Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial

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Abstract

Objective To investigate the effect of a structured warm-up programme designed to reduce the incidence of knee and ankle injuries in young people participating in sports.

Design Cluster randomised controlled trial with clubs as the unit of randomisation.

Setting 120 team handball clubs from central and eastern Norway (61 clubs in the intervention group, 59 in the control group) followed for one league season (eight months).

Participants 1837 players aged 15-17 years; 958 players (808 female and 150 male) in the intervention group; 879 players (778 female and 101 male) in the control group.

Intervention A structured warm-up programme to improve running, cutting, and landing technique as well as neuromuscular control, balance, and strength.

Main outcome measure The rate of acute injuries to the knee or ankle.

Results During the season, 129 acute knee or ankle injuries occurred, 81 injuries in the control group (0.9 (SE 0.09) injuries per 1000 player hours; 0.3 (SE 0.17) in training *v* 5.3 (SE 0.06) during matches) and 48 injuries in the intervention group (0.5 (SE 0.11) injuries per 1000 player hours; 0.2 (SE 0.18) in training *v* 2.5 (SE 0.06) during matches). Fewer injured players were in the intervention group than in the control group (46 (4.8%) *v* (76 (8.6%); relative risk intervention group *v* control group 0.53, 95% confidence interval 0.35 to 0.81).

Conclusion A structured programme of warm-up exercises can prevent knee and ankle injuries in young people playing sports. Preventive training should therefore be introduced as an integral part of youth sports programmes.

Introduction

Studies from Scandinavia document that sports injuries constitute 10-19% of all acute injuries seen in emergency departments. The most common types are knee and ankle injuries.[1] The highest incidence of serious knee injuries, such as injuries to the anterior cruciate ligament, is seen in adolescents playing pivoting sports such as football, basketball, and team handball. In these sports, women are three to five times more likely to contract a serious knee injury than men.

Injuries to the anterior cruciate ligament may require surgery, always entail a long rehabilitation period, and drastically increase the risk of long term sequelae.[2] Effective methods for preventing injuries therefore need to be developed.

Some studies indicate that it may be possible to reduce the incidence of knee and ankle injuries among adults and adolescents. However, these studies are small and mainly non-randomised, with important methodological limitations.

We conducted a randomised controlled trial to investigate the effect of a structured programme of warm-up exercises used to prevent acute injuries of the lower limb in young people playing sports. To minimise overlap within clubs, we used a cluster design.

Methods

All 145 clubs in the 16 year and 17 year divisions from central and eastern Norway, organised by the Norwegian Handball Federation, received an invitation to participate in the study during one eight month season (September 2002 to April 2003). Of these, 123 clubs agreed to participate, and were block randomised to an intervention or control group. To reduce potential confounding, we matched the clubs by region, playing level, and sex and number of players. Clubs allocated to the intervention group received a programme of warm-up exercises. Clubs in the control group were asked to train as usual during the season, and would receive the intervention programme at the start of the subsequent season.

Intervention

The warm-up programme was developed by medical staff from the Oslo Sports Trauma Research Center and coaching staff from the Norwegian Handball Federation. Its feasibility had been tested in four clubs during the previous season. The programme included four different sets of exercises, each of increasing difficulty.

At the start of the league season (September), clubs in the intervention group received one visit from an instructor from the handball federation, with a follow up visit midway through the season (January). The instructors had been familiarised with the programme during a two hour seminar. The clubs received an exercise book, five wobble boards and five balance mats. The coaches were asked to use the programme at the beginning of every training session for 15 consecutive sessions and then once a week during the remainder of the season.

The main focus of the exercises was to improve players' awareness and control of knees and ankles during standing, running, cutting, jumping, and landing. The programme consisted of exercises with the ball, including the use of the wobble board and balance mat, for warm up, technique, balance, and strength (see bmj.com).

