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**ACL injury incidence in female handball 10 years after the Norwegian ACL prevention study—  
Important lessons learned**

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Running title: ACL incidence in female handball players

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Success in injury prevention in the short run is possible. Several studies have documented that injuries can be prevented if program compliance is sufficient.[1-6] However, that an intervention is efficacious in a controlled trial does not mean that it will be widely adopted and sustained and have an impact on public health.[7-9] Finch[9] outlined the Translating Research into Injury Prevention Practice (TRIPP) framework, emphasizing that only research that can and will be adopted by the participants, the coaches and sporting bodies will succeed in the long run.

ACL injuries is an example where there are controlled studies showing promising efficacy (that the intervention is capable of producing the desired effect);[5, 10-13] however, their efficiency (whether the desired effect occurs under real-life conditions) is not known. We wanted to know ‘Have ACL injury prevention initiative taken in Norway during the last decade been successful in the long run?’ We report our experience with Norwegian handball as an example, as this is an area where several initiatives (table 1) building on prevention trials have coincided with an ongoing surveillance program.

### **The Norwegian female handball experience: a 13-year and ongoing story**

*ACL Injury Prevention Study.* The 1998-99 season served as the baseline for the ACL Injury Prevention Study; during the 1999-2000 season an injury prevention program was introduced in the top three divisions in female handball in Norway.[10] The intervention consisted of a neuromuscular training program with exercises on a wobble board, a balance mat and handball-specific exercises. In the first season (1999-2000), the intervention was based on coaches delivering the program after being instructed by the investigators. However, as compliance was low, physical therapists were engaged to take charge of delivery of the program during the second intervention season (2000-01). Compared to a baseline rate of 0.48 ACL injuries per team, the incidence during the second intervention season was 0.33 injuries per team (OR, 0.64; CI, 0.35-1.18; p=0.15).[10] However, compliance was variable and in the elite division, the risk of injury was much lower among those who completed the prevention program compared with those who did not (OR, 0.06; CI, 0.01–0.54; p<0.01).[10]

**Table 1** Prevention initiatives from 1998 through 2011

<b>Year</b>	<b>Activities</b>
1998	ACL Injury Surveillance Program started (see Box 1), no prevention program
1999	ACL Injury Prevention Study – coach-delivered
2000	ACL Injury Prevention Study intensified with physio delivery, terminated summer of 2001
2005	Launch of DVD (Achilles), intensified coach education seminars
2005	Publication of BMJ RCT [5]- reduced injuries in junior handball
2008	Launch of new website ( <a href="http://www.skadefri">www.skadefri</a> ) and DVD (Skadefri)

After the ACL Injury Prevention Study was terminated at the end of the 2000-01 season, teams were allowed to keep their equipment (balance mats, wobble boards and DVD with the exercises program), but whether or not teams chose to continue with prevention exercises depended on each team. Also, the physical therapists who took part in the intervention were no longer paid by the Oslo Sports Trauma Research Center to work with the teams. However, elite division teams and some of the first division teams had their own physical therapists who continued their regular work with the teams but there are no data on how preventive exercises were used. Our injury surveillance showed that from 2001 the ACL injury rate increased gradually to 0.56 injuries per team in the 2004-2005 season (figure 1), i.e. at least as high as before the intervention started. Interviews with the players injured during this period also revealed that few of their teams were using the prevention program (data not shown). This in contrast to the results presented in the prevention study among female football teenage girls by Kiani et al.[4] They found

that one year after the finalizing of the study 44% of the teams did use components of the prevention program, while 19% of the teams reported using the entire program.[4]

### **Insert figure 1 near here**

From these interviews with injured players, we realized that the promising findings from the ACL Injury Prevention Study, which were published in 2003, did not result in the program being implemented as a regular part of training by coaches or players. Our strategy of using physical therapists to improve compliance with the program and quality of exercise execution had been a success in the short run; however, it may have taken much of the responsibility for the player education away from the coach.

*2005: New DVD-Achilles.* To increase knowledge and improve attitudes among coaches and managers we organized a series of regional coach seminars, free of charge, in 2005. We emphasized the rationale for both prevention and performance benefits when performing this type of exercises.[8] At the end of the 2-hour seminar every attendee received a DVD including video clips of all the prevention exercises. We held seminars in Norway's 5 largest cities and approximately 500 coaches, managers (and some players) attended.

