DISSERTATION FROM THE
NORWEGIAN SCHOOL OF
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Hilde Fredriksen

Prevention of shoulder injuries in handball

The challenge of implementation of preventive measures

NORWEGIAN SCHOOL
OF SPORT SCIENCES

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Oslo Sports Trauma
RESEARCH CENTER

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"Intuition is the source of scientific knowledge." (Aristotle)

Knowledge is of no value unless you put it into practice." (A. Tsjekhov)

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Hilde Fredriksen

Oslo, October 2020

List of papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals:

I. Fredriksen H, Myklebust G. Norwegian translation, cross-cultural adaptation and validation of the Kerlan-Jobe Orthopaedic Clinic shoulder and elbow questionnaire. BMJ Open Sport Exerc Med. 2019; 5(1):e000611. https://doi.org/10.1136/bmjsem-2019-000611

II. Fredriksen H, Cools A, Bahr R, Myklebust G. Does an effective shoulder injury prevention program affect risk factors in handball? A randomized controlled study. Scand J Med Sci Sports. 2020. https://doi.org/10.1111/sms.13674

III. Fredriksen, H., Cools, A. & Myklebust, G. (2020). Development of a short and effective shoulder external rotation strength program in handball: A delphi study. Physical Therapy in Sport 44, 92-98. doi:10.1016/j.ptsp.2020.05.005

IV. Fredriksen, H., Cools, A. & Myklebust, G. No added benefit of 8-weeks of shoulder external rotation strength training for youth handball players over usual handball training alone: a randomized controlled trial. Accepted for publication in the Journal of Orthopaedic & Sports Physical Therapy. Reproduced with permission. Copyright ©Journal of Orthopaedic & Sports Physical Therapy®, Inc.

Summary

Introduction

Handball players are at high risk of shoulder injuries with frequent recurrences and exacerbations. Although a newly developed shoulder injury prevention program reduced the risk of shoulder problems in handball, the adherence to the program is low because players deem it too time-consuming and have little motivation to participate. Therefore, efforts to reduce the program length is needed.

Since a previous injury is the strongest predictor of a new injury, efforts are needed to recognise a new injury as early as possible (secondary prevention) and ensure proper rehabilitation and return-to-play decisions (tertiary prevention). The Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow (KJOC) questionnaire is a valuable tool to monitor the status and health of an overhead athlete's shoulder though it is not available in the Norwegian language.

Methods

This dissertation is based on three separate research projects. In the first project, we translated and culturally adapted the KJOC questionnaire to Norwegian and evaluated the measurement properties of the questionnaire (Paper I). In the second project, we conducted a randomized controlled study to assess the effect of the Oslo Sports Trauma Research Center (OSTRC) shoulder injury prevention program on shoulder external rotation (ER) strength and internal rotation (IR) range of motion (ROM) (Paper II). Both ER and IR ROM are considered to represent key risk factors for shoulder injury among adolescent players. In the third project, through a Delphi consensus study, we developed a short shoulder ER strength program to which handball players would likely adhere (Paper III). The effectiveness of this program was thereafter assessed in adolescent handball players through an 8-week randomized controlled study (Paper IV).

Main Results

The Norwegian version of the KJOC questionnaire was found to be a reliable (ICC = 0.967, SEM = 3.05), valid and internally consistent questionnaire (Cronbach's $\alpha = 0.952$) for Norwegian overhead athletes (Paper I). The OSTRC prevention program for shoulder injuries in handball affected neither shoulder ER strength (estimated group difference 0.06N/kg, 95% CI -0.04 to 0.17) nor IR ROM in a cohort of young handball players (Paper II). In Paper III, we reached a consensus for both efficacy and adherence in two exercises: ER in 90° abduction in a bent-over

squat position and ER in 90° abduction combined with horizontal abduction and trunk rotation in a push-up position. Finally, the short ER strength program had no effect (estimated group difference 0.06N/kg, 95% CI -0.01 to 0.14) on ER strength in adolescent handball players (Paper IV).

Conclusion

The OSTRC shoulder injury prevention program did not affect shoulder ER strength or IR ROM. Therefore, the preventive effects of the program must have been due to other factors or the interaction of risk factors. In addition, the short shoulder ER strength program did not increase shoulder ER strength in adolescent handball players. A higher dosage might thus be needed for strength improvement in already strong players.

Our results suggest that the Norwegian version of the KJOC questionnaire is a reliable and valid tool for evaluating shoulder and elbow-related problems in Norwegian overhead athletes.

Sammendrag (Summary in Norwegian)

Innledning

Flere studier har vist at håndballspillere er utsatt for skulderskader, både akutte og belastningsskader. Spillerne fortsetter ofte å trene og konkurrere til tross for skuldersmerter, og plagene har derfor en tendens til å bli kroniske og tilbakevendende. Det er imidlertid mulig å forebygge disse skadene. Et nylig utviklet forebyggende skulderprogram har vist en reduksjon av risiko for skulderskader blant utøvere som gjennomførte programmet. Imidlertid var oppslutningen om programmet lav, hovedsakelig fordi spillere og trenere syntes det var for langt. I tillegg var spillerne lite motivert for å gjennomføre programmet. Forfatterne konkluderte derfor med at det er behov for et kortere program.

Den største risikofaktoren for skader er en tidligere skade. Derfor er det viktig å oppdage en belastningsskade tidlig, så man kan sette inn fornuftige tiltak raskt for å forhindre at skaden får utvikle seg (sekundærforebygging). Det er også viktig å gjennomføre en grundig rehabilitering og sørge for at spilleren ikke slippes tilbake til konkurranser før han/hun er klar for de kravene idretten stiller (tertiærforebygging). Et spesifikt spørreskjema – Kerlan-Jobe Orthopaedic Clinic skulder og albue (KJOC) spørreskjema – ble utviklet for å kartlegge skulder- og albuestatus hos kastutøvere. Dette skjemaet er et godt supplement til fysiske tester for å monitorere spillerens progresjon i rehabiliteringen og for å avgjøre når spilleren er klar for å gå tilbake til full trenings- og kampaktivitet. Imidlertid finnes ikke dette skjemaet på norsk.

Metoder

Denne avhandlingen er basert på tre ulike forskningsprosjekter. I det første prosjektet oversatte vi KJOC spørreskjema til norsk og gjorde kulturelle tilpasninger i henhold til internasjonale retningslinjer. Vi lagde en elektronisk versjon av skjemaet og evaluerte skjemaets måleegenskaper (artikkel I). I det andre prosjektet gjennomførte vi en randomisert kontrollert studie for å undersøke om Senter for idrettsskadeforsknings forebyggende skulderprogram påvirket skulderens utadrotasjonsstyrke og innadrotasjonsbevegelighet – to antatt viktige risikofaktorer for skulderskader – blant unge håndballspillere (16-18 år) (artikkel II). I det tredje prosjektet gjennomførte vi en Delphi-konsensus studie for å utvikle et kort styrketreningsprogram for skulderens utadrotatormuskulatur. Målet var å komme fram til effektive øvelser som det var stor sannsynlighet for at spillerne ville gjennomføre (artikkel III). Styrke-effekten av dette programmet testet vi ut hos unge håndballspillere gjennom en åtte-ukers randomisert kontrollert studie (artikkel IV).

Resultater

Den norske versjonen av KJOC spørreskjema var reliabel (ICC= 0.967, SEM = 3.05), valid og internt konsistent (Cronbach's $\alpha = 0.952$) blant norske kastutøvere (artikkel I). Senter for idrettsskadeforsknings forebyggende skulderprogram hadde ingen effekt verken på utadrotasjonsstyrke (estimert forskjell mellom intervensjons- og kontrollgruppen: 0.06N/kg, 95% CI -0.04 til 0.17) eller innadrotasjonsbevegelighet (ingen endring i noen av gruppene) i skuldre blant unge håndballspillere (artikkel II). I artikkel III nådde vi konsensus for kombinasjonen høy effektivitet og høy sannsynlighet for gjennomføring av to øvelser, 1) utadrotasjon i 90° abduksjon i en framoverbøyd stilling og 2) utadrotasjon i 90° abduksjon kombinert med horisontal abduksjon og trunkusrotasjon i en push-up-stilling. Det korte styrketreningsprogrammet for skulderens utadrotatormuskulatur hadde ingen effekt på utadrotasjonsstyrken (estimert forskjell mellom intervensjons- og kontrollgruppen: 0.06N/kg, 95% CI -0.01 til 0.14) hos unge håndballspillere (artikkel IV)

Konklusjon

Senter for idrettsskadeforsknings forebyggende skulderprogram påvirket verken utadrotasjonsstyrke eller innadrotasjonsbevegelighet. Den forebyggende effekten av programmet på skulderskader må derfor skyldes andre faktorer eller et samspill av risikofaktorer. Det korte styrketreningsprogrammet for skulderens utadrotatormuskulatur økte ikke utadrotasjonsstyrken hos unge håndballspillere. Det er mulig det er nødvendig med en høyere dosering av styrketreningen for å oppnå en styrkeøkning hos allerede sterke utøvere.

Den norske versjonen av KJOC spørreskjema er et reliabelt og valid verktøy for å evaluere skulder- og albue-relaterte problemer blant norske kastutøvere.

Abbreviations

ABD	Abduction
CI	Confidence Interval
Con	Concentric
COSMIN	COnsensus-based Standards for the selection of health Measurement INstruments
DASH	Disabilities of the Arm, Shoulder and Hand questionnaire
Ecc	Eccentric
ER	External Rotation
F-MARC	Fédération Internationale de Football Association Medical Assessment and Research Centre
FAST	The Functional Arm Scale for Throwers
GIRD	Glenohumeral Internal Rotation Deficit
HHD	Hand-held dynamometer
HR	Hazard Ratio
HRR	Hazard Rate Ratio
ICC	Intraclass Correlation
IR	Internal Rotation
KJOC	Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow questionnaire
LOA	Limits of Agreement
MDC	Minimal Detectable Change
N	Newton
OR	Odds Ratio
OSTRC	Oslo Sports Trauma Research Center
PROMs	Patient Reported Outcome Measures
RCT	Randomized Controlled Trial
RIR	Repetitions in Reserve
RM	Repetition Maximum
ROM	Range of motion
RR	Relative Risk
SEM	Standard Error of Measurement
TROM	Total Range of Motion
TUT	Time Under Tension
WOSI	Western Ontario Shoulder Instability Index

Introduction

Handball players are at high risk of shoulder injuries (Aasheim, Stavenes, Andersson, Engbretsen, & Clarsen, 2018; Andersson, Bahr, Clarsen, & Myklebust, 2017; Giroto, Hespanhol Junior, Gomes, & Lopes, 2017; Rafnsson, Valdimarsson, Sveinsson, & Árnason, 2019; Seil, Rupp, Tempelhof, & Kohn, 1998). A recent study demonstrated that it is possible to reduce the prevalence of shoulder injuries by 28% (Andersson et al., 2017). However, although the prevention program effectively reduced the prevalence of injuries, only 24% of the athletes reported that they would continue using the program (Andersson, Bahr, Olsen, & Myklebust, 2019). Their main concern was that the program was too time-consuming. Therefore, there is a need to make shorter programs. Since the shoulder prevention program included multiple exposures (stretching, proprioceptive training and strength training of rotator cuff, scapular muscles and the whole kinetic chain), it is difficult to determine exactly why the program works and which parts are effective in the prevention of shoulder injuries. In order to make more condensed programs, we must assess whether or not the program has an effect on the hypothesised risk factors (Asker, Brooke, et al., 2018).

Shoulder injuries in handball are frequently recurrent and tend to become chronic. Today, there is no specific criteria for return-to-sport after a shoulder injury (Ardern et al., 2016). A tool to monitor players' shoulder status during rehabilitation and return-to-play to prevent recurrences would be useful. The Kerlan-Jobe Orthopaedic Clinic (KJOC) shoulder and elbow questionnaire (Alberta et al., 2010) is indeed specific to shoulders for overhead athletes, but it is not yet available in Norwegian. Therefore, a proper translation and cultural adaptation is needed.

Literature search

Three different PubMed searches were performed to gain information for this dissertation. Firstly, a literature search was completed to identify studies reporting prevalence and incidence of shoulder injuries in handball to get an overview of the extent of the problem. Secondly, a search to obtain information about the internal modifiable risk factors for shoulder injuries in handball was performed. Only prospective cohort studies were included. Finally, a search was carried out to find studies examining exercises aimed at affecting shoulder ER strength. This included both experimental studies on the effectiveness of these exercises and electromyographic studies to investigate activation of shoulder muscles during commonly used exercises. This search was conducted in the initial phase of this PhD and is therefore limited to studies published before December 2017.

A detailed description of the different literature search strategy and selection of studies are provided in appendix I-III.

Background

Handball

Handball is a popular team sport, particularly in Europe, and has been an Olympic sport since 1972. In Norway, handball is the third most popular sport after football and skiing. Two opponent teams play on a 20 m x 40 m court, aiming to score most goals. There are seven players from each team on the court: six field players (three back players, two wing players, one line player) and one goalkeeper.

General physical demands

A handball match consists of two periods of 30 minutes and is both aerobic and anaerobic with high-intensity bursts, which imposes high physical and physiological demands on the players (Kniubaite, Skarbalius, Clemente, & Conte, 2019; Michalsik & Aagaard, 2015; Michalsik, Aagaard, & Madsen, 2013). The game includes sprints, rapid direction changes, cuts, jumps, duels and tackles as well as various types of throws and passes (Karcher & Buchheit, 2014; Michalsik et al., 2013; Michalsik, Madsen, & Aagaard, 2014, 2015). In elite handball, the high training loads are often combined with tight competition schedules and little time for recovery. In 2019, this led to a campaign called #DontPlayThePlayers, in which some of the most prominent handball stars raised their voices against the immense workload on the players. Additionally, the best adolescent players often play for several different teams at a time (different age teams in their own clubs; regional teams; national junior and senior teams). In Norway, this amounts to 80 matches per season for some players (Norwegian Handball Association, personal communication).

Throwing and shoulder specific demands

Throwing ability, which includes both throwing velocity and accuracy, is one of the most important skills in handball (Van Den Tillaar & Cabri, 2012). Angular velocities up to 5000°/s have been recorded. Some elite players complete up to 1200 throws per training week (Prestkvern, 2013). This repetitive throwing with high angular velocities and forces places extensive demands on the shoulder joint (Jobe, Moynes, Tibone, & Perry, 1984; Karcher & Buchheit, 2014). In addition, the game includes hard body tackles, often directly to the shoulder.

There is a large variation in throwing techniques: jump throw; standing throw with a pre-running phase; standing throw without a pre-running phase (Skejø, Møller, Bencke, & Sørensen, 2019). However, regardless of the throwing technique, the throwing kinematics have been reported to be quite similar (Wagner, Pfusterschmied, von Duvillard, & Muller, 2011). There is a large shoulder ER in the acceleration phase, followed by a forceful concentric IR which peaks shortly before ball release, and finally an eccentric activation of the external rotators during the follow-through phase (Escamilla & Andrews, 2009; Fradet et al., 2004; Skejø et al., 2019; van den Tillaar & Ettema, 2007; Wagner et al., 2011). The external rotators must produce a high eccentric force to decelerate the movement and provide stability to the shoulder joint during the follow-through phase (David et al., 2000). This requirement of both mobility and stability led to the term, "thrower's paradox". "The thrower's shoulder must be mobile enough to allow excessive rotation but stable enough to prevent symptomatic humeral head subluxations, thus requiring a delicate balance between mobility and functional stability" (Wilk, Obma et al., 2009).

Shoulder injuries in handball

The overall injury risk in handball is high. The incidence ranges from 3 injuries per 1000 training hours up to 108 injuries per 1000 match hours during major international tournaments (Bere et al., 2015; Langevoort, Myklebust, Dvorak, & Junge, 2007; Mónaco et al., 2019). While knee and ankle injuries are the most frequent acute injuries, shoulder problems are the predominant overuse injuries (Aasheim et al., 2018; Andersson et al., 2017; Giroto et al., 2017; Rafnsson et al., 2019; Seil et al., 1998).

The high demands due to repetitive throwing combined with hard tackles to the arm and shoulder make the shoulder region vulnerable to both acute and overuse injuries (Kelly, Barnes, Powell, & Warren, 2004; Vlak & Pivalica, 2004). Although handball players are prone to injury with overall high incidence rates, shoulder injuries account for only 3-9% of all the injuries (Langevoort et al., 2007; Mónaco et al., 2019). This low percentage is probably due to the commonly used time-loss definition of injuries (Clarsen, Myklebust, & Bahr, 2013; Fuller et al., 2006). Two thirds of handball players have reported a gradual onset of pain (Forthomme et al., 2018; Myklebust, Hasslan, Bahr, & Steffen, 2013). Additionally, players with overuse injuries often continue to play despite the pain, and their performance, participation and training volume are affected. Therefore, the time-loss injury definition seldom captures overuse shoulder injuries (Clarsen et al., 2013).

More recent epidemiological studies in handball have used a broader definition of injury, including all physical complaints, which also captures overuse injuries (Clarsen et al., 2013). These studies have demonstrated that the prevalence of shoulder problems in handball is high (17-41%) among both senior and adolescent players (Table 1) and that players continue to play despite sustained shoulder pain (Aasheim et al., 2018; Achenbach et al., 2020; Andersson, Bahr, Clarsen, & Myklebust, 2018; Asker, Holm, Kallberg, Walden, & Skillgate, 2018; Clarsen et al., 2015; Mohseni-Bandpei, Keshavarz, Minoonejhad, Mohsenifar, & Shakeri, 2012; Myklebust et al., 2013).

Although participating in sport is supposed to be healthy and fun, injuries can lead to several negative consequences. Besides the obvious pain and reduced participation, performance and joy, the injuries might lead to early retirement from sport, impaired team performance and high treatment costs (Ekstrand, 2013; Hagglund et al., 2013). Since a player's personal identity and social status are often defined by his/her sport, injuries can also lead to reduced mental and social well-being and reduced quality of life (Raya-González, Clemente, Beato, & Castillo, 2020). This emphasizes the importance of injury prevention.

Table 1 Prevalence of shoulder injuries in handball

Reference **Design, country and period**	**Population**	**Injury definition and registration**	**Prevalence of injuries**	**Prevalence of substantial injuries**
Aasheim et al. (2018)	10 junior male teams	OSTRC questionnaire, self-reported bi-weekly through the season (8 months)		
Prospective cohort,	145 players			
1 season, Norway	Age 16-18	Average prevalence	17% (95%CI 16-19%)	7% (95%CI 7-8%)
Achenbach et al. (2019)	70 boys/ 68 girls Mean age 14.0±0.8	OSTRC questionnaire, self-reported five times through the season (7 months)		
Prospective cohort, 1 season		Seasonal prevalence	26% (OSTRC)	
Elite, youth, Germany		WOSI score, cut-off value of 20%	12% (WOSI)	
Andersson et al. (2018)	23 teams (12 males, 11 females), elite.	OSTRC questionnaire, self-reported every month (six times) through the season (6 months)		
Prospective cohort, 1 season, Norway	329 players	Average prevalence	23% (95%CI 21-26%)	8% (95%CI 7-9%)
Asker et al. (2018)	471 players (54% females)	OSTRC questionnaire, self-reported weekly through the season (8 months)		
Prospective cohort, 2 seasons	Age: 15-18	Average prevalence	25% (95%CI 23-27%)	6% (95%CI 5-7%)
		Seasonal prevalence	44% (95%CI 40-48%)	23% (95%CI 20-27%)
Clarsen et al. (2014)	206 males	OSTRC questionnaire, self-reported bi-weekly through the season (9 months)		
Prospective cohort, 1 season		Average prevalence	28% (95%CI 25-31%)	12% (95%CI 11-13%)
Elite, men, Norway				

Reference **Design, country and period**	**Population**	**Injury definition and registration**	**Prevalence of injuries**	**Prevalence of substantial injuries**
Mohseni-Bandpei et al. (2012)	138 players	Questionnaire on prevalence of shoulder pain (not specified)		
Cross sectional, elite	Gender not specified	-point prevalence	19.6%	
		-6-month prevalence	26.8%	
		-annual prevalence	40.6%	
		-lifetime prevalence	44.2%	
Myklebust et al. (2013)	179 players, female	Fahlström questionnaire		
Cross sectional, 2 seasons, elite		Point prevalence	36%	
Lubiatowski et al. (2018)	41 players, male	Pain > 2 on VAS scale with duration of > 1-week last month		
Retrospektive, elite		monthly prevalence	41%	
Oliveira et al. (2017)	Adolescents	Self-reported shoulder pain		
Retrospective	78 players, 49 males, 29 females	Current year	48.7%	
		Last year	62.8%	

Abbreviations: OSTRC, Oslo Sports Trauma Research Center; WOSI, Western Ontario Shoulder Instability Index; CI, Confidence Interval

Prevalence of injuries: any problems; Prevalence of substantial injuries: problems leading to moderate or severe reductions in training volume or performance, or a total inability to participate

Prevention of injuries

The definition of prevention is "the act of preventing or hindering" (Merriam-Webster, 2020). Primary prevention prevents the onset of injury before the process begins by mandating safe and healthy practices (e.g. prevention programs or education about healthy or safe habits). Secondary prevention consists of measures that lead to early diagnosis and treatment to prevent more serious problems from developing (e.g., regular exams and screenings, health monitoring through regular questionnaires, and modification of workload) (Institute for Work & Health, 2015). Tertiary prevention refers to stopping or delaying the progression of an already existing injury or illness (Institute for Work & Health, 2015). This includes rehabilitation and proper return-to-play decisions. The phrase "injury prevention" in sports is usually synonymous with primary prevention.

A systematic approach is needed to study prevention of sports injuries. The most commonly used model is the four-step "sequences of prevention" of sport injuries (van Mechelen, Hlobil, & Kemper, 1992). The first step of this model is to determine the extent of injuries in the population of interest. Step two is to determine the aetiology and mechanisms of the injuries, including risk factors. The third step is to develop and implement a prevention strategy, and the fourth step is to assess the effectiveness of the prevention strategy. This model has later been expanded by Finch et al. (Finch, 2006) by adding implementation issues and finally by van Tiggelen et al (Van Tiggelen, Wickes, Stevens, Roosen, & Witvrouw, 2008). In the last model, the efficiency, compliance level and risk-taking behaviour of the individual have been added to van Mechelen's model (Figure 1).

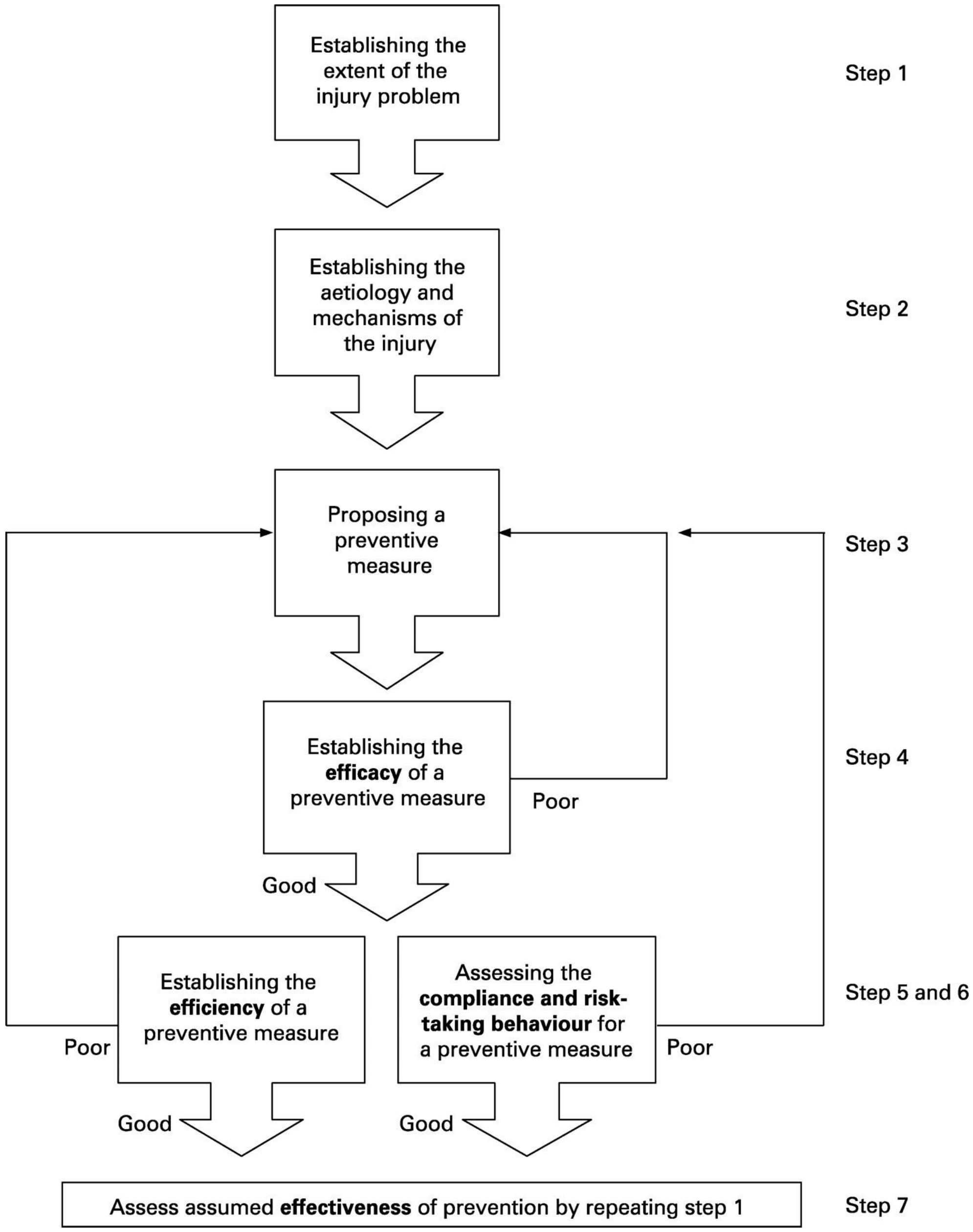

Figure 1. Sequence of prevention of overuse injuries (from Van Tiggelen et al., 2008)

The extent of the injury problem

To establish the extent of the problem and compare results from different studies, it is important to standardize the methodology and definition of an injury. The Fédération Internationale de Football Association Medical Assessment and Research Centre (F-MARC) therefore hosted a consensus meeting in 2006 to establish definitions and methods for collecting and reporting data from studies of football injuries (Fuller et al., 2006). The recommendations from this meeting have been adopted in studies of several sports.

The F-MARC consensus statement defined an injury as: "Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities. An injury that results in a player receiving medical attention is referred to as a 'medical attention' injury, and an injury that results in a player being unable to take a full part in future football training or match play as a 'time loss' injury." It is obvious that the three different injury definitions, "any physical complaint", "medical attention" injury and "time loss" injury will lead to different incidence or prevalence numbers. The most used injury definition is time-loss, which is easy to count and therefore considered reliable. However, most overuse injuries are underreported using this definition, since athletes with overuse injuries rarely have complete time-loss. Instead they often adjust their training and competition, for instance, by changing their throwing technique or intensity. Injury incidence only captures new injuries and is therefore less suitable to capture overuse injuries, since they tend to have a fluctuating course with relapses and exacerbations (Bahr, 2009).

Since assessing injury incidence underestimates the impact of overuse injuries, Clarsen et al. developed a new injury questionnaire to assess injury prevalence, which is the proportion of athletes with injuries at a certain time point. The Oslo Sports Trauma Research Center (OSTRC) overuse injury questionnaire consists of four questions about participation, training volume, performance and pain (Clarsen et al., 2013). This prevalence-based measure captured ten times as many overuse injuries as the time-loss approach did (Clarsen et al., 2013) and has been advocated as the metric of choice to identify athlete availability and needs of treatment (Nielsen et al., 2019). The last years, this has thus been the method in most studies to gauge the prevalence of overuse injuries. In handball, this method has revealed a prevalence of shoulder injuries of 17-41% (Table 1) (Aasheim et al., 2018; Achenbach et al., 2020; Andersson et al., 2018; Asker, Holm, et al., 2018; Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014).

Causes of overuse injuries

The causes of overuse injuries are multifactorial, resulting from an interaction of internal and external risk factors (Meeuwisse, 1994). Athletes have internal risk factors, which predispose them to injury. These factors can be non-modifiable (e.g., age and gender) or modifiable (e.g., strength, ROM, neuromuscular control). The predisposed athletes are subsequently exposed to external risk factors, like training load, equipment, opponent players or environments, which modify injury risk by making the athletes more susceptible to injury. Finally, an inciting event might exceed tissue tolerance, and an injury can occur. This linear model was modified later several times to:

1. Include global and detailed biomechanical descriptions of the inciting event (Figure 2) (Bahr & Krosshaug, 2005)
2. Take into account the repeated exposure to sports participation, leading to adaptation or maladaptation, and thereby changes in risk factors (Meeuwisse, Tyreman, Hagel, & Emery, 2007)
3. Include workload in a recursive model (Figure 3) (Windt & Gabbett, 2017)

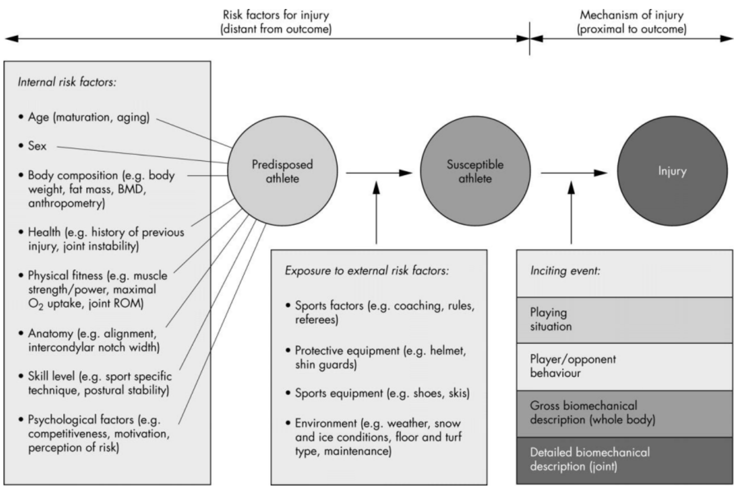

Figure 2 A model of injury causation by Meeuwisse et al. 1994, modified by Bahr and Krosshaug 2005

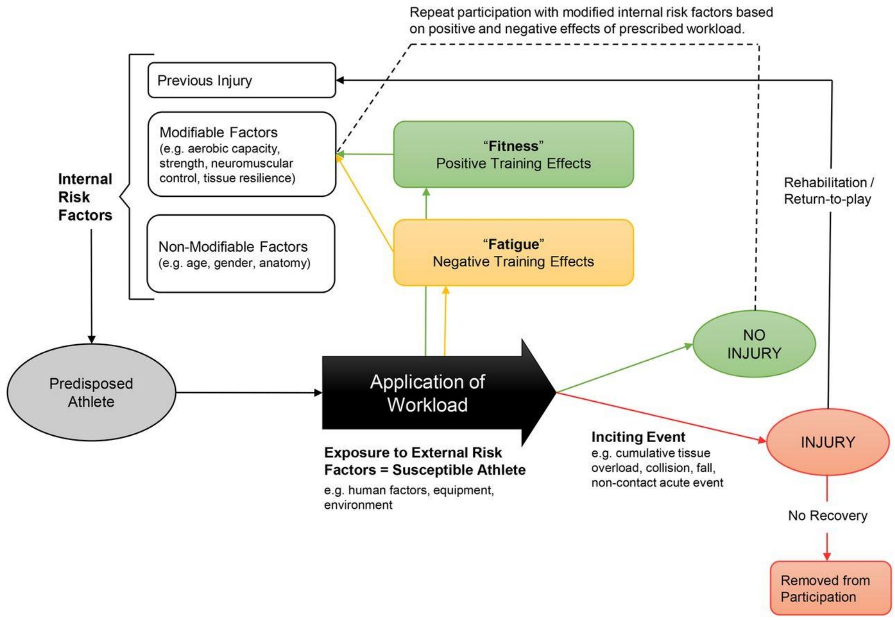

Figure 3 The workload–injury aetiology model by Windt et al. 2017

As can be seen from the workload–injury aetiology model, workload can have both positive and negative influences on injury risk. Adequate workloads are required to achieve positive adaptions to increase performance and reduce injury risk. However, high absolute workloads or rapid increase in workload might lead to cumulative tissue overload leading to injury (Windt & Gabbett, 2017). Additionally, the model also shows that previous injury is an internal risk factor. In fact, across a variety of injury types and sports, a previous injury is the strongest risk factor for a new injury (Arnason, 2004; Freckleton & Pizzari, 2013; Giroto et al., 2017; Moller, Attermann, Myklebust, & Wedderkopp, 2012; Ryan, DeBurca, & Mc Creesh, 2014; Wiggins et al., 2016; Witchalls, Blanch, Waddington, & Adams, 2012).

Risk factors for overuse shoulder injuries in handball

In handball, commonly described internal risk factors for shoulder injuries are related to rotator cuff weakness or imbalances, decreased or increased rotational range of motion (ROM) and scapular dyskinesis. External rotation (ER) weakness is the most frequently reported internal modifiable risk factor for shoulder injuries in handball (Table 2). Five recent studies have identified ER weakness or low ER/IR ratios as risk factors (Achenbach et al., 2020; Asker, Walden, Kallberg, Holm, & Skillgate, 2020; Clarsen et al., 2014; Edouard et al., 2013; Moller et al., 2017), while one study did not find any association between strength and injury risk (Andersson et al., 2018).

While glenohumeral internal rotation deficit has been found as a risk factor in overhead sports in general, particularly in baseball (Myers, Laudner, Pasquale, Bradley, & Lephart, 2006; Scher et al., 2010; Shanley et al., 2011), this is not the case in handball, in which the results of five studies are highly conflicting (Table 3) (Achenbach et al., 2020; Andersson et al., 2018; Asker et al., 2020; Clarsen et al., 2014; Moller et al., 2017). Both increased ER (Achenbach et al., 2020) and IR ROM (Andersson et al., 2018), reduced total ROM (Clarsen et al., 2014) and glenohumeral internal rotation deficit (Achenbach et al., 2020) have been identified as risk factors, though two studies did not find any association between ROM and risk of shoulder injury at all (Asker et al., 2020; Moller et al., 2017).

Another apparent internal risk factor is scapular dyskinesis (Table 4). Three studies have identified scapular dyskinesis as a risk factor in handball (Asker et al., 2020; Clarsen et al., 2014; Moller et al., 2018), while two studies found no association between scapular dyskinesis and injury risk (Achenbach et al., 2020; Andersson et al., 2018).

Recently, Moller et al. reported an association between injury risk and a 60% increase in handball load; this effect was exacerbated in players with reduced ER strength. Furthermore, they found an association between injury risk and an increase in handball load between 20 – 60%, which was exacerbated in players with ER rotation weakness and scapular dyskinesis (Moller et al., 2017).

In a recent systematic review of risk factors of overuse shoulder injuries in overhead athletes, a history of shoulder pain was the most commonly reported risk factor (Tooth et al., 2020). A previous injury is a non-modifiable internal risk factor. However, the quality of the rehabilitation of the injury and return-to-play decisions are modifiable and will influence the consequences of an injury.

Table 2 Studies investigating association between shoulder external rotation strength and shoulder injury in handball

Reference **Design and period** **Level and country**	**Study group**	**Injury definition and registration**	**Strength measures, instrumentation and procedures**	**Results**
Achenbach et al. (2019) **Prospective cohort, 1 season** **Elite, youth, Germany**	70 boys / 68 girls Mean age 14.0±0.8	Shoulder problems affecting players participation, training or performance or shoulder pain last 7 days, (OSTRC questionnaire) self-reported five times through the season	Isometric (HHD, N, N/kg) • IR * • ER Eccentric (HHD, N, N/kg) • ER	Reduced ER strength associated with increased probability of injury, OR (isom): 1.2 (1.0-1.4) per 0.1 N/kg OR (ecc, male): 5.89 (1.2-29.9)
Andersson et al. (2018) **Prospective cohort, 1 season** **Elite, Norway**	168 male / 161 female	OSTRC questionnaire, self-reported six times through the season	Isometric (HHD, N/kg), IR and ER supine (six different raters)	No associations between strength and injury risk
Asker et al. (2020) **Prospective cohort, 1 (2) seasons, youth, Sweden**	341 players (452 player-seasons) 50% females	Modified OSTRC questionnaire, reporting last 2 months or past season	Isometric (HHD, N/kg), • IR and ER seated • ABD standing (30°abd) Eccentric (HHD, N/kg) • ER seated	Reduced ER and IR strength associated with increased risk of injury in female HRR (ER): 2.37 (1.03-5.44) HRR (IR): 2.44 (1.06-5.61)
Clarsen et al. (2014) **Prospective cohort, 1 season** **Elite, men, Norway**	206 males	OSTRC questionnaire, self-reported bi-weekly through the season	Isometric (HHD, N/kg), IR and ER supine (two raters)	Reduced ER strength associated with increased injury, OR: 0.71 per 10N change

Reference Design and period Level and country	Study group	Injury definition and registration	Strength measures, instrumentation and procedures	Results
Edouard et al. (2013) **Prospective cohort, 1 season, elite, Brazil**	16 females Mean age 18		Isokinetic torque (Nm/kg) IR and ER seated 60, 120, 240°/s con, 60°/s ecc	Ratios of ERcon: IRcon at 240°/s <0.69, RR 2.57 (95%CI 1.60-3.54) and ratios of IRecc/ERcon at 60°/s > 1.61, RR 2.08 (95%CI 1.18-2.98) associated with injury
Forthomme et al. (2018) **Prospective cohort, 1 season,**	108 males, high level Mean age 24	Monthly questionnaire, not specified, self-reported Not defined shoulder injury	Isokinetic torque (Nm/kg) IR and ER supine 60 and 240°/s con, 60°/s ecc	Reduced con IR associated with increased risk of traumatic injury OR: 0.93 (95%CI:0.87-1.0) No other associations between strength and injury risk
Moller et al. (2017) **Prospective cohort, 1 season,** **Elite youth, Denmark**	679 players Age: 14-18	Any handball related shoulder problem irrespective of time loss and medical attention, self-reported weekly	Isometric (HHD, N) IR and ER supine ABD standing	ER:IR ratio<0.75 accentuated the effect of handball load on shoulder injury rate at an increase in weekly handball load between 20 and 60% (HR 4.0, 95%CI 1.1-15.2) or above 60% (HR 4.2, 95%CI 1.4 -12.8)

Abbreviations: HHD, Hand-held dynamometer; N, Newton; IR, Internal Rotation; ER, External Rotation; ABD, Abduction; OR, isom, isometric; con, concentric; ecc, eccentric; Odds Ratio; HHR, Hazard Rate Ratio; RR, Relative Risk; HR, Hazard Ratio

** test position not mentioned*

Table 3 Studies investigating association between shoulder range of motion and shoulder injury in handball

Reference **Design and period** **Level and country**	**Study group**	**Injury definition and registration**	**ROM measures, instrumentation and procedures**	**Results**
Achenbach et al. (2019) **Prospective cohort, 1 season** **Elite, youth, Germany**	70 boys / 68 girls Mean age 14.0±0.8	Shoulder problems affecting players participation, training or performance or shoulder pain last 7 days, self-reported five times through the season	IR and ER; goniometer (°)	ER gain >7.5° associated with increased risk in female; OR: 15.2 (1.1-185.3) GIRD >7.5° associated with increased risk in female; OR: 12.5 (1.4-114.6) and in male; OR: 0.61 (0.5-0.8)
Andersson et al. (2018) **Prospective cohort, 1 season** **Elite, Norway**	168 male / 161 female	Shoulder problems affecting players participation, training or performance or shoulder pain last 7 days, self-reported six times through the season	IR and ER, supine; digital inclinometer (°) (six different raters)	Increased IR was associated with risk of injury
Asker et al. (2019) **Prospective cohort, 1 (2) seasons, youth, Sweden**	341 players (452 player-seasons) 50% females	Modified OSTRC questionnaire, reporting last 2 months or past season.	IR and ER, supine; digital inclinometer (°)	No association between ROM and risk of injury
Clarsen et al. (2014) **Prospective cohort, 1 season** **Elite, men, Norway**	206 men	OSTRC questionnaire, self-reported bi-weekly through the season	IR and ER, supine; digital inclinometer (°)	Reduced TROM associated with injury, OR: 0.77 per 5° change

Reference **Design and period** **Level and country**	**Study group**	**Injury definition and registration**	**ROM measures, instrumentation and procedures**	**Results**
Moller et al. (2017) **Prospective cohort, 1 season** **Elite youth, Denmark**	679 players Age: 14-18	Any handball related shoulder problem irrespective of time loss and medical attention, self-reported weekly	IR and ER, supine; digital inclinometer (°)	No association between ROM and risk of injury

Abbreviations: ROM, Range of Motion; IR, Internal Rotation; ER, External Rotation; GIRD, Glenohumeral Internal Rotation Deficit; TROM, Total Range of Motion; OR, Odds Ratio; OSTRC, Oslo Sports Trauma Research Center

Table 4 Studies investigating association between scapular dyskinesis and shoulder injury in handball

Reference **Design and period** **Level and country**	**Study group**	**Injury definition and registration**	**Measures of scapular function, instrumentation and procedures**	**Results**
Achenbach et al. (2019) **Prospective cohort, 1 season** **Elite, youth, Germany**	70 boys / 68 girls Mean age 14.0±0.8	Shoulder problems affecting players participation, training or performance or shoulder pain last 7 days, self-reported five times through the season	Subjective evaluation during bilateral elevation by one rater. External load: 2kg (boys) and 1kg (girls) Categorisations: • Yes/no • Absent/moderate/severe dyskinesis	No association between scapular dyskinesis and injury risk
Andersson et al. (2018) **Prospective cohort, 1 season** **Elite, Norway**	168 male / 161 female	Shoulder problems affecting players participation, training or performance or shoulder pain last 7 days, self-reported six times through the season	Subjective evaluation during bilateral ABD and FLEX by six different raters. External load: 5kg (males) and 3kg (females)	No association between scapular dyskinesis and injury risk
Asker et al. (2019) **Prospective cohort, 1 (2) seasons, youth, Sweden**	341 players (452 player-seasons) 50% females	Modified OSTRC questionnaire, reporting last 2 months or past season.	Subjective evaluation during bilateral ABD and FLEX by one rater (video). External load: 2kg (males) and 1kg (females) Categorisations: Yes/no	Scapular dyskinesis during ABD was associated with increased risk in males HRR: 3.43 (1.49-7.92) No association between scapular dyskinesis in Flex and injury risk

Reference **Design and period** **Level and country**	**Study group**	**Injury definition and registration**	**Measures of scapular function, instrumentation and procedures**	**Results**
Clarsen et al. (2014) **Prospective cohort, 1 season** **Elite, men, Norway**	206 men	OSTRC questionnaire, self-reported bi-weekly through the season	Subjective evaluation during bilateral ABD and FLEX by one rater (live + video). External load: 5kg Categorisation: slight/normal/obvious	Obvious scapular dyskinesis associated with increased injury risk, OR: 8.41
Moller et al. (2017) **Prospective cohort, 1 season,** **Elite youth, Denmark**	679 players Age: 14-18	Any handball related shoulder problem irrespective of time loss and medical attention, self-reported weekly	Subjective evaluation during bilateral ABD and FLEX by one rater (live). External load: 5kg Categorisation: slight/normal/obvious	Any scapular dyskinesis accentuated the effect of handball load on shoulder injury rate at an increase in handball load between 20 and 60% HR 4.8, (95%CI 1.3-18.3)

Abbreviations: ABD, Abduction; FLEX, Flexion; OSTRC, Oslo Sports Trauma Research Center; HHR, Hazard Rate Ratio; OR, Odds Ratio; HR, Hazard Ratio

Preventive measures

Whereas several studies have contributed with knowledge of shoulder injuries in handball to step one and two in the van Mechelen model, only one study has developed and implemented a prevention program (step three) and tested its effectiveness through a randomized controlled trial of elite handball players (Andersson et al., 2017). The prevention program was a 10-minute warm-up program over 18 weeks, carried out three times per week as a part of the regular handball warm-up. With different variations and levels, it consisted of five groups of exercises, targeting ER strength, IR ROM, scapular dyskinesis, activation of the kinetic chain and mobility of the thoracic spine. The program reduced the prevalence of shoulder problems by 28% and the prevalence of substantial shoulder problems by 22% among the players in the intervention group compared to the those of the control group.

Interestingly, subgroup analysis revealed that the prevalence was reduced by 35% when including only players with shoulder problems at baseline. There were no group differences in risk reduction when including only players without shoulder problems at baseline (Andersson et al., 2017). This indicates that the program was more effective as rehabilitation or tertiary prevention rather than primary prevention.

Adherence to prevention programs

As stated by Finch et al. (Finch, 2006), since the prevention study was conducted under controlled settings, it assessed the efficacy under ideal conditions of the program, as opposed to the effectiveness in "real world" situations. Therefore, Andersson et al. conducted another study to evaluate the attitudes, beliefs and behaviours toward shoulder injury prevention and to identify the facilitators and barriers of implementation of the program (Andersson et al., 2019). All captains and coaches from the 44 handball teams in the prevention study participated. Most participants believed that handball players are at high risk of shoulder injuries and that the prevention program would be favourable. Despite these beliefs, only a minority would adhere to the full program. The main barriers were the purported extensive time consumption of the program and the lack of player motivation. In order to reduce the number of exercises and thereby the length of the program, the authors suggested to investigate how the different risk factors are affected among players who are performing the program. We therefore aimed to do this in paper II.

Multiple versus single exposure prevention programs

Through a systematic review, Lauersen et al. (2014) found that strength training reduced sports injuries in general to less than 33% and overuse injuries to about 50% (Lauersen, Bertelsen, & Andersen, 2014). Multiple exposure programs including strength exercises were also effective but to a lesser extent. By including several additional factors, the proportion of the beneficial exercises would be reduced, thereby decreasing the preventive effect of the program. Also, including more exercises would increase the program length which would raise the risk of lower adherence. They therefore suggested that "designs of multiple exposure interventions should at least be built from well-proven single exposures and that further research into single exposures remains pivotal". We thus aimed to develop a short program targeting ER strength only and assess whether this program affected ER strength (paper III and IV).

Exercise selection

There is currently no consensus about exercise selection to increase shoulder ER strength in handball players. We found 10 studies that have investigated the effect of shoulder ER strength exercise programs, consisting of 36 different exercises, in different populations (Batalha, Raimundo, Tomas-Carus, Marques, & Silva, 2014; Carter, Kaminski, Douex, Knight, & Richards, 2007; Genevois et al., 2014; Hibberd, Oyama, Spang, Prentice, & Myers, 2012; Lin & Karduna, 2016; Malliou, Giannakopoulos, Beneka, Gioftsidou, & Godolias, 2004; Mascarin, de Lira, Vancini, da Silva, & Andrade, 2017; Moncrief, Lau, Gale, & Scott, 2002; Niederbracht, Shim, Sloniger, Paternostro-Bayles, & Short, 2008; Uhl, Rice, Papotto, & Butterfield, 2017). Of the ten studies, six were randomized controlled trials (RCT). Two RCTs demonstrated a significant group by time interaction effect after the exercise intervention. Battalia et al. showed increased ER strength and ER/IR ratio, measured isokinetic in young swimmers after a 16-week intervention, consisting of three exercises (standing abduction with ER, standing scaption and standing overhead press) (Batalha et al., 2014). The exercise protocol was performed three times per week, and each exercise was performed with two sets of twenty repetitions and one set to failure. Lin et al. found increased isometric ER in a population of 18 healthy subjects after 4 weeks of intervention (Lin & Karduna, 2016). Three times a week, the subjects in the training group had supervised training, consisting of three sets of six different exercises (standing full-can, side lying ER, prone full can, diagonal exercise, push-up and balance in a push-up position). In addition, they conducted 10 to 20 repetitions of three exercises at home every day. Three RCTs reported an increase in ER strength after six and eight weeks of different strength training programs, but they found no group by time interaction effect (Carter et al., 2007; Malliou et al., 2004; Mascarin et al., 2017). Finally, Hibberd et al. found no effect of a 6-week strength program, consisting of 11 different exercises (Hibberd et al., 2012).

Several studies have used electromyography to evaluate the activation of ER muscles when performing exercises commonly used in rehabilitation of shoulder problems (Edwards, Ebert, Littlewood, Ackland, & Wang, 2017). Most of these exercises are single-plane exercises below 90° of shoulder elevation (Wright, Hegedus, Tarara, Ray, & Dischiavi, 2018). However, our experience is that healthy athletes usually find these exercises boring and will not adhere to them. Handball coaches and physiotherapists working with athletes have therefore created more "functional exercises", but the efficacy of these exercises have not been evaluated (Wright et al., 2018). Using a Delphi method, we thus aimed to develop a short and effective program, targeting shoulder ER strength, with a high likelihood of adherence to a handball population (paper III).

Prescribing exercise dosage

When designing strength training programs, we must consider program variables, such as exercise selection, load, volume and frequency (Bird, Tarpenning, & Marino, 2005). Load is the amount of weight moved during an exercise set and is probably the most important variable when designing resistance training programs (Bird et al., 2005). Load is usually described as the x repetition maximum (xRM), which is the weight that can be lifted x times without rest. Load can therefore be described as a percentage of 1RM (i.e. 70% of 1RM) or as a predefined number of RM (i.e. 10RM). According to Bird et al., "Prescribing load via the RM method is thought to be superior to using a percentage of 1RM. This eliminates the need for repeated 1RM testing to keep the exercise stimulus effective*"* (Bird et al., 2005).

There are two main principles in strength training: the specificity and progressive overload (DeLorme, 1945). The specificity principle states that different RM models give different strength outcomes, meaning that different loads are necessary for different strength qualities. The load recommendations are: 1-3 RM for power, 3-8 RM for maximum strength, 8-15 RM for hypertrophy and >20RM for muscular endurance (Bird et al., 2005). Progressive loading means increasing the load as the subject becomes stronger. An increase of load by 2-10% is recommended when the subject can perform one or two repetitions more than the predefined number of RM.

Training volume is described as the number of repetitions per set and the number of sets per training session, and training frequency is the number of training sessions within a specified period, usually per week (Bird et al., 2005). The recommended dosage to gain strength in the upper extremities is six to nine sets per muscle group each training session (Ralston, Kilgore, Wyatt, Buchan, & Baker, 2018), two to three times per week with high intensity (Naclerio et al., 2013).

We used the evidence regarding exercise load, volume, frequency and progression and the exercise selection from our Delphi study to develop the strength training program evaluated in paper IV.