The players were encouraged to be focused and conscious of the quality of their movements, with emphasis given to core stability and position of the hip and knee in relation to the foot (the "knee over toe" position). They were also asked to watch each other closely and give each other feedback during the train-

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Table 1 Intention to treat analysis. Values are numbers (percentages) of injured players

	Intervention group (n=958)	Control group (n=879)	Intracluster correlation coefficient	Inflation factor	Number needed to treat	Relative risk (95% CI)*	P value (Wald's test)
All injuries	95 (9.9)	167 (19.0)	0.043	1.6	11	0.49 (0.36 to 0.68)	<0.0001
Lower limb injuries	66 (6.9)	115 (13.1)	0.050	1.7	16	0.51 (0.36 to 0.73)	<0.001
Acute knee or ankle injuries:	46 (4.8)	76 (8.6)	0.057	1.8	26	0.53 (0.35 to 0.81)	0.004
Acute knee injuries	19 (2.0)	38 (4.3)	0.071	2.0	43	0.45 (0.25 to 0.81)	0.007
Acute ankle injuries	28 (2.9)	40 (4.6)	0.071	2.0	59	0.63 (0.36 to 1.09)	0.097
Upper limb injuries	17 (1.8)	39 (4.4)	0.071	2.0	38	0.37 (0.20 to 0.69)	0.002

*Relative risk obtained from Cox model taking into account the cluster randomisation.

ing. They were instructed to spend 4-5 minutes on each exercise group for a total duration of 15-20 minutes.

Data on injury and exposure were anonymised and reported by the physiotherapists and confirmed by the coaches. See bmj.com for definitions used in registering injuries.

Outcome measures

We defined the primary outcome as an acute injury to the knee or ankle. A secondary outcome was defined as any injury to the lower limbs. We also included secondary analyses of injuries overall (including all injuries) and injuries to the upper limb. We included all injuries reported after an intervention club had completed the first session of the training aiming to prevent injuries (and from the same date in the control clubs randomised in the same block), to compare the number of injured players and incidence of injury between the intervention group and the control group.

Ten research physiotherapists who were blinded to group allocation recorded injuries in both groups, using definitions and a standardised injury questionnaire (Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury pattern in youth team handball: a comparison of two prospective registration methods. Submitted for publication to *Scand J Med Sci Sports*).

The physiotherapists were in contact with the coaches at least every month to record injured players and exposure data. They interviewed injured players, in most cases within four weeks (range one day to four months). They were responsible for roughly the same number of clubs from each of the groups (11 to 13 clubs each).

The coaches of the clubs receiving the intervention recorded compliance on a designated form as the number of injury prevention sessions, the duration of each session in minutes, and the average attendance of the players (in per cent). At the end of the season we also obtained information on prevention training conducted by the control clubs, including the types and volume of exercises used.

Statistical methods

We used the relative risk of the number of injured players, according to the intention to treat principle, to compare the risk of an injury in the intervention and control groups. We used Cox regression for the primary and secondary outcomes, taking into account the cluster randomisation. We calculated the number needed to treat to save one injury, and exposures to training and matches and incidence of injury.

We compared the rate ratio between the two groups (intervention *v* control), sex (female *v* male), severity of injury (slight, minor, moderate, major), and club activities (match, training). See bmj.com for details.

Results

After exclusions, 61 clubs (958 players) were analysed in the intervention group and 59 clubs (879 players) in the control group. Players in the two groups were similar in sex distribution, age, and dropout rates (see bmj.com). All but eight (13%) of the clubs in the intervention group used the programme of warm-up exercises to prevent injuries during the study period. Also, 13 (22%) of the clubs in the control group used specific exercises intended to prevent injuries (including training on the balance mat and wobble board) as a part of their training.

Injury characteristics

During the eight month season, 262 (14%) of the 1837 players who were included in the study contracted a total of 298 injuries. Of these, 241 (81%) were acute injuries and 57 (19%) were overuse injuries (see bmj.com).

Effect of prevention

Significantly fewer injured players were in the intervention group than in the control group for injuries overall, lower limb injuries, acute knee or ankle injuries, and acute knee and upper limb injuries, whereas a 37% reduction in acute ankle injuries did not reach significance (table 1). The degrees of clustering at the club level (intracluster correlation coefficient) were estimated to be 0.043 to 0.071. The number needed to treat to prevent one injury varied from 11 to 59 players.