*Research exposure in peer-reviewed major medical journal:* In the same period, the results from a large randomized controlled trial from Norwegian handball by Olsen & coworkers was published in BMJ.[5] In this study of 1837 girls and boys aged 15-17 years, we tested a 20-min structured warm-up program to improve running, cutting, and landing technique as well as neuromuscular control, balance, and strength, thus building on the principles of the first program. The program reduced the risk of lower extremity injuries by 49% in the intervention group (relative risk intervention group v control group 0.51, 95% confidence interval 0.36 to 0.73), and the risk of severe knee ligament injuries was also reduced substantially compared to the control group doing regular warm-up exercises (relative risk 0.20, 95% confidence interval 0.06 to 0.70).[5]

This study received extensive media attention and was also featured in the Norwegian Handball Magazine, received by every member of the Norwegian Handball Federation. In addition, the researchers who were in contact with the coaches to interview them about knee injuries always used the opportunity to remind them of the importance of ACL prevention training.

As shown in figure 1, there was a substantial reduction in ACL injury rate after we began the information campaign from the 2005-06 season and onwards compared to the post-intervention seasons 2001-05.

*2008: New website & DVD- Skadefri.* To strengthen our knowledge translation activities, the Oslo Sports Trauma Research Center launched a new website in May 2008 ([www.skadefri.no](http://www.skadefri.no)). This has been designed to provide information on injury prevention program in a format targeting coaches and athletes, and includes videos of exercises from various prevention programs (e.g. knee, ankle, hamstring injuries). Specifically, the website displays the ACL/knee injury prevention programs developed in Norway,[5, 6, 10] but also exercise programs from other groups working in this field.[11]

### **Did teams and players use the programs?**

Since the 2005-2006 season we have included questions on self-reported compliance with the prevention exercise programs in our interviews with coaches and injured players (see Box 1 for definitions).

“However, it should be noted that compliance was self-reported by coaches and players and, as illustrated in table 2, there is a substantial discrepancy between coaches and players in their perception of compliance.” This could of course mean that in these cases, the team had a program which the injured

player did not follow, or vice versa. However, it seems more likely that compliance was overreported by coaches. Therefore we have not attempted to compare injury rate between compliant vs. non-compliant teams.

**Table 2** Compliance as reported by the coach and player (n=125)

Coach response	Player response	
	Yes	No
Yes	20	47
No	13	45

### **Our lessons, clinical implications, suggestions for sports organizations**

Our ACL Injury Surveillance Program has revealed that the ACL injury incidence among Norwegian female handball players has remained low after the introduction of various measures to promote injury prevention exercise programs (see figure 1). However, we cannot be certain if other changes may have occurred during the same period which have contributed towards lower injury rates. If anything, training loads and the intensity of the game has increased during the past 10-year period; if so, injury risk would likely have increased. However, one factor which may have changed is the quality of flooring in new gyms being built during this period, from old-style high-friction artificial floors to using modern materials with less friction.[14] Still, there are relatively few new floors, and we believe that it is unlikely that this factor alone can explain the sustained low injury rates observed during recent years.

Helping the individual make healthy choices (e.g. healthy eating, cessation of smoking, active living) is a key feature of health promotion, often combining legislative and engineering measures (e.g. laws requiring car manufacturers to put seat belts in cars) with health information (e.g. campaigns promoting their use by the individual). In sports, many of the choices which relate to injury risk are made by a coach on behalf of an individual, for good or for bad. This means that in team sports there is a unique opportunity for working with coaches to institute exercise programs to prevent injury.[15]

*Coach as a key partner:* We have tried to take advantage of the coach as a key partner in injury prevention during the past 10-year period. However, this has not been uniformly successful, as our experience from the initial phase of the ACL Injury Prevention Study showed.[10] Despite site visits to all teams where we ran practical sessions with players and teams, buy-in among coaches was variable and few teams followed the prescribed program. To rectify this, we had to engage physical therapists to follow up the prevention training, which improved compliance substantially. It is therefore not surprising that when our physical therapists withdrew from the clubs after the intervention study, follow-up by coaches was limited. In some clubs, prevention training was left to the players themselves, and there are controlled trials showing that this approach is ineffective.[16, 17]

It is therefore somewhat surprising that the various initiatives which were taken from 2005 and onwards seem to have been successful. There are several factors which may explain the sustained low ACL injury rates. First, by 2005 we had ample evidence to show that the programs developed were efficient. The data from the ACL Injury Prevention Study and the BMJ paper on junior handball had been published,[5, 10] and both studies received substantial attention, both in the media and in the handball community. Similar findings were also reported from studies in other sports and other countries. This meant that the message we delivered to coaches in seminars, through pamphlets, interviews and on our website was no longer “may reduce injury risk”, but “will reduce injury risk by at least 50%”. This ‘specific’ information meets one of the Heath Brothers’ criteria for ‘sticky’ messages - messages that have influence.[18] This may have been a decisive factor. Another may be the persistent effort to promote injury prevention over several

years, using every opportunity available, including the semiannual telephone calls to all coaches in the top three divisions.

