethe Myklebust, Norwegian Institute of Sports Medicine, PO Box 3808 Ullevål Hageby, 0806 Oslo, Norway

Accepted for publication 5 February 1998

Studies based on the National Collegiate Athletics Association Injury Surveillance System have shown that female athletes are at increased risk for injuries compared to men in certain US sports, i.e. basketball, soccer and gymnastics (1, 2). The same studies show a notable gender difference in the rate of knee injuries, in particular injuries involving the anterior cruciate ligament (ACL) (1, 2). Arent & Dick found that the rate of ACL injury among women was 2.4 times higher in soccer and 3 times higher in basketball compared to men (2).

The reasons for these gender differences are unknown. A number of hypotheses have been suggested, e.g. differences in lower extremity alignment, notch dimensions, ligament size, muscle strength and coordination, level of skill and conditioning. As reviewed by Arent & Dick recently (2), no firm conclusions can be reached regarding any of these factors, and there is clearly a need for further research.

In addition, it has been suggested that there may be sex differences in ligamentous laxity, possibly related to cyclic hormonal effects (1), but there are no studies supporting this hypothesis. However, it is interesting to note that Møller-Nielsen & Hammar (3) found that women soccer players were more susceptible to injuries during the premenstrual and menstrual phases compared to the rest of the menstrual cycle. They also observed that women using oral contraceptives had a lower injury rate than those who did not. However, this study examined traumatic injuries in general, and did not include specific data on knee injuries or ACL injuries.

The aim of this study was to examine gender differences in the incidence of ACL injuries in a population of high-level team handball players with a prospective study design. We also wanted to examine injury mechanisms and possible risk factors for ACL injuries, including menstrual status.

Table 1. Competition activity level and number of ACL injuries sustained during official and unofficial games during the 1993–94, 1994–95 and 1995–96 seasons

	ACL injuries		Player hours*	
	Men	Women	Men	Women
1993–94	0	9	4023	4268
1994–95	3	7	4344	4403
1995–96	0	5	4804	4480
Total	3	21	13171	13151

* Competition exposure has been calculated as the number of matches multiplied by the duration of each match multiplied by 7 players on each team.

Methods

A prospective cohort study of ACL injuries in Norwegian elite team handball was carried out during the 1993–94, 1994–95, and 1995–96 seasons. A total of 24 teams (12 men's and 12 women's teams), all of the teams playing in the elite division of the Norwegian Handball Federation (NHF) league system, agreed to take part in the study. The players on these teams are either amateurs or semi-professionals. The matches were played with equipment and rules in accordance with the regulations of the International Handball Federation (4).

The teams were followed for 12 months each season (June–May). Information about injured players was gathered from team coaches, physiotherapists and physicians, the insurance company, and other team officials. An ACL injury was registered if it occurred during organized handball training or games. All the injured players consented to participate in a personal or telephone interview. Among the information requested in each case was personal data, training history, family history (ACL injury among parents or siblings), menstrual history, and mechanism of injury. The menstrual cycle date was adjusted to an average cycle length of 28 days, with day 1 of the cycle designated as that day on which menstrual flow began. Injuries were classified as occurring in four different menstrual phases (day 1–7: menstrual phase; day 8–14: follicular phase; day 15–21: early luteal phase; day 22–28: late luteal phase). The diagnosis of ACL injury and information on associated ligament injuries, meniscal injuries or osteochondral injuries were obtained from the operating surgeon. The study was approved by the Ethics Committee of the Norwegian Research Council.

The coaches supplied information on the number of official training games, tournament games, and cup and league games each season. Competition exposure for each team was calculated as the number of games multiplied by the duration of each game

(some tournament games lasted less than the regulation time of 2×30 min) multiplied by 7 players. Training exposure was calculated based on the average weekly number of training hours reported by the injured players each season multiplied by 48 wks multiplied by 12 players. Injury incidence was calculated as the number of ACL injuries reported per 1000 player hours (competition and/or training, as appropriate).

Statistical methods

Results are given as the mean±SEM unless otherwise noted. Comparisons of activity type (match vs. training), and gender were done using the Mantel-Haenszel test for cohort data with a person-time denominator (5). Comparison of the risk of injury during the four menstrual phases was done using chi-square statistics with three degrees of freedom.