Use of elastic bands as resistance

Ideally, shoulder ER strength training should be a part of regular strength training in a gym, where all necessary equipment is available. However, not every adolescent handball team is doing regular strength training or has access to a gym. Therefore, it would be feasible to do the strength training as a part of their handball training and use elastic bands as resistance. Elastic bands are commonly used in the rehabilitation and strengthening of shoulder muscles. They are portable (low weight and size), versatile and cheap, and exist in different colors, representing different resistance levels. When athletes use elastic bands, the load is defined by the resistance of the band. The resistance of the elastic band increases nearly linearly when the band is stretched (Behm 1988; Hughes 1999; Simoneau 2001), and depends on the elastic coefficient (constant), the amount of elastic material (thickness of the band) and the percent change in length ($F=K*CSA*\Delta L$, F=force, k=constant, CSA=cross sectional area, ΔL=length change). However, the resistance to the body is also dependent on the moment arm, which is the perpendicular distance from the line of force application to the axis of rotation (Lieber & Bodine-Fowler, 1993). The moment arm changes through the ROM and is highest when the band-to-arm angle is 90°(Figure 4) (Hughes, Hurd, Jones, & Sprigle, 1999). When elastic bands are used, the combination of increased resistance with stretching and the length of the moment arm will give a bell-shaped torque curve quite similar to "the torque generating capability in many human movements" (Figure 5) (Aboodarda et al., 2013; Hughes et al., 1999; Simoneau et al., 2001).

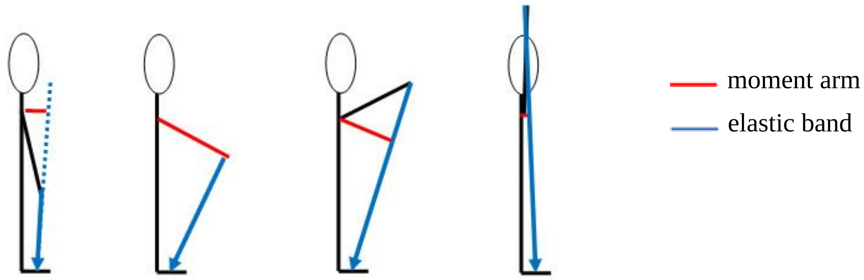

Figure 4 Variation of moment arm with different arm positions during elongation of the elastic band. From: http://exerciseeducation.com/moment-arm/

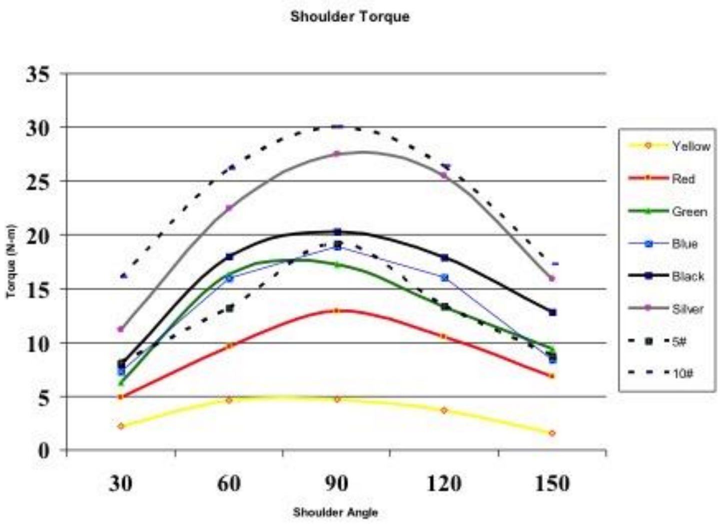

Figure 5 Resistive torque curves for different colour of elastic bands (from: Hughes et al., 1999)

By using electromyography, Skals et al. demonstrated high levels of shoulder muscle activity during high intensity exercises using elastic bands (Skals et al., 2018). Through a meta-analysis, Aboordarda et al. found that elastic resistance produces similar muscle activation as isoinertial resistance does over a wide range of exercises (Aboodarda, Page, & Behm, 2016). This illustrates that using elastic bands for strength training is a good alternative to traditional training devices such as free weights and resistance machines.

Measurements

An outcome measure is a tool to evaluate the status of a patient or an athlete on the effectiveness of an intervention. Two of the most-used physical outcome measures in sports medicine are strength and ROM, which can both be measured objectively by standardized methods.

Ever since the time of Hippocrates nearly 2500 years ago, listening to the patient has been an important part of medicine, science and practice (Revicki, Hays, Cella, & Sloan, 2008). Patient reported outcome measures (PROMs) are questionnaires, which ask about the patient's or player's subjective perception of symptoms and function. Recently, there has been a trend to replace physical outcome measures with PROMs because the latter target issues that are important to patients (Revicki et al., 2008). However, self-reported and objective measurements may represent different entities. Therefore, both objective and PROMs need to be assessed and are often combined to provide baseline data and to capture effects of interventions.

Muscle strength

Muscle strength is usually tested either by isokinetic dynamometers or manually by handheld dynamometers (HHD).

Isokinetic dynamometers are computerized machines, which measure different elements of strength, such as peak force, time to peak force, power or endurance at a preset and constant velocity, either concentric (during muscle shortening) or eccentric (during muscle lengthening). These instruments are big, stationary devices. Isokinetic dynamometry is considered to be a reliable and valid tool to measure several aspects of muscle strength and is stated to be "the gold standard" of muscle testing (Stark, Walker, Phillips, Fejer, & Beck, 2011), mainly because the measurements are not dependent on the strength of the examiner (Revicki et al., 2008). There are, however, several factors to be aware of when conducting isokinetic measurements. Both body and joint position as well as type of muscle contraction and testing velocity may affect the strength (Forthomme et al., 2011; Greenfield, Donatelli, Wooden & Wilkes, 1990). There is currently no consensus on the optimal or preferred testing position or angular velocities when testing shoulder isokinetic strength in throwing athletes.

Hand-held dynamometers are portable devices, placed between the rater's hand and the subject's relevant body part. The rater provides manual resistance to an isometric contraction of isolated muscles or muscle groups. This method is frequently used to quantify muscle force during manual muscle testing in a clinical setting. There is a lack of standardization of the position of the player, joint position, position of the rater, stabilization, placement of the HHD and rate of force application when testing in general (Stark et al., 2011). A review from my own PhD in-depth study (22 studies) showed the same for using HHD on shoulder ER and IR in throwers (Appendix). However, most of the studies have tested the players in a supine position with the shoulder in 90° of abduction in the frontal plane and in 0° of rotation.

Range of motion

Range of motion is usually tested manually with either a manual goniometer or a digital goniometer or inclinometer. Several testing protocols exist, and there is a lack of standardization of the position of the player, position of the arm, stabilization and end-range of movement definition.

Since there is currently no consensus on the optimal or preferred testing protocol for strength or ROM testing in throwing athletes, it is important to describe the protocol used in different studies in order to be able to compare the results.

Patient reported outcome measures

Patient reported outcome measures are tools to provide a patient-centered approach to components important to the patient. They assess not directly measurable constructs of several dimensions, such as functional status, health and quality of life (Mokkink et al., 2010b; Weldring & Smith, 2013). The PROMs can be generic, region-, disease- or injury- specific. The OSTRC overuse questionnaire is a generic PROM, which assesses the symptoms, function, participation and performance related to all types of overuse injuries throughout the body and can be used among most athletes. On the contrary, the KJOC questionnaire is region-specific (shoulder and elbow) and population-specific (overhead athletes).

A shoulder-specific questionnaire for overhead athletes would be a good tool for therapists to monitor the players' shoulder problems during rehabilitation and to aid the return-to-play decisions. The KJOC questionnaire comprises ten items that are combined to produce a total score between 0 and 100, to evaluate the athletes' shoulders with regards to performance, function and pain. A higher score indicates better function. The KJOC consists of more questions about throwing-related function and performance than other upper limb questionnaires do. It is a valid, reliable and responsive tool in the evaluation of overhead athletes. Originally, the questionnaire was developed and validated for English-speaking overhead athletes. For this to be useful to a Norwegian population, a rigorous translation and cultural adaptation process is necessary to maintain the content validity of the instrument at a conceptual level. Therefore, this was the aim of study I.

Measurement properties

A measurement property is defined as "a feature of a measurement instrument that reflects the quality of the measurement instrument" (Mokkink et al., 2010b). The measurement instrument or method must be reliable and valid when measuring physical characteristics like strength and ROM and when using PROMs.

Reliability

Reliability refers to the consistency or repeatability of a measure (Thomas & Nelson, 1996). Reliability pertains to measurement error, which is the difference between the observed score and the true score. A test is reliable if it gives the same result during repeated measures under the same testing conditions (Vincent, 2005). The more reliable an assessment tool or method, the more sensitive it will be to detect small but important changes (Edouard et al., 2011). There are several forms of reliability: intra-rater, inter-rater and test-retest reliability. Intra-rater reliability refers to what degree one rater achieves the same result under the same conditions, whereas inter-rater reliability refers to the agreement between two or more raters. The reliability of PROMs is not rater-dependent and is therefore termed test-retest reliability.

Relative reliability gives an estimate of how well two tests (two data sets) are associated or correlated. It describes to what degree individuals keep their position consistent when measured repeatedly (Atkinson & Nevill, 1998) and is usually presented as intraclass correlation (ICC). However, correlation does not assess individual agreement and thus cannot be used for addressing clinically relevant questions (Altman, 2009).

Absolute reliability gives information about the extent to which repeated measures vary for individuals and provides more clinically useful information than ICC does. Absolute reliability is presented as standard error of measurement (SEM), minimal detectable change (MDC) or Bland and Altman 95% limits of agreement (LOA) (Atkinson & Nevill, 1998; Bruton, Conway, & Holgate, 2000; Moller et al., 2018). SEM is an estimate of the random error of a score and is presented in the actual units of measurement, which means the smaller the SEM, the more reliable the measurement. MDC is the minimal change that falls outside the SEM and is used to decide if changes between measurements are real and not due to measurement error. A high ICC does not have to correspond with a high SEM or LOA. If there is a heterogeneous group of subjects with high variability among their scores, there is a high probability of achieving a high

ICC despite relative high measurement error. On the contrary, SEM and MDC are not affected by the range of the measurements (Atkinson & Nevill, 1998). Internal consistency refers to "the interrelatedness among the items" of a scale (Mokkink et al., 2010b), which means that the different items in a questionnaire measure various aspects of the same construct.

Validity

Validity refers to whether a test is measuring what it is supposed to measure (Vincent, 2005). The validity of PROMs is accumulated through different studies, which evaluate different kinds of validity, such as construct validity, content validity and criterion validity.

Construct validity refers to how well an instrument measures the constructs that it was designed to measure, thereby allowing inferences to be made from the scores (Davidson & Keating, 2014). Known-groups validity is one aspect of construct validity and refers to if an instrument can discriminate between two groups known to differ in the variable of interest (Buuck & Davidson, 1996). Content validity is a judgement about the relevance and comprehensiveness of the test and should be done by the end-users and experts in the field (Terwee et al., 2007). Face validity, or logical validity, which is an aspect of content validity, refers to whether a test looks as though it reflects the construct of interest (Davidson & Keating, 2014; Thomas & Nelson, 1996) (Mokkink et al., 2010b). A test must be reliable to be valid, and it should always be validated in the population of interest.

Aims of the thesis

The overall aim of this PhD is to contribute knowledge to the field of sports medicine to prevent shoulder injuries in handball.

The following aims were addressed in the four studies:

I. To translate, culturally adapt and validate the KJOC for a Norwegian context (KJOC-N), to make an electronic version of the KJOC-N, and to evaluate the measurement properties of KJOC-N

II. To assess if the intervention in the OSTRC shoulder prevention program targets key risk factors: ER strength and IR ROM

III. To develop a short and effective program to target shoulder ER strength, with high likelihood of adherence in a handball population

IV. To assess if a short shoulder ER strength program, using elastic bands, is effective in a population of adolescent handball players

Methods

Study design and approach

The four different papers in this dissertation are the result of three different projects. In the first project, we translated and culturally adapted the Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow (KJOC) questionnaire to Norwegian. We then evaluated the measurement properties of the Norwegian version of the KJOC questionnaire (Paper I).

In the second project, we conducted a randomized controlled study to assess the effect of the OSTRC shoulder injury prevention program on external rotation (ER) strength and internal rotation (IR) range of motion (ROM), considered to represent key risk factors for injury (Paper II).

In the third project, we aimed to develop a short and effective shoulder ER strength program that handball players would adhere to. This resulted in two papers: Paper III describes the development of the program through a Delphi consensus study, and Paper IV assesses the effectiveness of the program in adolescent handball players through a randomized controlled study.

Participants

For the first part of paper I, we recruited 33 overhead athletes for face- and known-group validation of the questionnaire. They were recruited as follows: 1) Patients attending the physiotherapy department at the Norwegian Olympic Sports Center; 2) Overhead athletes training at the Norwegian Olympic Training Center; 3) Handball players from a local handball club. Subsequently, we recruited 38 handball players from two local handball clubs (one male and one female) for reproducibility and concurrent validity testing (Paper I). This was a convenient sample with teams recruited through the researcher's contact network.

On two different occasions, we invited all handball teams (age 16-18 years old), within or close to Oslo, Norway, to participate in two different studies (Paper II and Paper IV). In both studies, we excluded teams with fewer than 12 players, and in paper II, we excluded teams who already performed shoulder injury prevention programs as parts of their training routines. Teams were randomly selected: four teams in paper II and six teams in paper IV. We visited the included teams during preseason to inform and invite the players to participate. Fifty-seven players agreed to participate in paper II and 92 players in paper IV.

We invited 17 experts from all over the world with special competence in the field of shoulder research, shoulder rehabilitation, handball- or strength training or combinations of these fields, representing physiotherapy, medicine, handball coaching and -playing to be the panel members for the first part of the third project (Paper III). Sixteen experts from nine countries accepted to participate in the project.

The first project (Paper I) was approved by the Norwegian Centre for Research Data. The South-Eastern Regional Committee for Medical and Health Research Ethics stated that approval was not necessary since the study did not include an intervention.

The second project (Paper II) and second part of the third project (Paper IV) were approved by the South-Eastern Regional Committee for Medical and Health Research Ethics.

The first part of the third project (Paper III) was approved by the Norwegian Centre for Research Data.

All participants received written information about the aims of the projects, the procedures involved, and any potential risks involved with participation and their rights, and they signed a written consent form.

Translation and cultural adaptation of KJOC questionnaire

We conducted this study in two phases (Figure 6). The first phase comprised translation and cultural adaption of the KJOC questionnaire to Norwegian and evaluation of face- and known-group validity. In the second phase, we adapted the KJOC-N from paper to an electronic version and evaluated concurrent validity and test-retest reliability of the latter.

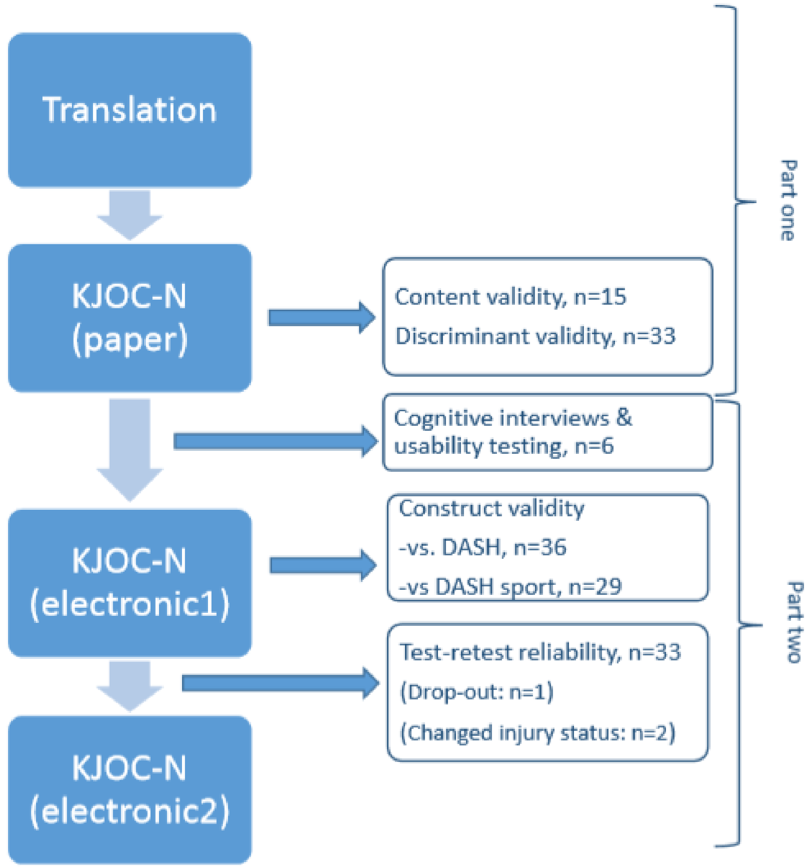

Figure 6 Flow chart of the two parts of the study

Translation and cultural adaptation of the questionnaire followed the principles of good practice from the International Society of Pharmacoeconomics and Outcome research (Wild et al., 2005) and the guidelines by Beaton et al (Beaton, Bombardier, Guillemin, & Ferraz, 2000).

- Forward translation by two independent bilingual Norwegian residents, whose native tongue is Norwegian
- Synthesis of the translation: The project manager held separate meetings with each of the translators to address discrepancies, seek agreement and make a synthesis of the two translations.
- Back translation by two independent Norwegian residents, whose native tongue is English

- Harmonisation: The harmonisation group consisted of the four translators, a language-competent research physiotherapist and the project manager, in close contact with the original developer. Decisions were made to obtain semantic, idiomatic, experiential and conceptual equivalence between the original questionnaire and the Norwegian version.
- Tests of the harmonized version were conducted among 33 overhead athletes, who responded to the questionnaire and were interviewed about the meaning of the items, the responses and the relevance to their sport. Additionally, two coaches, one medical doctor and three physiotherapists were interviewed about the questionnaire.
- The results from the interviews were reviewed, and a final version of the questionnaire was proofread.

Known-group validity

The 33 athletes who completed the harmonised version were also asked about previous shoulder injuries and instructed to assign themselves to one of three categories: 1) playing without pain; 2) playing with pain; 3) not playing due to pain.

Measurement equivalence between the paper-based and electronic version of the Norwegian KJOC questionnaire.

When adapting the KJOC-N from paper to the electronic version, we made no change in the content or meaning of the questionnaire. We conducted small-scale cognitive interviews and usability testing (Coons et al., 2009; Muehlhausen et al., 2015). Six randomly selected players completed the paper-based KJOC-N version during a training session and the electronic version online three to six days later. Thereafter, they were interviewed about whether the electronic version changed the way they interpreted the questions, how they decided on an answer or how they responded to the questions.

Concurrent validity (KJOC-N vs DASH) and reproducibility of the electronic version of KJOC-N

We sent the electronic version of the KJOC-N and DASH questionnaires to 38 handball players to evaluate the concurrent validity. To evaluate the test-retest reliability, we asked them to fill out the KJOC-N again one week later and to note if injury status had changed during that week.

Assessment of the effect of exercise programs on risk factors

Shoulder testing

Testing at baseline and at post-intervention (Paper II and IV) were conducted in the afternoon under standardized conditions and included manual measurements of isometric ER and IR and measurements of ER and IR ROM in both paper II and IV, and isokinetic strength measurements in paper II. The players were instructed to refrain from training prior to the testing on the same day. Manual testing of isometric strength and ROM after 6 and 12 weeks were conducted in the handball clubs' facilities (Paper II). The same experienced therapist and assistant conducted the manual testing both in paper II and paper IV. Two different therapists were responsible for the isokinetic testing at baseline and post-intervention (Paper II). In a pilot study prior to baseline testing, we assessed the test-retest repeatability (intra-rater reliability) of the manual strength and ROM measurement with 1-week intervals in 30 shoulders.

Prior to testing, the players performed a standardized warm-up, consisting of multiplane shoulder movements. The testing procedure started with ROM measurements, followed by isometric and isokinetic strength measurements. Measurements were randomized between sides. All the manual measurements of strength and ROM were performed with the player in supine with the shoulder abducted to 90° in the frontal plane and neutral rotation.

Baseline questionnaires

At baseline, we registered demographic data, hand dominance, years playing handball, shoulder problems the previous year and whether the players were playing with or without shoulder pain.

Isometric strength testing

Maximum isometric ER and IR was measured using a HHD (MicroFET, Hoggan Health Industries, Salt Lake City, Utah, USA). We used the same procedures as those described by previous authors (Andersson et al., 2018; Cools et al., 2014; Oliver, Plummer, & Brambeck, 2016). However, to keep a stable and consistent resistance, the rater stabilized her own elbow against the iliac crest with the forearm at a right angle to the subject's forearm. Additionally, to restrict shoulder adduction during the test, the examiner placed her medial hand against the bench on the caudal side of the players elbow (Figure 7).

Figure 7 Isometric shoulder external rotation strength measurement

Range of motion testing

IR and ER ROM were measured using a digital goniometer (Easyangle, Meloq AB, Stockholm, Sweden). We used the same procedures with scapula stabilization as those described by Wilk et al. (Wilk et al., 2009). We ensured the player was completely relaxed and used no overpressure (Figure 8).

Figure 8 Shoulder internal rotation range of motion measurement

Detailed test protocols for the manual tests are attached as appendix IV.

Isokinetic strength testing

The isokinetic ER and IR testing was performed on a Humac NORM isokinetic dynamometer (CSMi, Stoughton, MA) and mainly followed the procedure described by van Cingel et al. (van Cingel, Habets, Willemsen, & Staal, 2017). The range tested was from 80° ER to 40° IR. We conducted concentric testing at 60°/s and 300°/s, followed by eccentric testing at 60°/s. At each velocity, the players completed three submaximal repetitions for practice before performing five maximal contractions.

Intervention

In paper II, the OSTRC shoulder prevention program (Andersson et al., 2017) (appendix V) was implemented during regular handball warm-up three times a week for 18 weeks in the intervention group. The program consisted of five exercises aimed to increase ER strength, IR ROM, scapula stabilization, thoracic mobility and kinetic chain involvement. One physiotherapist for each team delivered and supervised the program once or twice a week. The program took approximately 15 minutes to complete.

In paper IV, the intervention group conducted the shoulder ER strength program based on results from the Delphi consensus study (appendix VI). The program consisted of eight shoulder ER strength exercises, two of which were paired (one single plane exercise in 90˚abduction and one combined exercise, including the kinetic chain) and were performed each training session. Both exercises were conducted with elastic bands in three sets of eight repetitions with two repetitions in reserve. The program was implemented after handball training, three times per week for eight weeks, and the pair of exercises were changed every second week. One physiotherapist for each team delivered and supervised the program once or twice a week. The program took 5–10 minutes to complete.

Weekly questionnaires

A questionnaire was sent to the participants each Sunday during the intervention period through an online survey software (Briteback AB, Sweden). In paper II, the players reported the time, in minutes, they had completed the exercise program, and in paper IV, the players reported how many times they had completed the program. The total number of minutes or times completed was divided by the number of respondents in order to calculate the weekly adherence to the program. Players also reported their exposure to handball training and matches as well as additional shoulder training. The total number of minutes completed was divided by the number of respondents to calculate the weekly exposure in each group.

The prevalence of shoulder problems, other injuries and illnesses was recorded using the OSTRC injury and illness questionnaire (Clarsen et al., 2013) in both paper II and paper IV and the KJOC questionnaire in paper II, to monitor whether these factors influenced the players' adherence to the program.

Development of a Short and Effective Shoulder External Rotation Strength Program in Handball

To develop a short and effective shoulder ER strength program that handball players would adhere to, we conducted a worldwide modified Delphi study, which included experts in the fields of shoulders, strength training and handball. The flowchart of the study is provided in Figure 9. Prior to the rounds, we conducted a literature review of electromyographic studies on shoulder exercises to find exercises with a high activation of shoulder ER muscles. The eight exercises with the highest activation of ER muscles were selected and described in detail. In the first round, the experts were asked to rate the eight pre-defined shoulder ER exercises, using a visual analogue scale (VAS), on efficacy and adherence and to suggest other preferred exercises. They were also asked about progression and if ER strength training should be performed during handball warm-up or as separate strength training sessions. In round two, they were asked to rate and comment on the new exercises from round one. In round three, they received a statistical summary of the panels’ scores of all the exercises, their own scores and a summary of the suggestions from the two previous rounds. Based on the feedback, the experts were asked to revise their responses.

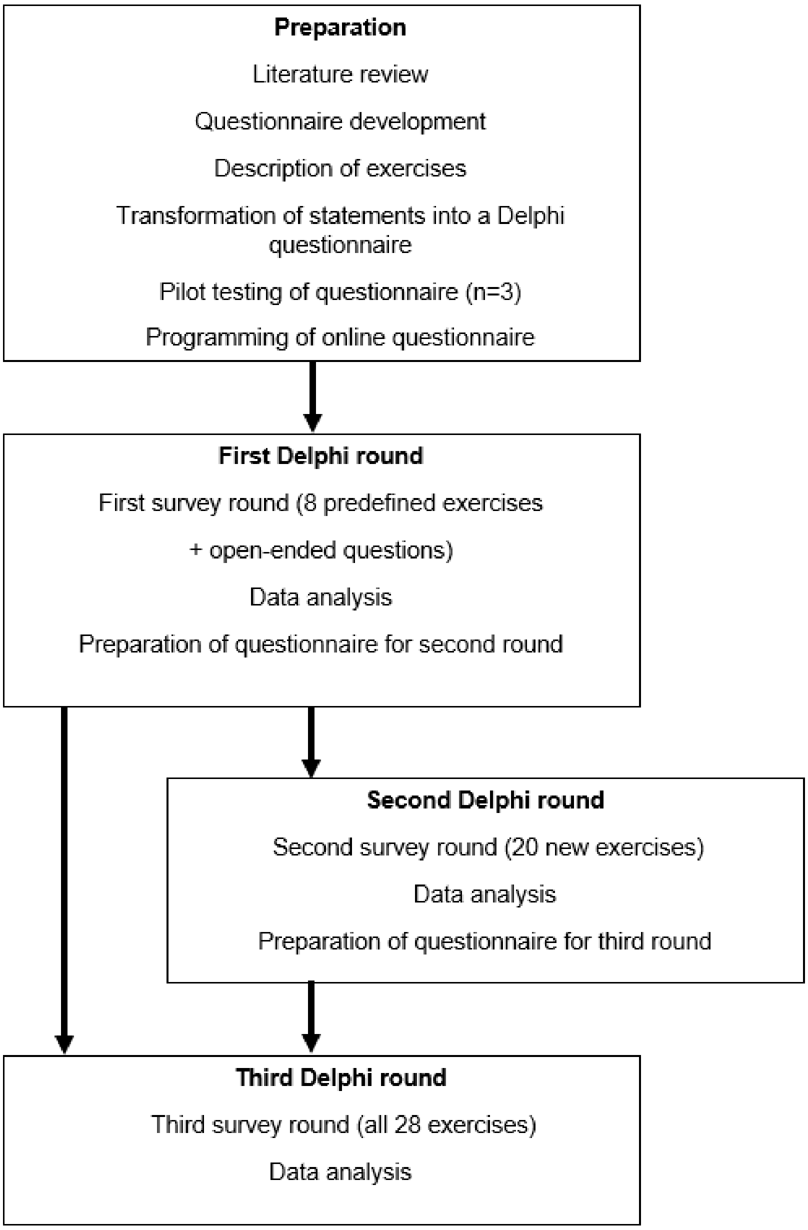

Figure 9 Flowchart of the Delphi study

Statistics

Data were analyzed using SPSS 24 for Windows (IBM Corporation, New York, USA) for all the projects.

Paper I

Internal consistency was evaluated using Cronbach's alpha. A paired T-test was used to test for systematic differences between the two rounds. Test-retest reliability of the KJOC-N was calculated using a two-way mixed effects model, single measurement and absolute agreement ($ICC_{2,1}$). Absolute reliability was determined by calculating SEM and Bland and Altman 95% LOA. The Mann-Whitney test was used to examine known-group validity by comparing players with and without a history of shoulder injury to players playing with and without pain. Spearman's correlation test was used to examine the correlation of the KJOC-N with DASH total and DASH sports/performing arts scores, and one-sample t-test test was used to compare the KJOC-N and DASH total.

Paper II and Paper IV

Prior to the projects, we estimated the sample size based on a previous study examining shoulder ER strength effects of a rubber band shoulder training program (Mascarin et al., 2017) and values from our reliability testing of isometric ER strength. With a 15% increase in ER strength from baseline to the end of the study, the expected between-group difference was set at 0.31N/kg with a SD of 0.35N/kg. Both papers used a significance level (α) of .05, and a drop-out rate of 15%. By using a power of 80% (Paper II), we needed 24 players per group, and by using a power of 90% (Paper IV), we needed 36 players per group.

Analyses were based on the intention-to-treat principle, in which all randomized participants were included in the analyzes according to their group assignment. Repeated measures linear mixed-effect models with random intercept were used to assess the between-group differences on each outcome variable. Time was defined as a categorical variable with four levels (baseline, 6, 12 and 18 weeks) in paper II and two levels (baseline and post intervention) in paper IV. Group (two levels: intervention and control), time and group*time interaction were fixed variables. In paper IV, team and shoulder pain at baseline were defined as covariates. By using all available data at each time, linear mixed models handle missing data. Therefore, imputation of missing data was not conducted.

Paper III

Descriptive statistics was used to calculate the median scores and interquartile ranges for each statement in each of the three rounds. The Wilcoxon signed rank test was used to compare results from round one and two with those from round three. A consensus was based on two criteria: 1) agreement with the statement if median score > 65; and 2) consensus among the panel members if 75% of the panel (12/16) scored above 50.

Results and discussion

Norwegian Translation, Cross-Cultural Adaptation and Validation of the Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Questionnaire (Paper I)

Translation

During the translation and cultural adaptation of the KJOC, we made small consensus-based adjustments to reach conceptual equivalence with the original version. Athletes, coaches and medical personnel found the questionnaire relevant, easy to understand and complete. The comparison between the paper and electronical version yielded no differences, but the athletes preferred the electronic version.

Measurement properties

The questionnaire distinguished between players who were playing with and without shoulder pain and between players with or without a history of shoulder pain (known-group validity).

The electronic version of the KJOC showed excellent internal consistency (Cronbach's α = 0.952) and relative test-retest reliability (ICC = 0.967). SEM, MDC and LOA were 3.05, 8.45 and -9.2 to 7.7 respectively. These results were comparable to previous translations (Merolla et al., 2017; Oh et al., 2017; Turgut & Tunay, 2018).

The concurrent validity vs DASH was moderate (Spearman's rho = -0.642). The KJOC had a wider range in scores than the DASH had and discriminated better between players playing with and without pain (table 5). This supports the intention behind the development of the KJOC to capture overhead athletes' functional status (Alberta et al., 2010).

Table 5 Kerlan-Jobe Orthopaedic Clinic scores and Disability of Arm Shoulder and Hand scores, comparing groups playing with and without shoulder pain (n=35)

Category	**n**	**KJOC-N**	**DASH**
Playing without pain	19	95.1 (6.2)	2.9 (4.2)
Playing with pain	16	77.8 (19.0)	7.2 (6.9)†
Difference		17.3 (6.9 to 27.8)*	4.4 (-8.2 to -0.5)**

*Mean (SD) is presented for the observed values within each group. Mean (95%CI) is presented for the estimated difference between the categories * p<0.001, ** p= 0.062, † Difference between KJOC and DASH scores p=0.004*

Limitations of the study

The main limitation of this study is the limited sample size. Another limitation is the inclusion of only handball players for the reproducibility and concurrent validity measures. Since handball is the dominant overhead sport in Norway, it was a convenient sample, consisting of one male team and one female handball team. In the current study, the KJOC score ranged from 60.1 to 100, which reflects a quite healthy population. However, this represented the population of interest, handball teams, in which more than half the population have no shoulder problems. The results thus cannot be generalized to handball players with moderate to severe shoulder problems.

To evaluate concurrent (criterion) validity, a "gold standard" is required for comparison. Today, there is no gold standard for assessing functional upper limb status in overhead athletes, but the DASH is the most-used PROM for this purpose. We therefore used the DASH as the criterion. However, the intention of the KJOC was to develop a questionnaire to measure the functional status of the upper extremity in overhead athletes, particularly those without limitations in their daily activities and only with problems (not captured through previous PROMs) during their sport (Alberta et al., 2010). Therefore, we did not expect a strong correlation with the DASH. According to the Terwee et al., hypothesis testing of expected correlation between measures (with no gold standard) is a part of construct validity (Terwee et al., 2007). We may therefore have labelled the correlation testing with the DASH as construct validity. An overview of our assessment the measurement properties of KJOC is provided in Figure 10 (COSMIN taxonomy of relationships of measurement properties) (Mokkink et al., 2010a).

Another limitation is that we did not study the KJOC-N's responsiveness, a psychometric property important to judge treatment outcome or monitor changes over time. Interpretability refers to "the degree to which one can assign qualitative meaning to quantitative scores" (Terwee et al., 2007), or in other words, identifying what score might be clinically meaningful. The lack of an established clinical important change reduces the interpretability. However, providing scores for subgroups of the population, such as players with and without previous shoulder problems or players playing with or without shoulder pain, could help interpret the scores in a clinical setting.

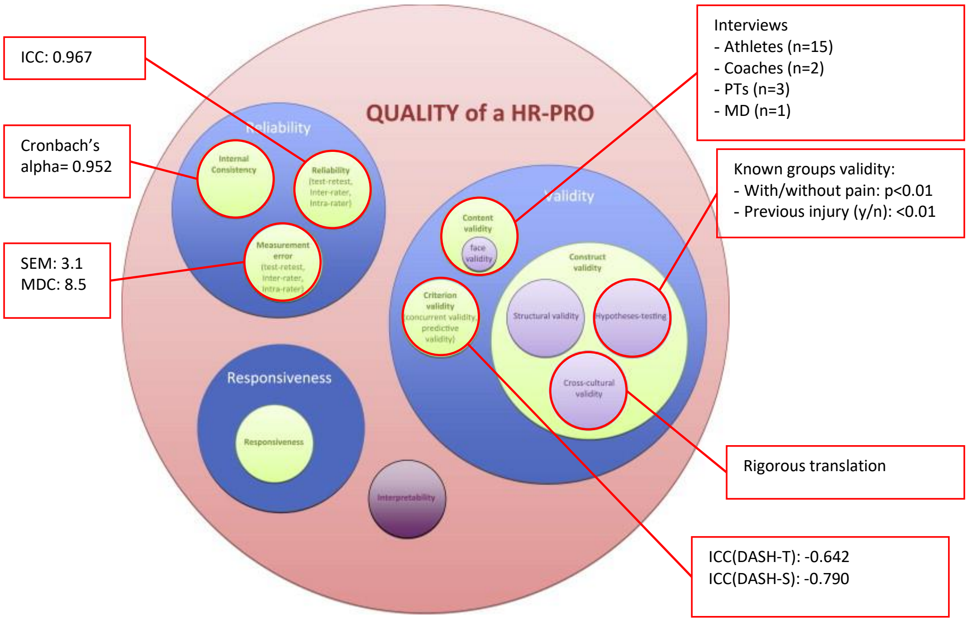

Figure 10 Our results, superimposed on the figure from The COSMIN Checklist for Assessing the Methodological Quality of Studies on Measurement Properties of Health Status Measurement Instruments: An International Delphi Study.(Mokkink et al., 2010a) (permission for reuse obtained from the author) Abbreviations: COSMIN, COnsensus-based Standards for the selection of health Measurement INstruments; HR-PRO, health related-patient reported outcome; ICC, Interclass Correlation Coefficient; SEM, Standard Error of Measurement; MDC, Minimal Detectable Change; PT, Physical Therapy;, MD, Medical Doctor; DASH-T, Disability of the Arm, Shoulder and Hand-Total score; DASH-S, Disability of the Arm, Shoulder and Hand-Sport score

Although the KJOC captures throwing-related impairments, functional limitations and disability, it does not include items of activities of daily living or psychological factors, unrelated to sports. To assess the full impact of the injury on the athlete's life or to assess improvements from an early stage after a serious injury, another (or several) questionnaire must be added. Recently, a new upper extremity region-specific and population-specific patient-reported outcome scale for throwing athletes has been developed, called the Functional Arm Scale for Throwers (FAST) (Huxel Bliven, Snyder Valier, Bay, & Sauers, 2017; Sauers, Bay, Snyder Valier, Ellery, & Huxel Bliven, 2017). The questionnaire contains 22 items, which can be divided into the following five sub-scores: pain, throwing, activities of daily living, psychological impact and advancement. The FAST was demonstrated to be a reliable, valid and responsive upper-extremity specific scale for measuring patient-reported outcomes in baseball and softball players with injuries. The FAST is more comprehensive than the KJOC and shorter than the DASH. However, the results cannot be generalized to other overhead sports, and a rigorous translation and cultural adaptation must be conducted before the FAST can be used among Norwegian overhead athletes. In the meantime, the KJOC questionnaire is the best evaluation tool for Norwegian overhead athletes.

Does an Effective Shoulder Injury Prevention Program Affect Risk Factors in Handball? A Randomized Controlled Study (Paper II)

Our results are based on 57 players (age 17.1±0.8 (SD) years), 28 players in the intervention group (5 males, 23 females) and 29 players in the control group (6 males, 23 females).

Shoulder strength

Mean dominant shoulder isometric ER strength increased significantly in both the intervention (10%) and in the control group (6%). The estimated group difference was 0.06 N/kg (95% CI -0.04 to 0.17). We found no significant differences between the intervention and the control group for any of the other strength outcome variables: isometric IR strength, ER/IR strength ratio, isokinetic strength at 60°/s or 300°/s or type of contraction (con/ecc).

Two previous studies have examined the effect of a 6-week shoulder strength program in handball (Genevois et al., 2014; Mascarin et al., 2017). They both found large effect sizes, but like our study, they found no group by time interaction effect. At baseline, our players' ER isometric strength were comparable to the reference values for adult handball players and greater than reported for adolescent players. In contrast, Mascarin et al. included players with ER weakness only. Therefore, the strength gain potential might have been lower in our study.

Shoulder range of motion

Mean IR ROM did not change in either group during the intervention and neither did any of the other ROM outcome measures: ER ROM, GIRD or total ROM.

A recent systematic review concluded that the cross-body stretch may be effective to improve GIRD in the immediate and short term (4 weeks), but the sleeper stretch was not effective (Mine, Nakayama, Milanese, & Grimmer, 2017). In our study, the players conducted the cross-body stretch for 6 weeks (week 7 through 12) with no effect. At baseline, our players had normal dominant shoulder IR, with an average of 64° and a side-to-side difference of 8°. This might imply less room for improvement in our athletes compared to the subjects of other studies that have demonstrated an effect of stretching in populations with GIRD ≥15° (Asker, Brooke, et al., 2018; Chepeha, Magee, Bouliane, Sheps, & Beaupre, 2018).

Dose-response

One possible explanation for our results could be insufficient dosage to achieve improvements. The dosages used in our study was lower than recommended dosages for strength gain in the upper extremities (Naclerio et al., 2013; Ralston et al., 2018) and for increased shoulder IR ROM (Chepeha et al., 2018; Mine et al., 2017).

During this study, our measurements were highly reliable, the follow-up of the players were more attentive, the adherence to the program was higher and the players' responses to the weekly questionnaire was more frequent than in the original study by Andersson (Andersson et al., 2017). This implies that our results are reliable. We therefore concluded that the preventive effect of the OSTRC prevention program must be due to other factors, not evaluated in our study.

Limitations of the study

The inclusion of male teams was challenging, so we ultimately used three female teams and one male team. Since we randomized the players within each team, gender distribution between the intervention and control groups was unaffected. According to Peitz et al. (Peitz, Behringer, & Granacher, 2018), gender does not affect resistance training related outcome when comparing males and females of same age. However, our sample size is too small to do gender subgroup analyses.

The study was conducted with youth handball players, so we cannot generalize our results to adult players.

Development of a Short and Effective Shoulder External Rotation Strength Program in Handball: A Delphi Study (Paper III)

We had a 100% response rate in all three rounds. Two exercises, ER in 90° of abduction in a bent-over squat position (Figure 11) and ER in 90° of abduction combined with horizontal abduction and trunk rotation in a push-up position (Figure 12), reached consensus between panel members for both efficacy and adherence.

Figure 11 Shoulder external rotation in a bent-over squat position

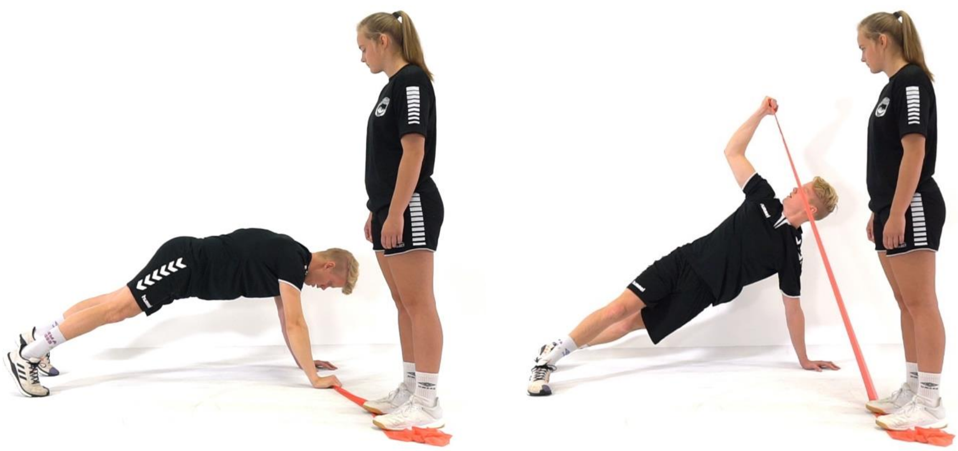

Figure 12 Shoulder external rotation in 90° of abduction combined with horizontal abduction and trunk rotation in a push-up position

The aim of the study was to develop a short and effective shoulder ER strength program. Six sets per muscle group per training session have been shown to be effective for improving upper body maximum strength and average power (Naclerio et al., 2013). Therefore, three sets of each of the two ER strength training exercises can be expected to constitute an effective dose. However, in order to target the whole muscle group and to improve player motivation and adherence, we wanted to use a variation of exercises. Eight exercises fulfilled the criteria of combined median VAS scores >65 on efficacy and >60 on adherence, of which four were single plane exercises (shoulder ER in 90° of abduction) and four were combined exercises. A short strength program can consist of a pair of exercises, one single plane and one combined exercise each training session, and the pair of exercises can be changed after some weeks for variation.

Limitations of the study

We did not do a formal search for experts, but used a purposive sampling based on the authors' knowledge about the experts in the field. By doing so, we have missed several well-qualified experts, and our panel is therefore not a representative sample.

Despite the limitations, the results are based on a consensus among a group of international experts in the field. However, consensus does not mean the results are true. To conduct an extension of this study, we therefore planned an RCT to test if the exercise program would increase ER strength in handball players.

No added benefit of 8-weeks of shoulder external rotation strength training for youth handball players over usual handball training alone: a randomized controlled trial (Paper IV)

Strength and ROM outcome measures

The mean estimated effect size in shoulder ER strength was 0.06 N/kg (95% CI -0.01 to 0.14). The intervention had no effect on any of the secondary outcome variables.

Response rate, adherence and exposure

The mean weekly response rate to the questionnaire was 95% in the intervention group and 88% in the control group. On average, the shoulder strength program was completed 2.5 times a week (range 2.3 to 2.8). The average weekly exposure to handball training, match play and additional shoulder training was not different between the groups.

Study limitations

We used six sets per muscle group each training session, three training sessions per week, and aimed for high intensity (8 repetitions with 2 repetitions in reserve) (Naclerio et al., 2013; Ralston et al., 2018; Zourdos et al., 2016). This was within the recommended dosage to obtain strength gain in the upper extremities in college team sport athletes with no previous resistance training experience (Naclerio et al., 2013). However, our study participants were more experienced handball players (8.8 years) and were strong at the time of inclusion. Their baseline strength measurements were comparable to the reference values for adult handball players (Cools et al., 2016) and higher than reported for adolescent players (Genevois et al., 2014; Moller et al., 2018). Since the dose-response for muscular strength development is dependent on the players' training status and experience (i.e. more advanced athletes need higher dosages to optimize strength gain), the dosage might not have been high enough to improve strength in our sample.

We defined our strength training program in terms of traditional descriptors of strength training: load magnitude, number of repetitions and sets, sessions per week and duration of experimental period. However, according to Toigo et al., there are several other important resistance determinants of molecular and cellular muscle adaptation (Toigo & Boutellier, 2006). These are displayed in Table 6 together with the descriptors used in our study.

Table 6 Strength training descriptors (Toigo & Boutellier, 2006) of the exercises performed in the intervention group

Load magnitude	8 RM
Number for repetitions	Until 2RIR
Number of sets	6 sets (3 per exercise)
Rest in-between sets	-
Sessions per week	3
Duration of experimental period	8 weeks
Time under tension	-
Contraction modes per repetition (concentric/isometric/eccentric)	-
Rest in-between repetitions	-
Volitional muscular failure	2 RIR
Range of movement	Defined for each exercise
Rest between exercise sessions	-
Anatomical definition of exercise	Yes

Abbreviations: RM, Repetition Maximum; RIR, Repetitions in Reserve

Rest periods of 2 – 5 min between sets have been recommended to improve maximal strength ("American College of Sports Medicine position stand. Progression models in resistance training for healthy adults," 2009; de Salles et al., 2009; Grgic, Schoenfeld, Skrepnik, Davies, & Mikulic, 2018). Since time is a main barrier to player adherence to prevention programs, we aimed to make the strength training program as short as possible. Therefore, we did not define a rest in-between sets, but the players' rest was defined as the time it took their partners to complete one exercise set. In order to complete the program within 10 min, the players had less than 90 s rest periods (in practice around 60 s). This could possibly have impaired the training effect of the program. Another important determinant of muscular adaption is time under tension (TUT). TUT is the total time of concentric, quasi-isometric and eccentric contractions during an exercise set and represents the time factor of the strength training stimulus (Toigo & Boutellier, 2006). A longer TUT has been demonstrated to be superior to a shorter TUT to increase myofibrillar protein synthesis. We did not define TUT in our study; we only told the players to work through the full ROM without ballistic movements. It is our experience that in order to achieve the recommended dosage, TUT and rest in-between sets, longer training sessions than 10 min are required.

Methodological considerations (paper II and IV)

We slightly adjusted previously described testing to reduce the measurement error with manual muscle testing using HHD. We ensured that the examiner had a stable position, which enabled her to withstand great forces without problems. The examiner's medial hand was placed against the bench on the caudal side of the players elbow to restrict shoulder adduction during the tests. Eliminating the adduction momentum would probably lead to purer rotational measurements, which would affect the results. Additionally, one very experienced physiotherapist conducted all the testing to ensure consistency.

Pre- and post-intervention testing was conducted in the afternoon in a test lab (paper II) or in a physiotherapy clinic (paper IV). The players were instructed to refrain from training prior to testing on the same day. However, strength can be influenced by fatigue and level of recovery from previous load, like participation in a recent tournament (Skillington, Brophy, Wright, & Smith, 2017). We did not control for this factor in our studies, which may have influenced our results.

There is a possibility of contamination when we do simple randomization within the teams. However, the intervention and control groups were separated during the intervention in paper II, and in paper IV, the players in the control group left the training area after finishing handball training. Additionally, the players in the control group did not report doing any part of the intervention exercises, and the exposure to additional shoulder training was similar in the two groups. In our extensive experience working with handball players, both as physical therapists and coaches, we have recognized that they mainly want to play handball, rather than additional training like strength or preventive training. The risk of low adherence is thus probably higher than the risks of contamination or confounding effect.

Conclusions

1. The KJOC shoulder and elbow questionnaire is designed to evaluate the overhead athletes' performance, function and pain. We have conducted a rigorous translation and cultural adaptation of the questionnaire to Norwegian. Our results suggest that the KJOC-N is a reliable and acceptable tool for evaluating shoulder and elbow-related problems in Norwegian overhead athletes (handball players).

2. The OSTRC shoulder injury prevention program did not affect the risk factors ER strength or IR ROM. The preventive effect must therefore be due to other factors not assessed in our study, or ER strength and IR ROM are not important risk factors. Continued research of preventative mechanisms is warranted.

3. There is currently no consensus about exercise selection to increase shoulder ER strength in handball players. Through a Delphi study, we reached a consensus for both efficacy and adherence to two ER strength exercises. Continued research is needed to test if these exercises are effective in the population of interest.

4. A short shoulder ER strength program using exercises from the Delphi study had no effect on shoulder ER strength when implemented after handball training in adolescent handball players.

Future perspectives

Previous research has demonstrated that it is possible to reduce shoulder problems in handball. However, players and coaches reported that the main barriers to completing the shoulder prevention program were lack of time and motivation. Since the teams are also advised to do prevention programs for other body parts, like the knee and ankle, one may question if “they get an adequate return on time investment” (Fuller, 2019).

Despite having a preventive effect on shoulder injuries, the OSTRC shoulder injury prevention program did not affect the proposed risk factors, ER strength and IR ROM, in adolescent handball players. The preventive effect on shoulder injuries must therefore be due to other factors. One explanation is that the program is a well-designed warm-up program to prepare the players for the shoulder demands from playing handball. More specifically, a warm-up prior to activity leads to increased performance through temperature-, metabolic- and neural mechanisms (Bishop, 2003; McGowan, Pyne, Thompson, & Rattray, 2015). One might assume that these mechanisms also have a preventive effect. Particularly, improved function of the nervous system with increased transmission speed of nervous impulses may play a role in sports as they require complex movements and rapid reactions. Using the principles for effective warm-up programs (Bishop, 2003; McGowan et al., 2015), coaches and sports therapists might use exercises from existing effective prevention programs for handball players to make condensed warm-up programs, taking into consideration both the performance and preventive perspectives. Until the effect of such programs is tested, players and coaches should be encouraged to use programs that have already demonstrated efficacy. Additionally, focusing on performance enhancement would be motivation to drive the players and coaches to implement such warm-up programs.

Another explanation for the preventive effect of the program is the potential interaction of various risk factors, described as the web of determinants by Bittencourt et al. (Bittencourt et al., 2016). This interaction was further explored by Moller et al, showing that a quick increase in workload was the most important risk factor in adolescent handball, but the effect was modified by ER strength and scapular dyskinesis.

Therefore, gradually developing the players’ load capacity, both sport- and structure-specific, will result in robust athletes, who are well-prepared for the demands of their sport. This will result in better performance and probably fewer injuries (Malone, Hughes, Doran, Collins, & Gabbett, 2019). To increase strength in players without a strength deficit, higher dosages than used in our studies are probably needed. We therefore suggest focusing on strength improvement during the off-season and maintenance throughout the season. We also suggest doing this training as separate strength training sessions, rather than as a part of handball training.

