NIH NORWEGIAN SCHOOL OF SPORT SCIENCES

This file was dowloaded from the institutional repository Brage NIH - brage.bibsys.no/nih

Andersson, S. H., Bahr, R., Clarsen, B., Myklebust, G. (2016). Preventing overuse shoulder injuries among throwing athletes: a cluster-randomised controlled trial in 660 elite handball players. *British Journal of Sports Medicine*, under utgivelse. doi:10.1136/bjsports-2016-096226

Dette er siste tekst-versjon av artikkelen, og den kan inneholde små forskjeller fra forlagets pdf-versjon. Forlagets pdf-versjon finner du på bjsm.bmj.com: http://dx.doi.org/10.1136/bjsports-2016-096226

This is the final text version of the article, and it may contain minor differences from the journal's pdf version. The original publication is available at bjsm.bmj.com: http://dx.doi.org/10.1136/bjsports-2016-096226

PREVENTING OVERUSE SHOULDER INJURIES AMONG ELITE THROWING ATHLETES:

A CLUSTER RANDOMISED CONTROLLED TRIAL IN 660 ELITE HANDBALL PLAYERS

Stig Haugsboe Andersson, Roald Bahr, Benjamin Clarsen, Grethe Myklebust

Corresponding Author

Stig Haugsboe Andersson
Oslo Sports Trauma Research Center
Department of Sports Medicine
Norwegian School of Sport Sciences
Email: s.h.andersson@nih.no

Co-authors

Roald Bahr
Oslo Sports Trauma Research Center
Department of Sports Medicine
Norwegian School of Sport Sciences, Oslo, Norway

Benjamin Clarsen
Oslo Sports Trauma Research Center
Department of Sports Medicine
Norwegian School of Sport Sciences, Oslo, Norway

Grethe Myklebust
Oslo Sports Trauma Research Center
Department of Sports Medicine
Norwegian School of Sport Sciences, Oslo, Norway

Keywords

Sports injury prevention
Throwing athletes
Overuse shoulder injuries

Word count: 4 102

ABSTRACT

Objective To evaluate the effect of a comprehensive exercise program designed to reduce the prevalence of shoulder problems in elite handball.

Design Stratified cluster-randomised controlled trial with teams as the unit of randomisation.

Setting 45 handball teams (22 female, 23 male) from the two upper divisions in Norway (22 in the intervention group, 23 in the control group) were followed for one competitive season (7 months).

Participants 660 players aged 16-47 (331 in the intervention group, 329 in the control group).

Intervention Ten-minute comprehensive exercise program to increase glenohumeral internal rotation, external rotation strength and scapular control, as well as improve kinetic chain and thoracic mobility, to be delivered by coaches and team captains three times per week as a part of the handball warm-up throughout the season.

Main outcome measures Prevalence of shoulder problems and substantial shoulder problems.

Results The average prevalence of shoulder problems during the season was 17% (95% CI: 16% to 19%) in the intervention group and 23% (95% CI: 21% to 26%) in the control group (mean difference: 6%). The average prevalence of substantial shoulder problems was 5% (95% CI: 4% to 6%) in the intervention group and 8% (95% CI: 7% to 9%) in the control group (mean difference: 3%). Using generalized estimating equation models, a 28% lower risk of shoulder problems (OR 0.72, 95% CI: 0.52 to 0.98, p=0.038) and 22% lower risk of substantial shoulder problems (OR 0.78, 95% CI: 0.53 to 1.16, p=0.23) was observed in the intervention group compared to the control group.

Conclusion A comprehensive exercise program reduced the prevalence of shoulder problems in elite handball.

Trial registration Controlled-trials ISRCTN96217107

INTRODUCTION

Shoulder injuries, predominantly from overuse, have been reported to be highly prevalent in a wide variety of throwing sports,[3-14] where the shoulder is exposed to large demands due to repeated overhead motion at high velocity.[1 2] Thrower's shoulder is a widely used term, referring to a range of different symptoms commonly experienced by throwers, as well as a range of pathologies observed in their dominant shoulder.[1 2 15] The main symptom is deep shoulder pain, often difficult to localize. Symptoms often occur in the late cocking phase of the throwing motion, when the glenohumeral joint is abducted and external rotated. Painful clicking and catching can also be present during the throwing motion, in addition to reduced velocity and accuracy of the throw. Symptom onset is in most conditions gradual.[1 2 15]