Results

Exposure and injury rate

All the 12 men's and women's teams participating in the elite divisions were followed during the three seasons for a total of 26 321 player hours of game participation (Table 1) and 131 328 player hours of training (62 208 h for women and 69 120 h for men). During this period, there were 28 ACL injuries, 23 among women (incidence: 0.31 ± 0.06 injuries per 1000 player hours) and 5 among men (0.06 ± 0.03 inj./1000 h; $P<0.001$ vs. women; risk ratio: 5.0). Of the 28 injuries, 24 occurred during competition (0.91 ± 0.19 inj./1000 h; women: 1.60 ± 0.35 inj./1000 h; men: 0.23 ± 0.13 inj./1000 h; $P<0.001$ vs. women; risk ratio: 7.0) and 4 during training (0.03 ± 0.02 inj./1000 h;

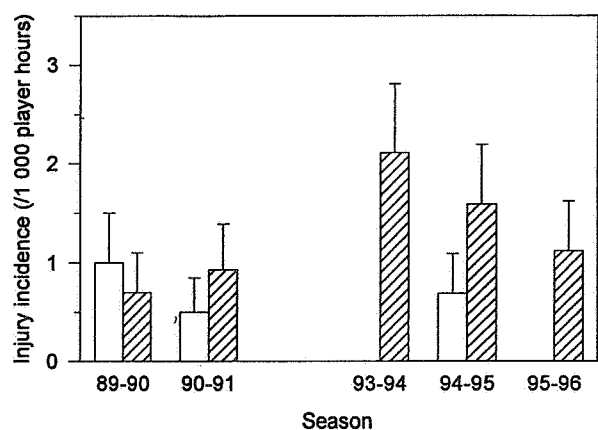


Fig. 1. Yearly rate of ACL injuries during official and unofficial matches in the elite division in Norwegian team handball among male (open bars) and female players (hatched bars). Standard errors are shown with error bars. Data for the 1989–90 and 1990–91 seasons have been estimated from Myklebust et al. (12).

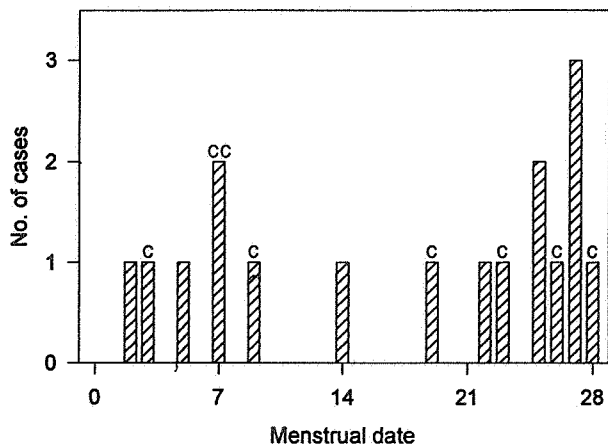


Fig. 2. Distribution of the number of ACL injuries in relation to menstrual date ($n=17$). C: Contraceptive users.

$P < 0.001$ vs. competition; risk ratio: 29.9). There was no apparent change in ACL injury incidence in the time period from 1989 to 1996 (Fig. 1).

Patient characteristics and risk factors

The age of the injured players was 21.9 ± 3.4 (SD) yrs among women and 23.4 ± 3.9 yrs among men. They started playing handball at age 9.1 ± 2.0 yrs (women) and 8.8 ± 2.3 yrs (men), and had played 3.8 ± 3.5 yrs (women) and 2.4 ± 1.7 yrs (men) in the elite division. They reported practicing for 9.0 ± 2.3 h/wk (women) and 10.0 ± 1.4 h/wk (men). Six of the players reported a family history of ACL injury. Nine of the players had evidence of an associated lateral meniscus injury at surgery, 4 had a medial meniscus injury, and 11 had chondral injuries.

A reliable menstrual history could be obtained in 17 of the 23 cases among females. Of these, 8 used oral contraceptives and 9 had regular menses. Five of the injuries occurred in the menstrual phase, 2 in the follicular phase, 1 in the early luteal phase and 9 in the late luteal phase (chi-square_{3 d.f.} = 13.2; $P < 0.01$; Fig. 2).

Injury mechanisms

All but two players were handling the ball when injured; both of these were performing defensive actions (both were non-contact). The other 26 injuries occurred in the attacking phase; only three of these occurred as a contact injury, the other 23 were non-contact injuries, 17 of these when moving at high speed. Of the 23 non-contact injuries, 19 occurred during faking/cutting movements, whereas 4 occurred when landing from a jump. In all but one of the non-contact injuries (male), the player reported that there was nothing unusual with the action performed when injured. Of the

non-contact injuries, 18 players reported that the foot was firmly fixed to the floor at the time of injury, in 10 cases with a rotation causing the tibia to be externally rotated in relation to the femur and in 7 cases with internal rotation of the tibia. One player reported a valgus stress and six were not sure.