A previous injury is the strongest predictor of a new injury (Bahr & Krosshaug, 2005; Emery, 2003; Toohey, Drew, Cook, Finch, & Gaida, 2017; Tooth et al., 2020; van der Worp et al., 2015). One reason might be that the player is not fully recovered when returning to play and competition. Another challenge with overuse injuries is that athletes continue to play despite the pain, and the problem is often not detected and addressed until it has reached a certain magnitude, prolonging the rehabilitation period. By regularly monitoring the players' functional status with a questionnaire (like the KJOC shoulder and elbow questionnaire and the OSTRC injury and illness questionnaire), one can more easily detect the problems at an earlier stage to start interventions (secondary prevention) and to ensure proper rehabilitation and return-to-sport. The KJOC questionnaire might be a good tool in combination with physical testing and clinical evaluation to monitor progress through a rehabilitation and to evaluate when the player is ready for return-to-play and competition (tertiary prevention).

References

Aasheim, C., Stavenes, H., Andersson, S. H., Engbretsen, L., & Clarsen, B. (2018). Prevalence and burden of overuse injuries in elite junior handball. *BMJ Open Sport Exerc Med, 4*(1), e000391. doi:10.1136/bmjsem-2018-000391

Aboodarda, S. J., Page, P. A., & Behm, D. G. (2016). Muscle activation comparisons between elastic and isoinertial resistance: A meta-analysis. *Clinical Biomechanics (Bristol, Avon), 39*, 52-61. doi:10.1016/j.clinbiomech.2016.09.008

Achenbach, L., Laver, L., Walter, S. S., Zeman, F., Kuhr, M., & Krutsch, W. (2020). Decreased external rotation strength is a risk factor for overuse shoulder injury in youth elite handball athletes. *Knee Surgery, Sports Traumatology, Arthroscopy, 28*(4), 1202-1211. doi:10.1007/s00167-019-05493-4

Alberta, F. G., ElAttrache, N. S., Bissell, S., Mohr, K., Browdy, J., Yocum, L., & Jobe, F. (2010). The development and validation of a functional assessment tool for the upper extremity in the overhead athlete. *American Journal of Sports Medicine, 38*(5), 903-911. doi:10.1177/0363546509355642

Altman, D. G. (2009). Assessing new methods of clinical measurement. *British Journal of General Practice, 59*(563), 399-400. doi:10.3399/bjgp09X420905

American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. (2009). *Medicine and Science in Sports and Exercise, 41*(3), 687-708. doi:10.1249/MSS.0b013e3181915670

Andersson, S. H., Bahr, R., Clarsen, B., & Myklebust, G. (2017). Preventing overuse shoulder injuries among throwing athletes: a cluster-randomised controlled trial in 660 elite handball players. *British Journal of Sports Medicine, 51*(14), 1073-1080. doi:10.1136/bjsports-2016-096226

Andersson, S. H., Bahr, R., Clarsen, B., & Myklebust, G. (2018). Risk factors for overuse shoulder injuries in a mixed-sex cohort of 329 elite handball players: previous findings could not be confirmed. *British Journal of Sports Medicine, 52*(18), 1191-1198. doi:10.1136/bjsports-2017-097648

Andersson, S. H., Bahr, R., Olsen, M. J., & Myklebust, G. (2019). Attitudes, beliefs, and behavior toward shoulder injury prevention in elite handball: Fertile ground for implementation. *Scandinavian Journal of Medicine and Science in Sports, 29*(12), 1996-2009. doi:10.1111/sms.13522

Ardern, C. L., Glasgow, P., Schneiders, A., Witvrouw, E., Clarsen, B., Cools, A., . . . Bizzini, M. (2016). 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. *British Journal of Sports Medicine, 50*(14), 853-864. doi:10.1136/bjsports-2016-096278

Arnason, A. (2004). Risk Factors for Injuries in Football. *American Journal of Sports Medicine, 32*(90010), 5S-16. doi:10.1177/0363546503258912

Asker, M., Brooke, H. L., Walden, M., Tranaeus, U., Johansson, F., Skillgate, E., & Holm, L. W. (2018). Risk factors for, and prevention of, shoulder injuries in overhead sports: a systematic review with best-evidence synthesis. *British Journal of Sports Medicine, 52*(20), 1312-1319. doi:10.1136/bjsports-2017-098254

Asker, M., Holm, L. W., Kallberg, H., Walden, M., & Skillgate, E. (2018). Female adolescent elite handball players are more susceptible to shoulder problems than their male counterparts. *Knee Surgery, Sports Traumatology, Arthroscopy, 26*(7), 1892-1900. doi:10.1007/s00167-018-4857-y

Asker, M., Walden, M., Kallberg, H., Holm, L. W., & Skillgate, E. (2020). Preseason Clinical Shoulder Test Results and Shoulder Injury Rate in Adolescent Elite Handball Players: A Prospective Study. *Journal of Orthopaedic and Sports Physical Therapy, 50*(2), 67-74. doi:10.2519/jospt.2020.9044

Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine, 26*(4), 217-238.

Bahr, R. (2009). No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *British Journal of Sports Medicine, 43*(13), 966-972. doi:10.1136/bjsm.2009.066936

Bahr, R., & Krosshaug, T. (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. *British Journal of Sports Medicine, 39*(6), 324-329. doi:10.1136/bjsm.2005.018341

Batalha, N. M., Raimundo, A. M., Tomas-Carus, P., Marques, M. A., & Silva, A. J. (2014). Does an in-season detraining period affect the shoulder rotator cuff strength and balance of young swimmers? *Journal of Strength and Conditioning Research, 28*(7), 2054-2062. doi:10.1519/jsc.0000000000000351

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine, 25*(24), 3186-3191. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11124735

Bere, T., Alonso, J. M., Wangensteen, A., Bakken, A., Eirale, C., Dijkstra, H. P., . . . Popovic, N. (2015). Injury and illness surveillance during the 24th Men's Handball World Championship 2015 in Qatar. *British Journal of Sports Medicine, 49*(17), 1151-1156. doi:10.1136/bjsports-2015-094972

Bird, S. P., Tarpenning, K. M., & Marino, F. E. (2005). Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Medicine, 35*(10), 841-851. doi:10.2165/00007256-200535100-00002

Bishop, D. (2003). Warm up I: potential mechanisms and the effects of passive warm up on exercise performance. *Sports Medicine, 33*(6), 439-454. doi:10.2165/00007256-200333060-00005

Bittencourt, N. F., Meeuwisse, W. H., Mendonca, L. D., Nettel-Aguirre, A., Ocarino, J. M., & Fonseca, S. T. (2016). Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition-narrative review and new concept. *British Journal of Sports Medicine*. doi:10.1136/bjsports-2015-095850

Bruton, A., Conway, J. H., & Holgate, S. T. (2000). Reliability: What is it, and how is it measured? *Physiotherapy, 88*(2), 6.

Buuck, D. A., & Davidson, M. R. (1996). Rehabilitation of the athlete after shoulder arthroscopy. *Clinics in Sports Medicine, 15*, 655-672.

Carter, A. B., Kaminski, T. W., Douex, A. T., Jr., Knight, C. A., & Richards, J. G. (2007). Effects of high volume upper extremity plyometric training on throwing velocity and functional strength ratios of the shoulder rotators in collegiate baseball players. *Journal of Strength and Conditioning Research, 21*(1), 208-215. doi:10.1519/r-19315.1

Chepeha, J. C., Magee, D. J., Bouliane, M., Sheps, D., & Beaupre, L. (2018). Effectiveness of a Posterior Shoulder Stretching Program on University-Level Overhead Athletes: Randomized Controlled Trial. *Clinical Journal of Sport Medicine, 28*(2), 146-152. doi:10.1097/JSM.0000000000000434

Clarsen, B., Bahr, R., Andersson, S. H., Munk, R., & Myklebust, G. (2014). Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study. *British Journal of Sports Medicine, 48*(17), 1327-1333. doi:10.1136/bjsports-2014-093702

Clarsen, B., Bahr, R., Heymans, M. W., Engedahl, M., Midtsundstad, G., Rosenlund, L., . . . Myklebust, G. (2015). The prevalence and impact of overuse injuries in five Norwegian sports: Application of a new surveillance method. *Scandinavian Journal of Medicine and Science in Sports, 25*(3), 323-330. doi:10.1111/sms.12223

Clarsen, B., Myklebust, G., & Bahr, R. (2013). Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *British Journal of Sports Medicine, 47*(8), 495-502. doi:10.1136/bjsports-2012-091524

Cools, A. M., De Wilde, L., Van Tongel, A., Ceyssens, C., Ryckewaert, R., & Cambier, D. C. (2014). Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *Journal of Shoulder and Elbow Surgery, 23*(10), 1454-1461. doi:10.1016/j.jse.2014.01.006

Cools, A. M., Vanderstukken, F., Vereecken, F., Duprez, M., Heyman, K., Goethals, N., & Johansson, F. (2016). Eccentric and isometric shoulder rotator cuff strength testing using a hand-held dynamometer: reference values for overhead athletes. *Knee Surgery, Sports Traumatology, Arthroscopy, 24*(12), 3838-3847. doi:10.1007/s00167-015-3755-9

Coons, S. J., Gwaltney, C. J., Hays, R. D., Lundy, J. J., Sloan, J. A., Revicki, D. A., . . . Basch, E. (2009). Recommendations on evidence needed to support measurement equivalence between electronic and paper-based patient-reported outcome (PRO) measures: ISPOR ePRO Good Research Practices Task Force report. *Value in Health, 12*(4), 419-429. doi:10.1111/j.1524-4733.2008.00470.x

David, G., Magarey, M. E., Jones, M. A., Dvir, Z., Turker, K. S., & Sharpe, M. (2000). EMG and strength correlates of selected shoulder muscles during rotations of the glenohumeral joint. *Clin Biomech.(Bristol., Avon.), 15*(2), 95-102. Retrieved from PM:10627325

Davidson, M., & Keating, J. (2014). Patient-reported outcome measures (PROMs): how should I interpret reports of measurement properties? A practical guide for clinicians and researchers who are not biostatisticians. *British Journal of Sports Medicine, 48*(9), 792-796. doi:10.1136/bjsports-2012-091704

de Salles, B. F., Simão, R., Miranda, F., Novaes Jda, S., Lemos, A., & Willardson, J. M. (2009). Rest interval between sets in strength training. *Sports Medicine, 39*(9), 765-777. doi:10.2165/11315230-000000000-00000

DeLorme, T. L. (1945). Restoration of muscle power by heavy resistance exerises. *Journal of Bone and Joint Surgery (American Volume), 27*, 23.

Edouard, P., Degache, F., Oullion, R., Plessis, J. Y., Gleizes-Cervera, S., & Calmels, P. (2013). Shoulder strength imbalances as injury risk in handball. *International Journal of Sports Medicine, 34*(7), 654-660. doi:10.1055/s-0032-1312587

Edouard, P., Samozino, P., Julia, M., Gleizes Cervera, S., Vanbiervliet, W., Calmels, P., & Gremeaux, V. (2011). Reliability of isokinetic assessment of shoulder-rotator strength: a systematic review of the effect of position. *J Sport Rehabil, 20*(3), 367-383.

Edwards, P. K., Ebert, J. R., Littlewood, C., Ackland, T., & Wang, A. (2017). A Systematic Review of Electromyography Studies in Normal Shoulders to Inform Postoperative Rehabilitation Following Rotator Cuff Repair. *Journal of Orthopaedic and Sports Physical Therapy, 47*(12), 931-944. doi:10.2519/jospt.2017.7271

Ekstrand, J. (2013). Keeping your top players on the pitch: the key to football medicine at a professional level. *British Journal of Sports Medicine, 47*(12), 723. doi:10.1136/bjsports-2013-092771

Emery, C. A. (2003). Risk factors for injury in child and adolescent sport: a systematic review of the literature. *Clinical Journal of Sport Medicine, 13*(4), 256-268. doi:10.1097/00042752-200307000-00011

Escamilla, R. F., & Andrews, J. R. (2009). Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. *Sports Medicine, 39*(7), 569-590. doi:10.2165/00007256-200939070-00004

Finch, C. (2006). A new framework for research leading to sports injury prevention. *Journal of Science and Medicine in Sport, 9*(1-2), 3-9; discussion 10. doi:10.1016/j.jsams.2006.02.009

Forthomme, B., Croisier, J. L., Delvaux, F., Kaux, J. F., Crielaard, J. M., & Gleizes-Cervera, S. (2018). Preseason Strength Assessment of the Rotator Muscles and Shoulder Injury in Handball Players. *J Athl Train, 53*(2), 174-180. doi:10.4085/1062-6050-216-16

Fradet, L., Botcazou, M., Durocher, C., Cretual, A., Multon, F., Prioux, J., & Delamarche, P. (2004). Do handball throws always exhibit a proximal-to-distal segmental sequence? *Journal of Sports Sciences, 22*(5), 439-447. doi:10.1080/02640410310001641647

Freckleton, G., & Pizzari, T. (2013). Risk factors for hamstring muscle strain injury in sport: a systematic review and meta-analysis. *British Journal of Sports Medicine, 47*(6), 351. doi:10.1136/bjsports-2011-090664

Fuller, C. W. (2019). Assessing the Return on Investment of Injury Prevention Procedures in Professional Football. *Sports Medicine, 49*(4), 621-629. doi:10.1007/s40279-019-01083-z

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., . . . Meeuwisse, W. H. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *British Journal of Sports Medicine, 40*(3), 193-201. doi:10.1136/bjsm.2005.025270

Genevois, C., Berthier, P., Guidou, V., Muller, F., Thiebault, B., & Rogowski, I. (2014). Effects of 6-week sling-based training of the external-rotator muscles on the shoulder profile in elite female high school handball players. *J Sport Rehabil, 23*(4), 286-295. doi:10.1123/jsr.2012-0108

Giroto, N., Hespanhol Junior, L. C., Gomes, M. R., & Lopes, A. D. (2017). Incidence and risk factors of injuries in Brazilian elite handball players: A prospective cohort study. *Scandinavian Journal of Medicine and Science in Sports, 27*(2), 195-202. doi:10.1111/sms.12636

Grgic, J., Schoenfeld, B. J., Skrepnik, M., Davies, T. B., & Mikulic, P. (2018). Effects of Rest Interval Duration in Resistance Training on Measures of Muscular Strength: A Systematic Review. *Sports Medicine, 48*(1), 137-151. doi:10.1007/s40279-017-0788-x

Hagglund, M., Walden, M., Magnusson, H., Kristenson, K., Bengtsson, H., & Ekstrand, J. (2013). Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *British Journal of Sports Medicine, 47*(12), 738-742. doi:10.1136/bjsports-2013-092215

Hibberd, E. E., Oyama, S., Spang, J. T., Prentice, W., & Myers, J. B. (2012). Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in division I collegiate swimmers. *J Sport Rehabil, 21*(3), 253-265.

Hughes, C. J., Hurd, K., Jones, A., & Sprigle, S. (1999). Resistance properties of Thera-Band tubing during shoulder abduction exercise. *Journal of Orthopaedic and Sports Physical Therapy, 29*(7), 413-420. doi:10.2519/jospt.1999.29.7.413

Huxel Bliven, K. C., Snyder Valier, A. R., Bay, R. C., & Sauers, E. L. (2017). The Functional Arm Scale for Throwers (FAST)-Part II: Reliability and Validity of an Upper Extremity Region-Specific and Population-Specific Patient-Reported Outcome Scale for Throwing Athletes. *Orthop J Sports Med, 5*(4), 2325967117700019. doi:10.1177/2325967117700019

Institute for Work & Health. (2015). Primary, secondary and tertiary prevention. Retrieved from https://www.iwh.on.ca/what-researchers-mean-by/primary-secondary-and-tertiary-prevention

Jobe, F. W., Moynes, D. R., Tibone, J. E., & Perry, J. (1984). An EMG analysis of the shoulder in pitching. A second report. *American Journal of Sports Medicine, 12*(3), 218-220. doi:10.1177/036354658401200310

Karcher, C., & Buchheit, M. (2014). On-court demands of elite handball, with special reference to playing positions. *Sports Medicine, 44*(6), 797-814. doi:10.1007/s40279-014-0164-z

Kelly, B. T., Barnes, R. P., Powell, J. W., & Warren, R. F. (2004). Shoulder injuries to quarterbacks in the national football league. *Am. J. Sports Med, 32*(2), 328-331. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14977655

Kniubaite, A., Skarbalius, A., Clemente, F. M., & Conte, D. (2019). Quantification of external and internal match loads in elite female team handball. *Biology of Sport, 36*(4), 311-316. doi:10.5114/biolsport.2019.88753

Langevoort, G., Myklebust, G., Dvorak, J., & Junge, A. (2007). Handball injuries during major international tournaments. *Scandinavian Journal of Medicine and Science in Sports, 17*(4), 400-407. doi:10.1111/j.1600-0838.2006.00587.x

Lauersen, J. B., Bertelsen, D. M., & Andersen, L. B. (2014). The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. *British Journal of Sports Medicine, 48*(11), 871-877. doi:10.1136/bjsports-2013-092538

Lieber, R. L., & Bodine-Fowler, S. C. (1993). Skeletal muscle mechanics: implications for rehabilitation. *Physical Therapy, 73*(12), 844-856. doi:10.1093/ptj/73.12.844

Lin, Y. L., & Karduna, A. (2016). Four-week exercise program does not change rotator cuff muscle activation and scapular kinematics in healthy subjects. *Journal of Orthopaedic Research, 34*(12), 2079-2088. doi:10.1002/jor.23234

Malliou, P. C., Giannakopoulos, K., Beneka, A. G., Gioftsidou, A., & Godolias, G. (2004). Effective ways of restoring muscular imbalances of the rotator cuff muscle group: a comparative study of various training methods. *British Journal of Sports Medicine, 38*(6), 766-772. doi:10.1136/bjsm.2003.009548

Malone, S., Hughes, B., Doran, D. A., Collins, K., & Gabbett, T. J. (2019). Can the workload-injury relationship be moderated by improved strength, speed and repeated-sprint qualities? *Journal of Science and Medicine in Sport, 22*(1), 29-34. doi:10.1016/j.jsams.2018.01.010

Mascarin, N. C., de Lira, C. A. B., Vancini, R. L., da Silva, A. C., & Andrade, M. S. (2017). The effects of preventive rubber band training on shoulder joint imbalance and throwing performance in handball players: A randomized and prospective study. *Journal of Bodywork and Movement Therapies, 21*(4), 1017-1023. doi:10.1016/j.jbmt.2017.01.003

McGowan, C. J., Pyne, D. B., Thompson, K. G., & Rattray, B. (2015). Warm-Up Strategies for Sport and Exercise: Mechanisms and Applications. *Sports Medicine, 45*(11), 1523-1546. doi:10.1007/s40279-015-0376-x

Meeuwisse, W. H. (1994). Assessing causation in sport injury: A multifactorial model. *Clinical Journal of Sports Medicine, 4*, 166-170.

Meeuwisse, W. H., Tyreman, H., Hagel, B., & Emery, C. (2007). A dynamic model of etiology in sport injury: the recursive nature of risk and causation. *Clinical Journal of Sport Medicine, 17*(3), 215-219. doi:10.1097/JSM.0b013e3180592a48

Merolla, G., Corona, K., Zanoli, G., Cerciello, S., Giannotti, S., & Porcellini, G. (2017). Cross-cultural adaptation and validation of the Italian version of the Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow score. *Journal of Orthopaedics and Traumatology, 18*(4), 415-421. doi:10.1007/s10195-017-0467-6

Merriam-Webster. (2020). Prevention. In.

Michalsik, L. B., & Aagaard, P. (2015). Physical demands in elite team handball: comparisons between male and female players. *Journal of Sports Medicine and Physical Finess, 55*(9), 878-891. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/24947813

Michalsik, L. B., Aagaard, P., & Madsen, K. (2013). Locomotion characteristics and match-induced impairments in physical performance in male elite team handball players. *International Journal of Sports Medicine, 34*(7), 590-599. doi:10.1055/s-0032-1329989

Michalsik, L. B., Madsen, K., & Aagaard, P. (2014). Match performance and physiological capacity of female elite team handball players. *International Journal of Sports Medicine, 35*(7), 595-607. doi:10.1055/s-0033-1358713

Michalsik, L. B., Madsen, K., & Aagaard, P. (2015). Physiological capacity and physical testing in male elite team handball. *Journal of Sports Medicine and Physical Finess, 55*(5), 415-429. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/24402441

Mine, K., Nakayama, T., Milanese, S., & Grimmer, K. (2017). Effectiveness of Stretching on Posterior Shoulder Tightness and Glenohumeral Internal-Rotation Deficit: A Systematic Review of Randomized Controlled Trials. *J Sport Rehabil, 26*(4), 294-305. doi:10.1123/jsr.2015-0172

Mohseni-Bandpei, M. A., Keshavarz, R., Minoonejhad, H., Mohsenifar, H., & Shakeri, H. (2012). Shoulder pain in Iranian elite athletes: the prevalence and risk factors. *Journal of Manipulative and Physiological Therapeutics, 35*(7), 541-548. doi:10.1016/j.jmpt.2012.07.011

Mokkink, L. B., Terwee, C. B., Patrick, D. L., Alonso, J., Stratford, P. W., Knol, D. L., . . . de Vet, H. C. (2010a). The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. *Quality of Life Research, 19*(4), 539-549. doi:10.1007/s11136-010-9606-8

Mokkink, L. B., Terwee, C. B., Patrick, D. L., Alonso, J., Stratford, P. W., Knol, D. L., . . . de Vet, H. C. (2010b). The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. *Journal of Clinical Epidemiology, 63*(7), 737-745. doi:10.1016/j.jclinepi.2010.02.006

Moller, M., Attermann, J., Myklebust, G., Lind, M., Sorensen, H., Hebert, J. J., . . . Wedderkopp, N. (2018). The inter- and intrarater reliability and agreement for field-based assessment of scapular control, shoulder range of motion, and shoulder isometric strength in elite adolescent athletes. *Physical Therapy in Sport 32*, 212-220. doi:10.1016/j.ptsp.2018.04.005

Moller, M., Attermann, J., Myklebust, G., & Wedderkopp, N. (2012). Injury risk in Danish youth and senior elite handball using a new SMS text messages approach. *British Journal of Sports Medicine, 46*(7), 531-537. doi:10.1136/bjsports-2012-091022

Moller, M., Nielsen, R. O., Attermann, J., Wedderkopp, N., Lind, M., Sorensen, H., & Myklebust, G. (2017). Handball load and shoulder injury rate: a 31-week cohort study of 679 elite youth handball players. *British Journal of Sports Medicine, 51*(4), 231-237. doi:10.1136/bjsports-2016-096927

Mónaco, M., Rincón, J. A. G., Ronsano, B. J. M., Whiteley, R., Sanz-Lopez, F., & Rodas, G. (2019). Injury incidence and injury patterns by category, player position, and maturation in elite male handball elite players. *Biology of Sport, 36*(1), 67-74. doi:10.5114/biolsport.2018.78908

Moncrief, S. A., Lau, J. D., Gale, J. R., & Scott, S. A. (2002). Effect of rotator cuff exercise on humeral rotation torque in healthy individuals. *Journal of Strength and Conditioning Research, 16*(2), 262-270.

Muehlhausen, W., Doll, H., Quadri, N., Fordham, B., O'Donohoe, P., Dogar, N., & Wild, D. J. (2015). Equivalence of electronic and paper administration of patient-reported outcome measures: a systematic review and meta-analysis of studies conducted between 2007 and 2013. *Health Qual Life Outcomes, 13*, 167. doi:10.1186/s12955-015-0362-x

Myers, J. B., Laudner, K. G., Pasquale, M. R., Bradley, J. P., & Lephart, S. M. (2006). Glenohumeral Range of Motion Deficits and Posterior Shoulder Tightness in Throwers With Pathologic Internal Impingement. *Am.J.Sports Med.* Retrieved from PM:16303877

Myklebust, G., Hasslan, L., Bahr, R., & Steffen, K. (2013). High prevalence of shoulder pain among elite Norwegian female handball players. *Scandinavian Journal of Medicine and Science in Sports, 23*(3), 288-294. doi:10.1111/j.1600-0838.2011.01398.x

Naclerio, F., Faigenbaum, A. D., Larumbe-Zabala, E., Perez-Bibao, T., Kang, J., Ratamess, N. A., & Triplett, N. T. (2013). Effects of different resistance training volumes on strength and power in team sport athletes. *Journal of Strength and Conditioning Research, 27*(7), 1832-1840. doi:10.1519/JSC.0b013e3182736d10

Niederbracht, Y., Shim, A. L., Sloniger, M. A., Paternostro-Bayles, M., & Short, T. H. (2008). Effects of a shoulder injury prevention strength training program on eccentric external rotator muscle strength and glenohumeral joint imbalance in female overhead activity athletes. *Journal of Strength and Conditioning Research, 22*(1), 140-145. doi:10.1519/JSC.0b013e31815f5634

Nielsen, R. O., Debes-Kristensen, K., Hulme, A., Bertelsen, M. L., Moller, M., Parner, E. T., & Mansournia, M. A. (2019). Are prevalence measures better than incidence measures in sports injury research? *British Journal of Sports Medicine, 53*(7), 396-397. doi:10.1136/bjsports-2017-098205

Oh, J. H., Kim, J. Y., Limpisvasti, O., Lee, T. Q., Song, S. H., & Kwon, K. B. (2017). Cross-cultural adaptation, validity and reliability of the Korean version of the Kerlan-Jobe Orthopedic Clinic shoulder and elbow score. *JSES Open Acess, 1*, 6.

Oliver, G. D., Plummer, H., & Brambeck, A. (2016). HIP AND GLENOHUMERAL PASSIVE RANGE OF MOTION IN COLLEGIATE SOFTBALL PLAYERS. *International Journal of Sports Physical Therapy, 11*(5), 738-745.

Peitz, M., Behringer, M., & Granacher, U. (2018). A systematic review on the effects of resistance and plyometric training on physical fitness in youth- What do comparative studies tell us? *PloS One, 13*(10), e0205525. doi:10.1371/journal.pone.0205525

Prestkvern, S. (2013). *Skulderproblemer blant eliteseriespillere i norsk herrehåndball - Er det en sammenheng mellom pasnings- og skuddeksponering og spillernes skulderproblemer?* (Master). Norwegian School of Sport Sciences, Oslo.

Rafnsson, E. T., Valdimarsson, Ö., Sveinsson, T., & Árnason, Á. (2019). Injury Pattern in Icelandic Elite Male Handball Players. *Clinical Journal of Sport Medicine, 29*(3), 232-237. doi:10.1097/jsm.0000000000000499

Ralston, G. W., Kilgore, L., Wyatt, F. B., Buchan, D., & Baker, J. S. (2018). Weekly Training Frequency Effects on Strength Gain: A Meta-Analysis. *Sports Med Open, 4*(1), 36. doi:10.1186/s40798-018-0149-9

Raya-González, J., Clemente, F. M., Beato, M., & Castillo, D. (2020). Injury Profile of Male and Female Senior and Youth Handball Players: A Systematic Review. *International Journal of Environmental Research and Public Health, 17*(11). doi:10.3390/ijerph17113925

Revicki, D., Hays, R. D., Cella, D., & Sloan, J. (2008). Recommended methods for determining responsiveness and minimally important differences for patient-reported outcomes. *Journal of Clinical Epidemiology, 61*(2), 102-109. doi:10.1016/j.jclinepi.2007.03.012

Ryan, J., DeBurca, N., & Mc Creesh, K. (2014). Risk factors for groin/hip injuries in field-based sports: a systematic review. *British Journal of Sports Medicine, 48*(14), 1089. doi:10.1136/bjsports-2013-092263

Sauers, E. L., Bay, R. C., Snyder Valier, A. R., Ellery, T., & Huxel Bliven, K. C. (2017). The Functional Arm Scale for Throwers (FAST)-Part I: The Design and Development of an Upper Extremity Region-Specific and Population-Specific Patient-Reported Outcome Scale for Throwing Athletes. *Orthop J Sports Med, 5*(3), 2325967117698455. doi:10.1177/2325967117698455

Scher, S., Anderson, K., Weber, N., Bajorek, J., Rand, K., & Bey, M. J. (2010). Associations among hip and shoulder range of motion and shoulder injury in professional baseball players. *J Athl Train, 45*(2), 191-197. doi:10.4085/1062-6050-45.2.191

Seil, R., Rupp, S., Tempelhof, S., & Kohn, D. (1998). Sports injuries in team handball. A one-year prospective study of sixteen men's senior teams of a superior nonprofessional level. *Am.J.Sports Med., 26*(5), 681-687. Retrieved from PM:9784816

Shanley, E., Rauh, M. J., Michener, L. A., Ellenbecker, T. S., Garrison, J. C., & Thigpen, C. A. (2011). Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. *American Journal of Sports Medicine, 39*(9), 1997-2006. doi:10.1177/0363546511408876

Skals, S., Vinstrup, J., Sundstrup, E., Jakobsen, M. D., Andersen, C. H., & Andersen, L. L. (2018). Shoulder and arm muscle activity during elastic band exercises performed in a hospital bed. *Physician and Sportsmedicine, 46*(2), 233-241. doi:10.1080/00913847.2018.1441580

Skejø, S. D., Møller, M., Bencke, J., & Sørensen, H. (2019). Shoulder kinematics and kinetics of team handball throwing: A scoping review. *Hum Mov Sci, 64*, 203-212. doi:10.1016/j.humov.2019.02.006

Skillington, S. A., Brophy, R. H., Wright, R. W., & Smith, M. V. (2017). Effect of Pitching Consecutive Days in Youth Fast-Pitch Softball Tournaments on Objective Shoulder Strength and Subjective Shoulder Symptoms. *American Journal of Sports Medicine, 45*(6), 1413-1419. doi:10.1177/0363546516688657

Stark, T., Walker, B., Phillips, J. K., Fejer, R., & Beck, R. (2011). Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: a systematic review. *Pm r, 3*(5), 472-479. doi:10.1016/j.pmrj.2010.10.025

Terwee, C. B., Bot, S. D., de Boer, M. R., van der Windt, D. A., Knol, D. L., Dekker, J., . . . de Vet, H. C. (2007). Quality criteria were proposed for measurement properties of health status questionnaires. *Journal of Clinical Epidemiology, 60*(1), 34-42. doi:10.1016/j.jclinepi.2006.03.012

Thomas, J. R., & Nelson, J. K. (1996). *Research methods in physical activity*. Human Kinetics, Champaign, IL, USA.

Toigo, M., & Boutellier, U. (2006). New fundamental resistance exercise determinants of molecular and cellular muscle adaptations. *European Journal of Applied Physiology, 97*(6), 643-663. doi:10.1007/s00421-006-0238-1

Toohey, L. A., Drew, M. K., Cook, J. L., Finch, C. F., & Gaida, J. E. (2017). Is subsequent lower limb injury associated with previous injury? A systematic review and meta-analysis. *British Journal of Sports Medicine, 51*(23), 1670-1678. doi:10.1136/bjsports-2017-097500

Tooth, C., Gofflot, A., Schwartz, C., Croisier, J. L., Beaudart, C., Bruyère, O., & Forthomme, B. (2020). Risk Factors of Overuse Shoulder Injuries in Overhead Athletes: A Systematic Review. *Sports Health*, 1941738120931764. doi:10.1177/1941738120931764

Turgut, E., & Tunay, V. B. (2018). Cross-cultural adaptation of Kerlan-Jobe Orthopaedic Clinic shoulder and elbow score: Reliability and validity in Turkish-speaking overhead athletes. *Acta Orthopaedica et Traumatologica Turcica*. doi:10.1016/j.aott.2018.02.007

Uhl, T. L., Rice, T., Papotto, B., & Butterfield, T. A. (2017). Effectiveness of a Home-Based Eccentric-Exercise Program on the Torque-Angle Relationship of the Shoulder External Rotators: A Pilot Study. *J Sport Rehabil, 26*(2), 141-150. doi:10.1123/jsr.2017-0020

van Cingel, R., Habets, B., Willemsen, L., & Staal, B. (2017). Shoulder Dynamic Control Ratio and Rotation Range of Motion in Female Junior Elite Handball Players and Controls. *Clinical Journal of Sport Medicine*. doi:10.1097/jsm.0000000000000429

Van Den Tillaar, R., & Cabri, J. M. (2012). Gender differences in the kinematics and ball velocity of overarm throwing in elite team handball players. *Journal of Sports Sciences, 30*(8), 807-813. doi:10.1080/02640414.2012.671529

van den Tillaar, R., & Ettema, G. (2007). A three-dimensional analysis of overarm throwing in experienced handball players. *J Appl.Biomech., 23*(1), 12-19. Retrieved from PM:17585175

van der Worp, M. P., ten Haaf, D. S., van Cingel, R., de Wijer, A., Nijhuis-van der Sanden, M. W., & Staal, J. B. (2015). Injuries in runners; a systematic review on risk factors and sex differences. *PloS One, 10*(2), e0114937. doi:10.1371/journal.pone.0114937

van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Medicine, 14*(2), 82-99.

Van Tiggelen, D., Wickes, S., Stevens, V., Roosen, P., & Witvrouw, E. (2008). Effective prevention of sports injuries: a model integrating efficacy, efficiency, compliance and risk-taking behaviour. *British Journal of Sports Medicine, 42*(8), 648-652. doi:10.1136/bjsm.2008.046441

Vincent, W. J. (2005). *Statistics in kinesiology* (L. D. Robertson Ed. Third ed.). USA: Human Kinetics.

Vlak, T., & Pivalica, D. (2004). Handball: the beauty or the beast. *Croatian Medical Journal, 45*(5), 526-530.

Wagner, H., Pfusterschmied, J., von Duvillard, S. P., & Muller, E. (2011). Performance and kinematics of various throwing techniques in team-handball. *Journal of Sports Science & Medicine, 10*(1), 73-80.

Weldring, T., & Smith, S. M. (2013). Patient-Reported Outcomes (PROs) and Patient-Reported Outcome Measures (PROMs). *Health Serv Insights, 6*, 61-68. doi:10.4137/hsi.S11093

Wiggins, A. J., Grandhi, R. K., Schneider, D. K., Stanfield, D., Webster, K. E., & Myer, G. D. (2016). Risk of Secondary Injury in Younger Athletes After Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis. *American Journal of Sports Medicine, 44*(7), 1861-1876. doi:10.1177/0363546515621554

Wild, D., Grove, A., Martin, M., Eremenco, S., McElroy, S., Verjee-Lorenz, A., & Erikson, P. (2005). Principles of Good Practice for the Translation and Cultural Adaptation Process for Patient-Reported Outcomes (PRO) Measures: report of the ISPOR Task Force for Translation and Cultural Adaptation. *Value in Health, 8*(2), 94-104. doi:10.1111/j.1524-4733.2005.04054.x

Wilk, K. E., Reinold, M. M., Macrina, L. C., Porterfield, R., Devine, K. M., Suarez, K., & Andrews, J. R. (2009). Glenohumeral internal rotation measurements differ depending on stabilization techniques. *Sports Health, 1*(2), 131-136. doi:10.1177/1941738108331201

Windt, J., & Gabbett, T. J. (2017). How do training and competition workloads relate to injury? The workload—injury aetiology model. *British Journal of Sports Medicine, 51*(5), 428. doi:10.1136/bjsports-2016-096040

Witchalls, J., Blanch, P., Waddington, G., & Adams, R. (2012). Intrinsic functional deficits associated with increased risk of ankle injuries: a systematic review with meta-analysis. *British Journal of Sports Medicine, 46*(7), 515. doi:10.1136/bjsports-2011-090137

Wright, A. A., Hegedus, E. J., Tarara, D. T., Ray, S. C., & Dischiavi, S. L. (2018). Exercise prescription for overhead athletes with shoulder pathology: a systematic review with best evidence synthesis. *British Journal of Sports Medicine, 52*(4), 231-237. doi:10.1136/bjsports-2016-096915

Zourdos, M. C., Klemp, A., Dolan, C., Quiles, J. M., Schau, K. A., Jo, E., . . . Blanco, R. (2016). Novel Resistance Training-Specific Rating of Perceived Exertion Scale Measuring Repetitions in Reserve. *Journal of Strength and Conditioning Research, 30*(1), 267-275. doi:10.1519/jsc.0000000000001049

Paper I

BMJ Open Sport & Exercise Medicine

Norwegian translation, cross-cultural adaptation and validation of the Kerlan-Jobe Orthopaedic Clinic shoulder and elbow questionnaire

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ABSTRACT

The Kerlan-Jobe Orthopaedic Clinic (KJOC) shoulder and elbow questionnaire, with 10 items and a total score ranging from zero to 100, provides more clinically relevant information about overhead athletes than other shoulder or upper limb patient-reported outcomes.

Objectives To translate, cultural adapt and evaluate the measurement properties of the Norwegian version of KJOC shoulder and elbow questionnaire.

Methods 33 overhead athletes (age 18.6±4.2, 10 men/23 women) were included in the analysis of face validity and known-group validity, of whom 15 went through cognitive interviews. An electronic version was developed, and six handball players were interviewed to ensure measurement equivalence between the paper-based and electronic version of the questionnaire. Test–retest reproducibility (1-week interval) and concurrent validity with the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was investigated in 36 handball players (age 20.7±3.8, 17 men/19 women).

Results The translation was conducted, and smaller consensus-based adjustments were made. Athletes found the questionnaire easy to understand, with no differences between paper and electronic based version, and preferred the electronic version. The Norwegian electronic version of the KJOC showed excellent internal consistency (Cronbach's α=0.952) and relative test–retest reliability (Intraclass correlation coefficient, ICC=0.967). SEM, minimal detectable change (MDC) and limits of agreement were 3.1, 8.5 and −9.2 to 7.7, respectively. The concurrent validity versus DASH was moderate (Spearman's rho=−0.642). However, KJOC had a wider range in scores than DASH, distinguished better between players playing with and without pain and was more sensitive to capture players playing with pain.

Conclusion This study suggests that the Norwegian version of the KJOC is a reliable and acceptable tool for evaluating shoulder and elbow-related problems in overhead athletes (handball players).

Strengths and limitations of this study

- Initially, a face validation of the Norwegian Kerlan-Jobe Orthopaedic Clinic (KJOC-N) among users was conducted.
- A rigorous translation and cultural adaptation process ensure that the questionnaire can be used in multinational research projects.
- The use of electronic questionnaires makes easy to collect repeated measures.
- Responsiveness of the KJOC-N was not explored.
- Mainly handball players were included.

INTRODUCTION

Overhead athletes have high prevalence of shoulder and elbow injuries.[1–4] Many of these athletes experience no symptoms during activities of daily living, except during training or competition. Furthermore, they often continue to participate in training and competition despite injuries.[5] Therefore, commonly used patient-reported outcome measures developed for the normal population, such as DASH questionnaire and American shoulder and elbow surgeons society standardised shoulder assessment form fail to capture overhead athletes' functional status and changes in performance.[6]

To address this problem, Alberta *et al* developed the Kerlan-Jobe Orthopaedic Clinic (KJOC) shoulder and elbow questionnaire; a 10-item questionnaire that uses visual analogue scales (VAS) scales to evaluate the athletes' performance, function and pain.[5] The KJOC comprises more questions about throwing-related function and performance than other upper limb questionnaires. It is a valid, reliable and responsive tool in the evaluation of overhead athletes,[5] and is more accurate in evaluating outcome of upper limb surgery in overhead athletes than previously used questionnaires.[7–9] Additionally, KJOC discriminates between injured and uninjured athletes, and between those competing with and without pain.[5 6 10] The KJOC was developed and validated for English-speaking overhead athletes, and has recently been translated to other languages.[10–12]

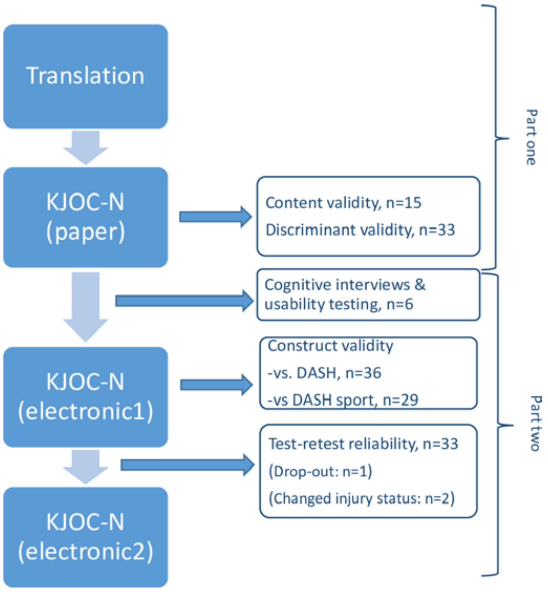

Figure 1 Flow chart of the two parts of the study. Part one: translation and cultural adaption of KJOC shoulder and elbow questionnaire into Norwegian. Part two: evaluation of test–retest reliability and construct validity of the KJOC-N versus DASH questionnaire. DASH, Disability of the Arm, Shoulder and Hand; KJOC, Kerlan-Jobe orthopaedic clinic; KJOC-N, Norwegian KJOC.

According to Beaton,[13] if a questionnaire is used across languages or cultures, a rigorous translation and cultural adaptation process are important to maintain the content validity of the instrument at a conceptual level. This will also ensure the questionnaire can be used in multinational research projects.

The aims of the study were to translate, culturally adapt and validate the KJOC for a Norwegian context, to make an electronic version of the Norwegian KJOC (KJOC-N) and to evaluate the measurement properties of KJOC-N.

MATERIALS AND METHODS

We conducted this study in two phases (figure 1). The first phase comprised translation and cultural adaption of the KJOC questionnaire into Norwegian and evaluation of face validity and known-group validity. In the second phase, we adapted the KJOC-N from paper to electronic version and evaluated concurrent validity and test–retest reliability of the electronic version.

Questionnaires

The KJOC questionnaire is a self-assessed patient-reported outcome measure to evaluate the shoulder and elbow function, performance and pain in overhead athletes.[5] It consists of 10 items, all of which use VAS from zero to 100. The total score is calculated as an average score of the 10 items, ranging from zero to 100. Higher scores indicate higher function.

To assess the concurrent validity of the KJOC-N, we compared it to the Norwegian DASH total and DASH sport/performing arts module.[14] DASH is a 30-item self-administered measure of symptoms and functional status.[15] Each item has five categorical options, ranging from 'no difficulty or symptoms' to 'unable to perform activity' or 'very severe symptoms'. A sum score ranging from zero to 100 is calculated. Higher scores indicate lower function. The DASH sport/performing arts module (also scored 0–100) is a subdivision of DASH, which include four items to capture difficulties related to the athletes' sports activity.

Translation and cultural adaptation of KJOC

Translation and cultural adaptation of the questionnaire followed the principles of good practice from the International Society of Pharmaecconomics and Outcome research[16] and the guidelines by Beaton *et al.*[13] The procedure was as follows:

We obtained permission to translate the KJOC questionnaire from the developer.[5]

Forward translation: Two independent bilingual Norwegian residents (T1 and T2) with Norwegian as their main language translated the questionnaire into Norwegian. T1 was a physical therapist, while T2 had no medical background.[13]

Synthesis of the translations: The project manager held separate meetings with each of the translators, to address discrepancies, seek agreement and make a synthesis of the two translations. She also consulted the questionnaire developer about unsolved questions or special phrases.

Back translation: Two independent Norwegian residents with English as their main language (BT1 and BT2) translated the synthesised forward translation back to English. BT1 was a physical therapist. BT2 had no medical background. The two translators were blinded to the original version of the questionnaire.

Harmonisation: The harmonisation group consisted of the forward translators and back translators, and a language-competent research physiotherapist. The project manager communicated with each member of the group, either by separate meetings or by e-mail. We contacted the developer by e-mail for minor questions. The team reached consensus and approved the harmonised version of the KJOC-N questionnaire.

To minimise non-responses and response errors due to misunderstanding of items, 33 overhead athletes completed the harmonised version of KJOC-N and were interviewed if the questionnaire was relevant to their sport, easy to understand and complete. We also interviewed two coaches (handball and tennis), one medical doctor and three physiotherapists, all of whom were involved in overhead sports, about the relevance and interpretation of the questionnaire.

The results from the interviews were reviewed and a final version of the questionnaire was proofread (online supplementary file 1).

Table 1 Characteristics of the overhead athletes recruited for face validation and known-group validation of the KJOC-N (n=33)	
Age (years), mean (SD)	18.6 (4.2)
Gender (n)	
Male	10
Female	23
Sport (n)	
Handball	23
Volleyball	8
Tennis	2
Sporting level (n)	
International elite level	7
National elite level	4
Lower levels	22

KJOC-N, Norwegian version of Kerlan-Jobe Orthopaedic Clinic shoulder and elbow questionnaire.

Table 2 Characteristics of the handball players recruited for reproducibility and concurrent validity testing of KJOC compared with DASH (n=36)	
Age (years), mean (SD)	20.7 (3.8)
Gender (n)	
Male	17
Female	19
Handball experience (years), mean (SD)*	13.4 (4.3)
Previous shoulder injury (yes/no)†	10/25
Shoulder injury status (n)†	
Playing without pain	19
Playing with pain	16
Sporting level (n)†	
International elite level	1
National elite level	13
Lower levels	21

*Missing: 1, 2
†Missing: 1.
DASH, Disability of the Arm, Shoulder and Hand questionnaire; KJOC-N, Norwegian version of Kerlan-Jobe Orthopaedic Clinic shoulder and elbow questionnaire.

Participants and recruitment

Initially, we recruited 33 overhead athletes for face validation and known-group validation of the questionnaire. They were recruited as follows: (1) patients attending the physiotherapy department at the Norwegian Olympic Sports Centre, (2) overhead athletes training at the Norwegian Olympic Sports Centre and (3) handball players from a local handball club. After completing the KJOC-N questionnaire, 15 consecutive athletes were selected for thorough interviews. We used a cognitive interview technique[17] to assess how they interpreted each item and if they would like to remove or add any questions. The initial 33 athletes were also asked about age, years of sports participation, type of sport, previous shoulder injury and to assign themselves to one of three categories: (1) playing without pain, (2) playing with pain and (3) not playing due to pain. No personal data were collected. Subsequently, we recruited handball players from two local handball clubs (one man and one woman) for reproducibility and concurrent validity testing. After an information meeting with the coaches and players, 38 players agreed to participate and signed written informed consent. Participant characteristics for the two parts of the study are presented in tables 1 and 2.

Measurement equivalence between the paper-based and electronic version of the KJOC-N questionnaire

When adapting KJOC-N from paper to an electronic version, we made no change in content or meaning of the questionnaire. The main modification was how the VAS was handled. In the electronic version, the respondent uses a slider to indicate their perception of their current state. Since there were only minor modifications, we did not conduct validity testing of the electronic version, but conducted small-scale cognitive interviews and usability testing.[18 19] Six players, randomly selected, completed the pen and paper KJOC-N version during a training session and the electronic version online 3–6 days later. Thereafter, they were interviewed about whether the electronic version changed the way they interpreted the questions, decided on an answer or responded.

Concurrent validity (KJOC-N vs DASH) and reproducibility of the electronic version of KJOC-N

We sent the electronic version of KJOC-N and DASH questionnaires to 38 handball players to evaluate the concurrent validity. To evaluate the test–retest reliability, they were asked to fill out KJOC-N again 1 week later. We chose 1-week interval to reduce the likelihood of change of injury status and recall bias. In all, 36 players completed the first questionnaire, of whom 35 returned a second questionnaire 1 week later. They were also asked if their injury status had changed during this week. In all, 33 players had not changed injury status. Both KJOC-N and DASH were completed online, using Infopad (Infopad AS, Svolvaer, Norway). All data were collected and stored in accordance with The Norwegian Personal Data Act §13, Health Register Act §16 and Health Research Act §2.

Patient and public involvement

We had a partial patient and public involvement in the validation process of the translation. As recommended in studies translating questionnaires, we had players, coaches, therapists and a medical doctor to evaluate the questionnaire with regard to the relevance and interpretation of the questionnaire, as described earlier in the method section.

Table 3 Kerlan-Jobe orthopaedic clinic scores of groups playing with and without shoulder pain (n=33)								
Category	**N**	**Min**	**Q1**	**Median**	**Mean**	**Q3**	**Max**	**SD**
Playing without pain	21	67	88	98	94	100	100	9.1
Playing with pain	11	31	64	69	71	90	94	17.6
Not playing	1							

Q1, first quartile; Q3, third quartile.

Statistical analysis

Statistical analysis was performed using SPSS V.24 for Windows. Internal consistency was evaluated using Cronbach's alpha, where α=0 indicate no internal consistency and α≥0.9 corresponds to excellent consistency.[20] Paired t-test was used to test for systematic differences between the two rounds. Test–retest reliability of the KJOC-N was calculated using a two-way mixed effects model, single measurement and absolute agreement ($ICC_{2,1}$). Absolute reliability was determined by calculating SE of measurement, SEM=SD*($\sqrt{1-ICC}$), minimal detectable change, MDC=SEM*1,96* $\sqrt{2}$, and Bland and Altman 95% limits of agreement (LOA). Mann–Whitney test was used to examine known-group validity by comparing players with and without a history of shoulder injury and players playing with and without pain. Spearman's correlation test was used to examine the correlation of KJOC-N with DASH total and DASH sports/performing arts scores, and one-sample t-test test was used to compare KJOC-N and DASH total.

The study was approved by the Norwegian Centre for Research Data (59158/2018). The south-east regional committee for medical and health research ethics stated that approval was not necessary since the study did not include an intervention.

RESULTS

Translation and cultural adaptation

During forward translation of KJOC, we mainly discovered discrepancies in choice of synonyms and prepositions. The phrases ‘popping out’ and ‘get loose’ are not commonly used in Norway. The project manager therefore contacted the main author to get a thorough explanation of the meaning. We also needed to describe the ‘level of competition’ in a way that corresponded with the Norwegian system. ‘Professional major league, professional minor league, intercollegiate and high school’ were replaced by ‘International elite level, national elite level, lower levels (please specify)’. Since the questionnaire is intended for use in all kind of overhead athletes, we changed ‘games’ to ‘competitions’ to include those athletes who do not play games, for example, javelin throwers.

In the original version, instruction to the athlete is given both prior to questions 1 and 5: ‘The following questions concern your physical functioning during game and practice conditions’ and ‘The following questions refer to your level of competition in your sport’. To simplify this, we combined the two instructions prior to question one: ‘The following questions refer to your physical function during competition and training, and the consequences of your function’.

When we compared the original with the back translated version of the questionnaire, we found only differences in largely synonymous words and prepositions. Examples are ‘arm trouble’ and ‘how much’ in the original version, compared with ‘arm complaints’ and ‘to what extent’ in the translated version.

The harmonisation group checked all the translations with the original one, and ensured that there were conceptual equivalence between the original and translated versions.

Cognitive interviews/pre-testing

Both athletes, coaches and medical personnel found the questionnaire very relevant and easy to understand and complete. Regarding question 2, ‘How much pain do you experience in your shoulder and elbow?’ with ‘no pain with competition’ as the best result: Some athletes had experienced to be pain free during competition, but the pain arose afterwards. Others had experienced pain during training but not during competition. We therefore changed the best alternative to ‘pain free during and after competition and training’. No one suggested removing or adding any questions. The KJOC-N scores by current participation status and previous injury are shown in tables 3 and 4. Players who were playing with pain had lower scores than those playing without pain ($p<0.01$). Players with a history of shoulder injury had

Table 4 Kerlan-Jobe orthopaedic clinic scores of groups with and without previous shoulder injury (n=33)								
Previous injury	**N**	**Min**	**Q1**	**Median**	**Mean**	**Q3**	**Max**	**SD**
No	18	79	89	100	97	100	100	5.3
Yes	15	31	64	69	71	86	90	15.4

Q1, first quartile; Q3, third quartile.