Several studies have investigated internal modifiable risk factors for shoulder injury among throwing athletes. Reduced glenohumeral joint range of motion, weakness in glenohumeral external rotation and low ratios of external to internal rotation strength have been linked to injury among both baseball and handball players.[3-6 16-21] Reduction in glenohumeral abduction strength has been associated with shoulder injury among baseball pitchers,[6] and recently scapular dyskinesis was linked to injury among elite male handball players.[3] In addition, reduced kinetic chain function and limited thoracic mobility are commonly proposed risk factors, although there is a lack of evidence associating them with shoulder injury.[22 23]

There are no randomised controlled trials targeting prevention of overuse shoulder injuries in elite throwing athletes.[24] Thus, the main objective of this randomised controlled trial was to evaluate the effect of a comprehensive exercise program designed to reduce the prevalence of shoulder problems, using handball as a model.

METHODS

Study design and participants

This was a two-armed cluster-randomised controlled trial. During the off-season (June to July 2014) we invited every male and female handball team (n=48) in the two top divisions in

Norway to participate in the study. Of these, 46 teams agreed to participate and were randomised by team into an intervention or control group, stratified by gender and competition level. A neutral, blinded person who had no further involvement in the study conducted the randomisation after the final team had been recruited.

We visited each team (n=46) during a training session in the pre-season (August to mid September 2014) and invited every player present to participate in the study. All players with a team contract were eligible for participation, irrespective of their baseline injury status or history (N=677). Players who consented to participate completed baseline questionnaires and were followed for the duration of the regular season (September 2014 through March 2015). Six times during the season, players reported any shoulder problems using the Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire,[25] as described in a previous study on risk factors for shoulder problems among male elite handball players.[3] During our baseline visit, we instructed teams in the intervention group on how to use the prevention program, to be implemented the subsequent week. We asked control teams to warm up as usual. Player participation was voluntary and we obtained written informed consent.

Baseline questionnaires

We registered demographic and anthropometric data, dominant arm, playing position and number of years as an active handball player. Players reported history of shoulder pain and current shoulder pain using a modified version of the Fahlström questionnaire, previously used in studies on elite handball players.[3 7] Players reported acute shoulder injuries within the last six months and shoulder surgery within the last 12 months. This information was crosschecked with the team medical staff. Finally, we asked them to report any shoulder problems during the previous weeks using the OSTRC Overuse Injury Questionnaire.[25]

Intervention

We created a preliminary version of the comprehensive exercise program based on risk factors for shoulder problems identified among elite handball players.[3 17 21] An expert panel consisting of a fitness coach employed by the Norwegian Handball Federation and four physiotherapists working with handball players nationally and internationally reviewed the

program. A female handball team in a lower division, not included in the study, tested the program and responded to a questionnaire based on the RE-AIM framework to provide information regarding their beliefs and experiences of content, duration, load and applicability of the program.[26 27]

The final version of the OSTRC Shoulder Injury Prevention Program consisted of five exercises with different variations and levels, aiming at reducing the prevalence of shoulder problems by increasing glenohumeral internal range of motion, external rotation strength and scapula control. In addition, exercises to improve the kinetic chain and thoracic mobility were included, based on recommendations from the expert panel. Examples of exercises included in the program are illustrated in figure 1. Detailed information on the prevention program is available as an online appendix.

Figure 1

Players in the intervention group were targets for the prevention program and coaches and team captains were delivery agents. We recommended implementing the program as a part of the team's regular warm-up, before any throwing activity. We emphasised the quality of movement, correct positioning of the scapula, centralisation of the head of the humerus in the glenoid, good posture and core stability. Teams received posters of the program, as well as the equipment needed. Team medical staff supervised the quality of the exercises and ensured that players experiencing pain conducted the exercises correctly and with the correct load. If a team did not have their own medical staff, we recruited a physiotherapist. We completed follow-up visits to all teams in the prevention group during the mid-season (December 2015 through January 2016) to supervise exercise quality, answer questions and encourage them to complete the program as recommended. Once players were familiar with the exercises, the program took about 10 min to complete.

Monitoring of shoulder problems

The OSTRC Overuse Injury Questionnaire was sent electronically by mail to all players in the study the last Sunday of each month from October 2014 through March 2015, six times in total, using online survey software (Questback V. 9692, Questback AS, Oslo, Norway).