Discussion

The main observations of this study were that the incidence of ACL injuries was 5-fold higher among women than among men and 30-fold higher during competition than during training. We also found that most of the injuries occurred in non-contact situations when the players performed high-speed plant-and-cut movements which they were well accustomed to. Many of the women sustained ACL injuries during the weeks prior to or after the onset of menses.

Rate of ACL injury

In any epidemiological study the reliability of the injury and exposure registration must be questioned. The present study was done using a prospective study design, where the teams were requested to report any knee injury as soon as they occurred. In addition, the investigators remained in close contact with the team coaches and medical staff throughout the study period. Also, the players were covered by the compulsory injury insurance policy of the NHF and all insurance claims were examined for additional ACL injuries. Even so, there is always a possibility that an injury may have been overlooked. However, an ACL injury usually causes pain, swelling and disability, and it is unlikely that a player may have developed an injury without the need for medical follow-up. Moreover, all the reported ACL injuries were later verified arthroscopically and reconstructive surgery was performed. It is therefore highly unlikely that there may have been 'false positive' ACL injuries during the study period.

With respect to exposure registration, it was not possible to base this on attendance records for all practices and matches during the study period. Data on the number of matches were obtained from the coaches, including out-of-season tournaments and training matches, which should ensure good reliability. The training data are less accurate, since these are based on the average number of training hours per week reported by the injured players and coaches. We have assumed that each team consisted of 12 players during training, so the exposure registration has not been adjusted for training attendance or seasonal variations. However, team rosters usually include 14–16 players, which means that we have assumed that some players were absent for various reasons.

Thus, we believe that the injury rates found, 0.31

ACL injuries per 1000 hours among women and 0.06 among men, and the 5-fold gender difference observed are reliable estimates. Arent & Dick estimated injury rates of 0.31 and 0.13 ACL injuries per 1000 exposures in soccer and 0.29 and 0.07 in basketball among women and men, respectively (2). Although the methods and units for exposure reporting are somewhat different, both studies show a marked gender difference.

There were no injuries among goalkeepers. Even so, we have included them in the injury incidence calculations. This has been done to allow for comparison with results from other studies and across different sports. To calculate the injury incidence among court players, one would simply have to multiply the present results by 7/6, i.e. a 17% increase.

Possible mechanisms for ACL injury

The mechanism for ACL injury, and in some cases also rupture of the medial collateral ligament and medial meniscus, is the forceful valgus-external rotation of the knee which can occur in skiing injuries, where the tip of the ski is caught in the snow or by an obstacle (6, 7). Other forced injury mechanisms have also been described (8, 9): Internal rotation-hyperextension, hyperflexion, backward fall ('boot-induced anterior drawer', seen in downhill skiing). However, recent studies have shown that ACL injuries can occur in team sports such as basketball (2, 10, 11) and team handball (12, 13). In a previous study from team handball we have shown that 95% of the ACL injuries were non-contact (12), and in the present study 89% of the injuries occurred without player contact.

The exact injury mechanism in these cases is not clear. It is noteworthy that of the 23 non-contact attack injuries observed in the present study, 19 occurred during plant-and-cut maneuvers, and in all but one of these the players reported that there was nothing unusual about the faking movement performed. In other words, the ACL 'popped' when the players were performing fakes that they had done hundreds or thousands of times before, as can be seen by the fact that the injured players were very experienced (at least 4 yrs at the elite level).

With respect to knee position at the time of injury, the information is less clear, some reporting external rotation of the tibia and some reporting internal rotation, but nearly all reported that their foot was planted on the floor at the time of injury. We were not able to gather reliable information on valgus-varus stresses on the joint.

Gender differences in ACL injury rates

Several different hypotheses have been suggested to explain the marked gender difference in ACL injury

rates, e.g. differences in lower extremity alignment (1, 14), notch dimensions (15, 16), ligament size (1), muscle strength and coordination (17, 18), and level of skill and conditioning (1, 2). It has also been suggested that there may be sex differences in ligamentous laxity, possibly related to cyclic hormonal effects (1), but there are no studies supporting this hypothesis. In this study, most of the injuries occurred during the weeks prior to or after the start of the menstrual period. This corresponds with the findings of Møller-Nielsen & Hammer (3), who observed an increase of traumatic injuries in general during the premenstrual and menstrual phases in female soccer players. In their study, players with premenstrual problems, such as irritability or swelling/discomfort of the breasts, were at greater risk of injury. In the present study we have no information about these factors. They also observed that women using oral contraceptives had a lower injury rate than those who did not.