Table 5 Kerlan-Jobe orthopaedic clinic scores and Disability of Arm Shoulder and Hand scores, comparing groups playing with and without shoulder pain (n=35)

Category	N	KJOC-N	DASH
Playing without pain	19	95.1 (6.2)	2.9 (4.2)
Playing with pain	16	77.8 (19.0)	7.2 (6.9)†
Difference		17.3 (6.9 to 27.8)*	4.4 (-8.2 to −0.5)**

Mean (SD) is presented for the observed values within each group. Mean (95% CI) is presented for the estimated difference between the categories *p<0.001, **p=0.062.
†Difference between KJOC and DASH scores p=0.004.

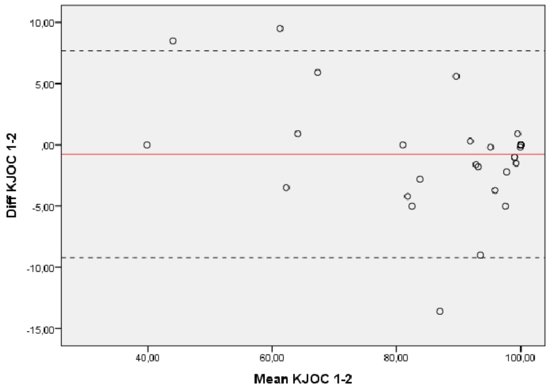

Figure 2 Bland–Altman plot showing the test–retest results of the KJOC questionnaire (n=33). solid line: mean difference. Dashed lines: upper and lower 95% CIs. KJOC, Kerlan-Jobe Orthopaedic Clinic,

lower scores than those without a history of shoulder injury (p<0.01).

Measure equivalence of the paper questionnaire and electronic questionnaire

Measurement equivalence, obtained by small-scale cognitive interviews of six players, revealed no change in content or meaning between the paper questionnaire and electronical questionnaire. The players reported the electronical version to be easier to complete than the paper version

Internal consistency and concurrent validity

Cronbach's alpha was 0.952, indicating excellent internal consistency among the 10 items. The correlation between KJOC-N and DASH total scores was −0.642, and between KJOC-N and DASH-sport was −0.790. However, KJOC-N had a wider range in scores than DASH total (60.1 and 23.3, respectively), distinguished better between players playing with and without pain and was more sensitive to capture players playing with pain (table 5).

Test–retest reproducibility

The mean response time between the two assessments was 9 days.

The 33 players who did not change shoulder injury status between the two assessments, had no systematic difference in the mean total score between the two rounds (difference −0.7, 95% CI −2.3 to 0.8). The relative test–retest reproducibility was excellent with an ICC of 0.967 (95%CI 0.935 to 0.984). SEM and MDC were 3.1 and 8.5, respectively. Bland–Altman's 95% LOA ranged from −9.2 to 7.7 and displayed no funnel effect (figure 2).

DISCUSSION

In this study, we translated and culturally adapted the KJOC into Norwegian and evaluated its measurement properties. The main findings of the study were that the KJOC-N is a reliable, valid and internally consistent questionnaire for Norwegian overhead athletes.

Translation and cultural adaptation

We experienced no difficulties during the translation and cultural adaptation and made only minor adaptions to reach conceptual equivalence with the original version of KJOC. Overhead athletes thought the questionnaire was easy to understand and fill out, and both athletes, coaches and medical personnel found it relevant. The comparison between the paper and the electronical version yielded no difficulties. The players were able to use the device and software appropriately. In fact, the interviewed players reported the electronical version to be easier to complete.

Internal consistency and concurrent validity

Our results showed that the Norwegian version of the KJOC has excellent internal consistency (Cronbach's α=0.952). These results are in accordance with previous translations.[10 11 5]

The concurrent validity versus DASH and DASH sport was moderate and strong, respectively. However, in our population of active handball players, KJOC-N had a much wider range in scores than DASH (60.1 and 23.3, respectively), distinguished better between players playing with and without pain (KJOC-N 17.3 points and DASH 4.4 points) and was more sensitive to capture players playing with pain. This suggests that KJOC-N discriminates better between overhead athletes playing with and without pain than the DASH-total does and supports the original idea behind the development of KJOC. The minimum detectable change at the 95% CI level has been reported to be 12.8–17.2 for the DASH.[21] Therefore, DASH might not capture the change in scores if a player is developing shoulder pain. Other patient-related outcome measures for the upper limb, such as DASH, assess activities of daily living and do not capture the specific demands of the overhead athlete. Therefore, the KJOC serves as a more precise assessment in this population.

Test–retest reproducibility

KJOC-N had excellent relative test–retest reliability (ICC=0.967), which is in accordance with previous translations,[10 11] and slightly higher than the developer presented.[5] Our measures of absolute reliability (SEM=3.05 and MDC=8.45) were slightly higher than other translated versions (Merolla: 0.81/2.42, Turgut: 1.98/5.49). This might be due to the age of the athletes. In our study, the athletes were younger than in previous studies, 20.7 years compared with 23.1–26.6 years. Another explanation could be the difference in sporting levels. Merolla and colleagues included professional athletes only, while in our study, all but one player were amateurs, playing at a national level. An older, professional athlete may be more accurate in everything he or she is doing related to their sport, including replying to questionnaires. Our 95% LOA (−9.2 to 7.7) indicate that, at an individual level, a change of more than 17 points is necessary before measurement error can be ruled out. The KJOC-N showed statistically significant differences between players who were playing with and without pain (median 98 vs 69.3) and players with and without a history of injury (median 99.6 vs 69.3). This is in agreement with other studies, which accurately distinguished between injured and uninjured athletes, and suggested that normal values of overhead athletes should be above 90.[5 9 10 22]

Strengths

We conducted a rigorous translation and cultural adaptation of the KJOC questionnaire to maintain the content validity of the questionnaire at a conceptual level. This means that the questionnaire can be used in the targeted Norwegian population and can be used in multinational research projects.

Limitations

The small sample size, smaller than recommended in the COSMIN guidelines, is a main limitation of our study. It was a convenient sample, consisting of one male and one female handball team. Handball is the dominant overhead sport in Norway. Therefore, we included handball players only for the reproducibility and concurrent validity measures, which is a limitation of the study. The sample is a random sample of one male and one female handball team and represent the population of interest, where more than half the population have no shoulder problems. Since these athletes often continue to participate in training and competition despite shoulder pain, it is important to have a tool that can distinguish between those with and without a problem. Such a tool can be used for monitoring changes over time in this population. To be used in overhead athletes with moderate to severe shoulder problems, the measurement properties of the questionnaire should be tested out in advance. In the cross-cultural adaption, we also included volleyball and tennis players, as well as coaches and medical personnel from overhead sports.

We did not study the KJOC-N's responsiveness, a psychometric property important for judgement of treatment outcome or monitor changes over time.[23] Both the original English and translated Italian version of the questionnaire are previously shown to be responsive in a mix of overhead athletes.[5 11] However, since this may vary between populations, it is important to evaluate it in the population of interest.[24]

Our results are comparable to the original KJOC and previously translated versions, showing that the KJOC-N is a reliable and valid questionnaire in the evaluation of shoulder and elbow-related problems in overhead athletes, and is a better evaluation tool in this population than traditional patient-related outcomes.

Perspectives

Our results suggest that the KJOC-N is a reliable and acceptable tool for evaluating shoulder and elbow-related problems in Norwegian overhead athletes (handball players). A rigorous translation and cultural adaptation process ensure that the questionnaire can be used in multinational research projects. Since KJOC-N is more clinically relevant for overhead athletes than traditional patient-related outcomes, we now have a better tool to evaluate this population. The KJOC is particularly useful for monitoring athletes with overuse injuries, who often play despite pain, and for evaluating symptoms and function, particularly in the late phase of rehabilitation. The use of electronic questionnaires makes is easy to collect repeated measures.

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Contributors Both authors conceived and designed the study. HF recruited the study subjects and performed data collection. HF performed the statistical analyses. Both authors have been involved in the data analyses, drafting and revision of the manuscript, and have approved the final manuscript.

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REFERENCES

1 Myklebust G, Hasslan L, Bahr R, *et al*. High prevalence of shoulder pain among elite Norwegian female handball players. *Scand J Med Sci Sports* 2013;23:288–94.
2 Clarsen B, Bahr R, Heymans MW, *et al*. The prevalence and impact of overuse injuries in five Norwegian sports: application of a new surveillance method. *Scand J Med Sci Sports* 2015;25:323–30.

3 Abrams GD, Renstrom PA, Safran MR. Epidemiology of musculoskeletal injury in the tennis player. *Br J Sports Med* 2012;46:492–8.
4 Sein ML, Walton J, Linklater J, *et al*. Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. *Br J Sports Med* 2010;44:105–13.
5 Alberta FG, ElAttrache NS, Bissell S, *et al*. The development and validation of a functional assessment tool for the upper extremity in the overhead athlete. *Am J Sports Med* 2010;38:903–11.
6 Hegedus EJ, Vidt ME, Tarara DT. The best combination of physical performance and self-report measures to capture function in three patient groups. *Physical Therapy Reviews* 2014;19:196–203.
7 Neri BR, ElAttrache NS, Owsley KC, *et al*. Outcome of type II superior labral anterior posterior repairs in elite overhead athletes: effect of concomitant partial-thickness rotator cuff tears. *Am J Sports Med* 2011;39:114–20.
8 Neuman BJ, Boisvert CB, Reiter B, *et al*. Results of arthroscopic repair of type II superior labral anterior posterior lesions in overhead athletes: assessment of return to preinjury playing level and satisfaction. *Am J Sports Med* 2011;39:1883–8.
9 Domb BG, Davis JT, Alberta FG, *et al*. Clinical follow-up of professional baseball players undergoing ulnar collateral ligament reconstruction using the new Kerlan-Jobe orthopaedic clinic overhead athlete shoulder and elbow score (KJOC Score). *Am J Sports Med* 2010;38:1558–63.
10 Turgut E, Tunay VB. Cross-Cultural adaptation of Kerlan-Jobe orthopaedic clinic shoulder and elbow score: reliability and validity in Turkish-speaking overhead athletes. *Acta Orthop Traumatol Turc* 2018;52:206–10.
11 Merolla G, Corona K, Zanoli G, *et al*. Cross-Cultural adaptation and validation of the Italian version of the Kerlan-Jobe orthopaedic clinic shoulder and elbow score. *J Orthop Traumatol* 2017;18:415–21.
12 JH O, Kim JY, Limpisvasti O, *et al*. Cross-cultural adaptation, validity and reliability of the Korean version of the Kerlan-Jobe Orthopedic Clinic shoulder and elbow score. *JSES Open Acess* 2017;1.
13 Beaton DE, Bombardier C, Guillemin F, *et al*. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine* 2000;25:3186–91.
14 Haldorsen B, Svege I, Roe Y, *et al*. Reliability and validity of the Norwegian version of the disabilities of the arm, shoulder and hand questionnaire in patients with shoulder impingement syndrome. *BMC Musculoskelet Disord* 2014;15:78.
15 Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med* 1996;29:602–8.
16 Wild D, Grove A, Martin M, *et al*. Principles of good practice for the translation and cultural adaptation process for patient-reported outcomes (pro) measures: report of the ISPOR Task force for translation and cultural adaptation. *Value Health* 2005;8:94–104.
17 Peterson CH, Peterson NA, Powell KG. Cognitive interviewing for item development: validity evidence based on content and response processes. *Measurement and Evaluation in Counseling and Development* 2017;50:217–23.
18 Coons SJ, Gwaltney CJ, Hays RD, *et al*. Recommendations on evidence needed to support measurement equivalence between electronic and paper-based patient-reported outcome (pro) measures: ISPOR ePRO good research practices Task force report. *Value Health* 2009;12:419–29.
19 Muehlhausen W, Doll H, Quadri N, *et al*. Equivalence of electronic and paper administration of patient-reported outcome measures: a systematic review and meta-analysis of studies conducted between 2007 and 2013. *Health Qual Life Outcomes* 2015;13:167.
20 Pallant J. *SPSS survival manual*. 6 edn. England: Open University Press, 2016: 325.
21 Beaton DE, Davis AM, Hudak P, *et al*. The DASH (disabilities of the arm, shoulder and hand) outcome measure: what do we know about it now? *The British Journal of Hand Therapy* 2001;6:109–18.
22 Kraeutler MJ, Ciccotti MG, Dodson CC, *et al*. Kerlan-Jobe orthopaedic clinic overhead athlete scores in asymptomatic professional baseball pitchers. *J Shoulder Elbow Surg* 2013;22:329–32.
23 Aaronson N, Alonso J, Burnam A, *et al*. Assessing health status and quality-of-life instruments: attributes and review criteria. *Qual Life Res* 2002;11:193–205.
24 Revicki D, Hays RD, Cella D, *et al*. Recommended methods for determining responsiveness and minimally important differences for patient-reported outcomes. *J Clin Epidemiol* 2008;61:102–9.

Paper II

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ORIGINAL ARTICLE

WILEY

Does an effective shoulder injury prevention program affect risk factors in handball? A randomized controlled study

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Abstract

Background: Shoulder problems are common in handball, but injury risk reduction is possible by implementing a prevention program. However, player compliance to the program remains a challenge, with feedback from players that the program is too time consuming.

Aim: To develop a more efficient program, we aimed to assess the effect of the Oslo Sports Trauma Research Center shoulder injury prevention program on external rotation (ER) strength and internal rotation (IR) range of motion (ROM), considered to represent key risk factors for injury.

Methods: Four youth handball teams (three females, one males, 57 players, mean age 17.1 years) were randomized to an intervention or control group. The intervention program was conducted three times per week as a part of handball warm-up for 18 weeks, supervised by physical therapists. The main outcome variables were the between-group differences in ER strength and IR ROM change from baseline to postintervention. Isometric ER strength was measured with a handheld dynamometer and IR ROM with a digital goniometer.

Results: Mean dominant shoulder isometric ER strength increased both in the intervention (10%) and the control group (6%) during the intervention, but there was no significant group by time interaction (group difference: 0.06 N/kg (95% CI: −0.04 to 0.17). IR ROM did not change in either group during the intervention.

Conclusion: The Oslo Sports Trauma Research Center shoulder injury prevention program did not affect the risk factors ER strength and IR ROM. The preventive effect of the program must therefore be due to other factors.

KEYWORDS
external rotation strength, handball, range of motion, shoulder

1 | INTRODUCTION

The handball shoulder is vulnerable for both acute- and overuse injuries due to repetitive throwing, as well as tackles to the throwing arm.[1] The prevalence of shoulder problems in handball is high, with an average prevalence of 17%-41%.[2-8] Recent studies have demonstrated that overuse shoulder problems dominate.[9,10]

Deficits in shoulder internal rotation (IR) range of motion (ROM) and external rotation (ER) weakness have been reported as risk factors for shoulder problems among overhead athletes in general,[11,12] as well as in handball players.[3,6,13-15] However, the evidence is conflicting.[4,16]

The Oslo Sports Trauma Research Center (OSTRC) shoulder injury prevention program is an exercise program developed to increase IR ROM, ER strength, and scapular muscle strength as well as to improve kinetic chain involvement and thoracic mobility.[9] In a recent cluster randomized controlled trial in 660 elite handball players, the program was implemented three times per week for eighteen weeks as a part of the handball warm-up. The study demonstrated 28% lower risk of shoulder problems in the intervention group than in the control group. However, despite of the effect on shoulder problems, only 24% of the athletes and 28% of the coaches reported that they would continue using the program.[17] Their main concern was that the program was too time consuming.

Since the outcome in the intervention study was injury risk, not the risk factors themselves, we do not know if the program influenced any of the previous identified risk factors, or if other mechanisms were involved.

The aim of this study was therefore to test the effect of the OSTRC shoulder injury prevention program on shoulder ER strength and IR ROM.

2 | METHODS

2.1 | Study design and participants

This RCT was registered in the International Standard Randomized Controlled Trial Number registry (ISRCTN13272376) and was reported in accordance with the Consolidating Standards for Reporting Clinical Trials.[18] During May to June 2018, we invited all handball teams (n = 14, age 16-18 years), within or close to Oslo, Norway, to participate in the study. We excluded teams performing shoulder injury prevention programs as part of their training routine and teams with fewer than 12 players. This left us with six eligible teams (two males and four females). We randomly selected two of the four eligible female teams to participate, in addition to the two male teams. One of the male teams turned out to have less than 12 players and were excluded. Therefore, we randomly selected another female team to participate (Figure 1). A person not otherwise involved in the project selected teams using opaque, sealed

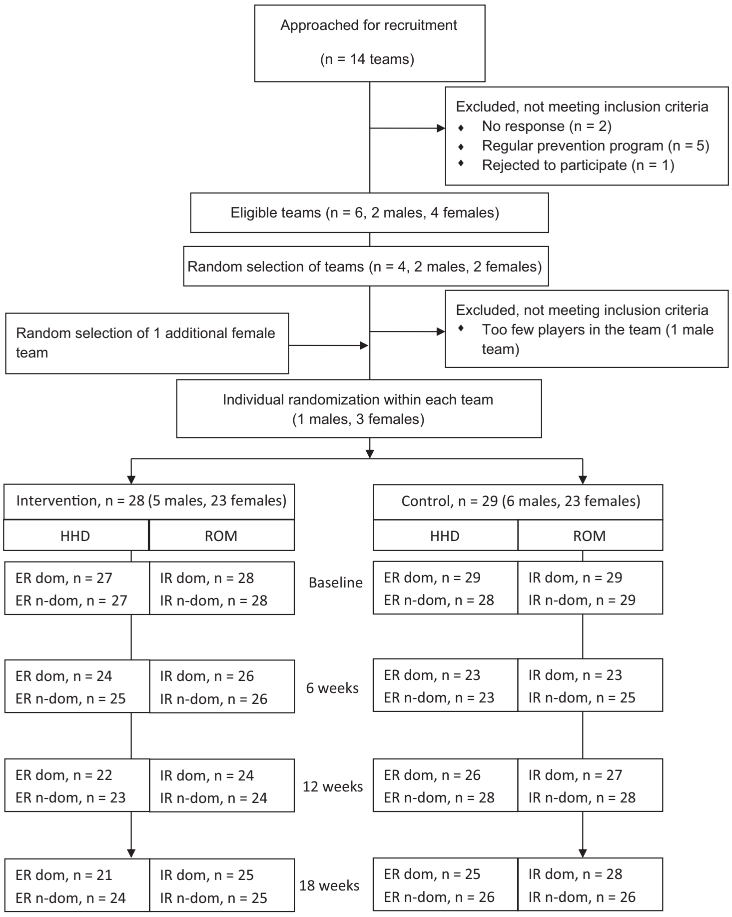

FIGURE 1 Study flowchart showing the enrollment, randomization, number of players included and tested at baseline, at six, twelve, and 18 weeks for the main outcome variables, external rotation (ER) strength, and internal rotation (IR) range of motion (ROM). HHD: Isometric strength tested with handheld dynamometer, dom: dominant shoulder, n-dom: non-dominant shoulder

envelopes containing the name of each team. We visited the included teams to inform and invite the players to participate. All players on the team were eligible, irrespectively of previous or current shoulder pain. The players received verbal and written information and signed a written consent form. Intervention and data collection took place from August 2018 to January 2019.

The study was approved by the Norwegian Regional Committee for Medical and Health Research Ethics, South East region (2018/412/REK sør-øst). Participants were neither invited to comment on the study design nor consulted to develop patient-relevant outcomes or interpret the results.

2.2 | Randomization

A statistician performed a computer-generated randomization of players into an intervention or a control group within each team. The first day of intervention, the physiotherapist responsible for providing the intervention program in the team received the group assignment from the statistician.

2.3 | Blinding

The main investigator was blinded to group allocation until all data collection was completed. Given the nature of the intervention, it was not possible to blind the players, coaches, or physiotherapists who provided the intervention program.

2.4 | Outcome measures

The primary outcome measures were between-group differences in shoulder ER strength changes, measured as isometric strength using a handheld dynamometer and IR ROM from before until after 18 weeks of intervention. Manual muscle testing was our primary outcome measure because this is an applicable field test. Secondary outcome measures were between-group differences in IR strength, ER/IR strength ratio, ER ROM, total ROM, and glenohumeral internal rotation deficit (GIRD, the difference in IR between dominant and non-dominant arm) at 6, 12, and 18 weeks of intervention. We also included isokinetic strength measurements (which is believed to represent the gold standard [19]) of shoulder ER and IR strength at baseline and after 18 weeks.

2.5 | Testing procedures

Testing at baseline and after 18 weeks was conducted at the Norwegian School of Sport Sciences and after 6 and 12 weeks in the handball clubs' facilities. A physiotherapist with more than 30 years of experience, conducted all the manual muscle strength and ROM testing, assisted by another therapist. Two therapists conducted the isokinetic strength measurements. The therapists went through extensive training to ensure they were well familiar with the testing equipment and procedures.

FIGURE 2 Glenohumeral internal rotation passive range of motion measurement, stabilizing the scapula with the thumb on the coracoid and the rest of the fingers grasping the spine of the scapula

Prior to testing, the players performed a standardized warm-up, consisting of multiplane shoulder movements. The testing procedure started with ROM measurements, followed by isometric and isokinetic strength measurements. Measurements were randomized between sides, and the same side was tested first for all the three measurements.

2.6 | ROM testing

IR and ER ROM were measured using a digital goniometer (Easyangle, Meloq AB). The player was in a supine position, with the shoulder abducted to 90° in the frontal plane. The main investigator stabilized the scapula with one thumb on the coracoid and the rest of the fingers grasping the spine of the scapula (Figure 2).[20] We tested pure passive ROM with the player completely relaxed and no overpressure. The assistant aligned the goniometer in line with the olecranon and the ulnar styloid process, read and recorded all measurements. The inclinometer was zeroed before each measurement using a fixed vertical reference. After a standardized instruction of the testing procedure and one familiarization trial, three ROM measurements were conducted and averaged for analysis.

2.7 | Isometric strength testing

Maximum isometric ER and IR was measured using a handheld dynamometer (MicroFET, Hoggan Health

Industries). The players were supine, with the shoulder abducted to 90° in the frontal plane and neutral rotation. The examiner stood in a stable position with her lateral elbow supported against her iliac crest and her forearm at a right angle to the player's forearm, placing the dynamometer 2 cm proximal to the player's ulnar styloid process, on the dorsal side of the wrist for ER and on the volar side for IR. The examiner's medial hand was placed against the bench on the caudal side of the players elbow to restrict shoulder adduction during the test (Figure 3). After a standardized instruction of the testing procedure and one familiarization trial, three maximal isometric make tests, where the subject exerts maximal force against a dynamometer which the rater holds stable,[21] were conducted. The participants were asked to gradually build their force to maximum effort over a 2-s period and thereafter continue the maximal effort for 3 s. The best of three attempts was used for analysis.

Detailed test protocols for the manual tests are attached as Appendix S1 and Appendix S2.

2.8 | Isokinetic strength testing

The isokinetic testing was performed on a Humac NORM isokinetic dynamometer (CSMi), and followed mainly the procedure described by van Cingel et al.[22] Athletes were tested in a supine position, with 90° of shoulder abduction, 0° of shoulder rotation, and 90° of elbow flexion. No gravity adjustments were done since both the IR and ER muscles moved with and against gravity during force production.[22] The player was stabilized with straps over the thorax and pelvis. The tests were conducted in the following order: concentric (con) IR and ER at 60°/s, con IR and ER at 300°/s, and finally eccentric (ecc) IR and ER at 60°/s. Before each test, the players conducted three submaximal familiarization trials, and they performed five maximal repetitions for each test. We chose to set the range from 80° ER to 40° IR, and the rest period between each trial was 60 s. Prior to the tests, the players received standardized instructions. They received verbal encouragement but were not allowed to watch the output screen during the tests. For each test, the highest peak torque was used for analysis.

FIGURE 3 Glenohumeral isometric external rotation strength measurement in 90° of abduction, using a handheld dynamometer. The rater stabilizes her hand, which holds the dynamometer by placing her forearm perpendicular to the players forearm and her elbow against her iliac crest. Adduction of the humerus is restricted by the rater's medial fist against the bench

2.9 | Reliability of the shoulder tests

To assess the reliability of the shoulder tests, we conducted a pilot study prior to the main study, including 30 shoulders from 15 healthy handball players (nine males, six females) with a mean age of 17.4 ± 1.3 years (SD). The test-retest repeatability of one tester with one-week interval was assessed by calculating the intraclass correlation; two-way mixed effect, single measurement ($ICC_{3,1}$) absolute agreement for the strength measures and two-way mixed effect, average measurement ($ICC_{3,k}$), absolute agreement for the ROM measures. We calculated the standard error of measurement (SEM) to assess absolute reliability.

2.10 | Baseline questionnaires

At baseline, we registered demographic data, hand dominance, and years playing handball. We also registered shoulder problems the previous year and whether the players were playing with or without shoulder pain.

TABLE 1 Baseline characteristics of the study participants (n = 57). Results are shown as the mean ± SD or numbers, as appropriate

	Intervention (n = 28)	Control (n = 29)
Age (years)	17.1 ± 0.7	17.1 ± 0.8
Height (cm)	173.0 ± 7.6	172.3 ± 6.5
Body mass (kg)	68.1 ± 10.9	68.6 ± 9.7
Handball experience (years)	9.9 ± 1.9	9.6 ± 1.8
Sex (females/males)	23/5	23/6
Shoulder pain last year (yes/no)	12/16	11/18
Shoulder status at baseline		
Playing without pain	19	18
Playing with pain	8	10
Not playing due to pain	1	1

2.11 | Intervention

The OSTRC shoulder prevention program[9] (Appendix S3) was implemented during regular handball warm-up three times a week for 18 weeks in the intervention group. The program consists of five exercises aimed to increase ER strength, IR ROM, scapula stabilization, thoracic mobility, and kinetic chain involvement. The ER strength and IR ROM exercises were done on the dominant side only. One physiotherapist for each team received standardized instructions and training on the execution of the exercises prior to intervention and delivered and supervised the program in their team once or twice a week. The program took about 15 min to complete.

2.12 | Weekly questionnaires

A questionnaire about adherence to the intervention, training and match exposure and prevalence of shoulder problems, other injuries and illnesses was sent electronically to the participants each Sunday during the intervention period, nineteen times in total, using an online survey software (Briteback AB).

2.13 | Adherence

The players reported how many minutes they had completed the exercise program weekly. The total number of minutes completed was divided by the number of respondents to calculate the weekly adherence with the program.

2.14 | Exposure

Players reported their exposure to handball training and matches, as well as eventual additional shoulder training every week. The total number of minutes completed was divided by the number of respondents to calculate the weekly exposure in each group.

TABLE 2 Mean (± SD) for isometric shoulder strength (normalized to body weight) at baseline, during (at 6 and 12 weeks) and after 18 weeks of intervention (n = 57)

		Intervention		Control	
		n	Mean ± SD	n	Mean ± SD
External rotation strength (N/kg)					
Dominant shoulder	Baseline	27	1.79 ± 0.29	29	1.93 ± 0.40
	6 weeks	24	1.87 ± 0.29	23	1.95 ± 0.34
	12 weeks	22	1.96 ± 0.26	26	2.02 ± 0.36
	18 weeks	21	1.92 ± 0.25	25	2.08 ± 0.42
Non-dominant shoulder	Baseline	27	1.79 ± 0.27	28	1.82 ± 0.37
	6 weeks	25	1.82 ± 0.34	23	1.82 ± 0.35
	12 weeks	23	1.76 ± 0.31	28	1.88 ± 0.40
	18 weeks	24	1.89 ± 0.35	26	1.96 ± 0.36
Internal rotation strength (N/kg)					
Dominant shoulder	Baseline	28	1.81 ± 0.31	29	1.95 ± 0.44
	6 weeks	26	1.89 ± 0.38	24	1.93 ± 0.36
	12 weeks	24	1.89 ± 0.31	27	2.00 ± 0.45
	18 weeks	24	1.91 ± 0.39	26	2.06 ± 0.51
Non-dominant shoulder	Baseline	28	1.80 ± 0.41	29	1.84 ± 0.41
	6 weeks	25	1.84 ± 0.35	25	1.86 ± 0.38
	12 weeks	23	1.89 ± 0.34	28	1.95 ± 0.49
	18 weeks	25	1.89 ± 0.37	26	1.96 ± 0.48
ER/IR ratio					
Dominant shoulder	Baseline	27	1.00 ± 0.08	29	1.00 ± 0.15
	6 weeks	24	1.04 ± 0.13	23	1.03 ± 0.15
	12 weeks	22	1.08 ± 0.16	26	1.03 ± 0.16
	18 weeks	21	1.07 ± 0.16	25	1.04 ± 0.16
Non-dominant shoulder	Baseline	27	1.02 ± 0.13	28	1.01 ± 0.13
	6 weeks	24	1.00 ± 0.14	23	1.01 ± 0.16
	12 weeks	23	0.94 ± 0.16	28	1.00 ± 0.14
	18 weeks	24	1.01 ± 0.13	26	1.03 ± 0.18

2.15 | Prevalence of shoulder problems

Prevalence of shoulder problems, other injuries, and illnesses was recorded using OSTRC injury and illness questionnaire[23] and the Kerlan-Jobe Orthopaedic Clinic shoulder and elbow questionnaire.[24]

2.16 | Sample size

The sample size calculation was based on a previous study examining shoulder ER strength effects of a rubber band shoulder training program[25] and values from our reliability testing of isometric ER strength. With a 15% increase in ER strength from baseline to the end of the study, the expected between-group difference was set at 0.31 N/kg with a SD of 0.35 N/kg. With a power of 80%, a significance level (α) of 0.05, and a dropout rate of 15%, we needed 24 players per group.

2.17 | Statistical analyses

Analyses were based on the intention-to-treat principle, where all randomized subjects were included in the analyses.

Repeated measures linear mixed-effect models with random intercept were used to assess the between-group differences on each outcome variable. Time was defined as a categorical variable with four levels (baseline, 6, 12, and 18 weeks) for the isometric and ROM variables and with two levels (baseline and 18 weeks) for the isokinetic variables. Group (two levels: intervention and control), time and group*time interaction were fixed variables. By using all available data at each time, linear mixed models handle missing data. Therefore, imputation of missing data was not conducted.[26] The between-group differences in baseline characteristics were assessed using an independent *t* test or Mann-Whitney *U* test, where appropriate.

All analyses were performed using SPSS Statistics for Windows V.24.0.

3 | RESULTS

3.1 | Participants

We enrolled 57 players (age 17.1 ± 0.8 (SD) years) in the study, 28 players in the intervention group (five males, 23 females), and 29 players in the control group (six males, 23 females). There were no differences between the intervention and control group in demographic data, handball experience, or shoulder pain at baseline or during the previous year (Table 1). Players reported 10 ± 2 (SD) years of handball experience.

The baseline data for ROM, isometric, or isokinetic strength were not different between groups (Tables 2 and 3, Appendix S4).

Dropout during the study and missing values are presented in Figure 1.

3.2 | Isometric ER strength

Mean dominant shoulder isometric ER strength increased significantly both in the intervention (10%) and in the control group (6%) (Table 2), but there was no significant group by time interaction (estimated group difference: 0.06 N/kg; 95% CI −0.04 to 0.17).

3.3 | IR ROM

Mean IR ROM did not change in either group during the intervention (Table 3).

3.4 | Secondary outcomes

There were no significant differences between the intervention and the control group for any of the secondary outcome variables: isometric IR strength, ER/IR strength ratio, ER ROM, GIRD, total ROM (Tables 2 and 3), or isokinetic strength at 60°/s or 300°/s, or type of contraction (con/ecc), neither in the dominant nor the non-dominant shoulder (Appendix S4).

3.5 | Reliability of the testing procedures

The test-retest reliability of isometric strength and ROM measurements is presented in Table 4.

3.6 | Response rate

The mean weekly response rate to the questionnaire was 76% in the intervention group, and 75% in the control group.

3.7 | Adherence

On average, the OSTRC shoulder injury prevention program was completed 32 min per week (range 24 to 45), which corresponds to two times per week.

3.8 | Exposure

The average weekly exposure to handball training, match play, and additional shoulder training was not different between the intervention and control group (Table 5).

TABLE 3 Mean (± SD) of rotational range of motion, measured in degrees, at baseline, during (at 6 and 12 weeks), and after 18 weeks of intervention (n = 57)

		Intervention		Control	
		n	Mean ± SD	n	Mean ± SD
Internal rotation range of motion (°)					
Dominant shoulder	Baseline	28	55 ± 8	29	54 ± 8
	6 weeks	26	55 ± 11	23	56 ± 8
	12 weeks	24	56 ± 9	27	56 ± 7
	18 weeks	25	56 ± 10	26	57 ± 8
Non-dominant shoulder	Baseline	28	63 ± 9	29	62 ± 7
	6 weeks	26	64 ± 10	25	61 ± 8
	12 weeks	24	66 ± 9	28	66 ± 8
	18 weeks	25	65 ± 8	26	63 ± 8
External rotation range of motion					
Dominant shoulder	Baseline	28	95 ± 9	29	90 ± 12
	6 weeks	26	96 ± 9	24	93 ± 10
	12 weeks	24	101 ± 10	27	96 ± 13
	18 weeks	25	98 ± 10	26	93 ± 11
Non-dominant shoulder	Baseline	28	84 ± 9	29	83 ± 13
	6 weeks	26	88 ± 9	25	87 ± 10
	12 weeks	24	92 ± 8	28	86 ± 9
	18 weeks	25	92 ± 9	26	87 ± 11
Total rotational range of motion					
Dominant shoulder	Baseline	28	150 ± 11	29	144 ± 17
	6 weeks	26	151 ± 13	23	149 ± 11
	12 weeks	24	156 ± 12	27	152 ± 12
	18 weeks	25	153 ± 15	26	150 ± 12
Non-dominant shoulder	Baseline	28	147 ± 11	29	145 ± 12
	6 weeks	26	151 ± 12	25	148 ± 9
	12 weeks	24	158 ± 12	28	152 ± 9
	18 weeks	25	157 ± 12	26	150 ± 10
Glenohumeral rotation deficit					
	Baseline	28	8 ± 9	29	8 ± 10
	6 weeks	26	9 ± 8	23	5 ± 10
	12 weeks	24	10 ± 8	27	9 ± 9
	18 weeks	25	9 ± 9	26	7 ± 7

4 | DISCUSSION

The main finding of the present study was that 18 weeks of training using the OSTRC prevention program for shoulder injuries in handball did not affect shoulder ER strength or IR ROM, considered to represent key risk factors for injury, in a cohort of young handball players.

4.1 | Strength exercises

Two previous studies have examined the effect of a 6-week shoulder strength training program in handball.[25,27] None of them found significant group by time interaction effects, which is similar to our results, but both found significant increase in ER strength, with large effect sizes. Mascarin et al only included players diagnosed with ER weakness. Therefore, their strength gain potential might have been higher than in our study. Key differences between these studies and ours are the number and selection of exercises, and the definition of progression. The studies mentioned used two exercises only, both targeting ER strength. Genevois et al used a pre-defined progression, while Mascarin et al used progression based on rating of perceived exertion.

Similar interventions have been conducted in swimming, and while Batalha et al demonstrated a significant

TABLE 4 Test-retest reliability of isometric shoulder rotation strength and rotational range of motion for youth handball players (n = 29)

Measurement	Day 1	Day 2	ICC	95%CI	SEM
ER strength (N)	146 ± 38	154 ± 38	0.941	0.852-0.974	9
IR strength (N)	155 ± 42	158 ± 42	0.921	0.835-0.962	12
ER ROM (deg)	94 ± 13	91 ± 13	0.945	0.862-0.976	3
IR ROM (deg)	62 ± 10	60 ± 9	0.861	0.712-0.934	4

Note: Strength data are presented in N ± standard deviation. Range of motion data are presented in degrees ± standard deviation.

Abbreviations: ER, external rotation; ICC, intraclass correlation, presented as mean with 95% confidence interval; IR, internal rotation; N, Newton; SEM, standard error of measurement.

TABLE 5 Mean (±SD) weekly exposure to handball training, match play, and additional shoulder training in intervention and control group, presented in minutes

Activity type	Intervention	Control
Handball training	231 ± 36	225 ± 31
Match play	40 ± 17	36 ± 15
Additional shoulder training	31 ± 10	32 ± 5

increase in ER peak torque and ER/IR ratio after a 16-week intervention, Hibberd et al found no significant effects after 6 weeks.[28] The latter study used eleven strength exercises for different muscle groups and two IR stretching exercises.[28,29]

In tennis, Niederbracht et al demonstrated a significant increase in eccentric ER total work capacity after a 5-week shoulder strengthening program, consisting of five exercises, four days per week.[30]

4.2 | Range of motion

Our intervention program did not affect IR ROM at all. A recent systematic review concluded that the cross-body stretch could be effective to improve GIRD in the immediate and short term (4 weeks), but the sleeper stretch was not effective.[31] In our program, the sleeper stretch was conducted week 1 through 6 and week 13 through 18, while the cross-body stretch was used week 7 through 12. However, we found no effect on the ROM at week 12, when the players had performed the cross-body stretch for 6 weeks. A recent RCT demonstrated a significant improvement in IR (19°) after 4 and 6 weeks of sleeper stretch training in overhead athletes with a GIRD of ≥ 15° at baseline.[32]

4.3 | Dose-response

One possible explanation for our results could be insufficient dosage to achieve improvements. Recommended dosage to obtain strength gain in the upper extremities is six to nine set per muscle group each training session,[33] two to three times per week,[34] with high intensity.

In our study, the volume of the strength exercises was one ER exercise each session, three sets of 8-20 repetitions, three times per week. The intervention does not include any criteria for progression, it was all up to the players themselves. With no defined resistance nor criteria for progression, we might assume the dosage was not sufficient for strength improvement.

Most studies reporting an effect of stretching were keeping the stretching for 30 to 60 s, three to five times per day, and five to seven days per week.[31,32] In our study, the stretching was performed three times 30 s, three days per week, which is probably too low dose to achieve an effect.

4.4 | Baseline measures

At baseline, the isometric ER strength was comparable to reference values from Cools et al for adult handball players (1.8-2.0 N/kg),[35] and greater than that reported by Møller et al for 14- to 18-year-old players (1.3-1.6 N/kg).[36] Our population displayed a high ER/IR ratio at baseline (>1.0), which is greater than the suggested cutoff values to identify players at risk of injury.[37] Therefore, our players might have had less room for improvement. However, the ratio is comparable to the reference values for adult players.[35] In addition, both ER, IR and the ER/IR ratio increased slightly in both groups during the intervention, with no group differences.

Our players had normal dominant shoulder IR, with an average of 64° and a side-to-side difference of 8°. This might imply less room for improvement compared with studies that have demonstrated an effect of stretching in populations with GIRD ≥ 15°.[31,32]

4.5 | Methodological considerations

4.5.1 | Study strengths

We conducted an RCT with single randomization within teams, which ensured that the intervention and control groups were as equal as possible. There were no between-group differences in weekly training and match exposure during the intervention period. We had good to excellent reliability of our measurements, and the main investigator was blinded to group allocation. Our supervision and follow-up of the participants during the intervention, with a dedicated physiotherapist present 1-2 times per week, were more intensive than in the original study by Andersson et al[9] The adherence with the program was also better in our study. This implies that our results are reliable.

We included both healthy players and players with current or a history of shoulder pain. A majority of players with chronic shoulder pain continue playing handball despite their pain.[5,9] Since one third of the players reported shoulder pain at baseline, the study population would have been biased if we excluded these players. Andersson et al also included players with shoulder pain at baseline in their study.[9] In fact, when players with and without shoulder pain at baseline were analyzed separately, they revealed a 35% lower risk of reporting shoulder pain during the season among those with shoulder problems, whereas there was no difference among players without shoulder pain.

Our study group is younger (17 years) than the players in the original intervention study, who were young adults (22 years). We made this decision because the prevalence of shoulder pain is comparable between adolescents and adults,[2,3,5,14] we want to start prevention early, and thought that using a younger group as the research population could be favorable. To our knowledge, no difference in response to strength training between adolescents (16-18 years) and young adults has been reported.

We chose isometric strength, measured manually as our primary outcome measures because it can be carried out in the field. Isokinetic measurements were also included, since this is believed to represent the gold standard for strength measurements. Our isometric findings were supported by the isokinetic findings, with no time by group interaction effect for any of the isokinetic variables. We had high reliability of our manual tests, comparable to the isokinetic tests. One reason is probably that all the manual tests were conducted by one experienced physiotherapist, who strictly kept to the standardized procedures.

4.6 | Limitations

Due to difficulties with including sufficient male teams, we ended up with three-female and one-male team. Since we randomized the players within each team, this did not affect the gender distribution between the intervention and control group. According to Peitz et al,[38] sex does not affect resistance training-related outcome when comparing males and females of same age. However, our sample size is too small to compare male to female players.

There is a possibility of contamination when we do simple randomization within the teams. However, the intervention and control groups were separated during the 15 min of intervention training. Additionally, the players in the control group did not report doing any part of the intervention, and the exposure to additional shoulder training was similar in the two groups.

Our procedures were slightly different from previously described procedures. To avoid concomitant shoulder adduction while testing isometric ER and IR, the rater placed her fist on the bench, creating a barrier against adduction. Eliminating the adduction momentum will probably lead to purer rotational measurements which will affect the results. Additionally, the rater positioned herself in a very stable position, to be able to withstand strong athletes, and had no trouble holding the position during testing (Figure 3).

Regarding the ROM testing, we used the scapula stabilization technique, described by Wilk et al,[20] and conducted pure passive ROM with no overpressure. Since we have experienced that several subjects find it difficult to relax during testing, we spent sufficient time for the player to familiarize themselves with the procedure and relax completely. Due to these modifications in our procedures, our measurements are therefore not directly comparable to others.

We did not measure scapula dyskinesis, which has been reported to be a risk factor for shoulder injuries in overhead athletes,[39] and one of the exercise groups in the original program aimed at increasing scapular strength.[9] Based on the existing research, the reliability and validity of scapular dyskinesis test (visual observation) are recognized to be fair to poor.[40] Studies of responsiveness are lacking. Although scapular-focused treatment improves pain and function, it is questionable if scapula kinematics changes accordingly.[41] Therefore, scapular dyskinesis was not evaluated in this study.

The study was conducted with youth handball players, and we can therefore not generalize our results to adult players.

5 | CONCLUSION

The OSTRC prevention program for shoulder injuries in handball did not affect the risk factors shoulder ER strength or IR ROM in young handball players. This might be due to insufficient dosage of the exercises, suboptimal exercise selection, or that these proposed risk factors are not important. The preventive effect on shoulder injuries must therefore be due to other factors, not evaluated in our study.

5.1 | Perspective

Although the OSTRC shoulder injury prevention program is an effective program,[9] player compliance remains a challenge, as the program is time consuming.[17] This study demonstrated that the program does not affect the risk factors, ER strength, and IR ROM. To increase the adherence with shoulder prevention programs, there is a need for a shorter program with exercises targeting the risk factors with dosages sufficient to achieve an effect. Subsequently, the effect of this program must be explored. Until such a program has been developed, players and coaches should be recommended and motivated to use the existing shoulder injury prevention program.

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CONFLICT OF INTEREST

None.

AUTHOR'S CONTRIBUTION

HF, GM, and RB authors conceived and designed the study. HF recruited the study subjects and performed data collection. All authors have been involved in the data analyses, interpretation of data, drafting and revision of the manuscript, and have approved the final manuscript.

ETHICAL APPROVAL

The study was approved by the Norwegian Regional Committee for Medical and Health Research Ethics, South East region (2018/412/REK sør-øst).

DATA SHARING STATEMENT

Data are available upon request from the corresponding author.

PATIENT INVOLVEMENT

Participants were neither invited to comment on the study design nor consulted to develop patient-relevant outcomes or interpret the results.

PATIENT CONSENT

Obtained.

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REFERENCES

1. Kelly BT, Barnes RP, Powell JW, Warren RF. Shoulder injuries to quarterbacks in the national football league. *Am J Sports Med*. 2004;32(2):328-331.
2. Aasheim C, Stavenes H, Andersson SH, Engbretsen L, Clarsen B. Prevalence and burden of overuse injuries in elite junior handball. *BMJ Open Sport Exerc Med*. 2018;4(1):e000391.
3. Achenbach L, Laver L, Walter SS, Zeman F, Kuhr M, Krutsch W. Decreased external rotation strength is a risk factor for overuse shoulder injury in youth elite handball athletes. *Knee Surg Sports Traumatol Arthrosc*. 2019;28(4):1202-1211.
4. Andersson SH, Bahr R, Clarsen B, Myklebust G. Risk factors for overuse shoulder injuries in a mixed-sex cohort of 329 elite handball players: previous findings could not be confirmed. *Br J Sports Med*. 2018;52(18):1191-1198.
5. Asker M, Holm LW, Kallberg H, Walden M, Skillgate E. Female adolescent elite handball players are more susceptible to shoulder problems than their male counterparts. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(7):1892-1900.
6. Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. 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;48(17):1327-1333.
7. Mohseni-Bandpei MA, Keshavarz R, Minoonejhad H, Mohsenifar H, Shakeri H. Shoulder pain in Iranian elite athletes: the prevalence and risk factors. *J Manipulative Physiol Ther*. 2012;35(7):541-548.
8. Myklebust G, Hasslan L, Bahr R, Steffen K. High prevalence of shoulder pain among elite Norwegian female handball players. *Scand J Med Sci Sports*. 2013;23(3):288-294.
9. Andersson SH, Bahr R, Clarsen B, Myklebust G. Preventing overuse shoulder injuries among throwing athletes: a cluster-randomised controlled trial in 660 elite handball players. *Br J Sports Med*. 2017;51(14):1073-1080.
10. Forthomme B, Croisier JL, Delvaux F, Kaux JF, Crielaard JM, Gleizes-Cervera S. Preseason strength assessment of the rotator muscles and shoulder injury in handball players. *J Athl Train*. 2018;53(2):174-180.
11. Forthomme B, Wieczorek V, Frisch A, Crielaard JM, Croisier JL. Shoulder pain among high-level volleyball players and preseason features. *Med Sci Sports Exerc*. 2013;45(10):1852-1860.
12. Shitara H, Kobayashi T, Yamamoto A, et al. Prospective multifactorial analysis of preseason risk factors for shoulder and elbow injuries in high school baseball pitchers. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(10):3303-3310.
13. Edouard P, Degache F, Oullion R, Plessis JY, Gleizes-Cervera S, Calmels P. Shoulder strength imbalances as injury risk in handball. *Int J Sports Med*. 2013;34(7):654-660.
14. Møller M, Nielsen RO, Attermann J, et al. Handball load and shoulder injury rate: a 31-week cohort study of 679 elite youth handball players. *Br J Sports Med*. 2017;51(4):231-237.
15. Almeida GP, Silveira PF, Rosseto NP, Barbosa G, Ejnisman B, Cohen M. Glenohumeral range of motion in handball players with and without throwing-related shoulder pain. *J Shoulder Elbow Surg*. 2013;22(5):602-607.
16. Tyler TF, Mullaney MJ, Mirabella MR, Nicholas SJ, McHugh MP. Risk factors for shoulder and elbow injuries in high school baseball pitchers: the role of preseason strength and range of motion. *Am J Sports Med*. 2014;42(8):1993-1999.
17. Andersson SH, Bahr R, Olsen MJ, Myklebust G. Attitudes, beliefs, and behavior toward shoulder injury prevention in elite handball: Fertile ground for implementation. *Scand J Med Sci Sports*. 2019;29(12):1996-2009.

18. Moher D, Hopewell S, Schulz KF, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *Int J Surg*. 2012;10(1):28-55.
19. Stark T, Walker B, Phillips JK, Fejer R, Beck R. Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: a systematic review. *PM&R*. 2011;3(5):472-479.
20. Wilk KE, Reinold MM, Macrina LC, et al. Glenohumeral internal rotation measurements differ depending on stabilization techniques. *Sports Health*. 2009;1(2):131-136.
21. Stratford PW, Balsor BE. A comparison of make and break tests using a hand-held dynamometer and the Kin-Com. *J Orthop Sports Phys Ther*. 1994;19(1):28-32.
22. van Cingel R, Habets B, Willemsen L, Staal B. Shoulder dynamic control ratio and rotation range of motion in female junior elite handball players and controls. *Clin J Sport Med*. 2017;28(2):153-158.
23. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *Br J Sports Med*. 2013;47(8):495-502.
24. Alberta FG, ElAttrache NS, Bissell S, et al. The development and validation of a functional assessment tool for the upper extremity in the overhead athlete. *Am J Sports Med*. 2010;38(5):903-911.
25. Mascarin NC, de Lira CAB, Vancini RL, da Silva AC, Andrade MS. The effects of preventive rubber band training on shoulder joint imbalance and throwing performance in handball players: A randomized and prospective study. *J Bodyw Mov Ther*. 2017;21(4):1017-1023.
26. Maurissen JP, Vidmar TJ. Repeated-measure analyses: Which one? A survey of statistical models and recommendations for reporting. *Neurotoxicol Teratol*. 2017;59:78-84.
27. Genevois C, Berthier P, Guidou V, Muller F, Thiebault B, Rogowski I. Effects of 6-week sling-based training of the external-rotator muscles on the shoulder profile in elite female high school handball players. *J Sport Rehabil*. 2014;23(4):286-295.
28. Hibberd EE, Oyama S, Spang JT, Prentice W, Myers JB. Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in division I collegiate swimmers. *J Sport Rehabil*. 2012;21(3):253-265.
29. Batalha NM, Raimundo AM, Tomas-Carus P, Marques MA, Silva AJ. Does an in-season detraining period affect the shoulder rotator cuff strength and balance of young swimmers? *J Strength Cond Res*. 2014;28(7):2054-2062.
30. Niederbracht Y, Shim AL, Sloniger MA, Paternostro-Bayles M, Short TH. Effects of a shoulder injury prevention strength training program on eccentric external rotator muscle strength and glenohumeral joint imbalance in female overhead activity athletes. *J Strength Cond Res*. 2008;22(1):140-145.
31. Mine K, Nakayama T, Milanese S, Grimmer K. Effectiveness of stretching on posterior shoulder tightness and glenohumeral internal-rotation deficit: a systematic review of randomized controlled trials. *J Sport Rehabil*. 2017;26(4):294-305.
32. Chepeha JC, Magee DJ, Bouliane M, Sheps D, Beaupre L. Effectiveness of a posterior shoulder stretching program on university-level overhead athletes: randomized controlled trial. *Clin J Sport Med*. 2018;28(2):146-152.
33. Ralston GW, Kilgore L, Wyatt FB, Buchan D, Baker JS. Weekly training frequency effects on strength gain: a meta-analysis. *Sports Med Open*. 2018;4(1):36.
34. Naclerio F, Faigenbaum AD, Larumbe-Zabala E, et al. Effects of different resistance training volumes on strength and power in team sport athletes. *J Strength Cond Res*. 2013;27(7):1832-1840.
35. Cools AMJ, Vanderstukken F, Vereecken F, et al. Eccentric and isometric shoulder rotator cuff strength testing using a hand-held dynamometer: reference values for overhead athletes. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(12):3838-3847.
36. Møller M, Attermann J, Myklebust G, et al. The inter- and intrarater reliability and agreement for field-based assessment of scapular control, shoulder range of motion, and shoulder isometric strength in elite adolescent athletes. *Phys Ther Sport*. 2018;32:212-220.
37. Cools AM, Johansson FR, Borms D, Maenhout A. Prevention of shoulder injuries in overhead athletes: a science-based approach. *Braz J Phys Therapy*. 2015;19(5):331-339.
38. Peitz M, Behringer M, Granacher U. A systematic review on the effects of resistance and plyometric training on physical fitness in youth- What do comparative studies tell us? *PLoS ONE*. 2018;13(10):e0205525.
39. Hickey D, Solvig V, Cavalheri V, Harrold M, McKenna L. Scapular dyskinesis increases the risk of future shoulder pain by 43% in asymptomatic athletes: a systematic review and meta-analysis. *Br J Sports Med*. 2018;52(2):102-110.
40. Ellenbecker TS, Kibler WB, Bailie DS, Caplinger R, Davies GJ, Riemann BL. Reliability of scapular classification in examination of professional baseball players. *Clin Orthop Relat Res*. 2012;470(6):1540-1544.
41. Bury J, West M, Chamorro-Moriana G, Littlewood C. Effectiveness of scapula-focused approaches in patients with rotator cuff related shoulder pain: A systematic review and meta-analysis. *Man Ther*. 2016;25:35-42.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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Paper III

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Original Research

Development of a short and effective shoulder external rotation strength program in handball: A delphi study

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ABSTRACT

Background: Weakness of the shoulder external rotators (ER) is one of the main risk factors for shoulder pain in handball. Short, effective shoulder ER strength programs the players will adhere to are lacking.
Objectives: to develop a short and effective shoulder ER strength program, handball players will adhere to.
Methods: We conducted a modified Delphi study, including experts in the field of shoulder, strength training and handball. In the first round, the experts were asked to rate eight pre-defined shoulder ER exercises on efficacy and adherence and to suggest other preferred exercises. In round two, they were asked to rate the new exercises from round one. In round three, they received a statistical summary of the panels scores, their own score and a summary of the suggestions. Based on the feedback, the experts were asked to revise their response.
Results: Sixteen experts completed three rounds with 100% response rate. Twenty-eight exercises were rated. We reached consensus for both efficacy and adherence for two exercises, ER in 90° abduction in a bent-over squat position and ER in 90° abduction combined with horizontal abduction and trunk rotation in a push-up position.
Conclusion: We reached consensus for both efficacy and adherence for two exercises.