Automatic reminders were sent to non-responders after three and seven days per email and SMS (Pling, Front Information DA, Oslo, Norway). In addition, we visited teams throughout the season to ensure a high response rate by asking non-responders to complete the questionnaire on paper. The questionnaire gathers information on to which extent overuse shoulder injuries, expressed as shoulder problems, affect participation, training volume and performance, as well as the level of shoulder pain experienced during the past week. Players were only asked about their dominant shoulder, with shoulder problems defined as any pain, ache, stiffness, instability, looseness or other complaints related to their shoulder.[25] In addition, players reported any acute injury to the dominant shoulder during the past week, defined as an injury caused by a single, identifiable event.[28 29] Team medical staff also reported any acute shoulder injury by mail at the end of each month (October 2014 to March 2015) and their records were crosschecked with player reports to avoid misreporting of an acute shoulder injury as an overuse injury. Acute injuries were excluded from the analyses.

Outcome measures

Primary outcomes were the prevalence of shoulder problems and substantial shoulder problems in the dominant arm, as measured six times during the season. We calculated the prevalence of shoulder problems in both groups by dividing the number of players who reported any problem (i.e. anything but the minimum value in any of the four questions) by the number of questionnaire respondents.[25] To filter problems with fewer functional consequences, we calculated the prevalence of substantial shoulder problems in the same way, but only including shoulder problems leading to moderate or severe reductions in training volume or performance, or a total inability to participate.[25] Secondary outcome was the severity score of shoulder problems reported during the season. The severity score ranged from 0 to 100 and was calculated on the basis of the four questions in the OSTRC Overuse Injury Questionnaire for every player reporting a shoulder problem.[25] The severity scores for all players were summed and divided by the number of respondents. In addition, we calculated the relative impact of shoulder problems in both groups by summing player severity scores during the season and dividing by the total number of responses.

Compliance

We monitored to which degree the players in the prevention group completed the prevention program according to our recommendations through self-reporting. Six times during the season, players reported how many times they had completed the program during the last seven days, both with the team and by themselves. The total number of sessions completed was summed and divided by the number of respondents to calculate the average weekly compliance with the program for each measure.

Exposure

Players reported their exposure to handball training, match play and additional strength training six times during the season. We calculated the average weekly exposure to handball training, match play and strength training (minutes) for each measure in both groups by summing up the number of minutes reported and dividing by the number of respondents.

Player involvement

No players were involved in setting the research question or the outcome measures, nor were they involved in developing plans for recruitment or design. No players were asked to advise on interpretation or writing up of results. We will disseminate the program and results of the study directly to athletes and coaches using digital tools such as our free Get Set - Train Smarter smartphone application and corresponding injury prevention website. In addition, the results will be disseminated through national and international sports governing bodies (The International Olympic Committee and relevant International Federations).

Sample size

We estimated the sample size on the basis of the average prevalence of shoulder problems (28%) and substantial shoulder problems (12%) reported in a prospective risk factor study of shoulder problems among male elite handball players.[3] We adjusted for cluster correlations (estimated ICC <0.1) based on ANOVA of within-subject and within-team prevalence, and assumed that we could include 15 players from each of the 48 available teams (n=720). Based on this, we estimated to be able to detect a 10% reduction in the prevalence of

shoulder problems with a power of 0.94, and a 6% reduction with a power of 0.87, at a 5% significance level.

Statistical methods

A priori, we set three responses to the OSTRC Overuse Injury Questionnaire as a minimum to include a player in the analyses. Initial data analyses showed that player response to the questionnaire was sufficient to estimate missing values using multiple imputations. We performed multiple imputations with the assumption of missing at random and used multivariate imputation by chained equation algorithm in combination with a predictive mean matching approach, which led to the pooled results of five multiple imputed datasets.[30] In order to assess differences in the prevalence of shoulder problems and substantial shoulder problems between the intervention and control groups over time, we used generalized estimating equations (GEE) models.[31] We used an exchangeable covariance matrix and the significance level (α) was 0.05 for all analyses. Any anthropometric or demographic variables showing a possible difference between groups at baseline ($p<0.2$) was added to the GEE models using a forward selection procedure. However, as we identified no confounding effects, univariate analyses were performed. All analyses were performed using SPSS statistical software (SPSS V.21, IBM Corporation, New York, USA).