The observation of an apparent relationship between menstrual phase and ACL injury risk must be interpreted with caution, since it is based on a small number of observations. Also, the players were not followed with a continuous record of menstrual status throughout the study period, and in some cases a reliable menstrual history could not be obtained. Further studies are therefore necessary to examine this relationship, but it is conceivable that the normal hormonal fluctuations during the menstrual cycle may have effects on ligamentous tissue. Liu et al. have recently demonstrated the presence of both estrogen and progesterone receptors in synoviocytes in the synovial lining and in fibroblasts in the stroma in human ACL specimens, suggesting that female sex hormones may have an effect on the structure and composition of the ligament (19). Increased joint laxity has been suggested as a possible factor for the increased injury incidence among women (1, 2), but the effects of female sex hormones on the material properties of ligaments have not yet been examined.

Conclusion

The incidence of ACL injuries was 5-fold higher among women than men and 30-fold higher during competition than training. Nearly all the injuries occurred in non-contact situations when the players performed high-speed plant-and-cut movements which they were well accustomed to. The results also suggest that there may be an increased risk of ACL injury during the week prior to or after the start of the menstrual period.

Acknowledgements

The study was supported by the Norwegian Handball Federation. We thank Ingar Holme PhD for statistical advice.

References

1. Hutchinson MR, Ireland ML. Knee injuries in female athletes. *Sports Med* 1995; 19: 288–302.
2. Arent E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. *Am J Sports Med* 1995; 23: 694–701.
3. Møller-Nielsen J, Hammar M. Women's soccer injuries in relation to the menstrual cycle and oral contraceptive use. *Med Sci Sports Exerc* 1989; 21: 126–9.
4. International Handball Federation. Rules of the game. Basel: IHF, 1993.
5. Elwood JM. Causal relationships in medicine. Oxford: Oxford Medical Publications, 1988.
6. Fetto JF, Marshall JL. The natural history and diagnosis of anterior cruciate ligament insufficiency. *Clin Orthop* 1980; 147: 29–38.
7. Johnson R, Ettlinger C. Alpine ski injuries: Changes through the years. *Clin Sports Med* 1982; 1: 181–97.
8. Grøntvedt T. Treatment of acute and chronic anterior cruciate ligament injuries. A clinical and biomechanical study (Thesis). Trondheim: The Norwegian University of Science and Technology, 1996.
9. Aune AK. The muscle stabilized knee. Significance of anterior cruciate ligament injury and reconstruction (Thesis). Oslo: University of Oslo, 1996.
10. Noyes FR, Pekka AM, Matthews DS, Butler DL. The symptomatic ACL deficient knee. *J Bone Joint Surg* 1983; 154–74.
11. Malone TR, Hardaker WT, Garrett WE et al. Relationship of gender to ACL injuries in intercollegiate basketball players. *J South Orthop Assoc* 1992; 2: 36–9.
12. Myklebust G, Mæhlum S, Engebretsen L, Strand T, Solheim E. Registration of cruciate ligament injuries in Norwegian top level team handball. A prospective study covering two seasons. *Scand J Med Sci Sports* 1997; 7: 289–92.
13. Strand T, Tvedte R, Engebretsen L, Tegnander A. ACL injuries in team handball. *J Nor Med Ass* 1990: 45–8.
14. Gray J, Taunton JE, McKenzie DC et al. A survey of injuries to the ACL of the knee in female basketball players. *Int J Sports Med* 1985; 6: 314–6.
15. LaPrade RF, Burnett QM. Femoral intercondylar notch stenosis and correlation to anterior cruciate ligament injuries. *Am J Sports Med* 1994; 22: 198–203.
16. Souryal TO, Freeman TR. Intercondylar notch size and anterior cruciate ligament injuries in athletes, a prospective study. *Am J Sports Med* 1993; 65: 535–9.
17. Laubach L. Comparative muscular strength of men and women: A review of the literature. *Aviat Space Environ Med* 1976; 47: 534–42.
18. Wilmore JH. The application of science to sport: Physiological profiles of male and female athletes. *Can J Appl Sports Sci* 1979; 4: 103–15.
19. Liu SL, Al-Shaikh R, Panossian V et al. Primary immunolocalization of estrogen and progesterone target cells in the human anterior cruciate ligament. *J Orthop Res* 1996; 14: 526–33.