1. Introduction

In handball, the shoulder joint is exposed to considerable stress due to repetitive throws and passes, and the prevalence of shoulder problems is high (22–28%) (Andersson, Bahr, Clarsen, & Myklebust, 2017; Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014; Forthomme et al., 2018).

Recently a shoulder prevention program consisting of exercises for ER strength, IR range of motion, scapula control, thoracic mobility and kinetic chain exercises was demonstrated to prevent overuse shoulder problems in handball (Andersson et al., 2017). However, the adherence with the program was low, and the main barriers were program length and lack of player motivation. The authors therefore suggested that a shortening of the program would be beneficial (Andersson, Bahr, Olsen, & Myklebust, 2019). External rotation (ER) weakness in the dominant shoulder is considered the most important internal modifiable risk factor (Achenbach et al., 2020; Asker, Walden, Kallberg, Holm, & Skillgate, 2019; Clarsen et al., 2014; Edouard et al., 2013; Moller et al., 2017). Although the existing shoulder prevention program included exercises to increase shoulder ER strength (Andersson et al., 2017), a recent study demonstrated that the program did not affect ER strength (Fredriksen, Bahr, Cools, & Myklebust, 2019).

We need effective exercises the players will adhere to. There is currently no consensus about exercise selection to increase shoulder ER strength in handball players. Neither is there consensus about dosage (load, repetitions and series), frequency (times per week), delivery (during warm up or strength training) or progression. Several studies have evaluated shoulder rehabilitation exercises based on EMG measurements. However, our experience is that healthy athletes find most of these exercises boring and will not adhere to them. Handball coaches and -physiotherapists working with athletes have therefore created more “functional exercises”, but the efficacy of these exercises have not been evaluated.

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Our aim is to develop a short and effective program to target shoulder external rotation strength, with high likelihood of adherence in a handball population, using a Delphi method.

2. Methods

2.1. Study design

A world-wide modified Delphi study was chosen to seek expert consensus on an effective program of ER strength exercises that handball players would likely adhere to. A Delphi study is an iterative process to seek consensus among a panel of experts through several rounds (Hasson, Keeney, & McKenna, 2000). In a Delphi study the experts do not have to meet face-to-face but can work from a distance. Therefore, it is a practical way to gather information from experts around the world. Since the experts are anonymous to each other, each voice has the same strength. It is also possible for the experts to change their opinion during the study. A flow chart of the study is provided in Fig. 1. Today no universal guidelines for conducting and reporting a Delphi study exists. Therefore we have followed the recommendations by Hasson et al. (Hasson et al., 2000) and Junger et al. (Junger, Payne, Brine, Radbruch, & Brearley, 2017)

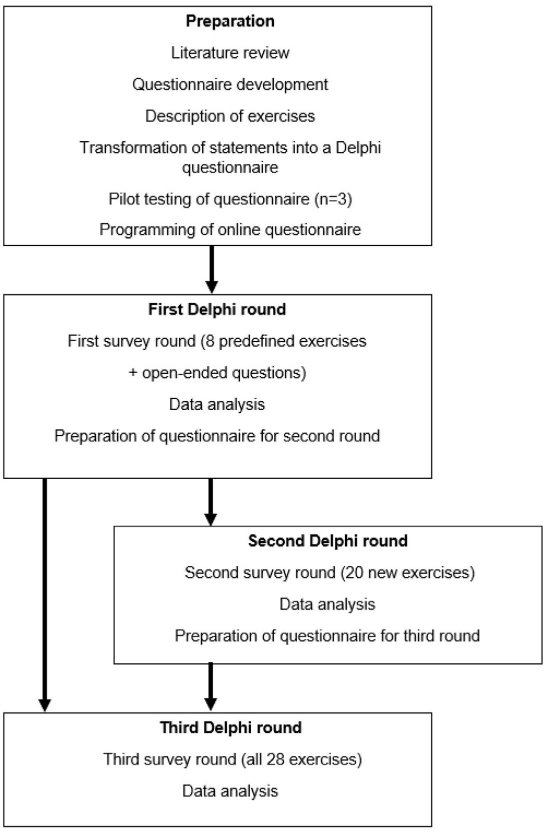

Fig. 1. Flow chart of the Delphi study.

2.2. Participants

We used a purposive sampling of experts based on selected criteria and their knowledge about the relevant population. The intention for the composition of the group was to include persons with expert knowledge of the efficacy of shoulder ER strength exercises as well as knowledge about barriers for adherence. We invited experts with special competence in the field of shoulder research, shoulder rehabilitation, handball- or strength training or combinations of these fields, representing physiotherapy, medicine, handball coaching and -playing.

2.3. Preparation

We conducted a literature review looking at electromyographic studies on shoulder exercises to find exercises with high activation of shoulder external rotator muscles (m. infraspinatus, m. supraspinatus and m. teres minor). We described each of the selected exercise in detail with illustrations and made two statements to each exercise: “The exercise is an effective exercise for ER strength” and “The exercise is an exercise that handball players will adhere to”. The experts were asked to rate their responses on a 100 mm visual analogue scale for each statement. Three physiotherapists working with shoulder and handball players were asked to review the questionnaire and suggest improvements to make it simpler and clearer. An invitation letter and informed consent was sent by e-mail to possible participants. The letter contained information about the Delphi study method, the purpose of the study, the research question, participant contribution, time required from participants, organization of the research, confidentiality and data protection (appendix 1).

2.4. Procedure

The original Delphi method included only open-ended questions in round one and used five rounds to reach consensus (Dalkey & Helmer, 1963). We used a modified Delphi method with the following two modifications: (1) A selection of eight exercises based on a literature review was added to the open-ended questions. (2) We limited the number of rounds to three.

The study took place between November 2018 and March 2019. The questionnaires were sent electronically to the experts using an online survey software (Briteback AB, Norrköping, Sweden).

2.5. First round

In the first round, the experts were asked to rate eight predefined exercises (appendix 2) based on one systematic and one narrative review (Cricchio & Frazer, 2011; Edwards, Ebert, Littlewood, Ackland, & Wang, 2017). We also included open-ended questions about how to improve the exercises, progress and increase adherence. In addition, we asked the experts to suggest other preferred exercises, to recommend how frequent a shoulder strength program should be conducted and whether it should be done during handball warm-up or as separate strength training session. They were also asked to explain their rationale behind their suggestions (appendix 2).

2.6. Second round

The second round included only the new exercise suggestions from the panel in round one and were presented in random order. The experts were asked to rate the exercises and comment and explain their ratings (appendix 3).

2.7. Third round

In round three the experts received a statistical summary of the panel's scores (median and interquartile range), their own score and a summary of the suggestions and comments (appendix 4). An unedited version of all the panel's comments was attached as a separate document (appendix 5). Based on the provided feedback, the experts were asked to revise their responses, by scoring each statement again and give reasons for their responses.

2.8. Analyses

Statistical analysis was performed using SPSS 24 for Windows. Descriptive statistics was used to calculate the median scores and interquartile ranges for each statement in the three rounds. Wilcoxon signed rank test was used to compare results from round one/two with round three. Consensus was based on two criteria, 1) agreement with the statement if median score >65 and 2) consensus among the panel members if 75% of the panel (12/16) scored above 50.

2.9. Ethical considerations

True anonymity is not possible in this kind of study. Only the main researcher knew the experts' identity, otherwise they were anonymous to each other.

The study was approved by the Norwegian Centre for Research Data (455,434/2018).

3. Results

3.1. Participants

Seventeen experts were invited to participate in the study, of which sixteen from nine countries accepted and completed three rounds of the survey. Table 1 describes the included experts. The medical experts were both involved in research and clinical practice.

3.2. Results from the rounds

We had 100% response rate in all three rounds. After round one, we combined identical or similar suggested exercises and ended up with 20 new exercises (appendix 3). These were presented to the experts in the second round, and all 28 exercises were included in the third round.

Results from the three rounds is presented in Table 2.

Two exercises, ER in 90° of abduction in a bent-over squat position (Fig. 2) and ER in 90° of abduction combined with horizontal abduction and trunk rotation in a push-up position (Fig. 3), reached agreement with the statement and consensus between panel members for both efficacy and adherence.

3.2.1. Efficacy of the exercises

After round three, nine of the exercises reached the predefined agreement with the statement and consensus between panel members (Fig. 4). The median scores ranged from 48 to 80 in round three and were lower than in round one and two for nearly all the exercises. However, the differences between round three and round one/two were significant only for exercise no.12.

3.2.2. Adherence to the exercises

After round three, three of the exercises reached the predefined agreement with the statement and consensus between panel members (Table 2). The median scores ranged from 50 to 73 in round three and were lower than in round one and two for nearly all the exercises, but the differences were significant only for exercises no.16 and no.22.

3.2.3. Delivery and frequency of the exercises

Five of the experts suggested to do the exercises during warm up, four during separate strength training sessions and seven suggested both. The main argument for doing the exercises during warm up was higher adherence, while the main argument for doing the exercises during separate strength training was that it was the best choice to increase strength. Fourteen of the experts suggested 2–3 sessions per week.

4. Discussion

In this Delphi study, we aimed to develop a short and effective program to target shoulder external rotation strength, with high likelihood of adherence in a handball population. We reached agreement with the statement and consensus between panel members for both efficacy and adherence for two exercises.

Three set of two exercises for one muscle group is defined as moderate training volume, which has been shown to be effective for improving upper body maximum strength and average power (Naclerio et al., 2013). Therefore, a program that consists of 3 sets of the two mentioned exercises could be an effective ER strength program. However, different exercises might target different regions of a muscle or muscle group. It is therefore recommended to use a variation of exercises to target the whole muscle or muscle group (Alenabi, Whittaker, Kim, & Dickerson, 2019; Calver et al., 2019).

4.1. Selection of exercises for an ER strength program for handball players

We wanted to use a variation of exercises, both to target the whole muscle group and for player motivation and adherence. Therefore, we needed more than the two exercises which reached consensus.

Table 1
Participants' characteristics (N = 16).

Gender	N	Country	N	Profession	N	Level of competence	N
Female	8	Australia	1	Physiotherapist	9	PhD	10
Male	8	Belgium	2	Naprapath	2	MSc	3
		Brazil	1	Medical doctor	1	National team coach	2
		The Netherlands	1	Physiologist	1	Olympic champion player	1
		Norway	5	Handball coach	2		
		Qatar	1	Strength coach	2		
		Sweden	2	Handball player	1		
		Switzerland	1				
		United Kingdom	2				

Table 2
Results from the three rounds of the Delphi process presented as median (interquartile range) for the exercises' efficacy and adherence and number of raters scoring above 50 (on a visual analogue scale).

Exercise		Efficacy				Adherence			
No.	Name	Round 1	Round 2	Round 3	N > 50	Round 1	Round 2	Round 3	N > 50
1	Side-lying ER 90°ABD	64 (51–87)		60 (54–72)	14†	61 (41–82)		59 (50–77)	10
2	Prone ER 90°ABD	83 (68–92)		80 (57–89)*	15†	53 (46–70)		53 (47–60)	9
3	Prone plyometric ER 90°ABD	83 (52–98)		80 (50–90)*	13†	59 (50–77)		58 (50–75)	11
4	Prone hor ABD with ER	64 (49–75)		60 (50–69)	12†	65 (46–80)		58 (51–73)	13†
5	Standing ER 90°ABD	78 (60–85)		68 (59–76)*	15†	73 (61–93)		64 (58–80)	15†
6	Standing scaption in ER	51 (43–85)		56 (50–68)	11	64 (50–79)		64 (52–70)	13
7	Push-up plus	54 (23–76)		53 (41–72)	9	73 (63–95)		73 (58–76)*	15†
8	Reverse catch plyometric	79 (64–88)		75 (46–79)*	11	79 (53–91)		73 (50–79)*	11
9	Bent-over-squat position ER 90°ABD		79 (64–89)	70 (56–85)*	14†		70 (52–83)	70 (51–79)*	13†
10	3-point kneeling position ER 90°ABD		71 (61–86)	66 (50–80)*	12†		69 (37–85)	61 (50–82)	12†
11	Prone on swiss ball, ER with hor ABD		75 (58–86)	68 (50–82)*	14†		67 (37–81)	62 (42–68)	10
12	Supine eccentric ER 90°ABD		69 (60–89)	62 (50–83)	11		68 (49–91)	59 (50–84)	10
13	Bent-over-squat position, hor ABD		61 (50–85)	60 (50–69)	12†		71 (50–84)	63 (50–80)	12†
14	Isometric ER with elevation and step-up		50 (38–72)	55 (50–67)	9		62 (41–77)	59 (51–75)	12†
15	Standing ER, 90°ABD and elevation (W–Y)		74 (47–88)	66 (52–76)*	14†		73 (50–88)	63 (50–73)	12†
16	Standing eccentric 1-arm Y-raise		68 (58–91)	61 (50–77)	10		76 (56–92)	58 (50–79)	9
17	Supine full rotational ROM 90°ABD		66 (46–83)	60 (50–67)	11		64 (44–87)	51 (44–67)	8
18	PU-position ER 90°ABD, hor ABD & trunk rot		81 (63–93)	68 (50–89)*	12†		71 (58–91)	69 (61–79)*	15†
19	Prone full rotational ROM 90°ABD		76 (69–92)	72 (63–80)*	14†		70 (50–86)	61 (50–70)	10
20	Standing hor ABD		55 (42–70)	52 (45–63)	9		56 (50–77)	56 (50–65)	10
21	Standing eccentric ER 90°ABD		68 (45–79)	58 (50–73)	10		61 (50–74)	57 (50–74)	9
22	Standing scaption combined with ER		67 (52–86)	60 (50–71)	12†		76 (52–89)	56 (50–71)	12†
23	3-point kneeling position horizontal ABD		54 (49–67)	57 (50–68)	11		51 (46–72)	55 (48–69)	10
24	Bent-over-squat position scaption		58 (50–78)	59 (50–72)	10		59 (43–77)	52 (47–67)	8
25	Resisted wall slide		50 (29–58)	48 (31–50)	12†		50 (45–66)	50 (43–60)	4
26	Protracted push up-position ER		59 (50–81)	54 (50–72)	10		53 (44–77)	50 (46–59)	6
27	Single-arm push-up		50 (34–71)	50 (46–66)	6		61 (44–78)	52 (45–61)	8
28	Standing ER 0°ABD		60 (50–73)	55 (50–62)	12†		75 (28–81)	50 (30–73)	8

No, exercise number; N > 50, number of raters scoring above 50; ER, external rotation; ABD, abductioin; hor, horizontal; ROM, range of motion; rot, rotation. * Median >65, † 75% of the raters scoring >50.

Fig. 2. Shoulder external rotation in a bent-over squat position.

If we combine the exercises with the highest median scores on both efficacy and adherence, we end up with ten exercises that scored >65 on efficacy, of which eight scored >60 on adherence (Fig. 4). Of these exercises, four were single plane exercises: shoulder ER in 90° of abduction in different starting positions, and four were combined exercises, including the kinetic chain. The eight exercises are presented in appendix 4. A short strength program could consist of a pair of exercises, one single plane and one combined exercise each training session, and the pair of exercises could be changed every second to third week.

Prone exercises were rated very effective, but scored low on adherence, mainly because the need for a bench or similar equipment to do the exercises. Many handball teams, especially youth teams, do not have access to a gym but must do all their strength and conditioning training on the handball field. Therefore, exercises that require much equipment are not feasible.

Fig. 3. Shoulder external rotation in 90° of abduction combined with horizontal abduction and trunk rotation in a push-up position.

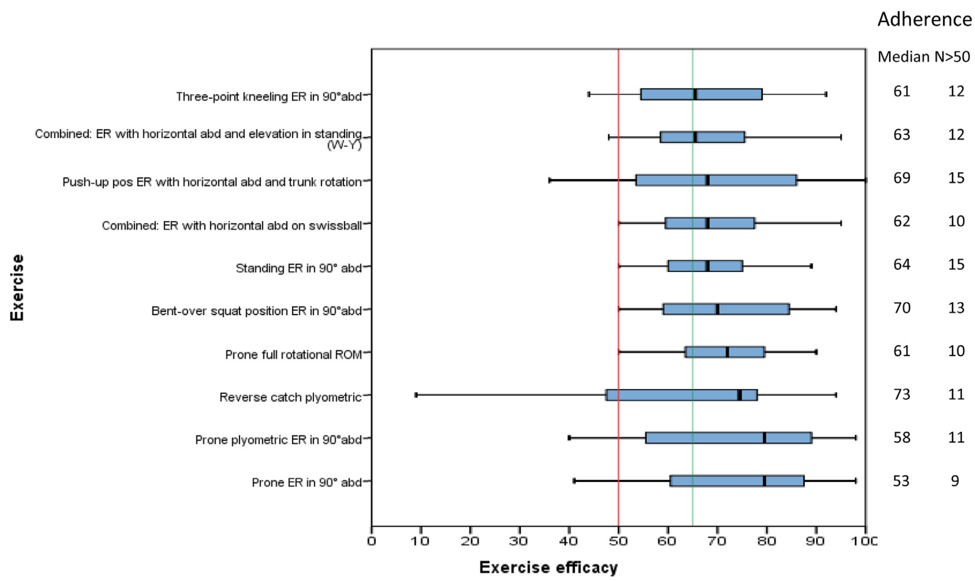

Fig. 4. Boxplot showing efficacy (measured on a visual analogue scale) of the nine exercises which reached predefined agreement with the statements (median above 65) and consensus between panel members (if 75% of the experts scored above 50). The reverse catch plyometric exercise is also included due to its high median score. The corresponding results for adherence are provided to the right.

There was no consensus on whether ER strength exercises should be done during regular handball warm-up or as separate strength training. However, if the goal is increased strength, the exercises should be carried out as separate strength training.

To our knowledge no other studies has used a Delphi method to seek consensus on exercise selection.

4.2. Strengths

A Delphi study does not require the experts to meet physically, which makes it possible to gather expert opinion from around the world. It also ensures anonymity between the experts, which prevents interaction between the participants and ensuring that everyone has an equal voice. We had an expert group with a diversity of expertise, scientific knowledge and experience from several countries. To develop an exercise program with effective exercises that players will adhere to, require knowledge from both researchers and practitioners in the field of shoulder and throwing, as well as from coaches and players, who are the target group of the intervention. However, the variability in expertise within the group probably made it difficult to reach the predefined consensus.

4.3. Limitations

We ended the study after three rounds although we reached consensus for two exercises only. Although there was a tendency of decreased scores both for efficacy and adherence from round one and two to round three, these changes were non-significant, suggesting stable results. We therefore found it inexpedient to continue with more rounds. Some authors recommend a meeting if consensus is not reached (Boulkedid, Abdoul, Loustau, Sibony, & Alberti, 2011). However, a meeting would interfere with the principle of anonymity between the panel members.

We used a purposive sampling of experts based on selected criteria and their knowledge about the relevant population. Since we did not conduct any formal search for experts, we have certainly missed many well qualified experts, and our panel, with an over-representation of physiotherapists, is therefore not a representative sample. However, the authors' knowledge about the experts in this field is quite comprehensive. Additionally, both knowledge, interest and willingness of the experts to take part in this kind of study is important. Due to our recruitment method, only one of the invited experts declined to participate and we had 100% response rate during the whole study. We realize that we probably should have included more than one handball player in our expert group, since this is our target population. However, to develop an effective program, we need to find effective exercises and thereafter select among these based on likelihood of adherence. Handball players are less likely to have expert knowledge of the efficacy of exercises. We therefore included two handball coaches and two physiotherapists who are previous handball players, and thereby familiar with the barriers for adherence. In round three, the panel members received a qualitative summary of the comments from the two preceding rounds. This is prone to researcher bias. However, the panel members also received an unedited copy of all the comments as an appendix.

Although the questions in the survey were related to handball players, we can assume the exercise efficacy scores would be the same if the questions were related to other overhead athletes. This is because the efficacy of a strength exercise is dependent on whether it targets the intended muscle group with adequate dosage. We cannot transfer the adherence results to other overhead athletes, because they may have other preferences, different routines or access to equipment.

5. Conclusion

Based on the predefined consensus definition, in a mixed group of experts, we reached consensus for both efficacy and adherence for two exercises. Since we want to develop a flexible program consisting of several alternating exercises, we will select the eight shoulder ER strength exercises with the highest efficacy and adherence scores, four single plane and four combined exercises. By grouping these exercises in pairs, with one single plane and one combined exercise, each training session can consist of one pair of these exercises and be alternated every second to third week.

A group consensus does not mean that the results are true. We therefore plan a randomized controlled trial to test if this exercise program will increase ER strength in handball players.

Ethical approval

The study was approved by the Norwegian Centre for Research Data (455,434/2018).

Approval from the regional committee for medical and health research ethics was not necessary in this kind of study.

All participants gave written informed consent.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. (Development of a Short and Effective Shoulder External Rotation Strength Program in Handball: A Delphi Study).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2020.05.005.

References

Achenbach, L., Laver, L., Walter, S. S., Zeman, F., Kuhr, M., & Krutsch, W. (2). Decreased external rotation strength is a risk factor for overuse shoulder injury in youth elite handball athletes. *Knee Surgery, Sports Traumatology, Arthroscopy, 28*(4), 1202–1211. https://doi.org/10.1007/s00167-019-05493-4.

Alenabi, T., Whittaker, R. L., Kim, S. Y., & Dickerson, C. R. (2019). Arm posture influences on regional supraspinatus and infraspinatus activation in isometric arm elevation efforts. *Journal of Electromyography and Kinesiology, 44*, 108–116. https://doi.org/10.1016/j.jelekin.2018.12.005.

Andersson, S. H., Bahr, R., Clarsen, B., & Myklebust, G. (2017). Preventing overuse shoulder injuries among throwing athletes: A cluster-randomised controlled trial in 660 elite handball players. *British Journal of Sports Medicine, 51*(14), 1073–1080. https://doi.org/10.1136/bjsports-2016-096226.

Andersson, S. H., Bahr, R., Olsen, M. J., & Myklebust, G. (2019). Attitudes, beliefs, and behavior toward shoulder injury prevention in elite handball: Fertile ground for implementation. *Scandinavian Journal of Medicine & Science in Sports, 29*(12), 1996–2009. https://doi.org/10.1111/sms.13522.

Asker, M., Walden, M., Kallberg, H., Holm, L. W., & Skillgate, E. (2019). Preseason clinical shoulder test results and shoulder injury rate in adolescent handball: A prospective study on female and male elite players. *Journal of Orthopaedic & Sports Physical Therapy*, 1–29. https://doi.org/10.2519/jospt.2020.9044.

Boulkedid, R., Abdoul, H., Loustau, M., Sibony, O., & Alberti, C. (2011). Using and reporting the Delphi method for selecting healthcare quality indicators: A systematic review. *PloS One, 6*(6), e20476. https://doi.org/10.1371/journal.pone.0020476.

Calver, R., Alenabi, T., Cudlip, A., Dickerson, C. R., Mondal, P., & Kim, S. Y. (2019). Regional activation of supraspinatus and infraspinatus sub-regions during dynamic tasks performed with free weights. *Journal of Electromyography and Kinesiology*. https://doi.org/10.1016/j.jelekin.2019.05.009. In press.

Clarsen, B., Bahr, R., Andersson, S. H., Munk, R., & Myklebust, G. (2014). Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: A prospective cohort study. *British Journal of Sports Medicine, 48*(17), 1327–1333. https://doi.org/10.1136/bjsports-2014-093702.

Cricchio, M., & Frazer, C. (2011). Scapulothoracic and scapulohumeral exercises: A narrative review of electromyographic studies. *Journal of Hand Therapy, 24*(4), 322–333. https://doi.org/10.1016/j.jht.2011.06.001. quiz 334.

Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management Science, 9*, 458–467.

Edouard, P., Degache, F., Oullion, R., Plessis, J. Y., Gleizes-Cervera, S., & Calmels, P. (2013). Shoulder strength imbalances as injury risk in handball. *Int J Sports Med, 34*(7), 654–660. https://doi.org/10.1055/s-0032-1312587.

Edwards, P. K., Ebert, J. R., Littlewood, C., Ackland, T., & Wang, A. (2017). A systematic review of electromyography studies in normal shoulders to inform post-operative rehabilitation following rotator cuff repair. *Journal of Orthopaedic & Sports Physical Therapy, 47*(12), 931–944. https://doi.org/10.2519/jospt.2017.7271.

Forthomme, B., Croisier, J. L., Delvaux, F., Kaux, J. F., Crielaard, J. M., & Gleizes-Cervera, S. (2018). Preseason strength assessment of the rotator muscles and shoulder injury in handball players. *Journal of Athletic Training, 53*(2), 174–180. https://doi.org/10.4085/1062-6050-216-16.

Fredriksen, H., Bahr, R., Cools, A., & Myklebust, G. (2019). Does an effective shoulder injury prevention program affect risk factors in handball? A randomized controlled study. *Scandinavian Journal of Medicine & Science in Sports*. submitted

for publication.
Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing, 32*(4), 1008–1015. https://www.ncbi.nlm.nih.gov/pubmed/11095242. (Accessed 30 November 2000).
Junger, S., Payne, S. A., Brine, J., Radbruch, L., & Brearley, S. G. (2017). Guidance on Conducting and REporting DElphi Studies (CREDES) in palliative care: Recommendations based on a methodological systematic review. *Palliative Medicine, 31*(8), 684–706. https://doi.org/10.1177/0269216317690685.
Moller, M., Nielsen, R. O., Attermann, J., et al. (2017). Handball load and shoulder injury rate: A 31-week cohort study of 679 elite youth handball players. *British Journal of Sports Medicine, 51*(4), 231–237. https://doi.org/10.1136/bjsports-2016-096927.
Naclerio, F., Faigenbaum, A. D., Larumbe-Zabala, E., et al. (2013). Effects of different resistance training volumes on strength and power in team sport athletes. *The Journal of Strength & Conditioning Research, 27*(7), 1832–1840. https://doi.org/10.1519/JSC.0b013e3182736d10.

Paper IV

No added benefit of 8-weeks of shoulder external rotation strength training for youth handball players over usual handball training alone: a randomized controlled trial

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The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article.

The Norwegian Regional Committee for Medical and Health Research Ethics, South East region (28912/REK sør-øst) approved this study. All participants gave written informed consent before data collection began.

The trial was registered in theInternational Standard Randomized Controlled Trial Number registry (ISRCTN19694168)

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No added benefit of 8-weeks of shoulder external rotation strength training for youth handball players over usual handball training alone: a randomized controlled trial

ABSTRACT

Objective: To assess the effectiveness of a short (5-10 min) shoulder external rotation strength program, using elastic bands, in adolescent handball players **Design:** Randomised controlled trial. **Participants:** Six adolescent handball teams (three female, three male, 92 players, mean age 16.6 years). **Methods:** Players were randomized within teams to an intervention group, which completed a shoulder external rotation strengthening program of 2 exercises performed 3 times/week after handball training for 8 weeks, or a control group of no treatment. The primary outcome was between-group difference in shoulder external rotation (ER) strength change, measured as isometric strength using a handheld dynamometer from pre- to postintervention (8 weeks). Secondary outcomes were between-group differences in internal rotation (IR) strength and ER/IR strength ratio from pre- to postintervention. **Results:** The estimated between-group difference in shoulder ER strength was 0.06 N/kg (95% CI -0.01 to 0.14) in favour of the intervention group. The estimated between-group differences in IR strength and ER/IR ratio were 0.03 (95% CI -0.02 to 0.08) and 0.02 (95% CI -0.08 to 0.13) respectively. **Conclusion:** The ER strength program resulted in a small improvement in ER strength, but the change was lower than the minimal detectable change in adolescent handball players. The program had no effect on IR strength or ER/IR ratio.

Key words: handball, shoulder, external rotation strength

INTRODUCTION

The prevalence of shoulder problems in handball is high (23-41%), both among senior and adolescent players**.**[2-4,7,11,28,31] The problems often persist, and players continue to play despite shoulder pain.[7,31] Overuse shoulder problems are the most common overuse injury in handball.[2,4,17 21]

It is possible to prevent shoulder injuries in handball. There was a 28% reduction in the prevalence of shoulder problems after implementing the Oslo Sports Trauma Research Center (OSTRC) shoulder injury prevention program.[4] However, adherence to th**e** program was low. Players and coaches reported that program length and poor motivation were the main barriers to completing the OSTRC program.[6] Our Norwegian colleagues encouraged research to evaluate the effect of the exercises in the OSTRC program on the specific risk factors their exercises targeted, to identify plausible ways to shorten the program.[6] External rotation (ER) strength is a modifiable risk factor for shoulder injuries in handball.[3,5,8,15,30] Although effective in preventing shoulder injuries, the OSTRC shoulder injury prevention program did not affect ER strength.[18]

To find the most effective ER strength exercises handball players would likely adhere to, we conducted a Delphi consensus study among 16 international experts in shoulder research, shoulder rehabilitation, handball- or strength training.[19] We developed a short shoulder ER strength program for handball players based on the opinions of the shoulder experts. The purpose of our trial was to assess if the program was effective in adolescent handball players. We hypothesized that adding a short shoulder ER strength program, using elastic bands, would increase shoulder ER strength in adolescent handball players compared to usual training.

METHODS

This randomized controlled trial was registered in the International Standard Randomized Controlled Trial Number registry (ISRCTN19694168) and was reported according to the Consolidated Standards for Reporting Trials (CONSORT) statement[27]. The eight-week intervention took place from October to December 2019. The main investigator was blinded to group allocation until data collection was complete. Given the nature of the intervention, it was impossible to blind the players, coaches or physiotherapists who provided the intervention program.

Participants

During May to June 2019 we invited all handball teams (n=48 teams, age 16-18 years), within or close to Oslo, Norway, to participate in our trial. The inclusion criterion was at least 12 players in the team. Of the 48 invited teams, 25 teams were eligible (11 male teams; 14 female teams). A person not otherwise involved in the project randomly selected three male and three female teams using opaque, sealed envelopes containing the name of each team. After the inclusion, coaches from one male and one female team reported that several players had quit after the team had accepted to participate in the study, which resulted in fewer than 12 players in the team. These teams were excluded and were replaced by another male and female team, randomly selected as described. (**FIGURE 1**).

There were 14 to 21 players in the included teams. All players on the teams were eligible, irrespectively of previous or current shoulder pain. The players received verbal and written information and signed a written consent form. A statistician performed a computer-generated randomization of players into an intervention- or a control group within each team.

We chose within team randomization to ensure the intervention and control groups were balanced. The teams received the group assignment from the statistician the first day of intervention. The study was approved by the Norwegian Regional Committee for Medical and Health Research Ethics, South East region (2019/28912/REK sør-øst).

Intervention

The intervention group conducted an eight-week, three times/week progressive shoulder strengthening program with AlfaCare fitness bands (Notodden, Norway) after handball training. AlfaCare fitness bands are elastic bands with different resistance, represented by different colors. We used yellow (x-light) to black (x-hard).

Eight exercises were selected via Delphi approach (16 international experts in shoulder research, shoulder rehabilitation, handball- or strength training, representing physiotherapy, medicine, and handball coaching and -playing).[19] We prescribed pairs of one single plane exercise and one combined exercise for each training session, and changed the pair of exercises every second week. Exercise pairs and order were determined a priori (appendix 1). Unilateral exercises were conducted with the dominant (throwing) arm only.

Participants completed 3 sets of each exercise every training session (total program time: 5-10 minutes). The level of resistance was defined by the target number of repetitions, which were eight repetition maximum, with two repetitions in reserve (2RIR). 2RIR corresponds to eight on the Resistance exercise-specific rating of perceived exertion scale.[38] The players were instructed, on an individual basis, to select resistance band according to this principle, and to increase the resistance if they were able to perform more than 12 repetitions with 2RIR.

Prior to the trial, we pilot tested the exercise program in a handball team. The players felt the strength program was inappropriate to perform before handball training because muscle fatigue impaired their throwing precision. Research supports the players' assertions.[25] We decided to ask participants to complete the program after handball training.

One physiotherapist for each team received standardized instructions and training on the execution of the exercises prior to intervention. Once or twice per week, the physiotherapist delivered the program and monitored how well the exercises were performed. We also provided the players and coaches with online instruction videos. The control group was instructed to train as usual and refrain from any additional shoulder strength training during the trial period.

Outcome measures

The primary outcome measure was between-group differences in shoulder ER strength changes, measured as isometric strength in N/kg. The secondary outcome measures were between-group differences in IR strength and ER/IR ratio from baseline until post intervention. We forgot to pre-specify IR strength and ER/IR ratio as outcome measures in the ISRCT trial registration protocol, but we measured them as part of our trial.

Testing procedures

All testing was conducted in the afternoon in a physiotherapy clinic. The players were instructed to refrain from training on the same day as they were tested. An experienced physiotherapist, familiar with the testing equipment and procedures, conducted all the testing, assisted by another therapist. Prior to testing, the players performed a standardized warm-up, consisting of multiplanar shoulder movements.

Isometric strength testing

Maximal isometric ER was measured using a handheld dynamometer (MicroFET, Hoggan Health Industries, USA). The players were supine, with the shoulder abducted to 90° in the frontal plane and neutral rotation. The examiner placed the dynamometer 2 cm proximal to the player's ulnar styloid process, on the dorsal side of the wrist. The examiner's medial hand was placed against the bench on the caudal side of the player's elbow to restrict shoulder adduction during the test (**FIGURE 2**). After a standardized instruction of the testing procedure and one familiarization trial, three maximal isometric tests were conducted.[35] The participants were asked to gradually build their force to maximum effort over a 2s period and continue the maximal effort for 3 s. The best of three attempts was used for analysis. Detailed test protocol is attached as appendix 2.

We have previously assessed the reliability isometric shoulder tests (n=30 shoulders) from healthy handball players with a mean age of 17.4±1.3 yrs (SD). The intraclass correlation was 0.94, standard error of measurements was 0.12N/kg, and minimal detectable change was 0.33N/kg.

Baseline questionnaires

At baseline, we registered demographic data, hand dominance, years playing handball, shoulder problems the previous year and whether the players were playing with or without shoulder pain.

Weekly questionnaires

A questionnaire was sent to the participants each Sunday during the intervention period, eight times in total, using online survey software (Briteback AB, Sweden).

The players reported how many times they had completed the exercise program. The total number of times completed was divided by the number of respondents to calculate the weekly adherence with the program.

Players reported their exposure to handball training and matches, as well as additional shoulder training. The total number of minutes completed was divided by the number of respondents to calculate the weekly exposure in each group.

Prevalence of shoulder problems, other injuries and illnesses was recorded using Oslo Sports Trauma Research Center injury and illness questionnaire[12] to monitor whether these factors influenced the players' adherence to the program.

Data analysis

The sample size calculation is based on a previous study examining shoulder ER strength effects of a rubber band shoulder training program[26] and values from our reliability testing of ER using a HHD. For a 15% increase in ER strength from baseline to the end of the study, the expected between group difference was set at 0.30N/kg with a SD of 0,34N/kg. With a power of 90%, a significance level (α) of .05, and a drop-out rate of 15% we needed 36 players per group.

Analyses were based on the intention-to-treat principle, where all randomized participants were included in the analyzes according to their group assignment.

Repeated measures linear mixed-effect models with random intercept was used to assess the between-group differences on each outcome variable. Time was defined as a categorical variable with two levels (baseline and post intervention). Group (two levels: intervention and control), time and group*time interaction were fixed variables. Team and shoulder pain at baseline were defined as covariates.

RESULTS

We enrolled 92 players (age 16.6±0.7 (SD) yrs) in the study, 45 players in the intervention group (24 males, 21 females) and 47 players in the control group (25 males, 22 females). Flow of participants is presented in **FIGURE 1**. There were no important differences between the intervention and control group in demographic data, handball experience, shoulder pain at baseline, shoulder pain during the previous year (**TABLE 1**) or baseline. shoulder isometric strength (**TABLE 2**).

Outcomes

The estimated between-group difference in mean dominant shoulder ER strength change from baseline to post-intervention was 0.06 N/kg (95% CI -0.01 to 0.14) in favour of the intervention group. The intervention had no effect on the secondary outcome variables (TABLE 2).

Response rate, adherence and exposure

The mean weekly response rate to the questionnaire was 95% in the intervention group, and 88% in the control group. On average the shoulder strength program was completed 2.5 times a week (range 2.3 to 2.8). The average weekly exposure to handball training, match play and additional shoulder training was not different between the groups (**TABLE 3**).

DISCUSSION

Eight weeks of shoulder ER strength training had a small effect (0.06N/kg, 95% CI: -0.01 to 0.14) on shoulder ER strength, in a cohort of adolescent handball players. This is less than minimal detectable change (0.33N/kg), and the effect may be due to measurement error. The intervention had no effect on the secondary outcome variables. Our results contradict two previous studies.[20,26] Different study design[20] or higher strength gain potential in weak players[26] might explain the difference.

Exercise selection

We worked with experts to design the training program,[19] aiming to find the most effective exercises handball players would adhere to. It is possible that a different exercise program may have yielded different results. The two exercises with highest efficacy scores (prone ER and prone plyometric ER in 90° ABD) scored very low on adherence, and we did not include them in the final program. Isolated exercises, with the upper arm supported may facilitate muscle recruitment and strength gains of the muscles in question.[9 37] Although the single plane exercises in our study aimed to achieve isolated ER, there were no stabilization, and compensatory movements could have happened.

Training principles and exercise dosage

We aimed to follow the training principles for strength training: specificity, intensity, progression, variation and individualization. We used six set per muscle group each training session, with an average of 2.5 training sessions per week, and aimed for high intensity (8 repetitions with 2RIR). This is within the recommended dosage to obtain strength gain in the upper extremities. Participants had long training experience (8.8 yrs) and were strong at the time of inclusion. At baseline their ER isometric strength were comparable to reference values for adult handball players,[13] and greater than reported for adolescent players.[20,29] The dose-response for muscular strength development is dependent on the populations training status and experience.[32] More advanced athletes need higher dosages to optimize strength gain. It is possible that our 8-week intervention could have been too short to achieve an effect. Although, previous studies have reported strength gains after six weeks.[26] We changed the exercises every second week, which might be too short time to ensure proper progression. However, the supervising physiotherapists reported satisfactory performance and resistance progression through the two weeks periods.

Timing of the exercises

Based on feedback from athletes we designed a program that was completed after handball training. The timing of strength training might have impaired the effect of the strength training—players who were already fatigued may have completed insufficient load for strength gains. However, strength improvement is both dependent on load magnitude and metabolic stress.[34] If the players were fatigued when they started the strength training this could increase the metabolic stress and have a positive effect on strength improvement.

Elastic bands as resistance

When using elastic bands as resistance, it is difficult to quantify the precise resistance. With increasing extension of the band, resistance increases, the moment arm changes through the range of motion and is highest when the band-to-arm angle is 90˚.[24] We tried to control resistance in three ways: 1) We aimed for an angle of 45° between the player’s forearm and the elastic band at end range. In this way, an increase in elastic band resistance and reduction of moment arm occurred simultaneously towards the end range of motion. 2) The targeted resistance was tailored by aiming for eight repetitions with two RIR, to target muscle strength. 3) Players were instructed to increase resistance if they were able to do more than 12 repetitions with 2RIR.

Strengths

An RCT with single randomization within teams ensured that the intervention and control groups were as equal as possible. Our experience is that different teams often have very different training regimes and match schedules. Therefore, a within team randomization was chosen. We used a Delphi consensus method to find the most effective ER strength exercises handball players would adhere to. We had a detailed description of the exercises, both written and videos, and a physiotherapist was presented in each team once or twice a week to instruct and supervise the players. An experienced physiotherapist conducted all the manual tests, which were found to have good to excellent test-retest reliability in a pilot study. The measurement error of our manual muscle testing was comparable to isokinetic shoulder measurements.[16,23] There were no between-group differences in weekly training and match exposure during the intervention, the drop-out rate was 3%, and the adherence with the program was 83%.

We included both healthy players and players with current or a history of shoulder pain, because a majority of players with chronic shoulder pain continue playing handball despite their pain.[4,7] Only 11% of the players had shoulder pain at baseline, and outcomes were similar between those with and without shoulder pain at baseline. We included adolescent players (16-18 years), because the prevalence of shoulder pain is comparable between adolescents and adults,[2,3,7,30] and because ER weakness is a risk factor, targeting this factor at young age could prevent future shoulder problems.

Limitations

Lack of blinding to group assignment is a limitation, but given the nature of the intervention, blinding was impossible. There is a possibility of contamination when we do simple randomization within the teams. Every attempt was made to decrease contamination between treatment and control group by supervising the treatment group during their exercise intervention without the control group present. Additionally, the players in the control group did not report doing any part of the intervention exercises, and the exposure to additional shoulder training was similar in the two groups. However, we cannot guarantee that contamination did not occur in the control group. During our long experience working with handball players, as physical therapists and coaches, we have experienced that handball players mainly want to play handball, not to do additional training like strength- or preventive training. The risk of low adherence is probably higher than risk of contamination/confounding effect. The players were well instructed on progression of the exercises, but the progression was not recorded. Our results in adolescent handball players cannot be generalized to adults, but to our knowledge, no difference in response to strength training between adolescents and young adults has been reported.

Because throwing is a plyometric action with high angular velocities, isokinetic measurements, particularly at high angular velocities and eccentric contractions might be more valid than isometric measurements. However, measurement error is higher when testing at higher angular velocities and eccentric contractions than at slow concentric contractions,[16,23] and also higher than our measurement error when testing isometric with HHD. Additionally, we chose isometric strength testing because it can be carried out in the field without expensive equipment.

We described the exercises in terms of load magnitude, number of repetitions and sets, training sessions per week and training period. However, description of contraction modes per repetition, time under tension for each repetition, and rest in-between sets and between sessions is also recommended to define the exercise dosage.[36] Longer time under tension can increase myofibrillar protein synthesis after a single bout of strength training session,[10] and is therefore an important determinant of strength training. Rest periods of 2-5 min between sets has been recommended to improve maximal strength.[1,14,22] To complete the strength training program within 10 minutes, participants had < 90 seconds rest periods. This could have reduced the training effect of our intervention. An adaptive effect of strength training is dependent on a balance between degenerative and regenerative processes. If there is insufficient time for recovery between the training sessions, degenerative processes will dominate and muscle mass will be lost.[36] We did not have control over the rest between sessions.

Although we had high self-reported adherence to the program, previous studies have shown that self-reported adherence to exercises are overestimated.[33] We assumed that having a physiotherapist present with each team 1-2 times/week, combined with high reported adherence would contribute to high performance quality of the exercises. However, the physiotherapists reported that about 2/3 of the intervention groups were on average present during the supervised training sessions. We therefore do not know the quality of 1/3 of the training sessions.

The listed limitations reflect that this is not a strict efficacy study, which would determine whether an intervention produces the expected results under ideal settings. However, since the study was performed in a controlled setting, we suggest that the effect under more "real-world" conditions—the effectiveness—would be negligible. It seems difficult to achieve an adaptive response, i.e. strength gain in already strong players within a time-frame of 5-10 minutes. To achieve a strength gain, one might need to conduct the strength training as separate training sessions, with better control of the loads and progression, higher dosages and longer rest between the sets than in our trial.

CONCLUSION

When an elastic band strengthening program of 2 exercises for shoulder external rotators performed 3 times/ week for 8 weeks in handball players was compared to a non-treatment control group, there was a small improvement in isometric strength.

KEY POINTS

Findings: Eight weeks of a short shoulder ER strength program conducted directly after handball training had a small effect on shoulder ER strength among adolescent handball players.

Implications: To achieve a strength gain, one might need to conduct the strength training as separate training sessions, with better control of the loads and progression, higher dosages and longer rest between the sets than in our study.

Caution: The program delivered in this specific setting had a smaller effect than minimal detectable change. We did not have full control for load and progression; thus, this was not an efficacy study. The risk of contamination across groups is a possibility as we did within-teams randomization and players were not blinded to group allocation. Our results among adolescent, already strong handball players, cannot be generalized to adults or to players with ER weakness.

STUDY DETAILS

Author Contributions

All authors made substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work; drafted the work or revised it critically; confirmed the final version of this manuscript.

Data Sharing

Summary data relevant to this study are included in this article, with full data available on request from the study's primary investigator, H. Fredriksen (hilde.fredriksen@nih.no). Please include how proposed data will be used.

Patient and Public Involvement

Prior to the study we pilot tested the exercise program in a handball team. The players' response was important when we decided on the implementation of the study.

REFERENCES

1. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc.* 2009;41(3):687-708. https://doi.org/10.1249/MSS.0b013e3181915670
2. Aasheim C, Stavenes H, Andersson SH, Engbretsen L, Clarsen B. Prevalence and burden of overuse injuries in elite junior handball. *BMJ Open Sport Exerc Med.* 2018;4(1):e000391. https://doi.org/10.1136/bmjsem-2018-000391
3. Achenbach L, Laver L, Walter SS, Zeman F, Kuhr M, Krutsch W. Decreased external rotation strength is a risk factor for overuse shoulder injury in youth elite handball athletes. *Knee Surg Sports Traumatol Arthrosc.* 2020;28(4):1202-1211. https://doi.org/10.1007/s00167-019-05493-4
4. Andersson SH, Bahr R, Clarsen B, Myklebust G. Preventing overuse shoulder injuries among throwing athletes: a cluster-randomised controlled trial in 660 elite handball players. *Br J Sports Med.* 2017;51(14):1073-1080. https://doi.org/10.1136/bjsports-2016-096226
5. Andersson SH, Bahr R, Clarsen B, Myklebust G. Risk factors for overuse shoulder injuries in a mixed-sex cohort of 329 elite handball players: previous findings could

not be confirmed. *Br J Sports Med.* 2018;52(18):1191-1198. https://doi.org/10.1136/bjsports-2017-097648

6. Andersson SH, Bahr R, Olsen MJ, Myklebust G. Attitudes, beliefs, and behavior toward shoulder injury prevention in elite handball: Fertile ground for implementation. *Scand J Med Sci Sports.* 2019;29(12):1996-2009. https://doi.org/10.1111/sms.13522
7. Asker M, Holm LW, Kallberg H, Walden M, Skillgate E. Female adolescent elite handball players are more susceptible to shoulder problems than their male counterparts. *Knee Surg Sports Traumatol Arthrosc.* 2018;26(7):1892-1900. https://doi.org/10.1007/s00167-018-4857-y
8. Asker M, Walden M, Kallberg H, Holm LW, Skillgate E. Preseason Clinical Shoulder Test Results and Shoulder Injury Rate in Adolescent Elite Handball Players: A Prospective Study. *J Orthop Sports Phys Ther.* 2020;50(2):67-74. https://doi.org/10.2519/jospt.2020.9044
9. Brostrom LA, Kronberg M, Nemeth G, Oxelback U. The effect of shoulder muscle training in patients with recurrent shoulder dislocations. *Scand J Rehabil Med.* 1992;24(1):11-15. Published 1992/01/01.
10. Burd NA, Andrews RJ, West DW, et al. Muscle time under tension during resistance exercise stimulates differential muscle protein sub-fractional synthetic responses in men. *J Physiol.* 2012;590(2):351-362. https://doi.org/10.1113/jphysiol.2011.221200
11. Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. 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;48(17):1327-1333. https://doi.org/10.1136/bjsports-2014-093702
12. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. *Br J Sports Med.* 2013;47(8):495-502. https://doi.org/10.1136/bjsports-2012-091524
13. Cools AM, Vanderstukken F, Vereecken F, et al. Eccentric and isometric shoulder rotator cuff strength testing using a hand-held dynamometer: reference values for overhead athletes. *Knee Surg Sports Traumatol Arthrosc.* 2016;24(12):3838-3847. https://doi.org/10.1007/s00167-015-3755-9
14. de Salles BF, Simão R, Miranda F, Novaes Jda S, Lemos A, Willardson JM. Rest interval between sets in strength training. *Sports Med.* 2009;39(9):765-777. https://doi.org/10.2165/11315230-000000000-00000
15. Edouard P, Degache F, Oullion R, Plessis JY, Gleizes-Cervera S, Calmels P. Shoulder strength imbalances as injury risk in handball. *Int J Sports Med.* 2013;34(7):654-660. https://doi.org/10.1055/s-0032-1312587
16. Edouard P, Samozino P, Julia M, et al. Reliability of isokinetic assessment of shoulder-rotator strength: a systematic review of the effect of position. *J Sport Rehabil.* 2011;20(3):367-383. Published 2011/08/11.
17. Forthomme B, Croisier JL, Delvaux F, Kaux JF, Crielaard JM, Gleizes-Cervera S. Preseason Strength Assessment of the Rotator Muscles and Shoulder Injury in Handball Players. *J Athl Train.* 2018;53(2):174-180. https://doi.org/10.4085/1062-6050-216-16
18. Fredriksen H, Bahr R, Cools A, Myklebust G. Does an effective shoulder injury prevention program affect risk factors in handball? A randomized controlled study *Scand J Med Sci Sports.* 2020;In press.