RESULTS

Participants

A total of 22 prevention teams (n=331) and 23 control teams (n=329) entered the study, with no group differences in gender or competition level. Dropout during the study and the numbers included in the analyses are shown in figure 2. The male players in the intervention group were younger compared to the control group, with no other group differences in anthropometrics or demographics (Table 1). Players reported to have played handball for an average of 14 yrs (SD 5, range 4 to 37). The majority were right handed (78%). There were no group differences in playing position, with 40% backs, 24% wings, 14% line players, 13% goalkeepers and 7% reporting multiple positions.

Figure 2

Table 1 Age, height and body mass by gender for both groups. Results are shown as the mean (SD).

	Intervention (n=331)		Control (n=329)	
Characteristics	Female (n=160)	Male (n=171)	Female (n=161)	Male (n=168)
Age (yrs)	22.5 (4.2)	*21.9 (3.7)**	21.6 (3.3)	*23.5 (4.8)**
Height (cm)	173.6 (5.7)	187.8 (7.1)	173.2 (5.8)	188.6 (6.8)
Body mass (kg)	70.0 (7.6)	88.8 (7.1)	70.1 (7.6)	91.0 (12.4)

*p<0.05 intervention vs. control group.

Shoulder pain and problems at baseline

At the time of inclusion, 145 players (45%) in the intervention group and 155 players (48%) in the control group reported a history of shoulder pain during the previous handball season. Current shoulder pain was reported by 93 players (29%) in the intervention group and 96 players (30%) in the control group. At baseline, 155 players (47%) in the intervention group and 156 players (48%) in the control group reported a shoulder problem during the previous seven days based on the OSTRC Overuse Injury Questionnaire. Of these, 45 players (14%) in the intervention group and 46 players (14%) in the control group reported a substantial shoulder problem. There were no group differences in the prevalence of shoulder pain or problems reported at baseline.

Shoulder injuries and surgery at baseline

Five players (1.6%) in the intervention group and 7 players (2.2%) in the control group reported an acute shoulder injury within the last six months; however, all participated in normal handball activity. Team medical staff confirmed this and specified the diagnoses: two SLAP lesions and three anterior shoulder dislocations in the intervention group and six SLAP lesions and one anterior dislocation in the control group. One player (0.3%) in the intervention group and two players (0.6%) in the control group had undergone shoulder surgery within 12 months before baseline; however, all three were participating in normal handball activity. There were no group differences in the prevalence of acute shoulder injuries or surgery reported at baseline.

Response rate

The average response rate for the OSTRC Overuse Injury Questionnaire was 87% (range 84 to 93%) in the intervention group, and 85% (range 82 to 87%) in the control group. Complete injury data were available from 57% and 65% of the players in the intervention and control group, respectively. Eighty per cent (n=264) of the players in the intervention group and 82% (n=270) in the control group met the a priori criteria of at least three responses. Female players had a higher response rate, with no group differences between the intervention (90%) and control groups (89%). The average response rate for the exposure data was 67% (range 58 to 79%) in the intervention group and 49% (range 30 to 67%) in the control group. The average response rate for the compliance data in the intervention groups was similar to the injury data, 87% (range: 84 to 92%).

Exposure

There were no group differences in the average weekly exposure to handball training or match play (Table 2). However, the players in the control group reported to have completed 17 more min of strength training per week on average (p=0.004).

Table 2 Average weekly exposure to handball training, match play and strength training in both groups. Data are shown in minutes with 95% confidence intervals.

Activity type	Intervention (n=331)	Control (n=329)
Handball training	366 (336-395)	371 (349-393)
Match play	32 (27-36)	34 (29-38)
Strength training	*83 (79-87)**	*100 (94-108)**

*p<0.05 intervention vs. control group.

Compliance

On average, the OSTRC Shoulder Injury Prevention Program was completed 1.6 times per week (range 1.4 to 1.8) in the intervention group, 53% of the 3 times recommended. Twenty-one players (7%) did not complete the program at all during the season. Seventy-nine players (28%) reported an average compliance of between 0.1 to 1.0, 91 players (32%) between 1.1 and 2.0, and 90 players (32%) >2.0 sessions per week. The average compliance

per week did not differ between players without shoulder problems compared to players with shoulder problems at baseline (1.57 vs 1.60, p=0.791).