*Lessons from other settings:* Successful injury prevention campaigns are seen in other sports. In New Zealand, rugby union has documented a large reduction in serious spinal injuries after introducing a nationwide injury prevention program, the “RugbySmart program.”[19] In a study among Swiss amateur soccer players a countrywide campaign to prevent soccer injuries was proven effective after implementing “The 11.”[20] More than 5000 coaches were trained, and 4 years later the number of injuries among teams performing “The 11” was 10.7% (matches) and 25.4% (training) lower than teams not using the program. In the South African Rugby Union “The BokSmart National Rugby Safety Programme” is aimed at safer rugby and fewer head, neck and spinal cord injuries.[21] The BokSmart programme has four main elements; a DVD-facilitated course for all coaches and referees, an entry-level rugby first aid short course aimed at training members of underprivileged rugby-playing communities, a SpineLine number assisting the head-, neck- and spine-injured rugby players to the nearest appropriate medical facility and finally the online resource [www.boksmart.com](http://www.boksmart.com), which provides researched documentation and practical advice on a variety of rugby-related topics.[21] The results from their program are not yet published; however the comprehensive nature of this initiative is promising. These and our study exemplifies the benefit of educational initiatives in injury prevention and the need for comprehensive injury surveillance systems for evaluating injury prevention initiatives in sport.[19]

In summary, the Norwegian ACL studies and our experience indicate that the ACL injury rate can be kept low through nationwide preventive initiatives and by focusing on the coach as a key partner. It still remains to understand which of our initiatives are most effective, as well as the ideal exercise prescription. Risk factor studies are necessary to identify the individual’s needs for special training and optimize the selection of preventive exercises. In the meantime, we suggest that team sports include prevention exercises in their warm-up, tailor the exercise program to the specific sport and focus on coach education as a key factor.

**Box 1.** How the data were collected

We established the ACL Injury Surveillance Program in Norwegian handball in 1998, as the basis for data collection for the ACL Injury Prevention Study, which was started the same year.[10] The surveillance covered all female teams in the top three divisions in the Norwegian Handball Federation through the 2010-2011 season (May 2011), except for the 2003-2004 season.

The Norwegian Handball Federation league system ranks the teams according to their skill level into 4 teams in most of the 6 (7) third division conferences. Each division/conference plays a double round-robin competition format from mid-September through mid-April. Two teams advance and 2 teams are relegated between divisions according to their final league standing at the end of each season. In addition, teams participate in a single-elimination cup for the Norwegian Cup Championship; teams normally also take part in other national and international tournaments throughout the season.

We contacted the team coach twice a year by phone to record any ACL injuries. Injury incidence was calculated as the number of ACL injuries reported per team per season. If the coach reported any acute knee injuries occurring during regular handball training or competition, we contacted the injured player by phone to confirm the type and severity of the injury. ACL injuries were verified by MRI and/or arthroscopy.

From 2005 we also interviewed the coach and injured players about ACL prevention training. They were categorized as “Yes” if the team (or injured player) had performed knee control exercises focusing on “hip-knee-toe” alignment, corresponding to the exercise prescription used in the ACL Injury Prevention Study. These could be balance exercises on the floor, on a balance mat or a wobble board, as well as jumping exercises with two foot landings and technique training with the same focus. The minimum training volume required was 1-2 times per week during the preseason and at least once weekly during the season. Teams (players) who responded only doing ordinary strength training were categorized as not using prevention training, as general strength training is a well-established part of the training schedule for all teams.

Table 3 shows the number of teams in each division followed between 1998 until 2011, as well as the number of ACL injuries recorded.

**Table 3** Total number of teams interviewed and number of ACL injuries recorded in the different seasons and divisions

<b>Season</b>	<b>Elite</b>	<b>1.div</b>	<b>2.div</b>	<b>Total</b>
1998-1999	12 (13)	12 (3)	36 (13)	60 (29)
1999-2000	12 (6)	13 (6)	33 (11)	58 (23)
2000-2001	12 (5)	11 (4)	29 (8)	52 (17)
2001-2002	12 (10)	13 (2)	35 (9)	60 (21)
2002-2003	14 (10)	12 (5)	43 (18)	69 (33)
2003-2004	-	-	-	-
2004-2005	12 (5)	14 (9)	44 (25)	70 (39)
2005-2006	12 (3)	14 (3)	62 (11)	88 (17)
2006-2007	12 (9)	14 (6)	64 (10)	90 (25)
2007-2008	12 (2)	12 (4)	67 (19)	91 (25)
2008-2009	12 (8)	13 (4)	63 (10)	88 (22)

2009-2010	12 (5)	14 (3)	63 (12)	89 (20)
2010-2011	12 (5)	13 (8)	68 (11)	93 (24)

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