19. Fredriksen H, Cools A, Myklebust G. Development of a short and effective shoulder external rotation strength program in handball: A delphi study. *Phys Ther Sport.* 2020;44:92-98. https://doi.org/10.1016/j.ptsp.2020.05.005
20. Genevois C, Berthier P, Guidou V, Muller F, Thiebault B, Rogowski I. Effects of 6-week sling-based training of the external-rotator muscles on the shoulder profile in elite female high school handball players. *J Sport Rehabil.* 2014;23(4):286-295. https://doi.org/10.1123/jsr.2012-0108
21. Giroto N, Hespanhol Junior LC, Gomes MR, Lopes AD. Incidence and risk factors of injuries in Brazilian elite handball players: A prospective cohort study. *Scand J Med Sci Sports.* 2017;27(2):195-202. https://doi.org/10.1111/sms.12636
22. Grgic J, Schoenfeld BJ, Skrepnik M, Davies TB, Mikulic P. Effects of Rest Interval Duration in Resistance Training on Measures of Muscular Strength: A Systematic Review. *Sports Med.* 2018;48(1):137-151. https://doi.org/10.1007/s40279-017-0788-x
23. Habets B, Staal JB, Tijssen M, van Cingel R. Intrarater reliability of the Humac NORM isokinetic dynamometer for strength measurements of the knee and shoulder muscles. *BMC Res Notes.* 2018;11(1):15. https://doi.org/10.1186/s13104-018-3128-9
24. Hughes CJ, Hurd K, Jones A, Sprigle S. Resistance properties of Thera-Band tubing during shoulder abduction exercise. *J Orthop Sports Phys Ther.* 1999;29(7):413-420. https://doi.org/10.2519/jospt.1999.29.7.413
25. Lauersen JB, Andersen TE, Andersen LB. Strength training as superior, dose-dependent and safe prevention of acute and overuse sports injuries: a systematic review, qualitative analysis and meta-analysis. *Br J Sports Med.* 2018. https://doi.org/10.1136/bjsports-2018-099078
26. Mascarin NC, de Lira CAB, Vancini RL, da Silva AC, Andrade MS. The effects of preventive rubber band training on shoulder joint imbalance and throwing performance in handball players: A randomized and prospective study. *J Bodyw Mov Ther.* 2017;21(4):1017-1023. https://doi.org/10.1016/j.jbmt.2017.01.003
27. Moher D, Hopewell S, Schulz KF, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *Int J Surg.* 2012;10(1):28-55. https://doi.org/10.1016/j.ijsu.2011.10.001
28. Mohseni-Bandpei MA, Keshavarz R, Minoonejhad H, Mohsenifar H, Shakeri H. Shoulder pain in Iranian elite athletes: the prevalence and risk factors. *J Manipulative Physiol Ther.* 2012;35(7):541-548. https://doi.org/10.1016/j.jmpt.2012.07.011
29. Moller M, Attermann J, Myklebust G, et al. The inter- and intrarater reliability and agreement for field-based assessment of scapular control, shoulder range of motion, and shoulder isometric strength in elite adolescent athletes. *Phys Ther Sport.* 2018;32:212-220. https://doi.org/10.1016/j.ptsp.2018.04.005
30. Moller M, Nielsen RO, Attermann J, et al. Handball load and shoulder injury rate: a 31-week cohort study of 679 elite youth handball players. *Br J Sports Med.* 2017;51(4):231-237. https://doi.org/10.1136/bjsports-2016-096927
31. Myklebust G, Hasslan L, Bahr R, Steffen K. High prevalence of shoulder pain among elite Norwegian female handball players. *Scand J Med Sci Sports.* 2013;23(3):288-294. https://doi.org/10.1111/j.1600-0838.2011.01398.x
32. Peterson MD, Rhea MR, Alvar BA. Applications of the dose-response for muscular strength development: a review of meta-analytic efficacy and reliability for designing training prescription. *J Strength Cond Res.* 2005;19(4):950-958. https://doi.org/10.1519/r-16874.1
33. Rathleff MS, Bandholm T, McGirr KA, Harring SI, Sorensen AS, Thorborg K. New exercise-integrated technology can monitor the dosage and quality of exercise performed against an elastic resistance band by adolescents with patellofemoral pain:

an observational study. *J Physiother*. 2016;62(3):159-163. https://doi.org/10.1016/j.jphys.2016.05.016
34. Schoenfeld BJ. Potential mechanisms for a role of metabolic stress in hypertrophic adaptations to resistance training. *Sports Med.* 2013;43(3):179-194. https://doi.org/10.1007/s40279-013-0017-1
35. Stratford PW, Balsor BE. A comparison of make and break tests using a hand-held dynamometer and the Kin-Com. *J Orthop Sports Phys Ther.* 1994;19(1):28-32. https://doi.org/10.2519/jospt.1994.19.1.28
36. Toigo M, Boutellier U. New fundamental resistance exercise determinants of molecular and cellular muscle adaptations. *Eur J Appl Physiol.* 2006;97(6):643-663. https://doi.org/10.1007/s00421-006-0238-1
37. Yu IY, Lee DK, Kang MJ, Oh JS. Effects of 3 Infraspinatus Muscle Strengthening Exercises on Isokinetic Peak Torque and Muscle Activity. *J Sport Rehabil.* 2019;28(3):229-235. https://doi.org/10.1123/jsr.2017-0110
38. Zourdos MC, Klemp A, Dolan C, et al. Novel Resistance Training-Specific Rating of Perceived Exertion Scale Measuring Repetitions in Reserve. *J Strength Cond Res.* 2016;30(1):267-275. https://doi.org/10.1519/jsc.0000000000001049

Table 1 Baseline characteristics of the participants (n=92)

	Intervention (n =45)	Control (n=47)
Age (yrs), mean (SD)	17 (0.7)	17 (0.7)
Height (cm)	177 (19)	177 (10)
Body mass (kg), mean (SD)	73 (11)	71 (11)
Hand dominance, n right (%)	40 (89)	41 (87)
Handball experience (yrs), mean (SD)	8.8 (2.2)	8.5 (2.7)
Gender, n female (%)	21 (47)	22 (47)
Shoulder pain last year, n yes (%)	11 (24)	18 (38)*
Shoulder status at baseline, n (%)		
- Playing without shoulder pain	36 (80)	42 (89)
- Playing with shoulder pain	6 (13)	4 (9)
- Not playing due to shoulder pain	0	0
- Not playing due to other injury or illness	3 (7)	1 (2)

*1 missing

Table 2 Mean (SD) isometric shoulder strength measurements (normalized to body weight) at baseline and post-intervention, and results of repeated measures mixed-model analyses of outcomes between intervention and control groups

Outcome	Raw data				Point estimates (95%CI)				Estimated between-group differences (95%CI) in change from baseline to post-intervention
	Baseline		Post intervention		Baseline		Post intervention		
	Intervention (n=45)	Control (n=47)	Intervention (n=43)	Control (n=46)	Intervention	Control	Intervention	Control	
ER strength *(N/kg)*									
D shoulder	1.97 (0.33)	1.95 (0.31)	2.07 (0.38)	1.98 (0.36)	1.97 (1.88-2.07)	1.95 (1.85-2.05)	2.06 (1.96-2.17)	1.98 (1.88-2.08)	0.06 (-0.01 to 0.14)
ND shoulder	1.96 (0.36)	1.97 (0.40)	2.00 (0.39)	1.99 (0.39)	1.96 (1.84-2.07)	1.97 (1.86-2.08)	1.98 (1.87-2.10)	1.99 (1.97-2.10)	0.01 (-0.07 to 0.08)
IR strength (N/kg)									
D shoulder	2.19 (0.42)	2.22 (0.41)	2.18 (0.51)	2.18 (0.46)	2.19 (2.06-2.33)	2.22 (2.09-2.35)	2.17 (2.04-2.30)	2.18 (2.05-2.31)	0.02 (-0.08 to 0.13)
ND shoulder	2.16 (0.42)	2.10 (0.42)	2.13 (0.46)	2.13 (0.48)	2.15 (2.02-2.29)	2.10 (1.97-2.23)	2.12 (1.99-2.26)	2.12 (1.97-2.25)	-0.05 (-0.14 to 0.04)
ER/IR ratio									
D shoulder	0.91 (0.12)	0.89 (0.12)	0.97 (0.17)	0.92 (0.15)	0.91 (0.87-0.95)	0.89 (0.85-0.93)	0.97 (0.93-1.02)	0.93 (0.89-0.97)	0.03 (-0.02 to 0.08)
ND shoulder	0.92 (0.12)	0.95 (0.13)	0.95 (0.12)	0.95 (0.14)	0.92 (0.88-0.96)	0.95 (0.91-0.98)	0.94 (0.90-0.98)	0.95 (0.91-0.99)	0.02 (-0.03 to 0.07)

Abbreviations: ER, external rotation; IR, internal rotation; D, dominant; ND, non-dominant

Table 3 Mean (SD) weekly exposure to handball training, match play and additional shoulder training in intervention and control group, presented in minutes

Activity type	Intervention	Control
Handball training	251 (10)	262 (17)
Match play	37 (12)	35 (11)
Additional shoulder training	22 (2)	24 (2)

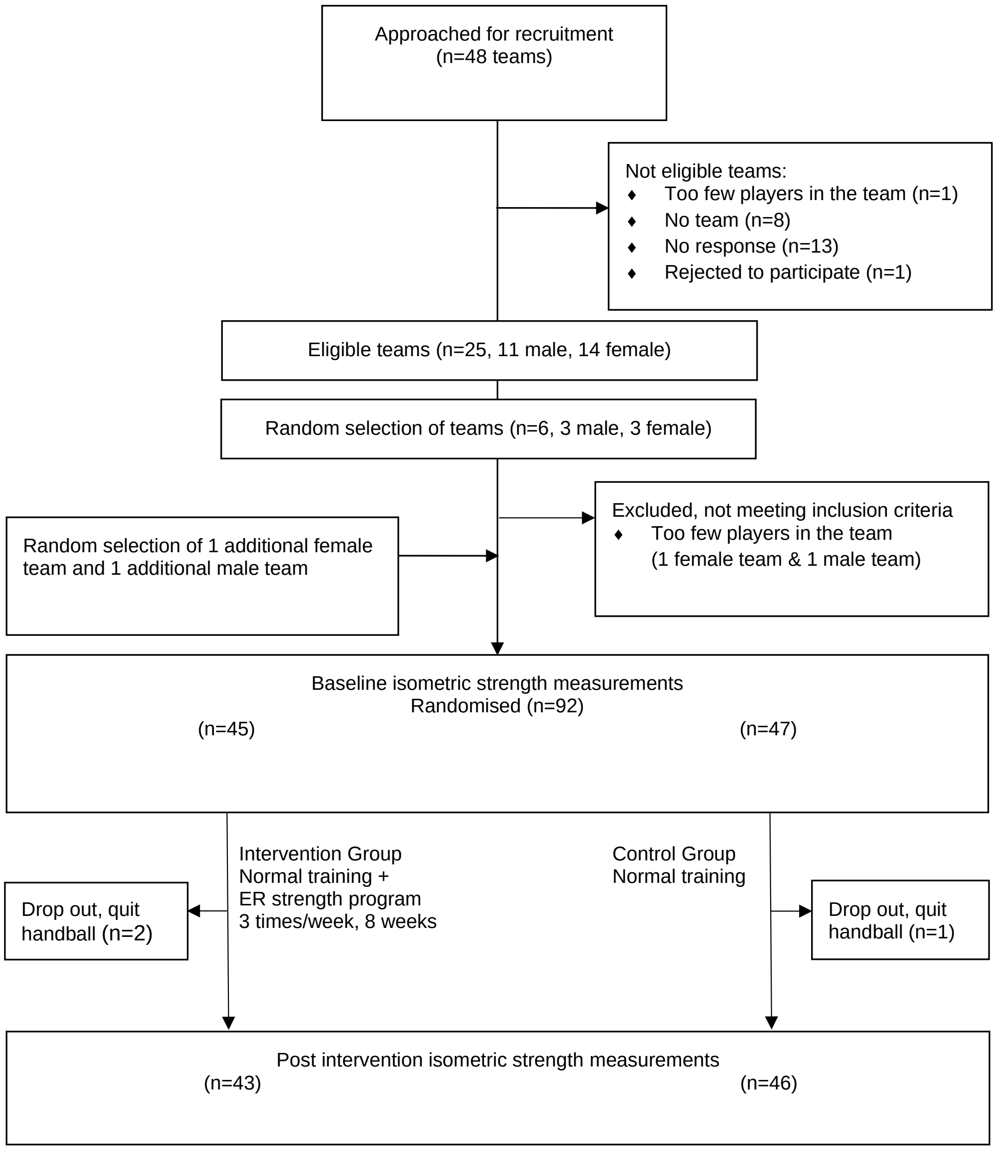


Figure 1 Study flow chart showing the enrollment, randomization, number of players included and tested at baseline and after eight weeks of intervention. ER= external rotation

Figure 2 Glenohumeral isometric external rotation strength measurement in 90° of abduction, using a handheld dynamometer

Appendix I

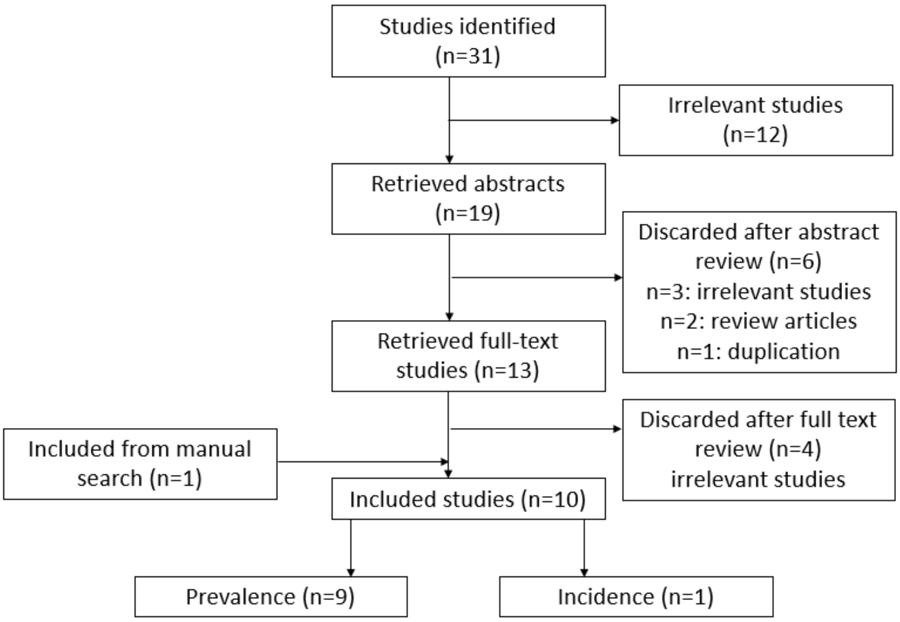
Literature searches performed to identify studies reporting on:

1. **Prevalence of shoulder injuries in handball**
2. **Risk factors for shoulder injuries in handball**
3. **Shoulder external rotation strength exercises**

Literature search 1

Prevalence of shoulder injuries in handball

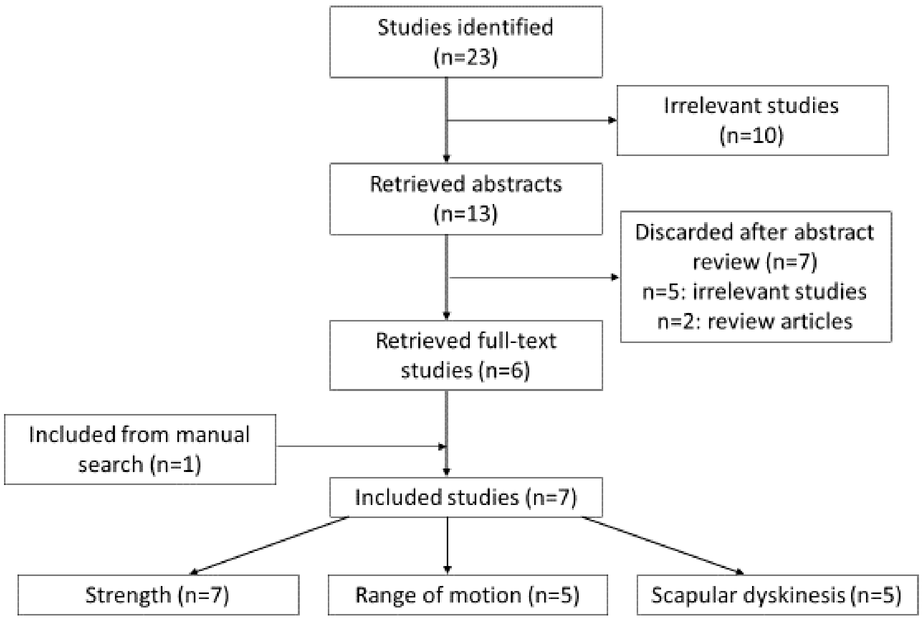
Search #1	Search #2	Search #3
Handball	Shoulder injury	Epidemiology
Handball player	Shoulder injur*	Prevalence
Handball play*	Shoulder problem	Incidence
Items found: 1108	Items found: 23464	Items found: 3152093
Search #1 AND Search #2 AND Search #3 AND“English”[lang] =31		



Literature search 2

Risk factors for shoulder injuries in handball (29.04.20)

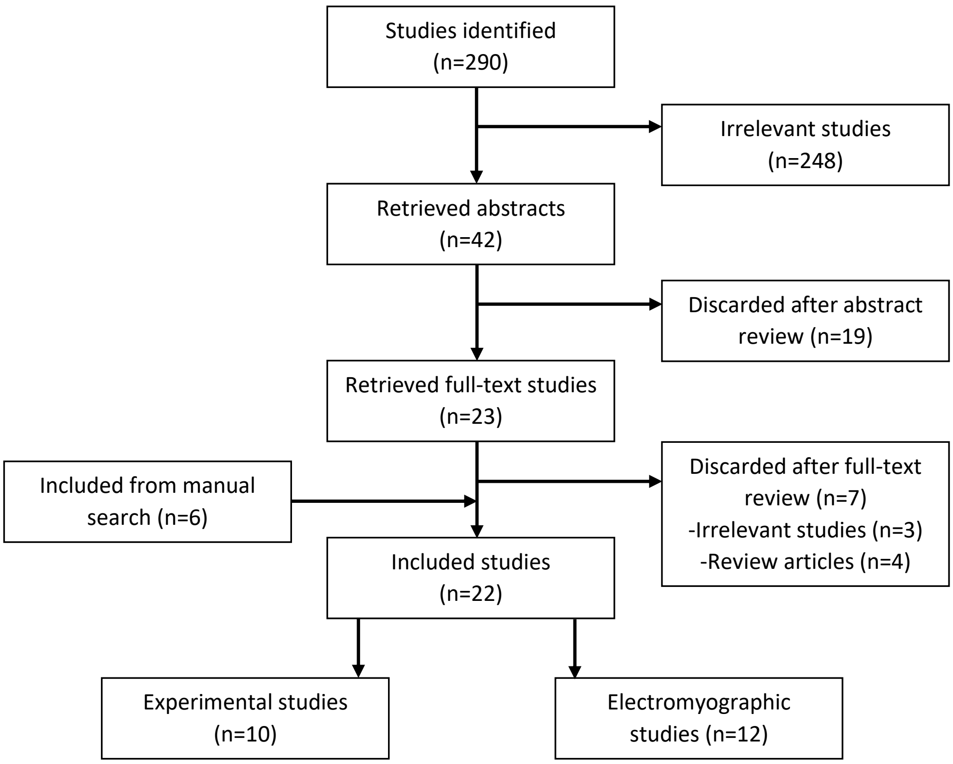
Search #1	Search #2	Search #3
Shoulder	"risk factor"	handball
"shoulder joint"	Injury risk	
"glenohumeral joint"		
Items found: 79655	Items found: 93843	Items found: 1108
Search #1 AND Search #2 AND Search #3 AND"English"[lang] = 23		



Literature search 3

Exercises aimed to affect shoulder external rotation strength
(studies published before 31.12.17)

Search #1	Search #2	Search #3	Search #4
"shoulder"[Mesh]	“external rotation”	“exercise therapy"[Mesh]	"muscle strength"[Mesh]
shoulder	“external rotat* muscles”	exercise	“muscle strength”
"shoulder joint"[Mesh]	Infraspinatus	training	“strength increase”
“glenohumeral joint”	“rotator cuff”		“muscle balance”
			“strength ratio”
			"electromyography"[Mesh]
Search #1 AND Search #2 AND Search #3 AND Search #4 AND“English”[lang] =290			



Appendix II

Informed consent forms and approval letters from the Norwegian Regional Committee for Medical and Health Research Ethics and the Norwegian Centre for Research Data (NSD).

Forespørsel om deltagelse i prosjektet:

Reliabilitets- og validitetstesting av norsk oversettelse av Kerlan Jobe spørreskjema

Bakgrunn for undersøkelsen

Prosjektet som skal gjennomføres er et masterprosjekt på Norges Idrettshøgskole. Formålet med det kommende prosjektet vil være å teste et spørreskjema om skulder- og albueplager som er oversatt til norsk. Det skal gjennomføres på norske håndballspillere. Spørreskjemaet er et nyttig verktøy for å kartlegge skulder- og albueplager hos utøvere og pasienter. Før en oversatt versjon av spørreskjemaet kan brukes i klinikk eller forskning, må man sørge for at det er tilpasset det norske språket og kulturen. Resultatene fra denne undersøkelsen vil være til stor nytte for norsk håndball, da skulderplager er et utbredt problem i håndball, i alle aldersklasser og hos begge kjønn. Senter for idrettsskadeforskning er en forskningsgruppe bestående av fysioterapeuter, kirurger og biomekanikere med kunnskap innen idrettsmedisin. Vår hovedmålsetting er å forebygge skader i norsk idrett, med spesiell satsning på håndball, fotball, ski og snowboard. Denne studien er en viktig brikke i arbeidet med å redusere omfanget av skulderproblemer.

Gjennomføring av undersøkelsen

Vi ønsker at du som håndballspiller deltar i denne studien, og deltakelsen er frivillig.

Spørreskjemaet besvares ved to ulike tidspunkt på internett via en link du får tilsendt på mail. Det vil ta 15 min.

Behandling av testresultatene

Dataene vil bli behandlet konfidensielt, og kun i forskningsøyemed. Forskere som benytter dataene er underlagt taushetsplikt. Data som publiseres vil være anonymisert og ikke kunne kobles til deg. Prosjektet planlegges å være ferdig innen desember 2019.

Studien er meldt til Personvernombudet for forskning, NSD - Norsk senter for forskningsdata AS.

Angrer du?

Du kan selvfølgelig trekke deg fra forsøket når som helst uten å måtte oppgi noen grunn. Alle data som angår deg vil uansett bli anonymisert.

Spørsmål?

Ring gjerne til Bettina Nævestad, tlf 45213016, hvis du har spørsmål om prosjektet, eller send e-post til bettinan@student.nih.no.

Samtykke til deltagelse

Jeg har mottatt informasjon om studien, og er villig til å delta

----
(Signert av prosjektdeltaker, dato)

Grethe Myklebust
Postboks 4014 Ullevål Stadion
0806 OSLO

Vår dato: 07.03.2018 Vår ref: 59158 / 3 / OASR Deres dato: Deres ref:

Tilrådning fra NSD Personvernombudet for forskning § 7-27

Personvernombudet for forskning viser til meldeskjema mottatt 12.02.2018 for prosjektet:

59158	*Reliabilitets- og validitetstesting av norsk oversettelse av Kerlan-Jobe Orthopaedic Clinic shoulder and elbow (KJOC) score questionnaire.*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Grethe Myklebust*
Student	*Bettina Nævestad*

Vurdering
Etter gjennomgang av opplysningene i meldeskjemaet og øvrig dokumentasjon finner vi at prosjektet er unntatt konsesjonsplikt og at personopplysningene som blir samlet inn i dette prosjektet er regulert av § 7-27 i personopplysningsforskriften. På den neste siden er vår vurdering av prosjektopplegget slik det er meldt til oss. Du kan nå gå i gang med å behandle personopplysninger.

Vilkår for vår anbefaling
Vår anbefaling forutsetter at du gjennomfører prosjektet i tråd med:
- opplysningene gitt i meldeskjemaet og øvrig dokumentasjon
- vår prosjektvurdering, se side 2
- eventuell korrespondanse med oss

Meld fra hvis du gjør vesentlige endringer i prosjektet
Dersom prosjektet endrer seg, kan det være nødvendig å sende inn endringsmelding. På våre nettsider finner du svar på hvilke endringer du må melde, samt endringsskjema.

Opplysninger om prosjektet blir lagt ut på våre nettsider og i Meldingsarkivet
Vi har lagt ut opplysninger om prosjektet på nettsidene våre. Alle våre institusjoner har også tilgang til egne prosjekter i Meldingsarkivet.

Vi tar kontakt om status for behandling av personopplysninger ved prosjektslutt
Ved prosjektslutt 31.12.2019 vil vi ta kontakt for å avklare status for behandlingen av personopplysninger.

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

Se våre nettsider eller ta kontakt dersom du har spørsmål. Vi ønsker lykke til med prosjektet!

Vennlig hilsen

Marianne Høgetveit Myhren

Øivind Armando Reinertsen

Kontaktperson: Øivind Armando Reinertsen tlf: 55 58 33 48 / Oivind.Reinertsen@nsd.no
Vedlegg: Prosjektvurdering
Kopi: Bettina Nævestad, bettinan@student.nih.no

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 59158

Formålet med prosjektet er å reliabilitets- og validitetsteste den norske digitale versjonen av Kerlan Jobe hos norske håndballspillere.

Du har opplyst i meldeskjema at utvalget vil motta skriftlig informasjon om prosjektet, og samtykke skriftlig til å delta. Vår vurdering er at informasjonsskrivet til utvalget er godt utformet. Du må imidlertid oppgi veileders kontaktinformasjon. Siden du også fungerer som det aktuelle lagets fysioterapeut ber vi om at det kommer klart frem at deltakelse i prosjektet ikke har betydning for eventuell behandling.

Det fremgår av meldeskjema at du vil behandle sensitive opplysninger om helseforhold.

Personvernombudet forutsetter at du behandler alle data i tråd med Norges idrettshøgskole sine retningslinjer for datahåndtering og informasjonssikkerhet.

Du/dere har opplyst i meldeskjema at Infopad AS benyttes som databehandler i prosjektet. Dersom det ikke allerede eksisterer en databehandleravtale mellom Norges idrettshøgskole og databehandleren, skal det inngås en skriftlig avtale om hvordan personopplysninger skal behandles, jf. personopplysningsloven § 15. For råd om hva databehandleravtalen bør inneholde, se Datatilsynets veileder: https://www.datatilsynet.no/regelverk-og-skjema/veiledere/databehandleravtale/

Prosjektslutt er oppgitt til 31.12.2019. Det fremgår av meldeskjema/informasjonsskriv at du vil anonymisere datamaterialet ved prosjektslutt.
Anonymisering innebærer vanligvis å:
- slette direkte identifiserbare opplysninger som navn, fødselsnummer, koblingsnøkkel
- slette eller omskrive/gruppere indirekte identifiserbare opplysninger som bosted/arbeidssted, alder, kjønn.

For en utdypende beskrivelse av anonymisering av personopplysninger, se Datatilsynets veileder: https://www.datatilsynet.no/globalassets/global/regelverk-skjema/veiledere/anonymisering-veileder-041115.pdf

Personvernombudet gjør oppmerksom på at også databehandler må slette personopplysninger tilknyttet prosjektet i sine systemer. Det inkluderer eksempelvis transkripsjoner, filer, logger og koblingsnøkkel mellom IP-/epostadresser og besvarelsene.

NORGES IDRETTSHØGSKOLE

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

FORESPØRSEL OM DELTAKELSE I PROSJEKTET:
”Hvordan kan vi best påvirke risikofaktorene for skulderskader i håndball? ”

Kjære ………….,

Senter for idrettsskadeforskning ved Norges idrettshøgskole jobber med et nytt prosjekt for å redusere omfanget av skulderproblemer blant håndballspillere.

Dette prosjektet vil være en videreføring av resultatene fra tidligere studier.

Belastningsskader i skulderen hos håndballspillere er svært utbredt. Studier viser at mellom 23 og 28% av spillerne har til enhver tid plager med skulderen i løpet av sesongen. Mange må redusere og/eller tilpasse treningen og plagene gjør at man ikke presterer optimalt. Det er også avdekket at nedsatt rotasjonsbevegelighet og -styrke er assosiert med skulderproblemer. Basert på disse resultatene ble det utarbeidet et forebyggende skuldertreningsprogram, og vi testet effekten av programmet på spillere i de to øverste divisjonene sesongen 2014/15. Resultatene viste at det er mulig å forebygge skulderskader i håndball. Deltakerne gjennomførte et 10 minutters treningsprogram som en del av oppvarmingen før håndballspill 3 ganger pr. uke. De som gjorde treningsprogrammet hadde 28% redusert risiko for å få smerter i skulderen.

Vi vet pr i dag ikke hvordan programmet påvirket risikofaktorene. Med kunnskap om dette kan vi lage mer effektive programmer for forebygging. Vi ønsker nå å se på hvilken effekt det nevnte forebyggingsprogram har på noen av de kjente risikofaktorene for skulderskader i håndball.

Vi vil invitere dine utøvere til å delta i en studie hvor vi undersøker spillernes skulderstyrke og bevegelighet. Testingen vil foregå ved Norges Idrettshøgskole og gjennomføres av erfarne fysioterapeuter fra Senter for Idrettsskadeforskning. Deretter vil halvparten av lagene som deltar i prosjektet bli instruert i et 10 minutters forebyggingsprogram som skal gjennomføres som en fast del av oppvarmingen til håndballtrening i 18 uker. De resterende lagene fortsetter aktivitet som normalt.

Spillerne som gjør øvelsesprogrammet får tilsendt en link til spørreskjema på e-post hver uke, der vil utøveren få noen korte spørsmål om belastningsskader i skuldrene og skulderfunksjon. Alle må fylle ut spørreskjemaene, uansett om de er skadet eller ikke. Det vil ta om lag 5 minutter å fylle ut skjemaene hver gang. Utøverne vil i spørreskjemaet også registrere hvor mye de trener og spiller håndball.

Etter de nevnte 18 uker vil alle spillerne, både de som har og de som ikke har gjennomført programmet bli testet på ny ved Norges Idrettshøgskole.

Om du bestemmer deg for å delta i studien, skal ditt lags deltagelse være konfidensiell. Alle personlige data vil bli anonymisert etter at innsamlingen er over, og det skal ikke være mulig å identifisere verken individer eller lag i rapporter fra studien.

Angrer du på ditt lags deltagelse på noe som helst tidspunkt, kan du selvfølgelig trekke laget fra studien uten å måtte oppgi noen grunn, og uten konsekvenser. Alle data som er samlet inn til da vil i så fall bli slettet.

Vi håper du og laget ønsker å delta, og derved vil bidra til å redusere omfanget av skulderproblemer blant håndballspillere.

Hvis du vil ha mer informasjon om studien, kan vi kontaktes på telefonnummer 23 26 23 70 eventuelt på e-post grethe.myklebust@nih.no.

Med vennlig hilsen

Grethe Myklebust Roald Bahr Hilde Fredriksen

Professor, Fysioterapeut . Professor dr. med. Fysioterapeut, stipendiat

NORGES IDRETTSHØGSKOLE

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

FORESPØRSEL OM DELTAKELSE I PROSJEKTET:
"Forebygging av skulderskader blant håndballspillere"

Bakgrunn for undersøkelsen:
Belastningsskader i skulderen hos håndballspillere er svært vanlig. Studier viser at ca hver fjerde spiller har plager med skulderen i løpet av sesongen. Mange må redusere og/eller tilpasse treningen og plagene gjør at man ikke presterer optimalt. En undersøkelse gjort på spillere i de to øverste divisjonene sesongen 2014/15 viste at det er mulig å forebygge skulderskader i håndball. Deltakerne gjennomførte et sammensatt 10 minutters treningsprogram som en del av oppvarmingen før håndballspill 3 ganger pr. uke. Det vi ikke vet er om eller hvordan dette programmet påvirker kjente risikofaktorer. Hvis vi kan finne ut dette, kan vi også lage mer effektive programmer for forebygging.

Senter for idrettsskadeforskning er en forskningsgruppe bestående av fysioterapeuter, kirurger og biomekanikere med kunnskap innen idrettsmedisin. Vår hovedmålsetting er å forebygge skader i norsk idrett. Denne studien er en viktig brikke i arbeidet med å redusere omfanget av skulderproblemer i håndball. Vi ønsker nå å se på hvilken effekt det nevnte forebyggingsprogrammet har på noen av de kjente risikofaktorene for skulderskader i håndball.

Gjennomføring av undersøkelsen
Vi ønsker at du som U18 spiller deltar i denne studien, og deltakelsen er frivillig. Testingen vil foregå på Norges Idrettshøgskole høsten 2018 og ved årsskiftet 2018/19. Vi vil gjennomføre ulike styrke- og bevegelighetstester for skulderen. I tillegg til disse testene vil du få utdelt et skjema, der vi spør om treningserfaring, spillerposisjon, tidligere skader og skulderfunksjon. Testingen vil ta ca 1 time. Deretter vil halvparten spillerne på laget trekkes ut (tilfeldig) til gruppen som skal gjennomføre forebyggingsprogrammet, 10-15 min, 3 ganger pr uke i 18 uker, mens den andre halvparten trener som vanlig. Alle spillerne får tilsendt en link til spørreskjema på SMS/E-post hver uke, der de vil få noen korte spørsmål om belastningsskader i skuldrene og skulderfunksjon. Alle må fylle ut spørreskjemaene, uansett om de er skadet eller ikke. Det vil ta om lag 5 minutter å fylle ut skjemaene hver gang. Utøverne vil i spørreskjemaet også registrere hvor mye de trener og spiller håndball.

Etter 6 og 12 uker vil det gjennomføres en kort test (10 min per spiller) av alle spillerne (både de som har og de som ikke har gjennomført programmet) ute i klubbene, og etter 18 uker vil alle spillerne testes på nytt på Norges Idrettshøgskole.

Behandling av testresultatene
Alle data vi samler inn vil bli avidentifisert og behandlet konfidensielt, og kun i forskningsøyemed. Alle som utfører testingen og forskere som benytter dataene er underlagt taushetsplikt.
Vi vil underveis i testingen ta bilder og video av dere som vi senere kan ønske å bruke i undervisnings- og formidlingssammenheng. Bildene og videopptakene inkluderer situasjoner der herrespillerne kun har på shorts, mens kvinnespillerne har shorts og sports BH. Dersom dere ikke vil at deres videopptak og bilder skal brukes, krysser dere av for det i samtykkeerklæringen.

Hva får du ut av det?
Du vil få kopi av dine testresultater.

Angrer du?
Du kan selvfølgelig trekke deg fra forsøket når som helst uten å måtte oppgi noen grunn. Da vil alle data som angår deg slettes.

Spørsmål?
Ring gjerne til Hilde Fredriksen, tlf: 99709997 hvis du har spørsmål om prosjektet, eller send epost til hilde.fredriksen@nih.no

SAMTYKKEERKLÆRING

Jeg har mottatt skriftlig og muntlig informasjon om studien *"Forebygging av skulderskader blant håndballspillere".* Jeg er klar over at jeg kan trekke meg fra undersøkelsen på et hvilket som helst tidspunkt uten å måtte oppgi grunn, og at alle data som angår meg da vil slettes.

☐ Jeg ønsker ikke at bilder og videoopptak av meg skal brukes i undervisningssammenheng

Sted ....   Dato ....

....
Underskrift

....
Navn med blokkbokstaver

....
Mobiltelefon

....
Epostadresse

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Henriette Snilsberg	22845531	05.06.2018	2018/412/REK sør-øst B
			Deres dato:	Deres referanse:
			08.05.2018	

Vår referanse må oppgis ved alle henvendelser

Hilde Fredriksen
Sognsveien 220

2018/412 Hvordan kan vi påvirke risikofaktorene for skulderskader i håndball?

Forskningsansvarlig: Norges idrettshøgskole
Prosjektleder: Hilde Fredriksen

Vi viser til søknad om prosjektendring datert 08.05.2018 for ovennevnte forskningsprosjekt.

Vurdering
Søknaden er behandlet av sekretariatet i REK sør-øst på delegert fullmakt fra REK sør-øst B, med hjemmel i helseforskningsloven § 11.

Endringene som det søkes om er beskrevet i skjema for prosjektendringer og er beskrevet slik:

Vi ønsker å gjennomføre reliabilitetstesting av målemetodene våre, som en pilot-test i forkant av selve prosjektet.

Styrketest med håndholdt dynamometer (HHD) samt bevegelighetstesting vil utføres av samme fysioterapeut på alle spillerne. Isokinetisk styrketest vil utføres av to fysioterapeuter. For å sikre best mulig datakvalitet, ønsker vi å gjennomføre reliabilitetstesting av disse målemetodene, intra-tester reliabilitet to forskjellige dager for alle testene, samt inter-tester reliabilitet (med en ukes mellomrom) for isokinetisk styrketesting.

Vi har beregnet at vi trenger å teste 32 skuldre. Antallet er basert på formelen for "limits of agreement" (LOA), samt tall fra tidligere reproduserbarhetsstudier for styrketesting med HHD: Standarddeviasjon lik 0,35 og LOA lik 0,4.

Studiepopulasjonen er håndballspillere U16-18, kvinner og menn.

Det vil benyttes statistiske (kvantitative) analysemetoder.Det vil innhentes muntlig, informert samtykke Personidentifiserbare opplysninger erstattes med et referansenummer som viser til en adskilt navneliste (koblingsnøkkel). Straks analysene er gjort, før igangsettingen av hovedstudien, vil datamaterialet anonymiseres.

Sekretariatet i REK har vurdert den omsøkte endringen.

Det beskrives i skjema for prosjektendring at det skal innhentes muntlig samtykke. REK godkjenner ikke dette og setter som vilkår at det innhentes skriftlig samtykke fra deltakerne, jamfør helseforskningslovens §13:

Det kreves samtykke fra deltakere i medisinsk og helsefaglig forskning, med mindre annet følger av lov. Samtykket skal være informert, frivillig, uttrykkelig og dokumenterbart. Samtykket skal bygge på spesifikk informasjon om et konkret forskningsprosjekt med mindre det er adgang til å avgi et bredt samtykke, jf §14.

Vedtak

Sekretariatet godkjenner prosjektet slik det nå foreligger på følgende vilkår før det kan igangsettes:

- Det skal innhentes skriftlig samtykke fra deltakerne. Samtykkeskrivet må sendes til komiteen til orientering.

Med hjemmel i helseforskningsloven § 9 jf. 33 godkjenner komiteen at prosjektet gjennomføres under forutsetning av at ovennevnte vilkår oppfylles.

I tillegg til vilkår som fremgår av dette vedtaket, er godkjenningen gitt under forutsetning av at prosjektet gjennomføres slik det er beskrevet i søknad og protokoll, og de bestemmelser som følger av helseforskningsloven med forskrifter.

Forskningsprosjektets data skal oppbevares forsvarlig, se personopplysningsforskriften kapittel 2, og Helsedirektoratets veileder for Personvern og informasjonssikkerhet i forskningsprosjekter innenfor helse og omsorgssektoren.

REKs vedtak kan påklages, jf. forvaltningslovens § 28 flg. Eventuell klage sendes til REK sør-øst B. Klagefristen er tre uker fra mottak av dette brevet.
Dersom vedtaket opprettholdes av REK sør-øst B, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering, jf. forskningsetikkloven § 10 og helseforskningsloven § 10.

Vi ber om at alle henvendelser sendes inn med korrekt skjema via vår saksportal: http://helseforskning.etikkom.no. Dersom det ikke finnes passende skjema kan henvendelsen rettes på e-post til: post@helseforskning.etikkom.no

Klageadgang
Du kan klage på komiteens vedtak, jf. helseforskningsloven § 10 og forvaltningsloven § 28 flg. Klagen sendes til REK sør-øst. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK sør-øst, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Med vennlig hilsen

Knut W. Ruyter
avdelingsdirektør
REK sør-øst

Henriette Snilsberg
komitésekretær

Kopi til: *grethe.myklebust@nih.no*
Norges idrettshøgskole ved øverste administrative ledelse: postmottak@nih.no

DELPHI STUDY INFORMATION SHEET

We would like to invite you to take part in a Delphi consensus study. Before you decide if you would like to take part, it is important for you to consider why the research is being done and what it will involve. Please read this information sheet carefully.

What is the purpose of the study?

The prevalence of shoulder problems in handball is high (22-28%) (Andersson 2017, Clarsen 2014, Forthomme 2018). A recent study demonstrated that prevention works! After completing an 18 weeks shoulder prevention program, the risk of reporting shoulder problems during the competitive season was 28% lower in the intervention group (Andersson2017). The prevention program was a 10 minutes warm-up program, carried out 3 times per week as a part of the regular handball warm-up, over 18 weeks, and consisted of five exercises with different variations and levels. The chosen exercises intended to increase the ER muscle strength and to improve IR ROM. It also included exercises to improve the neuromuscular control around the scapula and to improve kinetic chain activation and thoracic mobility. Despite the effect of the program, only 30% of the coaches and team captains would continue using the whole program. The main reason was that it was "Too time consuming".

Although limited evidence, external rotation weakness in the dominant shoulder is considered the most important internal modifiable risk factor in handball (Clarsen 2014, Edouard 2013, Moller 2017). Our aim is to develop a new, compressed prevention program to target the risk factor, ER strength in handball.

What is a Delphi study?

The Delphi technique seeks to obtain consensus on the opinions of experts, termed panel members, through a series of structured questionnaires. As part of the process, the responses from each round are fed back in summarized form to the participants who are then given an opportunity to respond again to the emerging data. The Delphi is therefore an iterative multi-stage process designed to combine opinion into group consensus.

Who is invited to take part?

We want to include the following experts in our international panel:

- Physiotherapists
- Medical doctors
- Researchers
- Strength coaches
- Handball coaches
- Handball players

Since the participants are supposed to be anonymous, to make sure they are not influenced by others, we cannot inform you about the other participants, except that there will be 15 to 20 participants, whom are world leading in their fields.

What will I be asked to do if I take part?

We are inviting you to participate as a Delphi panel member. This would involve completing a few brief questionnaires regarding strength training of the shoulder ER muscles, using an online survey. It is envisaged that this should take approximately 30 minutes to complete. The process is as follows:

- The first questionnaire will consist of predefined exercises based on recent systematic reviews. The respondents are asked to rank according to the exercise's efficiency and the likelihood of adherence in a handball population. It will also include open questions about additional exercises, dosage, frequency, delivery and criteria for progression.

- The next rounds/questionnaires will be based on the results from the preceding rounds. Each participant will receive a personalized questionnaire, including: a summary of the group's responses and the participant's own response
- The members of the group are able to revise their responses to the questionnaire after receiving the feedback.
- There will be a maximum of three rounds
- If consensus is reached the procedure will be ended
- If consensus is not after three rounds, we will organize a physical or skype meeting

In order to allow timely conclusion of the study we would respectfully request a response time of 2 week for completion of each round.

Who is organizing the research?
This research is part of a PhD project investigating prevention of shoulder injuries in handball. The Delphi study will be conducted by Hilde Fredriksen, an Oslo Sports Trauma Research Center (OSTRC) PhD candidate, and supervised by Professor Grethe Myklebust at the OSTRC and Professor Ann Cools at the Ghent University.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time, without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw. You have the right to request access to, deletion/correction/limitation of your personal data, as well as the right to data portability.

Confidentiality
No personal information, except for your name and email-adress, will be collected and survey responses will be collated using an identifying number known only to the lead investigator. All responses received in the study will be strictly confidential.

Data protection
Survey responses will be collected online using a quality-assured Sweden based survey company, utilizing an encrypted internet server (Briteback, Norrköping, Sweden). Further information is available from: http://www.briteback.com/en/privacy -policy. The data will be handled in accordance with the European Union Data Protection Laws.
The project is scheduled to end Dec 31th 2019.
To ensure verifiability, the collected data will be de-identified at the end of the project, replacing your name with a temporary ID, and stored for five years at the Norwegian School of Sport Sciences. The data and ID-keys will be stored separately. After five years, all information will be deleted.

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and

- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

We will process your personal data based on your consent

Based on an agreement with Oslo Sports Trauma Research Center (The Norwegian School of Sport Sciences), NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:

- Oslo Sports Trauma Research Center via Hilde Fredriksen (hilde.fredriksen@nih.no).
- Our Data Protection Officer: Karine Justad (personvernombud@nih.no).
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Best regards,

Hilde Fredriksen, PT, Phd candidate
Oslo Sports Trauma Research Center
hilde.fredriksen@nih.no
+47 99709997

Grethe Myklebust, PT, Phd, Prof
Oslo Sports Trauma Research Center
Grethe.myklebust@nih.no

Ann Cools, PT, Prof
Ghent University
ann.cools@ugent.be

I have received and understood information about the Delphi study to develop a compressed prevention program to target the risk factor, ER strength in handball and have been given the opportunity to ask questions.

I give consent to participate in *The Delphi study*

I give consent for my personal data to be processed until the end date of the project, approx 31.12.19.

....

(sign)

NORSK SENTER FOR FORSKNINGSDATA

NSD sin vurdering

Prosjekttittel

Developing a compressed prevention program to target the risk factors, external rotation strength in handball

Referansenummer

455434

Registrert

16.10.2018 av Hilde Fredriksen - hilde.fredriksen@nih.no

Behandlingsansvarlig institusjon

Norges idrettshøgskole / Seksjon for idrettsmedisinske fag

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Hilde Fredriksen, hilde.fredriksen@nih.no, tlf: 99709997

Type prosjekt

Forskerprosjekt

Prosjektperiode

05.11.2018 - 31.12.2019

Status

14.12.2018 - Vurdert

Vurdering (1)

14.12.2018 - Vurdert

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 14.12.2018, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte. MELD ENDRINGER Dersom behandlingen av personopplysninger endrer seg, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. På våre nettsider informerer vi om hvilke endringer som må meldes. Vent på svar før endringer gjennomføres. TYPE OPPLYSNINGER OG VARIGHET Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 31.12.2024. Dataene vil bli oppbevart ved behandlingsansvarlig institusjon frem til 31.12.2024 til etterprøvbarhet. LOVLIG GRUNNLAG Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a. PERSONVERNPRINSIPPER NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om: - lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen - formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke behandles til nye, uforenlige formål - dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet - lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet DE REGISTRERTES RETTIGHETER Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20). NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13. Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned. FØLG DIN INSTITUSJONS RETNINGSLINJER NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32). Briteback er databehandler i prosjektet. NSD legger til grunn at behandlingen oppfyller kravene til bruk av databehandler, jf. art 28 og 29. For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og/eller rådføre dere med behandlingsansvarlig institusjon. OPPFØLGING AV PROSJEKTET NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet. Lykke til med prosjektet! Kontaktperson hos NSD: Kajsa Amundsen Tlf. Personverntjenester: 55 58 21 17 (tast 1)

Vil du delta i forskningsprosjektet

” Test av et komprimert treningsprogram for utadrotasjonsstyrke i skulder hos håndballspillere",

som er en del av et større prosjekt på forebygging av skulderskader blant håndballspillere?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å *evaluere effekten av et kort treningsprogram for utadrotasjonsstyrke i skulder*. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Bakgrunn og formål

Senter for idrettsskadeforskning ved Norges Idrettshøgskole jobber med et prosjekt for å redusere omfanget av skulderproblemer blant håndballspillere. Dette prosjektet er en videreføring av resultatene fra tidligere studier.

Belastningsskader i skulderen hos håndballspillere er svært utbredt. Studier viser at ca hver fjerde spiller til enhver tid har plager med skulderen i løpet av sesongen. Mange må redusere og/eller tilpasse treningen og plagene gjør at man ikke presterer optimalt. Det er også avdekket at skulderproblemer kan ha sammenheng med nedsatt rotasjonsstyrke i skulderen. Vi ønsker derfor å teste effekten av et kort styrketreningsprogram for å bedre rotasjonsstyrke i skulderen hos håndballspillere.

Hvem er ansvarlig for forskningsprosjektet?

Senter for idrettsskadeforskning ved Norges Idrettshøgskole er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Vi har trukket ut 6 lag U16-18 i Oslo-regionen, hvor trenerne er positive til å delta i studien, og ditt lag er et av disse.

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet, innebærer det følgende:

- Vi vil gjennomføre to tester, begge ved Norges Idrettshøgskole, en før oppstart i sept/okt 2019 og en etter 8 ukers trening. Vi vil teste skulderstyrke og -bevegelighet. I tillegg til disse testene vil du få utdelt et spørreskjema, der vi spør om treningserfaring, tidligere skader og skulderfunksjon. Testingen vil ta ca 15min.
- Halvparten av spillerne på hvert lag blir trukket ut til å gjennomføre programmet. Programmet består av kun to øvelser, som skal gjøres 3 ganger pr uke i 8 uker etter håndballtreningen. De resterende spillerne på lagene fortsetter trening som normalt.
- Alle spillerne får tilsendt en link til spørreskjemaet på SMS hver uke, der du vil få noen korte spørsmål om belastningsskader i skuldrene og skulderfunksjon samt registrere hvor mye du trener og spiller håndball. Det vil ta ca 2 minutter å fylle ut skjemaene hver gang.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Det er kun prosjektleder og veileder som vil ha tilgang til dataene dine. Navnet og kontaktopplysningene dine vil jeg erstatte med en kode som lagres på egen navneliste adskilt fra øvrige data. Spørreskjemaene samles inn ved hjelp av det web-baserte verktøyet Briteback (Briteback, Norrköping, Sverige, www.briteback.com), og håndteres i henhold til EU's databehandlingsregler.
Deltakere vil ikke kunne gjenkjennes i fremtidige publikasjoner.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Prosjektet skal etter planen avsluttes 31.12.20. Av dokumentasjonshensyn skal opplysningene likevel bevares inntil 31.12.2025. Opplysningene skal lagres avidentifisert, dvs. atskilt i en nøkkel- og en opplysningsfil. Opplysningene skal deretter slettes eller anonymiseres, senest innen et halvt år fra denne dato.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges Idrettshøgskole har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:
- Senter for Idrettsskadeforskning, Norges Idrettshøgskole ved Hilde Fredriksen (hilde.fredriksen@nih.no)
- Vårt personvernombud: Karine Justad (personvernombud@nih.no).
- NSD – Norsk senter for forskningsdata AS, på epost (personverntjenester@nsd.no) eller telefon: 55 58 21 17.