Acute shoulder injuries

A total of 20 and 13 acute injuries were reported in the intervention and control group, respectively, corresponding to an average prevalence of acute shoulder injuries throughout the season of 1.4 % (95% CI: 0.8 to 1.9%) in the intervention group and 0.9% (95% CI: 0.5 to 1.2%) in the control group (mean difference 0.5%). These injuries were excluded from the following analysis examining the effect of the prevention program.

Effect of the intervention

The average prevalence of overuse shoulder problems during the season was 17% (95% CI: 16% to 19%) in the intervention group and 23% (95% CI: 21% to 26%) in the control group (mean difference: 6%). The average prevalence of substantial shoulder problems was 5% (95% CI: 4% to 6%) in the intervention group and 8% (95% CI: 7% to 9%) in the control group (mean difference: 3%). The six prevalence measures in both groups are illustrated in figure 3. GEE analysis revealed 28% lower risk of reporting shoulder problems over time in the intervention group compared to the control group (OR 0.72, 95% CI: 0.52 to 0.98, p=0.038). We did not detect a significant difference in the risk of reporting substantial shoulder problems over time between the intervention and control groups (OR: 0.78, 95% CI: 0.53 to 1.16, p=0.23).

Figure 3

Within the intervention group, compliance did not influence the risk of shoulder problems (Table 3). However, players in the intervention group who reported an average compliance of at least 0.1 sessions per week (n=248) had a 69% lower risk of reporting substantial shoulder problems than players reporting zero compliance (n=16) (OR: 0.31, 95% CI: 0.15 to 0.67, p=0.003).

Table 3 GEE model including players in the intervention group meeting the a priori criteria of sufficient injury data (n=264). Players reporting zero completed sessions during the season represent the reference group (n=16).

Compliance group (sessions/week)	n	Shoulder problem			Substantial shoulder problem		
		OR	(95% CI)	P value	OR	(95% CI)	P value
0.1-1.0	77	0.49	(0.20-1.21)	0.125	0.36	(0.16-0.82)	0.02
1.1-2.0	88	0.69	(0.27-1.75)	0.435	0.25	(0.10-0.60)	0.002
>2.0	83	0.58	(0.22-1.52)	0.271	0.35	(0.15-0.82)	0.02

The average severity score of the shoulder problems reported was 29 (95% CI: 28 to 31) in the intervention group and 35 (95% CI: 32 to 37) in the control group (mean difference: 5). The relative impact of shoulder problems was 64% lower in the intervention group (intervention group: 5.2 vs control group: 8.1).

GEE models including only players with shoulder problems at baseline revealed a 35% lower risk of reporting shoulder problems in the intervention group than the control group (OR: 0.65, 95% CI: 0.43 to 0.98, p=0.04). However, we detected no significant difference in the risk of reporting substantial shoulder problems between groups (OR: 0.86, 95% CI: 0.51 to 1.45, p=0.58). When only including players without shoulder problems at baseline, we identified no significant group difference in the risk of reporting shoulder problems (OR: 0.80, 95% CI: 0.47 to 1.37, p=0.42) or substantial shoulder problems (OR: 0.68, 95% CI: 0.36 to 1.31, p=0.25) during the season.

Unintended effects

No severe shoulder injuries were reported due to completion of the prevention program in the intervention group. However, at the start of the study a few coaches reported some cases of players experiencing muscle soreness after completing the prevention program.

DISCUSSION

Our main finding was that a 10-minute comprehensive exercise program, the OSTRC Shoulder Injury Prevention Program, reduced the prevalence of shoulder problems and substantial shoulder problems among elite handball players; the odds of reporting shoulder problems during the competitive season was 28% lower in the intervention group.

This is the first randomised controlled trial investigating a program designed to reduce overuse shoulder injuries in elite throwing athletes,[24] although similar observations were reported from a 6-month pilot study with 53 female junior handball players (three teams) in the intervention group.[32] They found that the prevalence of shoulder complaints decreased significantly during the intervention period among players completing specific shoulder-strengthening exercises. The program was completed as a part of the warm-up three times per week and consisted of three exercises, push-up plus, standing glenohumeral internal and external rotation with elastic band as resistance, similar to exercises included in the current study.