The exposure in hours for the intervention group was 93 812 (11 210 hours spent in matches, 82 602 hours in training) and in the control group 87 483 hours (10 783 hours in matches, 76 700 hours in training). Injuries overall, acute injuries, and acute knee or ankle injuries differed significantly, whereas reductions of 7-53% for slight injuries and 18-59% in minor injuries did not reach significance. The overall difference in the incidence of match and training injuries was also significant, whereas acute injuries and acute knee or ankle injuries differed only for matches (table 2). The 13 control clubs using training exercises to prevent injuries had a significantly lower incidence of injuries than the clubs in the control group doing no prevention training (rate ratio: all injuries 0.48, 95% confidence interval 0.31 to 0.73, $P<0.001$; lower limb injuries 0.35, 0.19 to 0.63; $P=0.001$; acute injuries 0.47, 0.29 to 0.76; $P=0.002$; acute knee or ankle injuries 0.22, 0.09 to 0.55; $P=0.001$). No category of injury differed by sex.

Table 2 Number of acute injuries, acute knee or ankle injuries, and incidence of injuries during matches and training. Incidence is reported as the number of injuries per 1000 player hours, with standard errors

	Intervention group (n=958)		Control group (n=879)		Rate ratio (95% CI)*	P value (z test)
	Injuries	Incidence	Injuries	Incidence		
No of acute injuries:	85	0.9 (0.08)	156	1.8 (0.06)	0.51 (0.39 to 0.66)	<0.0001
Match	53	4.7 (0.06)	111	10.3 (0.04)	0.46 (0.33 to 0.64)	<0.0001
Training	32	0.4 (0.14)	45	0.6 (0.12)	0.66 (0.42 to 1.04)	0.07
No of acute knee or ankle injuries:	48	0.5 (0.11)	81	0.9 (0.09)	0.55 (0.39 to 0.79)	0.001
Match	28	2.5 (0.06)	57	5.3 (0.06)	0.47 (0.30 to 0.74)	0.001
Training	20	0.2 (0.18)	24	0.3 (0.17)	0.78 (0.43 to 1.41)	0.41

*Rate ratio obtained from Poisson model.

Discussion

The rate of injuries in adolescent athletes using a structured warm-up programme as a part of their training improved clinically and statistically, especially the rate of severe injuries to the knee and ankle. The reduction in the relative risk is highly significant and has been adjusted for the cluster sampling. As far as we are aware, our study is the first randomised controlled trial among adolescents with a sufficient sample size to show that acute knee or ankle injuries can be reduced by 50% and severe injuries even more.

Data validation

The trial had good external and internal validity, and our method of injury and exposure registration should ensure good reliability and validity of these data, and also good reliability for comparing the data between the intervention and the control groups.

Compliance

We found considerably higher compliance (87%) among the youth clubs compared with 29% in a similar non-randomised study of adult players.[3] This study, and also our intervention study, may have motivated some of the youth clubs to include exercises to prevent injuries as part of their training programme, as evidenced by the crossover observed in 22% of the control clubs; these clubs also had a significantly lower incidence of injuries than the other control clubs.

Not all clubs continued to use the programme of warm-up exercises after the initial intensive introduction period. Since we used an intention to treat analysis, the effect of the programme may therefore be even higher.

Structured programme of warm-up exercises to prevent injuries

The exercises used in the programme were developed on the basis of previous intervention studies in team handball[3 4] and other sports,[5–7] and had been feasibility tested and modified to be suitable for team handball. The focus on alignment of the hip, knee, and ankle—especially the knee over toe position—was supported by data from Ebstrup and Bojsen-Moller[8] and Olsen et al.[9] The programme focused on the proper technique for planting and cutting movements, aiming at a narrower stance as well as a knee over toe position. Another programme of balance and cutting exercises focusing on knee control, found that dynamic balance was improved and maintained for at least 12 months.[10] A static balance training programme using a balance board has also shown a substantial decrease in the rate of injuries to the anterior cruciate ligament.[5]

The prevention programme that we tested is multifaceted and it is not possible to determine exactly which part of the programme may be effective. Our programme also focused on landing on both legs after jumps rather than just one leg, and with an emphasis on increased hip and knee flexion. The programme also included a strength exercise, the "Nordic hamstring lower" exercise. Since the hamstrings can act as agonists to the anterior cruciate ligament during stop and jump tasks, it is possible that stronger hamstring muscles can prevent injuries to the ligament, but this theory has never been tested.