Med vennlig hilsen

Prosjektansvarlig
Hilde Fredriksen

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *"Test av et komprimert treningsprogram for utadrotasjonsstyrke i skulder hos håndballspillere"*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- å delta i testing av styrke og bevegelighet i skulder og skuddhastighet
- å delta i styrketreningsprogram for utadrotasjonsstyrke skulder
- å fylle ut ukentlig spørreskjema om skulderplager, deltakelse i prosjektet, samt trening- og kamp-aktivitet
- at mine opplysninger behandles frem til prosjektet er avsluttet, ca. 31.12.2020
- at mine personopplysninger lagres etter prosjektslutt, av dokumentasjonshensyn inntil 31.12.2025

(Signert av prosjektdeltaker, dato)

Date
23.09.2019 14:15
From
REK
To
Hilde Fredriksen

Alle skriftlige henvendelser om saken må sendes via REK-portalen
Du finner informasjon om REK på våre hjemmesider rekportalen.no

REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst A	Elin Evju Sagbakken	22845502	23.09.2019	28912
			Deres referanse:	

Hilde Fredriksen

28912 Trening av utadrotasjonsstyrke for skulder hos håndballspillere

Forskningsansvarlig: Norges idrettshøgskole

Søker: Hilde Fredriksen

Søkers beskrivelse av formål:

Hensikten med prosjektet er å teste ut effekten av et nytt, komprimert program for å øke utadrotasjonsstyrken (som er en risikofaktor for skulderskader) i skulderen hos håndballspillere. Det vil bli gjennomført en randomisert kontrollert studie på U16-18 håndballspillere, kvinner og menn, 6 lag med enkel randomisering innad i lagene. Intervensjonsgruppen vil gjennomføre treningsprogrammet 3 ganger i uken i 12 uker. Styrke- og bevegelighetstesting samt skuddhastighet vil foretas før og etter intervensjonen, og registrering av skulderskader vil gjøres ukentlig via spørreskjema. Resultatene vil være nyttige for å kunne forbedre og/ eller effektivisere det gjeldende forebyggingsprogrammet. Målet på sikt er å redusere risikoen for skulderskade hos den enkelte spiller, noe som bidrar til at laget vil kunne ha flere uskadde spillere tilgjengelig. En reduksjon i skader vil også redusere offentlige utgifter til utredning og behandling.

REKs vurdering

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK sør-øst) i møtet 22.08.2019. Vurderingen er gjort med hjemmel i helseforskningslovens § 10.

Slik komiteen forstår søknad og protokoll er hensikten med prosjektet å undersøke effekten av et nytt treningsprogram for å øke utadrotasjonsstyrken (som er en risikofaktor for skulderskader) i skulderen hos unge håndballspillere.

Resultatene vil være nyttige for å kunne forbedre og/eller effektivisere det gjeldende forebyggingsprogrammet. Målet på sikt er å redusere risikoen for skulderskade hos den enkelte spiller.

På denne bakgrunn vurderes prosjektet som helseforskning og kan skaffe til veie ny kunnskap om helse og sykdom, jf. helseforskningsloven § 2 og § 4 a.

Komiteen merker seg at prosjektleder ikke har doktorgrad eller dokumentert tilsvarende forskerkompetanse. Det vises i den anledning til § 5 i Forskriften til helseforskningsloven, som sier at «prosjektleder skal ha slik faglig og vitenskapelig kompetanse som det aktuelle forskningsprosjektet krever for en forsvarlig gjennomføring».

Komiteen ber på dette grunnlag om at det til prosjektet knyttes en prosjektleder som oppfyller kravene til forskerkompetanse.

Vedtak

Godkjent med vilkår

Vi ber om at vilkårene sendes inn på e-post til: post@helseforskning.etikkom.no

Vennligst oppgi vårt referansenummer i korrespondansen.

REK har gjort en helhetlig forskningsetisk vurdering av alle prosjektets sider. Prosjektet godkjennes med hjemmel i helseforskningsloven § 10, under forutsetning av at ovennevnte vilkår er oppfylt.

Vi gjør samtidig oppmerksom på at etter ny personopplysningslov må det også foreligge et behandlingsgrunnlag etter personvernforordningen. Det må forankres i egen institusjon.

I tillegg til vilkår som fremgår av dette vedtaket, er godkjenningen gitt under forutsetning av at prosjektet gjennomføres slik det er beskrevet i søknad og protokoll, og de bestemmelser som følger av helseforskningsloven med forskrifter.

Godkjenningen gjelder til 31.12.2020.
Komiteens avgjørelse var enstemmig.

Av dokumentasjonshensyn skal opplysningene oppbevares i 5 år etter prosjektslutt. Opplysningene skal oppbevares avidentifisert, dvs. atskilt i en nøkkel- og en datafil. Opplysningene skal deretter slettes eller anonymiseres.

Klageadgang
Komiteens vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag, jf. helseforskningsloven § 10 tredje ledd og forvaltningsloven § 28. En eventuell klage sendes til REK sør-øst A. Klagefristen er tre uker fra mottak av dette brevet, jf. forvaltningsloven § 29.

Vennlig hilsen

Knut Engedal
Professor dr. med.
Leder REK sør-øst A

Appendix III

Questionnaires

1. Baseline questionnaire study I, KJOC translation and cultural adaptation
2. The Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow questionnaire (Norwegian)
3. Baseline questionnaire study II and IV
4. The Oslo Sports Trauma Research Center Overuse Injury Questionnaire on Shoulder Problems
5. Delphi study questionnaires, round 1-3

Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow baseline questionnaire

Navn_______________________________Alder _______ Kjønn___________

Høyrehendt ____Venstrehendt ____ Like ferdigheter på begge hender __________________

Dato for undersøkelsen: ___________________Idrett _______________ Posisjon ____________

Antall år aktiv i idretten __________

I de neste spørsmålene skal du KUN gi svar relatert til skadehistorikken til armen din.

1. Er du skadet i armen din nå? Ja___ Nei___

   I tilfelle hvilken arm? Høyre____ Ve____

2. Er du aktiv i idretten din nå? Ja___ Nei ___

3. Har du stått over konkurranse eller trening siste året på grunn av skade i skulder eller albue?

   Ja ___ Nei ___

4. Har du blitt diagnostisert med en skade i skulder eller albue annet enn forstuing eller strekk?

   Ja ___ Nei ___

   Hvis ja, hva var diagnosen? _______________

5. Har du blitt behandlet for en skade i skulder eller albue? Ja ___ Nei ___

   Hvis ja, hvilken type behandling? (Kryss av alle relevante)

      Hvile _____

      Terapi (vennligst beskriv) _____

      Operasjon (vennligst beskriv): ___________________

De følgende spørsmålene omhandler ditt konkurransenivå i din idrett. Bruk som svaralternativer: Internasjonalt toppnivå, nasjonalt toppnivå, lavere divisjoner/nivå (spesifiser)

6. Hva er det høyeste nivå du har konkurrert på? _____________

7. På hvilket nivå konkurrer du i dag? _____________________________

8. Hvis du nå konkurrerer på et lavere nivå enn du tidligere har gjort, opplever du at dette skyldes en skade i armen? Ja ___ Nei ___

Kryss av <u>den ene</u> kategorien som best beskriver din nåværende status:

a) Deltar i idretten min uten noen plager fra armen
b) Deltar, men med plager fra armen
c) Deltar ikke, grunnet plager fra armen

Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow questionnaire

Spørsmålene under omhandler din fysiske funksjon under konkurranse og trening, og konsekvensene av det.

Alle spørsmål under gjelder din skulder eller albue. Svar på spørsmålet ved å sette en X som beskriver din nåværende situasjon langs den horisontale linjen.

1. Hvor vanskelig er det for deg å bli varm og ledig i armen før en konkurranse eller trening?

Føles aldri ledig under konkurranse eller trening — Normal oppvarmingstid

2. Hvor mye smerte opplever du i din skulder eller albue?

Smerter i hvile — Smertefri i konkurranse

3. Hvor mye svakhet og/eller slitenhet (f.eks tap av styrke) opplever du i din skulder eller albu?

Svakhet eller slitenhet hindrer deltakelse i all konkurranse — Ingen svakhet, normal konkurranse

4. Hvor ustabil oppleves din skulder eller albue under konkurranse?

Hyppig følelse av at den «glipper» eller går ut av ledd — Ingen instabilitet

5. I hvilken grad har armplagene påvirket ditt forhold til din trener eller ledelse.

Stor påvirkning (f.eks sluttet på laget, blitt byttet til annet lag, ikke fått fornyet kontrakt eller mistet stipend — Ingen påvirkning

6. I hvilken grad har du måttet endre din kastbevegelse, serve, slag, skudd eller liknende, som følge av armplagene?

Fullstendig endret, utfører ikke bevegelsene lenger — Ingen endring i bevegelsene

7. I hvilken grad har hastighet og/eller kraft i armen din blitt hemmet av dine plager?

Mistet all hastighet eller kraft — Ingen endring i hastighet eller kraft

8. Hvilken begrensning i utholdenhet har du i konkurranser på grunn av armen din?

Betydelig begrensninger — Ingen utholdenhetsbegrensninger i konkurranser

9. I hvilken grad har din kontroll (av kast, serve, slag eller lignende) blitt hemmet på grunn av armen din?

Uforutsigbar kontroll på alle kast, server, slag eller liknende — Ingen tap av kontroll

10. I hvilken grad påvirker armen din ditt nåværende prestasjonsnivå i din idrett (f.eks., begrenser din arm deg fra å utøve ditt fulle potensiale?)

Kan ikke konkurrere, har måttet bytte idrett — Er på ønsket prestasjonsnivå

Baseline spørreskjema skulderstudien (studie II og IV)

Navn...Fødselsdato.......................................

Klubb..

Høyde...............................

Vekt.................................

Dominant arm/skuddarm (kryss av) Høyre ☐

Venstre ☐

Hvor mange år har du spilt håndball? .... år

Spillerplass (kryss av)

Målvakt ☐

Venstre kant ☐

Venstre bak ☐

Midt bak ☐

Høyre bak ☐

Høyre kant ☐

Strek ☐

Har du gjennomgått skulderoperasjon i løpet av det siste året?

Ja ☐

Evt spesifiser type operasjon ....

Nei ☐

Hadde du vondt/smerte i din dominante skulder (skuddarm) i løpet av forrige sesong?

Ja ☐

Nei ☐

Har du vondt/smerte i din dominante skulder (skuddarm) nå?

Ja ☐

Nei ☐

Kryss av den ene kategorien som best beskriver din nåværende status:

a) Deltar i idretten min uten noen plager fra skulderen ☐

b) Deltar, men med plager fra skulderen...................... ☐

c) Deltar ikke, grunnet plager fra skulderen................. ☐

d) Deltar ikke grunnet annen skade eller sykdom.......... ☐

Spørreskjema om problemer i din dominante skulder (OSTRC overuse injury questionnaire on shoulder problems)

Vennligst svar på alle spørsmålene uavhengig om du har hatt problemer i skulderen eller ikke. Velg det alternativet som passer best, og hvis du er usikker, svar så godt du kan. Begrepet skulderproblemer refererer til f.eks smerte, verking, klikking, hevelse, ustabilitet eller andre plager i skulderen din.

Når du svarer, tenk på hvordan din dominante skulder (skuddarmen) har vært de siste 7 dagene.

Deltagelse

Har du hatt vansker med å spille håndball (vanlig trening/kamp) på grunn av problemer i din dominante skulder (skuddarm) de siste 7 dagene?

- ◻ Deltar for fullt uten skulderproblemer
- ◻ Deltar for fullt, men med skulderproblemer
- ◻ Redusert deltakelse, på grunn av skulderproblemer
- ◻ Kunne ikke delta på grunn av skulderproblemer

Modifisert trening/kamp

I hvilken grad har du modifisert din trening eller kampdeltakelse på grunn av problemer med din dominante skulder de siste 7 dagene?

- ◻ Ingen reduksjon
- ◻ I liten grad
- ◻ I moderat grad
- ◻ I stor grad
- ◻ Kunne ikke delta

Prestasjon

I hvilken grad har problemer med din dominante skulder påvirket prestasjonsevnen i håndball (kamp/trening) de siste 7 dagene?

- ◻ Ingen påvirkning
- ◻ I liten grad
- ◻ I moderat grad
- ◻ I stor grad
- ◻ Kunne ikke delta

Smerte

I hvilken grad har du hatt smerter i din dominante skulder i forbindelse med håndballdeltagelse de siste 7 dagene?

- □ Ingen smerte
- □ I liten grad
- □ I moderat grad
- □ I stor grad
- □ Kunne ikke delta

Er disse plagene rapportert før, eller er det et nytt problem? (Hvis ikke plager i skulderen, hopp over spørsmålet)

- □ Rapportert før
- □ Nytt problem

Er dette en akuttskade (oppstått plutselig i forbindelse med en enkelt hendelse)?

- □ Ja
- □ Nei

Har du hatt fravær fra kamp og/eller trening på grunn av sykdom eller annen skade enn i skuddarmen?

- □ Ja
    - o Skade i ikke-dominant skulder
    - o Annen skade eller sykdom
- □ Nei

Registrering av trening og kamp

Hvor mange minutter har du spilt kamp de siste 7 dagene? (Angi svaret i minutter, men skriv bare tallet) …………….

Hvor mange minutter har du trent håndball de siste 7 dagene? (Angi svaret i minutter, men skriv bare tallet) …………….

Hvor mange minutter har du gjort skulderforebyggingsprogrammet de siste 7 dagene? (Angi svaret i minutter, men skriv bare tallet) …………….

Hvor mange minutter har du gjort annen skuldertrening (styrketrening / strikktrening mm) de siste 7 dagene? (Angi svaret i minutter, men skriv bare tallet) …………….

Eventuelle kommentarer til utfylling av skjemaet

…….

Delphi study questionnaire round 1

Welcome to this survey. Please evaluate each exercise according to its effectiveness and the likelihood that handball players will adhere to it. There are also open questions about dosage, frequency, delivery and criteria for progression. Your comments will be very valuable. Remember that the target population is healthy handball players.
It is of major importance to us that you share your favorite exercises as well.
Please do so.

Side-lying external rotation

The player is side-lying with the shoulder in neutral position and the elbow flexed to 90°. The scapula is kept slightly retracted while the player perform external rotation of the shoulder.

The side-lying external rotation exercise is an effective exercise for ER strength

Not effective Very effective

The side-lying external rotation is an exercise that handball players will adhere to

Not likely at all Very likely

Suggestions for improvement of the side-lying external rotation exercise, increased adherence and progression:

....

Prone external rotation in 90° of abduction

The player is lying prone on a bench with the shoulder abducted to 90° and the upper arm supported. The scapula is kept slightly retracted while the player perform ER of the shoulder.

The prone lying ER in 90° of abduction is an effective exercise for ER strength

Not effective Very effective

The prone lying ER in 90° of abduction is an exercise that handball players will adhere to

Not likely at all Very likely

Suggestions for improvement of the prone lying ER in 90° of abduction exercise, increased adherence and progression:

....

Prone plyometric external rotation in 90° of abduction

The player is lying prone on a bench with the shoulder abducted to 90° and the upper arm supported, holding a weight ball in her hand. Starting position is in full ER The player drops the ball and catches it immediately.

The prone plyometric ER in 90° of abduction is an effective exercise for ER strength

Not effective Very effective

The prone plyometric ER in 90° of abduction is an exercise that handball players will adhere to

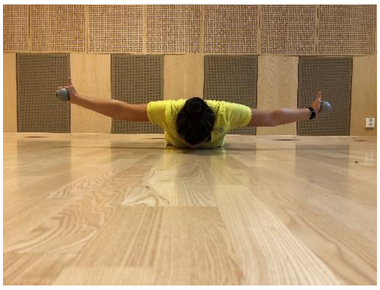
Not likely at all   Very likely

Suggestions for improvement of the prone plyometric ER in 90° of abduction exercise, increased adherence and progression:

....

Prone horizontal abduction in 90° of abduction with external rotation

The player is prone lying on the floor, with the shoulders abducted to 90° in ER. The player performs full horizontal abduction.



The prone horizontal abduction in 90° of abduction with external rotation is an effective exercise for ER strength

Not effective   Very effective

The prone horizontal abduction in 90° of abduction with external rotation is an exercise that handball players will adhere to

Not likely at all   Very likely

Suggestions for improvement of the prone horizontal abduction in 90° of abduction with external rotation exercise, increased adherence and progression:

....

Standing external rotation in 90° of abduction

The player is standing with the shoulder abducted to 90° and elbow flexed to 90°. Starting position is in full internal rotation. The scapula is kept slightly retracted while the player is performing ER through the full range of motion.

The standing external rotation in 90° of abduction is an effective exercise for ER strength

Not effective Very effective

The standing external rotation in 90° of abduction is an exercise that handball players will adhere to

Not likely at all Very likely

Suggestions for improvement of the standing external rotation in 90° of abduction exercise, increased adherence and progression:

....

Standing scaption with external rotation

The player is standing with the arms at the side. The player performs maximal elevation of the arms in the plane of the scapula (30° anterior of the frontal plane).


The standing scaption with external rotation is an effective exercise for ER strength

Not effective Very effective

The standing scaption with external rotation is an exercise that handball players will adhere to

Not likely at all Very likely

Suggestions for improvement of the standing scaption with external rotation exercise, increased adherence and progression:

....

Push-up plus

The player is lying prone with the hands shoulder-width apart. The player then extends her elbows to a standard push-up position and continues to rise by protracting the scapulas.


The push-up plus is an effective exercise for ER strength

Not effective Very effective

The push-up plus is an exercise that handball players will adhere to

Not likely at all Very likely

Suggestions for improvement of the push-up plus exercise, increased adherence and progression:

....

Reverse catch PLYOMETRIC exercise

The player is standing in a half kneeling position with her dominant knee flexed on the floor and contralateral leg in 90 degrees of hip and knee flexion directly in front of her. From behind the player a teammate throws the plyoball towards the player, who catches the ball in the 90/90 position , decelerates the ball, and then rapidly throws the ball back, maintaining the arm in the 90/90 position

The reverse catch plyometric is an effective exercise for ER strength

Not effective Very effective

The reverse catch plyometric is an exercise that handball players will adhere to

Not likely at all Very likely

Suggestions for improvement of the reverse catch plyometric exercise, increased adherence and progression:

....

Other recommended exercises

Are there other exercises you would recommend to include in the program?
Please list the exercises and explain why you think these are important, how they should be carried out and suggestion for progression
....
....
....

The following questions is about how to conduct this strength training program (consisting of 2-3 exercises)

Would you recommend to do the exercise program during handball warm-up or separate strength training sessions?

- ☐ During handball warm-up (please explain your choice)
- ☐ Separate strength training

How many times a week would you recommend to do this exercise program?............................

Other comments about the exercise program:..

Delphi study questionnaire round two

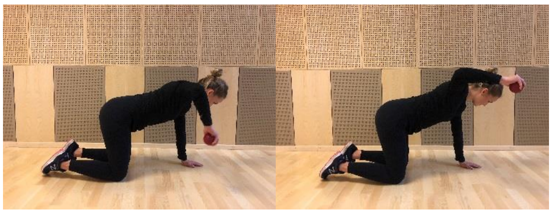
Welcome to this survey. This round contains the exercises suggested from the panel members in the first round. Please evaluate each exercise according to its efficacy and the likelihood that handball players will adhere to it. Remember that the aim of the study is to identify the most effective exercises to increase shoulder external rotation strength, and the target population is healthy handball players.

External rotation (ER) in 90° of abduction (ABD), in a bent over squat position

The player is standing in a bent over squat position with the shoulder ABD to 90°. The scapula is kept slightly retracted while the player performs ER of the shoulders.

ER in 90° of ABD, in a three-point kneeling position

The player is in a in a three-point kneeling position with the shoulder abducted to 90°. The scapula is kept slightly retracted while the player performs ER of the shoulder.

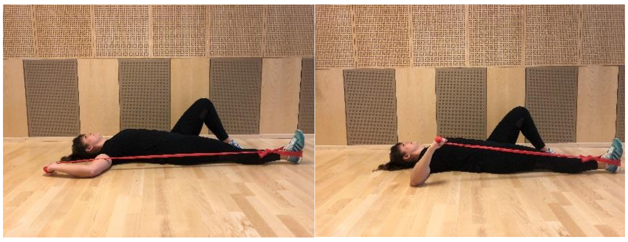


Combined exercise: ER with horizontal ABD prone on a swissball

The player is in a kneeling position with trunk on a swissball and feet against a wall. Push out (extend hips and knees) while moving into 90/90ER and horizontal ABD.

Eccentric ER in 90° of ABD in supine

The player is supine with shoulder ABD to 90°, theraband attached to ipsilateral foot. Flex ipsilateral hip, move to full shoulder ER, extend ipsilateral hip, slow eccentric ER.



Horizontal ABD in a bent over squat position

The player is standing in a bent over squat position. The scapula is kept slightly retracted while moving into full horizontal ABD with ER.

Isometric ER combined with elevation and step-up

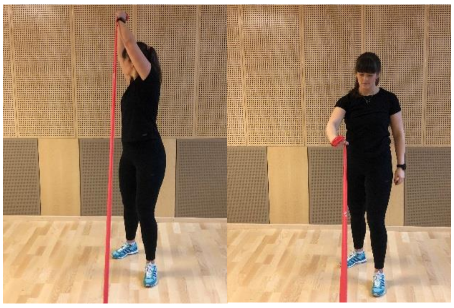
The player is standing, holding a theraband between hands, elbows 90° of flexion, scapula slightly retracted. Pull isometric ER and elevate arms while stepping up.

Combined exercise: ER with horizontal ABD and elevation (V-W-exercise) in standing

The player is standing, holding a theraband, attached in front of him/her with both hands. The scapulae are kept slightly retracted. Pull back into 90/90 ER/horizontal ABD (W) and move to full elevation (V).

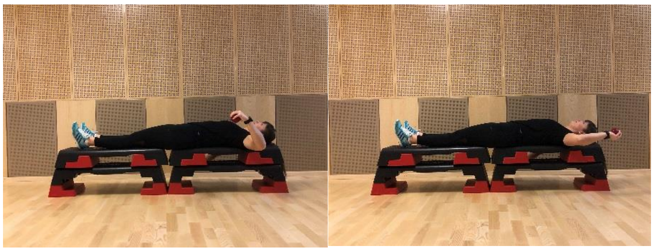
Eccentric single arm Y-raise in standing

The player is standing in a throwing position, holding a theraband with his/her throwing hand. Pull with help of the other hand into a throwing position, eccentric lowering of the throwing arm.



Full rotational range of motion in supine position

The player is lying supine on a bench with shoulder abducted to 90°. Move through full ROM (from full IR to full ER).



Combination exercise: Push up position, ER in 90°ABD with horizontal ABD and trunk rotation

The player is standing in a push-up position and perform a combined ER, horizontal abd (to the cocking position) and trunk rotation.

Full rotational range of motion in prone position

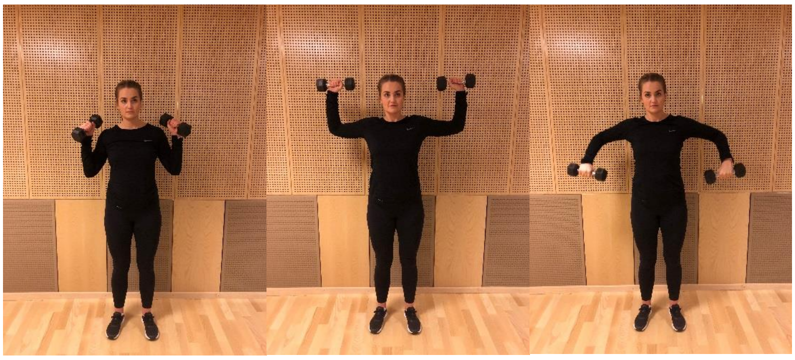
The player is lying prone on a bench with shoulder ABD to 90°. Move through full ROM (from full IR to full ER).

Horizontal ABD in standing

The player is standing, holding a theraband, attached in front of her/him with both hands, scapulae slightly retracted. Pull back into full horizontal ABD.

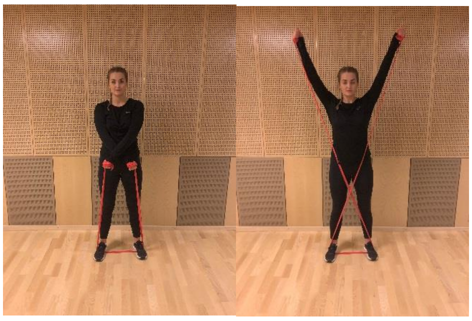
Eccentric ER in standing

The player is standing with full shoulder ER and elbow flexion. Elevate to 90°ABD (like "military press"). Eccentric ER.



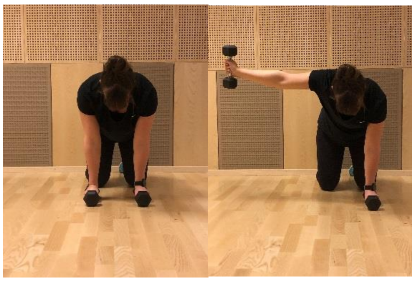
Scaption combined with ER in standing

The player is standing with arms internally rotated at contralateral hip. ER through diagonal elevation (scaption).



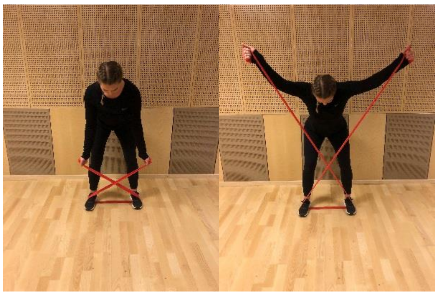
Horizontal ABD in a 3-point kneeling position

The player is standing in a 3-point kneeling position, moving into full horizontal ABD combined with ER



Scaption in a bent over squat position

The player is standing in a bent over squat position, scapulae slightly retracted. Starting with arms vertical and moving into full scaption combined with ER.



Resisted wall slide

The player is standing with the arm against the wall, holding a theraband between hand and ipsilateral foot. Slide upward until the arm is in full elevation

Combined exercise: ER with protraction

The player is in a push-up position on forearms, holding a theraband between hands. Pull into ER while performing plus-phase protraction.

Single-arm push-up

The player is performing a single arm push-up in either a regular or kneeling push-up position.

Standing ER in 0° of ABD

The player is standing with the shoulder in neutral position and the elbow flexed to 90°. The scapula is kept slightly retracted while the player performs ER of the shoulder.

The following two statements and one open-ended question was added to each exercise:

The…. exercise is an efficient exercise for ER strength

Not effective — Very effective

The ….exercise is an exercise that handball players will adhere to.

Not likely at all — Very likely

Comments:………………………………………………………………………………………………………..

Delphi study questionnaire round three

Dear panel member

Thank you for your contribution in the previous rounds of our Delphi study.
This round contains all the exercises from the first two rounds. Please revise your scores based on the summary from the previous rounds (sent as a separate email).
If you score outside the inter-quartile range, we ask you to provide your reasons for this position.

Remember the importance of distinguishing between whether an exercise is <u>effective</u> and if it is <u>likely to be carried out</u> in a handball population

Exercises:

- Side-lying external rotation
- Prone external rotation in 90° of abduction
- Prone plyometric external rotation in 90° of abduction
- Prone horizontal abduction in 90° of abduction with external rotation
- Standing external rotation in 90° of abduction
- Standing scaption with external rotation
- Push-up plus
- Reverse catch PLYOMETRIC exercise
- External rotation (ER) in 90° of abduction (ABD), in a bent over squat position
- ER in 90° of ABD, in a three-point kneeling position
- Combined exercise: ER with horizontal ABD prone on a swissball
- Eccentric ER in 90° of ABD in supine
- Horizontal ABD in a bent over squat position
- Isometric ER combined with elevation and step-up
- Combined exercise: ER with horizontal ABD and elevation (V-W-exercise) in standing
- Eccentric single arm Y-raise in standing
- Full rotational range of motion in supine position
- Combination exercise: Push up position, ER in 90°ABD with horizontal ABD and trunk rotation
- Full rotational range of motion in prone position
- Horizontal ABD in standing
- Eccentric ER in standing
- Scaption combined with ER in standing
- Horizontal ABD in a 3-point kneeling position
- Scaption in a bent over squat position
- Resisted wall slide

- Combined exercise: ER with protraction
- Single-arm push-up
- Standing ER in 0° of ABD

The following two statements and one open-ended question was added to each exercise:

The…. exercise is an efficient exercise for ER strength

Not effective Very effective

The ….exercise is an exercise that handball players will adhere to.

Not likely at all Very likely

Comments to your rating

……………………………………………………………………………………………………..

Appendix IV

Delphi study

Summary of responses from round 1 & 2

Unedited feedback from round 1& 2

Summary of responses from round one and two

- Statistical summary of the panel's scores (median and interquartile range)
- Your own score
- Summary of the comments

Side-lying external rotation

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Rolled towel between arm and trunk
- Proper instruction and coaching about trunk stability and scapular control

Suggestions for progression (positions):

- Different angles of flexion
- Combine with horizontal abduction
- Combine with side-plank

Several responders would rather do this exercise in standing

Prone external rotation in 90° of abduction

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Upper arm horizontal or above
- Different angles of abduction
- Move through full rotation ROM (from full ER to full IR)
- In 3-point kneeling position

Suggestions for progression (positions):

- Passive stabilization of upper arm-> unsupported upper arm
- Combine with horizontal abduction
- In 2-point kneeling position combined with extension contralateral leg
- Prone on Swiss ball or an incline bench (45-60 deg)
- Standing

Suggestions for increased adherence:

- Use other positions than on a bench

Prone plyometric external rotation in 90° of abduction

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Cue static scapula
- Upper arm horizontal or above
- Elbow above shoulder level (>90° abd)
- Stable trunk and pelvis

Suggestions for progression (positions):

- Passive stabilization of upper arm-> unsupported upper arm
- Different angles of abduction
- Combine with horizontal abd
- 3-point kneeling, prone on Swiss ball or standing
- In 2-point kneeling position combined with extension contralateral leg

Suggestions for increased adherence:

- Use other positions than on a bench

Prone horizontal abduction in 90° of abduction with external rotation

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Lying on a bench would use larger range
- Forehead supported on rolled towel
- Cue scapular position
- Arm above 90° (rather around 120-135°)

Suggestions for progression (positions):

- 4-point kneeling
- Prone on Swiss ball
- Standing (with theraband)
- Single leg standing

Suggestions for increased adherence:

- bent over squat position so athlete does not have to lay down

Standing external rotation in 90° of abduction

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Combination of hand held weight with theraband
- Place arm in scaption
- Cue on arm position (elevated above 90) and trunk control
- Support the weight of the arm against the wall so as to isolate cuff more /support elbow to control axis of rotation
- Important that they do it slowly with the dumbbell or the weights

Suggestions for progression (positions):

- Variation in the position of the upper body (hip tilt) ensures a better stimulation of the different shoulder joint/grind positions.
- One legged squat position static to dynamic squat

Suggestions for increased adherence:

- Use theraband /partner exercise

Standing scaption with external rotation

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Cue on scapular, head and trunk control
- Combine with diagonals starting with arm crossed in IR and ending in scaption/ER

Suggestions for progression (positions):

- Involve whole body with diagonals starting with arm crossed and squat position and ending in scaption
- Prone position or bent over squat position
- One legged squat position static to dynamic squat

Suggestions for increased adherence:

- Theraband/ partner exercise

Push-up plus

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Perform on forearms, theraband between hands and pull to ER bilaterally while performing the plus-phase protraction
- Insist on the push-up stage and to control the trunk position.

Suggestions for progression (positions):

- Starts on knee, next the position in the pic, next unstable surface
- Bring feet closer together to increase difficulty
- 1-arm push-ups
- Perform on forearms, theraband between hands and pull to ER, turn to side-plank with 90/90 abd/ER

Other comments:

- Several responders comment that this exercise is not a preferred exercise for strengthening the posterior cuff.

Reverse catch PLYOMETRIC exercise

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Suggestions for improvements:

- Standing

Suggestions for progression (load, type of contraction)

- heavier ball
- faster delivery
- stop eccentric control sooner
- return ball back to thrower

Suggestions for increased adherence:

- both players perform the exercise with back towards each other

Other comments:

- Let the player choose the color of the ball /target/ emphasize visual elements to increase motor learning elements.
- Some responders are concerned about the exercise being too technically difficult to get a good effect, particularly in the younger players.

ER in 90°ABD in a bent over squat position

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

Several responders find this exercise to be effective and that handball players will adhere, however, some have concerns about:

- the load on the lower back
- this exercise might be painful
- difficulties in positioning

ER in 90° of ABD, in a 3-point kneeling position

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

Several responders do not find this exercise functional, since it is not in standing position

There is disagreement whether this exercise engages the trunk/core

Combined exercise: ER with horizontal ABD prone on a Swiss ball

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comment is that the use of a Swiss ball ("too much gear") will reduce the adherence.

Others find the exercise functional and challenging for handball players.

Eccentric ER in 90° of ABD in supine

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are that this exercise is an effective and sport specific exercise

Some responders have concerns about:

- The load might be too low for healthy players
- The exercise might be too complicated to perform correct

Horizontal ABD in a bent over squat position

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main feedback is that this exercise is less specific for the ER

Positive comments are that the exercise is relevant for "long arm" shot, challenges scapular stability and is easy to perform

Isometric ER combined with elevation and step-up

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The negative comments are that this exercise is neither specific nor effective for ER strengthening

The main positive comment is that the exercise includes the kinetic chain.

Combined exercise: ER with horizontal ABD and elevation (V-W-exercise) in standing

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

It is stated that this exercise is well supported in EMG-studies

Several responders recommend doing this as a pair exercise to increase adherence

Eccentric single arm Y-raise in standing

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comment is that this is a sport specific exercise.

Responders recommend doing this as a pair exercise to increase adherence.

Full rotational range of motion in supine position

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are about too little resistance due to short lever arm for the ER and that the exercise requires a bench.

Combined exercise: Push up position, ER in 90°ABD with horizontal ABD and trunk rotation

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are that this exercise is challenging and relevant for handball. It includes the kinetic chain, but is probably not very effective ER strengthening exercise.

Full rotational ROM in prone position

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are that this is an effective exercise for the rotator cuff, but the downside is that it requires a bench.

Horizontal ABD in standing

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are that this exercise is not specific for the ER's, more activation of posterior deltoid and scapular muscles.

Eccentric ER in standing

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comment is that this exercise is difficult to perform correct.

There is disagreement whether this is an effective exercise or not.

Scaption combined with ER in standing

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

There is disagreement whether this is a specific exercise or not for ER strengthening.

Some comment that this exercise is favourable for the scapular muscles

Horizontal ABD in a 3-point kneeling position

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main feedback is that this exercise is not specific for ER strengthening.

Scaption in a bent over squat position

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are that this exercise is difficult to perform correctly, and is not specific for ER strengthening.

Resisted wall slide

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are that this exercise is not specific for ER and is too easy (low load).

Combined exercise: ER with protraction

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comment is that this exercise is difficult to perform correct. Some responders have concerns about a downward scapular rotation.

Single-arm push-up

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

Although handball players may find this exercise fun and challenging, the main comments are that it is difficult to perform properly, might be too heavy and is not specific for ER strengthening.

Standing ER in 0° of ABD

	Median	IQ-range	Your score
Effective exercise			
Adherence			

Comments:

The main comments are that this exercise is neither functional nor effective as a strengthening exercise. However, a couple of respondents find it relevant and functional.

Should the exercises be conducted during handball warm up or during separate strength training sessions?

During warm up: 5
During separate strength training: 4
Both: 7

The main argument for doing the training during warm up is <u>higher adherence</u>.
Other arguments:

- Cuff preparation exercises to "switch on the system" before throwing
- Successful injury prevention programmes has been implemented in the warm-up

The main argument for doing the exercises during separate strength training is that <u>the aim of the program is to increase external rotation strength</u>.
Other arguments:

- Strength training immediately before handball could reduce handball performance
- Less focused on strength training during handball warm up

How many times a week would you recommend to do this program?
The majority suggest 2-3 times per week (1-5 for separate strength training and 2 to every training session when doing the program during warm up)

Unedited feedback from the Delphi study external rotation exercises round one & two

Content

Exercises round one

(With suggestions for improvement, increased adherence and progression)

Side-lying ER

Typically it's a bit easy, even when you start to load things up, the player can cheat too readily with body rotation, and scapular substitution such that the posterior cuff isn't working that much - you are starting nearly at horizontal, mostly, so this is the hardest part of the exercise

Progression: different angles of flexion in shoulder to perform ER, combined with horizontal abduction exercise, progression to different contraction modes in combination for example plyometric contraction, eccentric overload contraction,... , progression to perfomance in side plank to include kinetic chain

Doing the exercise in standing position to incooperate more stability when shooting. Possible to use a rubber band, but I prefer dumbell because the load is more constant. Repetitions is conected to quality.

Important to have a range of loads/weights so that each player may choose the appropriate resistance. This is important for the following exercises as well.

A rolled towel under the arm would increase cuff activity. Need to coach that the scapula does not move during exercise. Need to get to inner range ER. Set reps at 12-14 max and increase weight accordingly- keeping excellent form

Progression from water bottle to dumbell. Increased adherence is possible by connecting the exercise to "throwing days" as preparation before training. We often start with dominant side (often weaker) and then non-dominant and finish off with dominant side, therefore the ratio is 2-1 in favour of dominant side.

Combine the side-lying ER exercise with side-plank(strengthening of trunk at the same time) . If there is no dumbbells available , between 2 players they can hold a TheraBand and do the exercise simultaneously

I would add a towel between the arm and trunk to better position the arm. A pillow would also be a good addition. If the player can do more than 8 reps than it is time for progression. I believe up to 8 reps is good for strength.

Standing external rotation against the resistance of an elastic band

This exercise will preferentially strengthen the shoulder external rotators in their lengthened range (outer range) and the axioscapular muscles in their stabiliser role ie to prevent the external rotators "gliding" the scapula toward the humerus. Most "throwing" athletes (& I am assuming handball players as well) experience shoulder pain more commonly in more elevated arm positions ie with the humerus in more flexion/abduction & the scapula upwardly rotated. Full range humeral flexion & abduction require the humerus to externally rotate ie require the shoulder external rotators to work into their shortened range (inner range). I have rated this exercise only moderately effective to increase external rotator strength in handball players because <u>it is not targeting the most appropriate range for strengthening these muscles & is not training them in the more functionally-</u>

relevant elevated shoulder position ie is only requiring the axioscapular muscles to function in their stabiliser role & not in also in their mover role to upwardly rotate the scapular. I think adherence to this exercise could be negatively affected because healthy handball players are likely to find it "easy" ie not challenging enough.

To start the exercice with 1 kg, and to increase the weight as soon as possible if no issue during the exercice.

In terms of targeting the posterior rotator cuff don't think this is the most effective way and would question its inclusion in preference to other options

My experience is that players adhere to the exercise better if they work in pairs with a thera-band, where one is holding the band while the other player performing ER. One can also progress the exercise where one player holding the band in an ER position (isometric contraction of the cuff) while the other player performing ER.

Performed in standing position with the shoulder in throwing position (90 abducted)

Prone external rotation in 90° of abduction

Prone lying ER exercise in 90° of abduction

To hard to organize for a whole team, but good in a strength program

I like this one, but remember it works the posterior cuff the most as you get to, and go above horizontal

Progression from passive stabilisation upper arm (sustained by surface on which athlete is performing the exercise) to active stabilisation of elbow (no contact with surface), progression to combination of different contraction modes as described above, combination with horizontal abduction, progression to kinetic chain exercise in 2 point kneeling position with extension heterolateral leg

If we think throwing or shooting in handball we always say that the elbow should be higher than the shoulder. In this picture she has the elbow in line or lower. The same progression here is to be standing to do the same exercise. I think that will be more likely. Repetition is connected to quality

The exercise can also be conducted on an incline bench (45-60 deg).

Cue static scapula and that arm needs to get to parallel with floor. Again appropriate reps for strength 12-14 rep max. Control concentric and eccentric component

Progression is from weight of the hand to water bottle to dumbell. Adherence is harder because of the bench, I believe therefore to perform it in a 4-point position with support from two knees and the opposite hand (if showed liked that I think adherence is more likely).

Combine with superman

Addition of a towel between arm and bench would also help in position of the arm.

Standing against the resistance of an elastic band

This exercise will preferentially strengthen the shoulder external rotators in their shortened range (inner range) and the axioscapular muscles in both their stabiliser & upward rotator roles &

therefore, is more complex & functionally relevant for throwing athletes. The disadvantage is that it does not address outer range external rotator strength which may be relevant if shoulder pain is experienced during follow through. Because it is a more challenging & functionally relevant motor control task it might be perceived as a more "interesting" exercise for healthy handball players thus increasing adherence, although the prone position is a less "convenient" exercise position than upright. I have 2 suggestions for this exercise: 1) to add "load" in a more functional manner the athlete could have their upper arm unsupported. This would require increased activity in posterior deltoid to hold the arm weight & activity in subscapularis to prevent posterior deltoid from gliding the humeral head posteriorly. Subscapularis activity to perform this stabiliser role would provide resistance in a functional manner for external rotators as both anterior & posterior rotator cuff muscles are active during shoulder abduction tasks (Rathi et al 2016; Wattanaprakornkul et al 2011, Reed et al 2016). In addition, activity in the axioscapular muscles in their stabiliser capacity will increase because posterior deltoid activity has increased. 2) If the athlete moved through full rotation range the motor pattern to "recruit" & "turn off" the external rotators as required ie as the forearm moved though the vertical position, would be added to the exercise. Increasing the speed of this exercise would further challenging the co-ordination of this task.

About the head, it could better to install the body of the player on a swissball. It's necessary to insist on the arm position (in throwing position) to be more efficient.

Whilst this is a great way of targeting the mobiliser role of the posterior cuff prone lying does perhaps make it less easy in terms of adherence as dependent on being near a plinth etc.

If one would use this as a warm-up routine, my experience is that there is often hard to find a bench or similar for the players lye on. In that case, I think the standing version as shown below is a better option.

Different angles of abduction depending on their preferred throwing technique.

Prone plyometric ER in 90° of abduction exercise

To hard to organize for a whole team, but good in a strength program

It's a bit more fun, but the "muscle" challenge is exceeded by the balance/catch challenge, so they get bored before they get tired

progression to kinetic chain exercise as described above

A good exercise to activate ER and relevant for handball. Doing the same exercise standing will challenge more stability but in same time of course other conected part of the shoulder. The same thing here as the other exercise about the elbow

Make sure that the movement is rapid and pain free with trunk and pelvis stable

Progression is from my point of view from light to medium theraband. It is trickier to use ball or weightball and also bench. If faced down I would recommend 4-point position (see above) but would recommend standing up and use theraband. Target is "speed" more than load.

Give a rhythm, to add speed

I prefer this one than the previous one.

On a bench with a hole for her face

My comments re the prone exercise above relate to this exercise as well. The motor pattern to "recruit" & "turn off" the external rotators in this exercise is being achieved by the dropping & catching of the ball & they are being recruited in inner range ie the more functionally relevant range for throwing athletes.

About the head, it could better to install the body of the player on a swissball. It's necessary to insist on the arm position (in throwing position) to be more efficient.

Comments as per previous exercises re usability and adherence- in addition dependent on whether pre season or in season in terms of fatigue and load.

Depending on what type of strength we are talking about, I think this exercise is good for increasing plyometrics/Speed-strength but for maximal strength/strength-speed I think that the other exercises are better.

Different angles of abduction depending on their preferred throwing technique.

Prone horizontal abduction in 90° of abduction with external rotation

Standing against the resistance of an elastic band

Good exercise and relevant for handball.

forehead supported on rolled towel

Doing this on a bench so you can use a larger range, watch out for dropping below 90 degrees of abduction

increased adherence in bent over squat position so athlete does not have to lay down, this also inhibits lumbar extensors to be overactive in this exercise/ progression: supersets with combination of varying arm positions like W-V exercise and V exercise lifting arms at high elevation

My guess is that this exercise will be difficult to load appropriately. The athletes feel a force-full contractions, but in fact the muscle tension is low (active insufficiency) and thus not very stimulating; at least for hypertrophy (which btw probably is highly underrated in injury prevention).

Progression from weight of hand to water bottle to dumbell. In my experience, players that are "stiff" in the thoracic area do not like this exercise and therefore adherence drops.

Standing, 2 players Theraband in each hand, progression with standing on 1 foot

progression: prone lying in a swiss ball

This exercise will strengthen the external rotators in the functionally relevant inner range position because they will have to maintain external rotation against the pull of subscapularis (an internal rotator) which will be active in a stabiliser role to prevent posterior deltoid from gliding the humeral head posteriorly. It will also strengthen axioscapular muscles in both their stabiliser & upward rotator roles. The long lever nature of this exercise will increase the activity & thus srtength in all these muscles. However, being basically an extension exercise it is not training the motor pattern predominant at the shoulder during handball & therefore, does not reinforce the functionally relevant motor pattern while strengthening external rotators. Because it is a challenging exercise handballers may be likely to adhere to it.

To safe the back, it could be better to install the player on a swissball. it's important to insist on the scapulae's position.

Easy to do - doesn't isolate mobiliser role so well or inner range posterior cuff but easy to apply and incorporates posterior deltoid which is also clearly important.

In the healthy player I would also chose to have the arm above 90° (rather around 120-135°) for more activation of the rotator cuff and for a more throwing-like position.

Performed in standing position simulating the throwing position. Elastic bands as resistance.

Standing external rotation in 90° of abduction

You can use heavier weights if you go "up as a military press" and then come down, in the eccentric phase as pictured

Not effective as resistance is 0 at end range ER/ combination of hand held weight with theraband, might be partner exercise in which each athlete takes one end of theraband and perform simultaneous ER/ progression to kinetic chain performance: One legged squat position static to dynamic squat

Relevant and good exercise. If we see it likely to throwing or shooting technique I will prefer the elbow higher. But isolated for the external rotation it is good.

Variation in the position of the upper body (hip tilt) ensures a better stimulation of the different shoulder joint/grind positions.

Place arm in scaption

Nice exercise but a lot of things can go "wrong", especially with "shoulder control". I would recommend theraband as mentioned above/previously. Adherence easier with theraband because weights are harder to keep in the bag.

Maybe a theraband would be better than with a weight in hands.

be careful that this does not lead to impingement

This exercise will preferentially strengthen the shoulder external rotators in their lengthened range (outer range) as in the sidelying exercise above. It is more functionally relevant, however, than the sidelying exercise because it is training the axioscapular muscles in both their stabiliser & scapular upward rotator roles. As with the sidelying exercise I think adherence to this exercise could be negatively affected because healthy handball players are likely to find it "easy" ie not challenging enough.

It's necessary to insist on the arm position (in throwing position) and trunk control to be more efficient.

support the weight of the arm against the wall so as to isolate cuff more /support elbow to control axis of rotation?

One of my favourites. Easy to instruct and perform both with dumbbells, weights or theta-bands. My experience is that when instructing it you have to see so the player get a posture in en end position and not protracting their head or extend their lower back to compensate for lack of thoracic and glen-humeral mobility.

Standing scaption with external rotation

Individualize the weights for the throwing and non-throwing arm - they should be able to do somewhere between 10 and 30% more for the throwing arm

resistance is 0 for ER end range as in previous exercise/ should be performed prone or in bent over squat position to have resistance

I think it will be better if you do the exercise like an shoulder press with the elbow out rotated and open hand forward

start with arms internally rotated and at contralateral hip and externally rotate through elevation

In this setting I would choose another exercise with the purpose to "load" more overhead or work static positions overhead. If I would choose this one than most likely as warm-up and with theraband.

Involve whole body with diagonals starting with arm crossed and squat position and ending in scaption. Theraband between 2 players could be nice too.

I would recommend this exercise only if the player has good scapular control.

This exercise will strengthen the external rotators through a large rotation range position because the humerus must be externally rotated to achieve full range abduction, as well as in their stabiliser role. It will also strengthen axioscapular muscles in both their stabiliser & upward rotator roles. The long lever nature of this exercise will increase the activity & thus strength in all these muscles. However, like the horizontal abduction exercise, it is not training the motor pattern predominant at the shoulder during handball & therefore, does not reinforce the functionally relevant motor pattern while strengthening external rotators. Because it is a challenging exercise handballers may be likely to adhere to it.

It's necessary to insist on the trunk control and scapulae's position (tightness).

Emphasise rotation - i.e. thumbs down to thumbs up - however don't think this emphasises rotations as effectively as other exercises and therefore less useful for ER specifically- more a total cuff workout

One of my favourites. Easy to instruct and perform both with dumbbells, weights or theta-bands. My experience is that when instructing it you have to see so the player get a posture in en end position and not protracting their head or extend their lower back to compensate for lack of thoracic and glen-humeral mobility.

Push-up plus

Easy to organise for a whole handball team in a hall for warm up

This doesn't light up the posterior cuff so much. It's a good exercise, but not so much for the posterior cuff

bring feet closer together to increase difficulty,

to increase ER strength in this exercise: perform on forearms, take theraband between hands and pull to ER bilaterally while performing the plus-phase protraction/ progression to: start in forearm plank position with theraband between hands pulling to ER, perform plus phase for one set, than perform another set holding the ER in the theraband and turn to side plank (in side plank both arms ar in 90° ABD, 90° ER at the end)

Push up is allways popular in handball, but I don't think I will prefer this for ER, but a good exercise for defence play

The exercise is ok, but probably most stimulating for the prime movers of shoulder flexion/adduction/internal rotation

A excellent position. However, I would use more movement for stabilisation of the Rotator Cuff and not primarily use this exercise as a external rotator exercise. I think adherence with the + very selldom works well.

This exercise is efficient for protraction but not really for upward rotation of scapula. I woould suggest more in a position loke downward dod or standing and lifting dumbells or pushing against a theraband

Progression: starts on knee, next the position in the pic, next unstable surface

Make the upper back more round

This exercise will strengthen the external rotators in their mid range length in their stabiliser role to prevent shoulder flexors from anteriorly gliding the humeral head. It will also strengthen axioscapular muscles in both their stabiliser & upward rotator roles. The high load nature of this exercise will strengthen all these muscles. However, it is not targeting functionally specific inner range external rotator strength. The closed chain nature of this exercise & the lack of dynamic shoulder rotation results in it not training the motor pattern predominant at the shoulder during handball & therefore, does not reinforce the functionally relevant motor pattern while strengthening external rotators. Because it is a challenging exercise handballers may be likely to adhere to it.

It's necessary to insist on the push-up stage and to control the trunk position.

Again a good general cuff work out and more ER specific if emphasise ER of hand - however more cocontraction than ER specifically?