The prevention program evaluated in this trial is comprehensive and includes exercises to improve glenohumeral rotation, external rotation strength and scapula control, all suggested to be included in prevention programs for shoulder problems.[3 17 21] In addition, the exercises target the kinetic chain and thoracic mobility, despite a lack of risk factor studies investigating their relation to shoulder injuries among throwing athletes. However, both the expert panel involved in the development process and the literature highlighted these factors.[2 3 23 33] For practical reasons, we did not conduct baseline or follow up testing to examine the effect of the program on the risk factors targeted.

No clear dose-response relationship was identified. However, players within the intervention group actually performing the prevention program had 69% lower odds of reporting substantial shoulder problems compared to players not performing the program in the intervention group. Sub-analyses including only players with a self-reported shoulder problem at baseline revealed 35% significantly lower odds of reporting shoulder problems during the season in the intervention group. In contrast, we found no significant effect of the

program when including only players without a shoulder problem at baseline, even if their compliance was as good as among players with shoulder problems at baseline.

Methodological considerations

A major strength of this trial is the use of cluster randomisation to avoid crossover effects between the intervention and control groups. We also stratified for gender and competition level to ensure that groups were comparable. An injury surveillance method recently developed and validated to study overuse injuries was employed, to capture the true extent of shoulder problems.[25 34] Parallel registration of acute shoulder injuries was done by players and team medical staff to avoid misreporting of acute injuries as overuse injuries. This allowed us to assess the effect of the prevention program on the prevalence of overuse problems alone. However, a limitation of the injury registration method is the lack of detailed diagnostic information on each case. Our definition of a shoulder problem encompasses all physical complaints and may have multiple causes, such as subacromial and internal impingement, tendon pathology, glenoid labrum injuries, glenohumeral joint instability and acromioclavicular joint dysfunction.[1 2 15 35] The effect of the prevention program reported in this trial may differ between these; we were unable to discriminate such relationships.

Traditionally, injury prevention studies exclude players injured at baseline and only record new cases throughout the study, with incidence as the measure for risk. Applying such an approach in the current trial would be inappropriate. First, excluding players reporting a shoulder problem at baseline would have resulted in a biased study population, not representative of athletes from throwing sports, where shoulder problems are very common. Therefore, we included all players participating in normal handball activity, irrespective of their baseline injury status or history. Second, overuse shoulder problems are often chronic, with periods of remission and exacerbation. Only a handful of the cases reported in this trial represented first-time problems. Therefore, the proportion of players affected by shoulder problems at any given time, the population prevalence, is a more appropriate measure of the magnitude of the problem.[34]

The prevalence of shoulder problems reported in the control group is lower than in a recent study on risk factors for shoulder problems among male elite handball players using the same injury registration method,[3] possibly due to a crossover effect. Before agreeing to participate in the study and before the randomisation process, all coaches and players received the same information about the study, both orally and in writing. This may have increased the awareness of shoulder problems in the control group, even though we encouraged them to train as usual. We had no control of whether the control group performed exercises similar to our prevention program. In fact, the control group reported a doing more strength training than the intervention group, possibly because they replaced the prevention program with additional strength training. Nevertheless, any bias arising from contamination would result in an underestimation of the preventive effect reported in this trial.

Simple comparison of prevalence measures between the intervention and control group revealed a lower average prevalence of shoulder problems and substantial shoulder problems reported during the season in the intervention group. The main benefits of this comparison are that it is easy to calculate and takes into account all available injury data. It is, however, made on crude summary measures of prevalence and does not account for change over time, confounding or missing. A high response rate and sufficient completeness of injury data allowed us to address missing using multiple imputation techniques and perform GEE analysis to include players meeting our a priori criteria of at least three responses to the OSTRC Overuse Injury Questionnaire. The GEE is a more robust analysis which accounts for repeated measures and allowed us to compare changes in prevalence of shoulder problems between the intervention and control group over time, revealing a significantly lower odds of reporting shoulder problems in the intervention group. However, we underestimated the number of players needed to establish the effects of the program on substantial shoulder problems.

Baseline demographics, anthropometrics or injury status/history of injury had no confounding effect on the comparison of prevalence of shoulder problems or substantial shoulder problems between groups over time. However, a limitation of our GEE analysis was the inability to include player exposure as a potential confounder, due to a lower response

rate for the exposure data, although we found no difference in the reported exposure to handball training or match play between groups.