Generalisability

Our result indicates that the youth elite as well as intermediate and recreational players would benefit from using the warm-up programme to prevent injuries. We do not know if the results can be generalised to other age groups or to other youth sports such as football, basketball, or volleyball. However, these sports have a high incidence and similar pattern of knee and ankle injuries, and the injury mechanisms are also compara-

What is already known on this topic

Sports injuries constitute 10-19% of all acute injuries treated in emergency departments, with injuries to the knee and ankle the most common types

The risk of serious knee injuries, such as injuries to the anterior cruciate ligament, is high among adolescents playing pivoting sports such as football, basketball, or team handball

It may be possible to reduce the incidence of knee and ankle injuries among young people, but studies showing this have been small and mainly non-randomised, with significant methodological limitations

What this study adds

A structured warm-up programme designed to improve awareness and knee and ankle control during landing and pivoting movements prevents knee and ankle injuries among youth athletes

The incidence of knee and ankle injuries can be reduced by at least 50%

Preventive training should be routine in training programmes for adolescents in pivoting sports

ble (most injuries resulting from pivoting and landing movements). It seems reasonable to assume that the prevention programme also could be modified for these sports. We also suggest that programmes focusing on technique (cutting and landing movements) and balance training (on wobble boards, mats or similar equipments) are implemented in players as young as 10-12 years, before they have established their motion patterns.

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Ethical approval: Ethical approval was not required by the regional committee for medical research ethics.

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Reproduction of chest pain by palpation: diagnostic accuracy in suspected pulmonary embolism

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Introduction

Chest pain associated with pulmonary embolism is usually sharp and worsens with deep inspiration, cough, and movement, resulting from pleural inflammation in peripheral emboli (pleuritic pain).[1] Conversely, chest pain that is reproduced by palpation is thought to be caused by pathology of the musculoskeletal chest wall and may prompt clinicians to discard pulmonary embolism as the cause, although cases of pulmonary embolism with isolated pain in the chest wall have been described.[2] Managing patients with chest pain is challenging because signs and symptoms of pulmonary embolism lack specificity, because it requires ruling out other life threatening conditions, and because a sizeable proportion of patients have musculoskeletal or pleural syndromes that require symptomatic treatment only.[3] We assessed whether chest pain that can be reproduced by palpation is likely to be more indicative of an absence of pulmonary embolism than chest pain caused by breathing, cough, or movement.

Participants, methods, and results

We analysed a database of consecutive outpatients included in a prospective management study that was designed to validate a diagnostic strategy for suspected pulmonary embolism.[4] Suspicion of pulmonary embolism was defined as acute onset of new or worsening shortness of breath or chest pain without another obvious aetiology. The study took place in Geneva and Lausanne University Hospitals, Switzerland, and Angers University Hospital, France, between October 2000 and June 2002. Exclusion criteria (n = 258) were ongoing treatment with coagulants, allergy to contrast iodine agents, creatinine clearance below 30 ml/minute, pregnancy, and life expectancy of less than three months. All patients gave informed consent. Before any test, the doctors in charge used eight variables to assess patients in the emergency ward on the basis of a validated prediction rule (the Geneva score): recent surgery, previous thromboembolism, age, hypocapnia, hypoxaemia, tachycardia, band atelectasis, and hemidiaphragm elevation on chest x ray.[5] The doctors completed a standardised data form. Chest pain was recorded, and doctors were asked to specify whether or not it was reproduced by palpation.

Prevalence of pulmonary embolism according to the presence of reproducible chest pain

	Pulmonary embolism (n=222)	No pulmonary embolism (n=743)
Chest pain reproduced by palpation (n=191)	38	153
No chest pain reproduced by palpation (n=774)	184	590

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