My experience is that if they do 1-arm push-ups instead they get much more activation around the posterior rotator cuff, especially in the senior elite players. Have to be strong enough though to do a 1-arm push-up. They can start on their knees and build it from there. Good exercise for Serratus anterior though and the player often adhere to the exercise.

Reverse catch PLYOMETRIC exercise

Show the exercise with a handball, if its not important it is a small "heavy" ball.

Fun exercise :-)

heavier ball, faster delivery, stop eccentric control sooner, return ball back to thrower

It's fun, so it's likely to be done, but it's not challenging enough for the posterior cuff IMO. You get bored or drop the ball before you truly get to fatigue failure

increased adherence when both players perform the exercise instead of one throwing the ball as assistant. Both players with back towards eachother/ functional

Very good execise. And here we see the elbow higher. It is even possible to have more rotation

Fun exercise the first 2-3 times but according to me a hard exercise technically to really get good effect. Also it takes a lot of time and is "player consuming". Sometimes it is better to Tango alone:-)

This exercise will preferentially strengthen the shoulder external rotators in their inner range as accelerators & decelerators & the axioscapular muscles in both their stabiliser & upward rotator roles & is training a motor pattern very relevant to handball. The disadvantage is that it does not address outer range external rotator strength which may be relevant if shoulder pain is experienced later in follow through. The obvious functional relevance of this exercise position with handball may increase athlete compliance.

To be vigilant to back and arm position.

Addresses important eccentric role and visual /functional link in terms of cortical elements. Let the player choose the colour of the ball /target/ emphasise visual elements to increase motor learning elements.

As mention above, depends on the type for strength we are looking for. For maximal strength I don't think it is that effective. The other problem is that the exercise depends on how accurate the teammate throw. Often not a problem in the older population but my experience in the younger is that i takes time for them to get a hang of the exercise and how to throw.

Performed in standing throwing position.

Suggestions for exercises after the first round (the first eight exercises)

Reserve catch, 12-15 reps pr arm, 2-3 sets
Push - ups plus, 10 reps, 2-3 sets
Side-lying external rotation, 12-15 reps pr arm, 2-3 sets
Standing Scaption, 12-15 reps, 2-3 sets
I selected these exercises to get one exercise for each "part" of the shoulder, and also exercises who is easy to organise for big group. The dosage and progression will be to mix with a periode with heavier weight and less reps, and so medium of reps, medium weight. Important to not be the same, so the muscles "will be used to it".

Eccentric ER with theraband:
Start prone eccentric ER with theraband: one end of theraband at homolateral foot, other end of theraband in hand,flex homolateral hip, go to ABD-ER 90-90, extend homolateral leg/hip, slow eccentric ER/ progression from upper arm supported on floor to upper arm active stabilisation just above the floor
Progression to kinetic chain performance in one legged squat on heterolateral leg: one end of theraband at homolateral foot, other end of theraband in hand, stand on heterolateral leg extended with homolateral hip flexed to 90° and arm at 90°ABD-90°ER, squat on heterolateral leg, extend homolateral leg backwards, slow eccentric ER from 90° ER to maximal IR at 90° ABD
Bilteral theraband ER pull isometric + flexion or scaption holding isometric ER throughout progression to kinetic chain performance with one legged squat
progression to supersets with one set dynamic elevation, one set ER at 0° elevation dynamically and one set ER at 90° elevation dynamically

I believe that the training volume of the side-laying, prone exertional rotation and push-ups should dominate in the initial training, and that there is a progression to the plyometric exercises. I believe that there is necessary to build solid muscular strength before the athlete can benefit optimally from the plyo-exercises.

Think need to make sure that the scapular stabilizers are functioning properly to give optimal platform for cuff

I recommend static to dynamic to elastic-dynamic (plyometric) exercises in that order. I would therefore recommend static exercises to start with either above your head and/or in the 4-point position (push-up position). I would then move to dynamic exercises with focus on control and load. In the end work with plyometric exercises. In addition I think it is VERY important to integrate the kinetic chain from the start, however you can perform 1-2 "isolated" RC exercises. From a dosage point of view I recommend 12 rep or up to 60 seconds static hold or 10-20 meters static hold while walking. The static hold will create resiliance in the RC and also teach the player control of the RC. In total 2-3 times/week depending on the load in the handball sessions. Also it should be more performance related than age or gender related.

Player lyes prone on hand and feet. One dumbbell in the hand, rotation of trunk and lifting the arm in the cocking position .

With elastic band extension against resistance, rowing exercise

Shoulder rotation in supine lying

This exercise is like the "reverse" of the shoulder rotation in prone exercise. It will preferentially strengthen the shoulder external rotators in their outer range & the axioscapular muscles in both their stabiliser & upward rotator roles, Used in combination with the "prone" exercise the external rotators can be strengthened throughout their range. Performed with the upper arm unsupported requires shoulder flexors to hold the arm weight. This in turn will require the posterior rotator cuff (external rotators) to function as stabilisers to prevent the shoulder flexors from gliding the humeral head anteriorly. This exercise trains the functionally relevant flexor motor pattern required in handball which requires the external rotators to work both as stabilisers of the humeral head & rotators of the humerus, as well as dynamic shoulder rotation associated with throwing activities.

Standing ER with elastic band in throwing arm position, it's important to manage the exercice during both stages (concentric and eccentric).

1. I like to use through range ER - short lever elevation with theraband and a step up- my belief is this sets the foundation of cuff activation and emphasises kinetic chain to increase local recruitment of posterior cuff and scapula muscles. Keep to optimise benefits of any strength training.
2. Supported cuff - eccentric in lying (using theraband round foot - great to specifically increase inner range ER and eccentric ER)
3. Consider ER with kinetic chain - e.g. step back , ER to 90/90 and through range elevation or push out over gym ball with ER 90/90

Exercises round two

ER in 90°ABD in a bent over squat position

Yes, but why can she not be in a standing position - like we do in handball?

It's a big load on the low back, so just add into the instructions something along the lines of "this exercise will also work your back quite hard, and you should also feel tired there at the end of the set"

effective because ER is in exercise - will adhere as it is heavy and is standing

The exercise is some relevant for handballplayer

invoves concentric and eccentric work. Will also require scapula stability

Easy to understand and perform. Also I prefer weights since load is constant through the movement.

Difficult to position correctly

I think the players will adhere to it, but I wouldn't choose these exercises as I believe there are more effective ones.

ER in 90° of ABD, in a 3-point kneeling position

Good, but can be done in standing position?

effective but unilateral so takes twice as much time

requires less rotation trunk stability

Performed with plyo-ball I believe will increase the likelyhood of performing the exercise due to the "variation" = FUN

Kneeling position is not very effective to engage the core, I would recommend plank

I like this exercise a lot specially because it also activates the core muscles.

exercise is much easier to control and weights can be adapated per armr

Very similar to exercise above but not in such a functionally relevant body position.

More effective with a dumbell than a ball

As per previous comment but less engagement kinetic chain

My experience is that when you moved away from standing position e.g. knees and hans likes this the compliance drops.

Combined exercise: ER with horizontal ABD prone on a swissball

A bit hard to organise

challenging exercise will increase adherence

I think to complicated and to much "gear".

Relevant for handballplayer because you make extend the hip and knees as you do in a shot

challenges trunk dynamic stability. Can add in lower limb if required

The use of extra material(swiss ball) could be a barrier

This exercises requires some practice and should be fine for a healthy population.

exercise will be effective, but they have to have a swiss ball available at the time they are doing it.

Trains the external rotators to be both movers ie rotators, as well as stabilisers with the anterior rotator cuff (RC) during abduction. On Swiss ball presumably designed to include core stability training but not in the upright, functionally relevant position for handball.

More dynamic so closer to the sports movement, requires more material

This fits my bias in that initiating with the kinetic chain will optimise impact exercise but potentially the swiss ball is a barrier in ease of performing exercise e.g. equipment

Same comment as above. Now we add one extra component (swiss ball) which increases the risk of low compliance

Eccentric ER in 90° of ABD in supine

Good

effective and sportspecific eccentric deceleration but need to lay down and unilateral to takes more time

Eccentric movements are important for handballplayers. Start and stop movements.

I will guess many athletes will perform this with too low force.

challengin

For healthy players I think load is to "small".

Very good exercise.

I like this exercise, because you can control the eccentric strengthening of this exercise much better than standing straight. Upper arm position still crucial

As with exercises above this exercise will strengthen external rotators mostly in their inner range ie mid to shortened length, but not in the upright, functionally relevant position for handballers.

More complicated for the coordination of the movements

Easy to do, easy to increase load and benefits of eccentric element. Athletes tend to like as they can really feel the effects in the posterior shoulder

My experience, especially with younger players is that they have trouble doing this correctly. Also, same comment as above. More components=lower compliance

Horizontal ABD in a bent over squat position

In the strength program

challenges scapular stability

Relevant for "long arm" shot

I would choose others.

will increase ER strength but not specific - easy to perform standing so likely they will adhere

I believe very good exercise and easy to perform. Players will feel "fatigue" = Likely to perform

Difficult to hold a good positionning

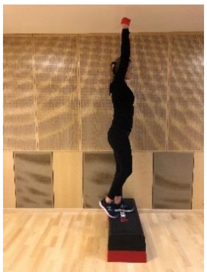
Don;t like the straight elbows, would much rather have it sitting down and with slightly bent arms. But they'll probably do the exercise

This exercise is basically an extension pattern which is likely to recruit the anterior RC (internal rotator) in its stabiliser role. There is little load on external rotators in their role to perform ER.

Demanding for the back, requires a good lumbar locking

Less specific effect for ER through range

Isometric ER combined with elevation and step-up



Dont understand why we need a bench

this is not isometric ER but isometric ABD in the picture (arms are extended)

recruits kinetic chain

Not for healthy players, rehab yes.

Easy to do and includes kinetic chain

If she in same time had lifted her right leg up to 90 degrees and put her heep forward it will be likely the shot

Not sure the step-up does anything -- it may reduce the isometric pull and end up as an ineffective exercise

This is a good one.

Players might like the involvement of the legs

This exercise will train external rotators in both mover (rotator) & stabiliser roles, is performed in the functionally relevant upright position but is training them statically & in approximately mid range. Inner (shortened) & outer (lengthened) range strength relevant to throwing may not be effectively achieved.

Isometric contraction of ERs, less specific

This is not intended as a strengthening exercise but a switch on exercise so something I would use as a warm up or switch on pre strengthening exercises to increase their effectiveness - reinforces 'normal' timing

Always good to combine exercises and make them sport specific. However, my experience is when I´ve tried this is that it either becomes a exercise for lower limb or shoulder. Hard for them to combine it. And therefore lower effectiveness for ER strength.

Combined exercise: ER with horizontal ABD and elevation (V-W-exercise) in standing

Even better like a pair exercise

recuperation during forward movement will delay the onset of fatigue - less likely they will do this if partner is needed / when performed with partner at same time so both athletes face eachother and do this excercise will increase adherence

Would be more effictive on 1 leg

Isometric contraction of ERs, more dynamic

works scapular stabilizers and can accentuate scapulr posterior tilt

Depending on how many exercises a player should perform but in my opinion not as good/effective as the above exercises w dumbell.

I am slightly worried about this exercise because again it can easily ead to overuse of the supraspinatus and pain. Why not bring the arms down as well?

This exercise is basically an extension pattern which is likely to recruit the anterior RC (internal rotator) in its stabiliser role. External rotators are being strengthened isometrically at end range ER - the deceleration phase of a throw requires them to work eccentrically into outer range (lengthened position)

V and W well supported in EMG studies (W> V) - would incorporate a step back to emphasise kinetic chain and optimise local recruitment.

In this exercise two players can do the exercise at the same time if they have two thera-bands. Either they can do it at the same time or one keep it still while the other one perform the exercise. Regardless my experience is fix components + pair exercise = higher compliance

Eccentric single arm Y-raise in standing

Even better like a pair exercise

Very relevant for handball

more for lateral rotation

Mimics the sport

Good you have the other arm to control it

recuperation possible in forward movement so less fatigue - same remark for partner as above

More likely because you can "prove" sport-specific parallell to the player.

This exercise will train external rotators in both mover (rotator) & stabiliser roles, is performed in the functionally relevant upright position but is training them statically & in approximately mid range. Inner (shortened) & outer (lengthened) range strength relevant to throwing may not be effectively achieved.

ERs eccentric contraction, elastic offers less resistance than a dumbell

Think this would have increased strengthening effect if emphasised 90/90 position at end but like eccentric element

Full rotational range of motion in supine position

To complicated to organise

a motor control exercise

Seems too simple

only small range of motion for ER and small lever arm so more IR strength training - need to staple 4 steps before you can start will decrease adherence

To much technique and to much ROM dependent. Risk for compensation when moving into IR.

This exercise will train external rotators in both mover (rotator) & stabiliser roles in outer (lengthened) range as well as train recruitment timing & co-ordination between anterior & posterior RC. Inner (shortened) range ER strength not addressed & not performed in the upright, functionally relevant position for handball.

Over compensation of shoulder (forward position during the ERs eccentric phase) in the supine position than in the prone position, requires more equipment

Easy to do but ? least effective in terms of action of cuff in supine?

Often hits the rotor cuff good and sport specific. Downside, have to have a table.

Combined exercise: Push up position, ER in 90°ABD with horizontal ABD and trunk rotation

Better with a handball/small ball?

likely they will do it as it is challenging - ER component is not large in this exercise so not most effective exercise

Good and relevant for handball

more functional

Healthy players often like these kind of exercises because they are challenging, maybe not the most effective ER.

nice and challenging

The external rotators are being strengthened isometrically at end range ER only, & at end position (as illustrated) I think the shoulder internal rotators will be maintaining the shoulder rotation position. Body positioned presumably designed to include core stability training but not in the upright, functionally relevant position for handball.

Difficult to execute, very specific of the handball gesture because combining arming and rotation of the trunk

Nice incorporation thorax and strengthening functional pattern

Full rotational ROM in prone position

For the gym

Better control than standing up, can still be painful

Request additional material, more analytic motion for ERs

same remark for adherence with the 4 steps setup - this is effective exercise

concentric and eccentric for rotator cuff and challenging scapular stabilizers

I think more or less the same effectiveness as standing but more gear needed so harder for teams to execute.

This exercise will train external rotators in their mover (rotator) role in inner (shortened) range as well as train recruitment timing & co-ordination between anterior & posterior RC. Outer (lengthened) range ER strength not addressed & not performed in the upright, functionally relevant position for handball.

Horizontal ABD in standing

Pairs?

not specific for ER - same remark for partner that holds theraband

To much rehab.

not specific

more scapular stability. could use for scapular humeral dissociation

This exercise is basically an extension pattern which is likely to recruit the anterior RC (int

Elastic offers less resistance than a dumbbell, ideal exercise for the inter-scapular muscles

Emphasis posterior deltoid versus ER? Also limits range of ER i.e. lacks inner and outer range?

Eccentric ER in standing

Gym

Low load exercise

I prefer in the lying position.

Coordination of the exercise is difficult

This may be difficult for the athletes to perform properly.

Hard to perform with good control because of limitations in IR.

not easy to perform correct, a lot of compensation so less effective probably

All exercises in standing position is likely to handball and with eccentric ER is good

This exercise will strengthen external rotators mostly in their outer range ie mid to lengthened position, &, being in the upright position, is being done in a functionally relevant position for handballers.

Scaption combined with ER in standing

Pair?

not specific for ER - easy to perform standing

Very goog exercise we use a lot

To much rehab.

Very specific, easy to perform

conditions through range humeral external rotation will condition scapular external rotation too

This exercise will train external rotatots in both a stabiliser (in conjunction with the anterior RC) & mover role with most load into abduction & much of the "rotation" being performed in the forearm ie by supinators

Elastic offers less resistance than a dumbbell, ideal exercise for the inter-scapular muscles

Limits the range in terms of inner and outer range ER with long lever and caption

Horizontal ABD in a 3-point kneeling position

Gym

not specific for ER - little bit boring exercise

concentric and eccentric ER with scapular stability required . Could integrate lower limb and trunk

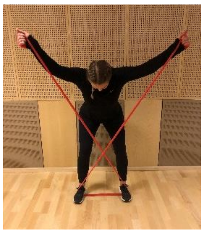
kneeling position not very demanding

More likely and more effective if done in a circuit with for example 2 more exercises in the same position.

This exercise is basically an extension pattern which is likely to recruit the anterior RC (internal rotator) in its stabiliser role. External rotators will be working in shortened range under relatively low load & not in upright position.

Personally believe and think EMG supports that need ER range to ensure strengthening though inner to outer range.

Scaption in a bent over squat position



Pair

not specific for ER - bent over is fun to train and needs no setup

Not very easy to perform correctly

very complicated

Request a good lumbar locking

Leaning forward increases effectiveness and on the "road" theraband is good. Otherwise I prefer dumbells.

This exercise is basically an extension pattern which is likely to recruit the anterior RC (internal rotator) in its stabiliser role. External rotators will be working in shortened range (near end range ER) under relatively low load.

As per previous comment - if emphasised ErRwould have more specific effect for ER - working long lever caption will increase mid range but ? through range limitations.

Resisted wall slide

To boring

To much rehab, to little "load" on ER.

More for Serratus Anterior

may be too easy

Not really specific of the posterior cuff

concentric and eccenrtric ER with scap contorl. Could add hip abduction and lower limb work

not specifif for ER - too easy for handball player / better for patients in shoulder pain, no reason to use semi-closed chain in athlete

This exercise will train external rotators in a stabiliser role associated with flexion, statically & in their outer (lengthened) range) only. Inner (shortened) range, dynamic strength relevant to throwing may not be effectively achieved.

Insufficient loading for strength effect- a potential warm up for emphasising recruitment but would only use this in acute pain population who need wall support as well as resistance to emphasise cuff recruitment

Combined exercise: ER with protraction

Looks very hard

very effective - challenging exercise so higher adherence

Relevant for underarm shot

Possibly will conditon scapular downward rotation

As warm-up YES but then I would recommend standing against the wall.

This seems to be very difficult and will require training.

bit compliacted, compared to the one standing up

Mid range contraction of external rotators in mover role. Body & arm position not functional for handball. Inner (shortened) & outer (lengthened) range strength relevant to throwing may not be effectively achieved.

Request a good control of the push-up position

Studies show that pulling out i.e. pulling band versus pushing out into loop of theraband reduces effectiveness as recruit internal rotators to resist the ER pull i.e. increase pecs

Single-arm push-up

Better up to w wall?

too heavy for some / Hard to execute

Needs good guidance to perform properly.

not specific for ER - on feet very heavy for recreational handball player (female)

requires scapular stability could facilitate protraction and scapular downward rotation

Same answer as above, FUN and CHALLENGING but maybe not the most effective.

This exercise will train external rotators statically in a stabiliser role associated with flexion under very, very high load. Inner (shortened) & outer (lengthened) range, dynamic strength relevant to throwing may not be effectively achieved.

Has a role in upper limb performance and general strength but ? not specific enough to improve ER optimally

Standing ER in 0° of ABD

To much rehab.

Not specific

functional. Concentric and eccentric ER

they can easily hold the band themselves

Relevant underarm shot. If you do this eccentric on the way back

For exercises to use before/in handball sessions its best with bands, balls or no exercises, will work best. Pair exercises is also good, thats not so boring. For exercises to do together/in the strength program, it work well with dumbbells.

The only barrier to implementation is the availability of the elastic, and the only issue with the exercise is calibrating the resistance which is always easier with weights than elastic.

boring exercise - athlete needs ER strength at higher abduction angles

This exercise will strengthen the external rotators as movers (rotators) mostly in inner (shortened) range. As not in an elevated shoulder position not functionally specific for handball.

Less effective because elbow to the body (at 0° of abduction) than at 90° of abduction, moreover, less effective than with a dumbell

My issue with this is I believe the evidence supports that least effective position is 0 degrees as more likely to over recruit lats and pecs in this position- better relative isolation at 30 degrees elevation and above - 90 most effective. One recent study supports 0 degrees but didn't measure impact on other muscles.

Reasons for doing the exercises during warm-up or as separate strength training

During handball warm up:

Then it is a part of the training and not something extra you need to do. I think it is easier to make the athletes to it when it is a part of the warm up and handballpart.

When you put the exercises into the warm-up/before court time, the players are not tired in the shoulders, and will do the exercises more correct then after the session.

will increase adherence, not most efficient to increase strength

good prep for cuff prior to play

From the exercises you have suggested I think they suits better as preparation exercises before throwing. If we discuss "strength" training I would prefer to perform these after practice.

It will increase the adherence

Some exercises during warm up and some during separate strength training. If included during warm up chances are greater they wil do it, but if warm up gets too long they will stop doing it. If they have separate strength training sessions that will be perfect, but this is not always the case for lower level players

If we ask only 2 or 3 exercices, the palyer can do them befor training as a warm up. By the way, we will be more certain that the player will be more compliant.

As separate strength training:

If the emphasis is on strength, then I think that's where the players should be doing it. I get it that warm up is logistically much easier, but, again just my opinion, to get real prevention benefits, this has to be actual strength training, so relatively high intensity (definitely >70% of 1RM) and about 3 sets, depending on training history

Because in warming up they are to much social, that meens they do warming up together and the quality will be less. But if the coach is postsive for this training it will be ok. But my experience tells me that we should have separate training.

I would say both if possible. During warm-up, a light version should be used, as too heavy strength training could reduce performance and even increase injury risk.

I believe warm-up has a different objective as preparing the player for the match.

The aim of the program is to increase external rotator strength. I think linking it to their "strength training program" would reinforce the importance of external rotation strength to maximise shoulder function & prevent injury.

In reality my real answer would be a combination of the two - key exercises to switch on the system would be a feature of warm up and strengthening sessions. I would utilise some of the strength exercises at lower level as part of warm up too - e.g. supported cuff- I would just not work to fatigue as part of warm up.

General comments

Dose: getting a high enough load to grow some muscle. Either going until true fatigue, which is logistically simplest, or occasionally doing a 1RM or predicted 1RM and work at least 70% of this in the sessions.

If we need to reenforce the ER muscles, it might be interesting to propose heavier loads

Important to have a range of loads/weights so that each player may choose the appropriate resistance.

I believe that there is necessary to build solid muscular strength before the athlete can benefit optimally from the plyo-exercises.

I recommend static to dynamic to elastic-dynamic (plyometric) exercises in that order.

I am a great believer in increasing the sensorimotor elements and cortical value of any preventative or pre-emptive exercises. Hence I like to use dynamic exercises that emphasise the whole kinetic chain and patterns plus something isolated to target the specific mobiliser role of the rotator cuff and deltoid.

Think need to make sure that the scapular stabilizers are functioning properly to give optimal platform for cuff

I think it is VERY important to integrate the kinetic chain from the start

Incorporation of exercises to the core.

Its i bit more funny to use exercises with a partner.

Every execise should have relvans for the technique in handball. Functional training

I would include music and rhythm

I think many of the exercises are very good and easy to perform for handball players. My experience We need some "extra" exercises to circle with so the players get something new to do every third or fourth week, not necessarily progression but just something other than what they are used to. Important both for effect and adherence.

Reasons for doing the exercises during warm-up:

Then it is a part of the training and not something extra you need to do. I think it is easier to make the athletes to it when it is a part of the warm up and handballpart.

When you put the exercises into the warm-up/before court time, the players are not tired in the shoulders, and will do the exercises more correct then after the session.

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In reality my real answer would be a combination of the two - key exercises to switch on the system would be a feature of warm up and strengthening sessions. I would utilise some of the strength exercises at lower level as part of warm up too - e.g. supported cuff- I would just not work to fatigue as part of warm up.

Appendix V

Protocols for testing of shoulder isometric strength and range of motion

Isometric rotational strength testing

Materials: Standard examination table, hand-held dynamometer, towel

Standardized warm-up procedure: Ten repetitions of full ROM flexion, abduction and circumduction, all performed at a smooth but rather quick velocity, and 10 repetitions of puh-ups against the wall.

The player is positioned supine on the examination table with the shoulder abducted 90° and the elbow flexed to 90°. The olecranon process should be at the side of the table.

If necessary, place a towel underneath the distal humerus. It should be folded sufficiently to ensure frontal plane alignment of the upper arm.

The arm not being tested rests on the belly.

The rater is standing in the opposite direction of the movement tested, holding the dynamometer with the lateral hand, while the medial hand stabilizes the players humerus by pressing the fist against the examination table on the medial side of humerus.

Passively move the arm in internal and external rotation before examination start, limiting the movement only to the glenohumeral joint, in addition to saying a standardized verbal instruction: *"I am going to test the strength of your shoulder's internal and external rotation. You should move your arm only in the direction showed. Your upper arm is not supposed to move. Your upper body should stay in contact with the examination table without moving. You will have one familiarization trial followed by three maximal trials. Increase the pressure against the dynamometer gradually when I tell you to and press with all your strength for 3 seconds on my count."*

The dynamometer is placed 2 cm proximal to the styloid process of the ulna on the dorsal (ER strength measurement) and on the ventral (IR strength measurement) forearm.

Instruct the player to apply and hold maximal pressure for 3 seconds by saying: *" Are you ready..... increase the pressure....press maximum, 1, 2, 3, stop." "Let me know if you experience any pain during the test."*

Perform three repetitions of three seconds of maximal voluntary effort using a make test (gradually increasing resistance up to maximum without breaking the subjects contraction) and calculate the mean.

Internal rotation strength is measured before external rotation strength

Glenohumeral rotational range of motion testing

Materials: Standard examination table, digital goniometer (Easy Angle), towel

Standardized warm-up procedure: Ten repetitions of full ROM flexion, abduction and circumduction, all performed at a smooth but rather quick velocity, and 10 repetitions of push-ups against the wall.

The player is positioned supine on the examination table with the shoulder abducted 90° and the elbow flexed to 90°. The olecranon process should be at the side of the table.

If necessary, place a towel underneath the distal humerus. It should be folded sufficiently to ensure frontal plane alignment of the upper arm.

The arm not being tested rests on the belly.

Passively move the arm in internal and external rotation before examination start, limiting the movement only to the glenohumeral joint, in addition to saying a standardized verbal instruction: *"I am going to test the movement of your shoulder's internal and external rotation. Try to relax as much as possible by feeling the "heaviness" of your arm. Let me know if you feel any pain You will have one familiarization trial before we conduct three measurements. "*

The goniometer is zeroed against a wall, in the same plane of measurement as the ROM measurement is taking place, immediately before measurement.

The rater is standing in the opposite direction of the movement tested, stabilizing the scapula with the medial hand; one thumb on coracoid and the rest of the fingers grasping the spine of the scapula. The lateral hand is grasping the players forearm, guiding the passive rotational ROM until the forearm stops moving.

An assistant measures the ROM, aligning the goniometer in line with the olecranon and the ulnar styloid process.

Perform three ROM measurements in each direction and calculate the mean

External rotation is measured before internal rotation.

Appendix VI

OSTRC shoulder prevention program (Norwegian)

Forebygging av skulderproblemer i håndball

Øvelsene gjennomføres som en del av oppvarmingen i forkant av kast med medspiller og målvaktsoppvarming. Minimum tre ganger per uke. De fem øvelsene skiftes ut hver sjette uke.

Under gjennomførelsen av øvelsene skal spilleren ikke oppleve smerte fra skuldrene.
Ved smerte reduseres progresjonsnivået.
Dersom nivå A også gir smerte kontaktes fysioterapeut for veiledning

Ved oppstart av en øvelse følges anbefalt antall repetisjoner. Ved behov kan antall repetisjoner økes, eventuelt hardere strikk eller tyngre vektball benyttes. Øvelsene skal være tunge for utøverne!

Ved spørsmål, kontakt Bettina Nævestad, epost: bettinan@student.nih.no, mobil: 45213016,
evt. Hilde Fredriksen, e-post: hilde.fredriksen@nih.no mobil: 99709997

Gå inn på *www.skadefri.no* og se video av øvelsene.

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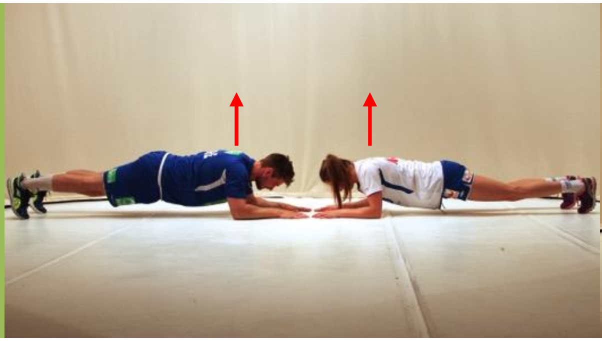
Øvelse 1

Nivå A, uke 1-6

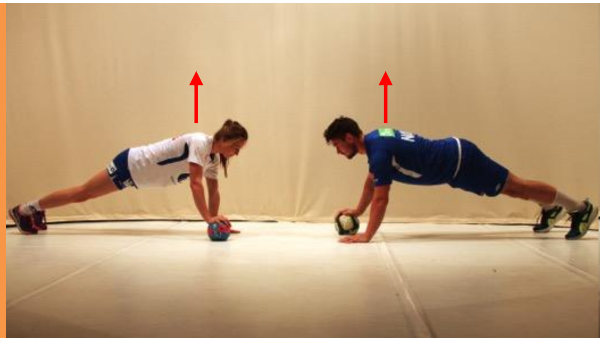


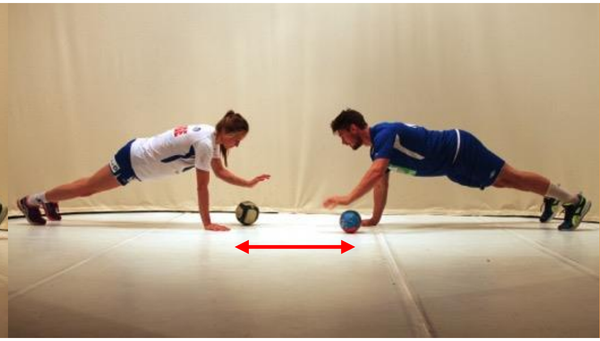
__Rotasjon av overkropp__

Planke-posisjon* på albuene
Løft den ene armen og roter opp mot taket med strak arm
Følg hånden med blikket
Rolig tempo
Vekselsvis mot høyre og venstre

10-16 repetisjoner x 3 serier

Nivå B, uke 7-12



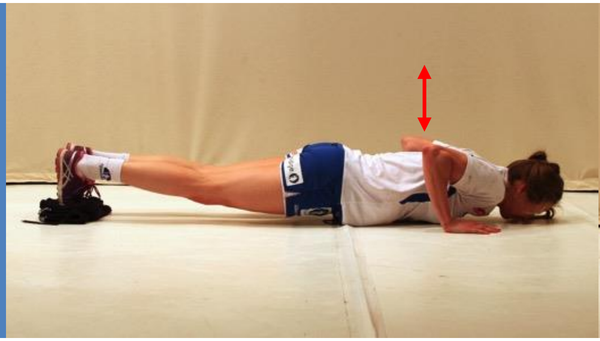


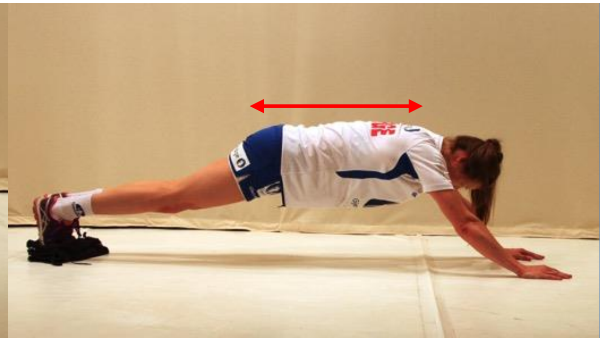
__Planke med pasning__

Parøvelse
Push-up pluss posisjon*
Front mot hverandre med ca 2m avstand
Trill ballen til hverandre
Annenhver hånd

10-16 repetisjoner x 3 serier

Nivå C, uke 13-18





__Push-up pluss med skyv__

Push-up pluss posisjon* med tær/knær på overtrekksvest
Gjennomfør en push-up, skyv deretter kroppen bakover med strake armer
Returner til startposisjon,- gjenta

10-15 repetisjoner x 3 serier

** Planke og push-up pluss posisjonen inntar du ved å presse hendene/albuene mot gulvet slik at overkroppen løftes.*
Under gjennomføring av disse øvelsene skal du stabilisere i mage og rygg for å holde en naturlig svai i korsryggen og unngå knekk i hofteleddet

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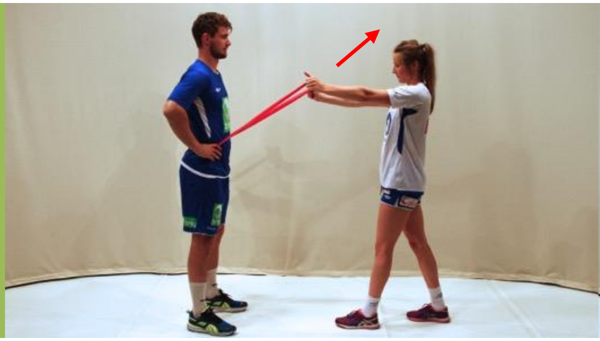
Øvelse 2

Nivå A, uke 1-6



Stående Y-flyes*

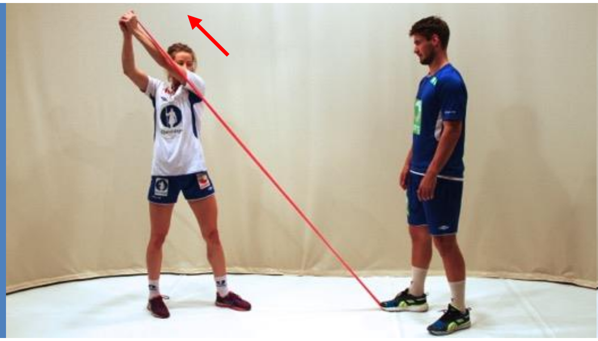
Parøvelse stående mot hverandre
Partner fikserer strikk (som krysses) fra hoftehøyde. Stå med føttene i skuddposisjon og press armene bakover i en Y-posisjon. Tomlene peker bakover.
Gjør et kort hold i ytterstilling.
10-15 repetisjoner x 3 serier

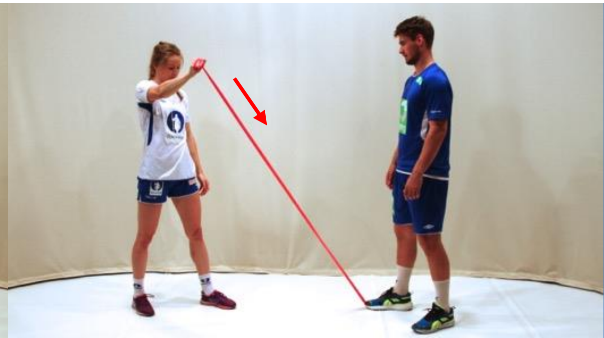
Uke 7-12

Pil og bue*

Parøvelse stående mot hverandre.
Partner fikserer strikk i skulderhøyde.
Stå i skuddposisjon og start med å trekke skulderen bak/ned.
Fortsett ved å trekke albuen bakover og roter mot samme side
Gjør et kort hold ytterstilling.
10-15 repetisjoner x 3 serier

Nivå C, uke 13-18





Rolig senkning av arm*

Parøvelse stående mot hverandre
Stå i skuddposisjon
Stram strikken ved å trekke den opp i skuddposisjon med 2 hender
Senk deretter rolig med EN hånd (skuddarmen) til utgangspunktet
Bruk 3 sek på senking av armen
10-15 repetisjoner x 3 serier

** Løft brystet og trekk skuldrene bak og ned før du starter øvelsen. Hold lave skuldre gjennom hele bevegelsen!*
Skift til hardere strikk når antall repetisjoner mestres uten anstrengelse!

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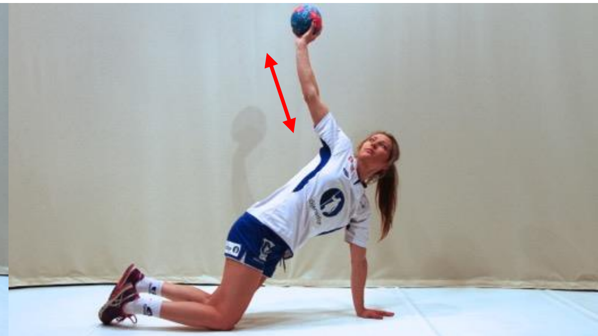
Øvelse 3

Nivå A, uke 1-6



Rotasjon av overkropp

4-fotstående med ball.
Roter opp mot taket med strak arm
Følg ballen med blikket
Vekselsvis mot høyre og venstre

10 repetisjoner x 3 serier

Nivå B, uke 7-12

Albu glidning langs vegg

Stå med albuene plassert mot en vegg
med skulderbreddes avstand
Press albuene opp langs veggen
Hold underarmene parallelle
Stabiliser i mage og rygg
og unngå svai i ryggen
Hold ytterstillingen i 30 sek
30 sekunder x 3 serier

Uke 13-18

Skulderpress mot vegg

Plasser armene i skulderhøyde inntil
veggen. Press armene opp over hodet
Sørg for at hender, underarmer, hode og
rygg er i kontakt med veggen
Kort hold ytterstillingen

10 repetisjoner x 3 serier

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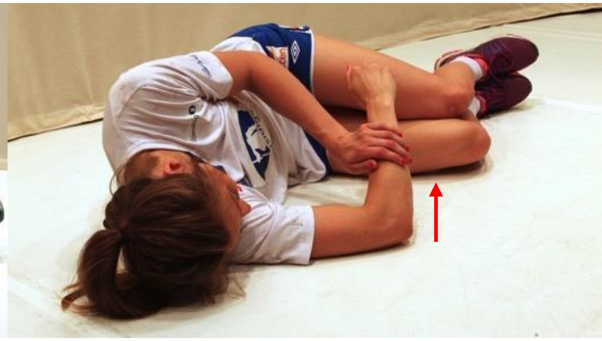
Øvelse 4

Uke 1-6 / 13-18

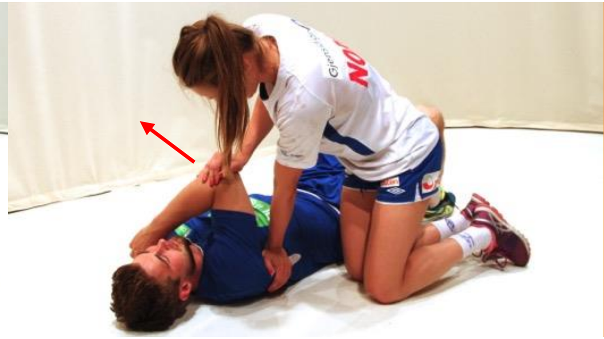


Sideliggende skuldertøyning

Ligg på siden på skulderen
Plasser skulderen litt under 90° bøy og albuen bøyd til 90°
Legg svakt press på underarmen med motsatt hånd, slik at skulderen innadroteres

3 x 30 sekunder

Uke 7-12/ 18-24



Ryggliggende skuldertøyning

Parøvelse
Plasser skulderen litt under 90° bøy med hånden på motsatt skulder.
Partner stabiliserer skulderbladet med ytterste hånd og presser albuen over midtlinjen med motsatt hånd

3 x 30 sekunder

Begge øvelser gjøres kun på skuddarmen!

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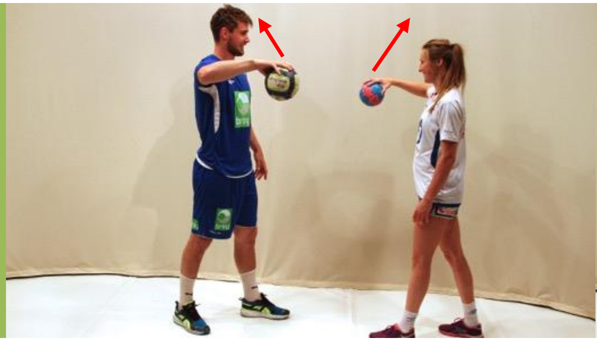
KLOKE AV SKADE

Øvelse 5

Nivå A, uke 1-6

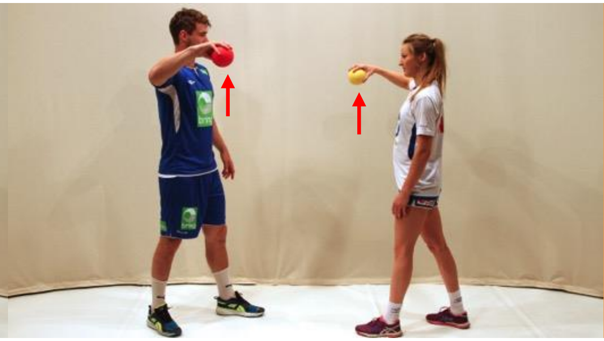


*Utoverrotasjon**

Albue og skulder plasseres i 90°
Bruk håndball eller liten vektball.
Start med skulderen innadrotert.
Utadroter deretter rolig og kontrollert

20 repetisjoner x 3 serier

Nivå B, uke 7-12



*Slipp og grip**

Albue og skulder plasseres i 90°
Bruk håndball eller liten vektball.
Slipp ballen og grip den umiddelbart
Returner til startposisjon

20 repetisjoner x 3 serier

Nivå C, uke 13-18

*Kast bakover**

Parøvelse
Utøver knestående som vist på bildet
Bruk håndball eller liten vektball.
Partner kaster ball over skulder
Utøver fanger ballen og kaster tilbake

20 repetisjoner x 3 serier

** Løft brystet og trekk skuldrene bak og ned før du starter øvelsen, og hold lave skuldre gjennom hele bevegelsen!*
Benytt tyngre vektball når øvelsene mestres uten anstrengelse.
NB: øvelsene gjøres kun med skuddarmen!

Appendix VII

Exercise description shoulder external rotation strength exercises

Shoulder external rotation strength exercises for handball players

Two shoulder external rotation exercises are performed AFTER regular handball training three times per week

The two exercises are changed every other week

The following applies to all exercises:

- Three set of each exercise
- In the starting position the elastic band is stretched to minimal resistance
- The goal is to use a resistance which the player is able to perform 8 repetitions with 2 reps in reserve (2RIR). THE EXERCISES ARE MENT TO BE HEAVY!
- If the player is able to perform more than 12 reps with 2RIR, increase the resistance

The resistance is increased by:

- Using a stronger elastic band (different colour)
- Make the elastic shorter by wrapping it around the hand

There should be no shoulder pain during the exercises, but your muscles are supposed to be tired. You might also experience muscle soreness afterwards due to the strength training.

External rotation in 90° of abduction, in a three-point kneeling position

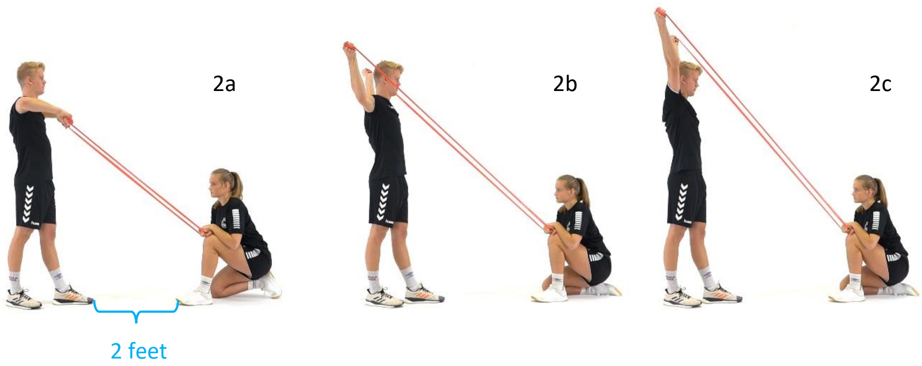
The player is in a in a three-point kneeling position (knees straight below hips, supporting hand straight below shoulder) with the shoulder abducted to 90° and the elbow flexed to 90°.

The elastic band is anchored by the partners foot, midway between the players knee and ankle (same side as dominant arm)

Start in full internal rotation (fig 1a) while the shoulder blade is kept slightly retracted

Rotate through full range of motion from full internal rotation (fig 1a) to full external rotation (fig 1b)

Combined exercise: external rotation with horizontal abduction and elevation (W-Y-exercise) in standing



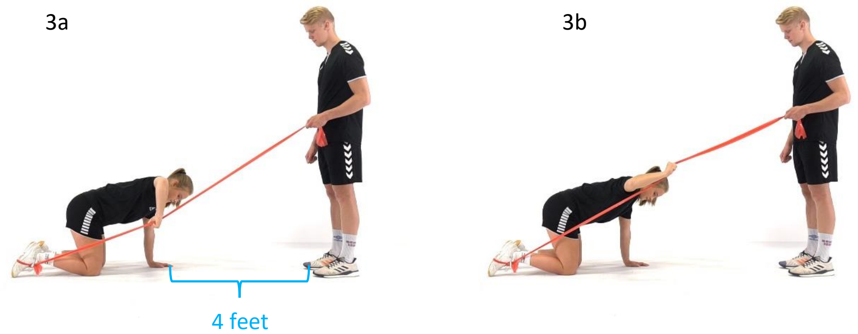
Player and partner are facing each other, the players feet are in a «throwing position». The distance between the players and partners toes is 2 feet (fig 2a).

The player grasps both ends of the elastic band, while the partner anchors the midpoint of the band at the same level as the players knees.

Start with the shoulders in 90° of abduction and full internal rotation, while the shoulder blades are kept slightly retracted and elbows in 90° of flexion. (fig 2a).

Rotate through the full range of motion (W, fig 2b) and extend the elbows to a Y-position (fig 2c)

Full rotational rotation in 90° of abduction in a three-point kneeling position



The player is in a in a three-point kneeling position (knees straight below hips, supporting hand straight below shoulder) with the shoulder abducted to 90° and the elbow flexed to 90°.

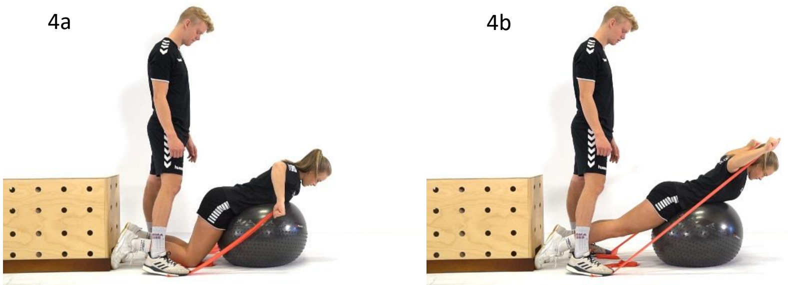
One end of the elastic band is anchored with a loop around the players foot (same side as dominant arm), the other end is held by a partner in front of the player, same direction as the players forearm when the shoulder is in maximum external rotation (fig 3b)

Distance from the players supporting hand to the partners toes is 4 feet (fig 3a)

Start in full internal rotation (fig 3a) while the shoulder blade is kept slightly retracted

Rotate through full range of motion from full internal rotation (fig 3a) to full external rotation (fig 3b)

Combined exercise: External rotation with hip extension prone on a Swiss ball



The player is in a kneeling position with trunk on a Swiss ball and feet against a wall

The elastic band is anchored by the partners' feet, beside the players knees

Start with the shoulders in 90° of abduction and full internal rotation, while the shoulder blades are kept slightly retracted and elbows in 90° of flexion. (fig 4a).

Push out (extend hips and knees) while moving into full external rotation (fig 4b)

External rotation in 90° of abduction in a bent over squat position

5a

Player and partner are facing each other. The distance between the players and partners toes is 1 foot. The player is standing in a bent over squat position, with parallel feet and upper body 45° inclined (fig 5a)

Start with the shoulders in 90° of abduction and in full internal rotation (fig 5a) while the shoulder blade is kept slightly retracted

Rotate through full range of motion from full internal rotation (fig 5a) to full external rotation (fig 5b)

Reverse catch plyometric exercise

6a

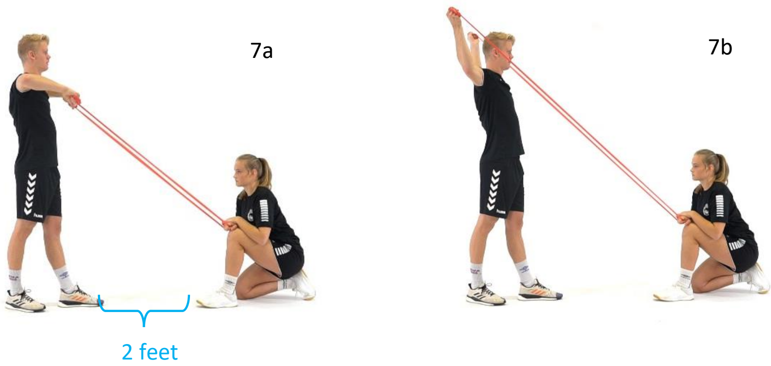
6b

6c

The player is in a half kneeling position with non-dominant in front (fig 6a)

From behind the player a partner throws a plyoball towards the player, who catches the ball in the 90/90 position , decelerates the ball, and then rapidly throws the ball back, maintaining the arm in the 90/90 position (fig 6a-c)

Standing external rotation in 90° of abduction



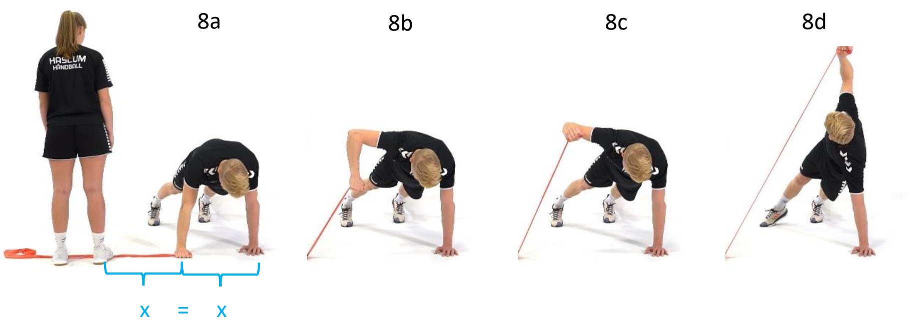
Player and partner are facing each other, the players feet are in a «throwing position». The distance between the players and partners toes is 2 feet (fig 7a).

The player grasps both ends of the elastic band, while the partner anchors the midpoint of the band at the same level as the players knees.

Start with the shoulders in 90° of abduction and full internal rotation, while the shoulder blades are kept slightly retracted and elbows in 90° of flexion. (fig 7a).

Rotate through the full range of motion (fig 7b)

Combined exercise: ER in 90° of abduction with horizontal abduction and trunk rotation in a push-up position



The player is in a push-up position with hands shoulder width apart

The elastic ban is attached under the partners foot, lateral to the players dominant arm, same distance as between the players hands (fig 8a)

The player lifts the elbow (fig 8b), rotates the shoulder externally through full range of motion (fig 8c), pulls the arm backwards as in throwing (the hand is leading the movement) and rotates the trunk (fig 8d)

Hilde Fredriksen // Prevention of shoulder injuries in handball