Implications

Our results suggest that a comprehensive exercise program targeting glenohumeral internal rotation, external rotation strength, scapular control, kinetic chain and thoracic mobility should be included as a part of the general warm-up. We used male and female handball players from the two upper divisions as our model, as this is the largest homogenous sample of throwing athletes available in Norway. Whether the preventive effect observed in this trial can be generalised to other throwing athletes is not known. However, the internal modifiable risk factors associated with shoulder problems in other throwing sports are similar to handball.[3-6 16-21] It therefore seems reasonable to assume that the OSTRC Shoulder Injury Prevention Program could benefit other throwing athletes, as well.

ACKNOWLEDGEMENTS

The authors would like to thank A Aune, A Skjølberg, C Skovly, D Major, E E Eriksen, H K Vileid, K Røed, K Søderstrøm, M Fagerheim, M J Olsen, O T Østvold, R M Kristensen and R Nesje for their assistance in data collection. We also thank all players and coaches who participated in the study, as well as the team medical staff. The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport, and Norsk Tipping AS.

CONTRIBUTORS

All authors contributed to project planning, data collection and manuscript preparation. SA was responsible for data analysis. SA is responsible for the overall content as the guarantor.

FUNDING

This study received no specific funding.

COMPETING INTERESTS

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

ETHICAL APPROVAL

The South-Eastern Norway Regional Committee for Research Ethics approved the study. Participation was voluntary and we obtained individual written informed consent from players or guardians.

TRANSPARENCY

The lead author (the manuscript´s guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

DATA SHARING

All data are available upon request.

REFERENCES

1. Wilk KE, Obma P, Simpson CD, et al. Shoulder injuries in the overhead athlete. J Orthop Sports Phys Ther 2009;**39**(2):38-54.
2. Kibler WB, Kuhn JE, Wilk K, et al. The disabled throwing shoulder: spectrum of pathology-10-year update. Arthroscopy 2013;**29**(1):141-61 e26.
3. Clarsen B, Bahr R, Andersson SH, et al. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study. Br J Sports Med 2014.
4. Shanley E, Kissenberth MJ, Thigpen CA, et al. Preseason shoulder range of motion screening as a predictor of injury among youth and adolescent baseball pitchers. J Shoulder Elbow Surg 2015;**24**(7):1005-13.

5. Shanley E, Rauh MJ, Michener LA, et al. Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. Am J Sports Med 2011;**39**(9):1997-2006.
6. Byram IR, Bushnell BD, Dugger K, et al. Preseason shoulder strength measurements in professional baseball pitchers: identifying players at risk for injury. Am J Sports Med 2010;**38**(7):1375-82.
7. Myklebust G, Hasslan L, Bahr R, et al. High prevalence of shoulder pain among elite Norwegian female handball players. Scand J Med Sci Sports 2011.
8. Lyman S, Fleisig GS, Andrews JR, et al. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. Am J Sports Med 2002;**30**(4):463-8.
9. Moller M, Attermann J, Myklebust G, et al. Injury risk in Danish youth and senior elite handball using a new SMS text messages approach. Br J Sports Med 2012;**46**(7):531-7.
10. Giroto N, Hespanhol Junior LC, Gomes MR, et al. Incidence and risk factors of injuries in Brazilian elite handball players: A prospective cohort study. Scand J Med Sci Sports 2015.
11. Krajnik S, Fogarty KJ, Yard EE, et al. Shoulder injuries in US high school baseball and softball athletes, 2005-2008. Pediatrics 2010;**125**(3):497-501.
12. Lyman S, Fleisig GS, Waterbor JW, et al. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. Med Sci Sports Exerc 2001;**33**(11):1803-10.
13. Sauers EL, Dykstra DL, Bay RC, et al. Upper extremity injury history, current pain rating, and health-related quality of life in female softball pitchers. J Sport Rehabil 2011;**20**(1):100-14.
14. Ranson C, Gregory PL. Shoulder injury in professional cricketers. Phys Ther Sport 2008;**9**(1):34-9.
15. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. Arthroscopy 2003;**19**(4):404-20.
16. Wilk KE, Macrina LC, Fleisig GS, et al. Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. Am J Sports Med 2011;**39**(2):329-35.
17. Almeida GP, Silveira PF, Rosseto NP, et al. Glenohumeral range of motion in handball players with and without throwing-related shoulder pain. J Shoulder Elbow Surg 2013;**22**(5):602-7.
18. Myers JB, Laudner KG, Pasquale MR, et al. Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. Am J Sports Med 2006;**34**(3):385-91.
19. Ruotolo C, Price E, Panchal A. Loss of total arc of motion in collegiate baseball players. J Shoulder Elbow Surg 2006;**15**(1):67-71.
20. Trakis JE, McHugh MP, Caracciolo PA, et al. Muscle strength and range of motion in adolescent pitchers with throwing-related pain: implications for injury prevention. Am J Sports Med 2008;**36**(11):2173-8.
21. Edouard P, Degache F, Oullion R, et al. Shoulder strength imbalances as injury risk in handball. Int J Sports Med 2013;**34**(7):654-60.
22. Kibler WB, Ludewig PM, McClure PW, et al. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the 'scapular summit'. Br J Sports Med 2013.

23. Lintner D, Noonan TJ, Kibler WB. Injury patterns and biomechanics of the athlete's shoulder. Clin Sports Med 2008;**27**(4):527-51.
24. Lauersen JB, Bertelsen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. Br J Sports Med 2014;**48**(11):871-7.
25. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology. Br J Sports Med 2012.
26. Donaldson A, Finch CF. Planning for implementation and translation: seek first to understand the end-users' perspectives. Br J Sports Med 2012;**46**(5):306-7.
27. Finch CF, White P, Twomey D, et al. Implementing an exercise-training programme to prevent lower-limb injuries: considerations for the development of a randomised controlled trial intervention delivery plan. Br J Sports Med 2011;**45**(10):791-6.
28. Fuller CW, Molloy MG, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. Clin J Sport Med 2007;**17**(3):177-81.
29. Timpka T, Alonso JM, Jacobsson J, et al. Injury and illness definitions and data collection procedures for use in epidemiological studies in Athletics (track and field): consensus statement. Br J Sports Med 2014;**48**(7):483-90.
30. van Buuren S. *Flexible Imputation of Missing Data*. Boca Raton: Chapman & Hall/CRC Press, 2012.
31. Twisk J, W., R. Multilevel analysis in longitudinal studies. Applied multilevel analysis. New York: Cambridge University Press, 2010:166.
32. Osteras H, Sommervold M, Skjolberg A. Effects of a strength-training program for shoulder complaint prevention in female team handball athletes. A pilot study. J Sports Med Phys Fitness 2015;**55**(7-8):761-7.
33. van der Hoeven H, Kibler WB. Shoulder injuries in tennis players. Br J Sports Med 2006;**40**(5):435-40; discussion 40.
34. Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. Br J Sports Med 2009;**43**(13):966-72.
35. Dean BJ, Gwilym SE, Carr AJ. Why does my shoulder hurt? A review of the neuroanatomical and biochemical basis of shoulder pain. Br J Sports Med 2013;**47**(17):1095-104.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Shoulder injuries are highly prevalent among throwing athletes and are dominated by overuse characteristics. Reduced glenohumeral rotation, external rotation weakness and scapula dyskinesis have been identified as risk factors, but exercise programs addressing these factors to prevent overuse shoulder injuries in throwing sports have not been tested in controlled trials.

WHAT THIS STUDY ADDS

The OSTRC Shoulder Injury Prevention Program, a comprehensive exercise program targeting glenohumeral internal rotation, external rotation strength, scapular control, kinetic chain control and thoracic mobility, reduced the risk of shoulder problems in elite handball by 28% and should be included as a part of the warm-up in throwing sports.

FIGURE LEGEND

Figure 1. Examples of exercises aiming to improve glenohumeral range of motion (1a-b), thoracic mobility (2a-b), external rotation strength (3a-b), scapula control (4a-b) and kinetic chain (4a-b; a, start position; b, end position).

Figure 2. Study flow chart showing the dropout and the number of players included and analysed.

Figure 3. Prevalence of shoulder problems and substantial shoulder problems in the intervention group (open squares, shoulder problems; filled squares, substantial shoulder problems) and control group (open triangles, shoulder problems; filled triangles, substantial shoulder problems), with 95% confidence intervals, measured six times during the season.