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SPORTS MEDICINE

Decreased external rotation strength is a risk factor for overuse shoulder injury in youth elite handball athletes

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Abstract

Purpose Overuse shoulder injuries are common in youth handball, but research is limited. The purpose of this study was to identify pre-season risk factors associated with overuse shoulder injuries in this population.
Methods One-hundred and thirty-eight (70 boys and 68 girls) youth elite players (age 14.1 ± 0.8 years, height 175.2 ± 8.2 cm, weight 64.0 ± 9.6 kg) completed a pre-season screening protocol. Passive glenohumeral range of motion and maximum external (ER) and internal rotation (IR) strength were measured with a manual goniometer and a hand-held dynamometer. Scapular dyskinesia and maximum throwing velocity were also assessed. Players completed standardised questionnaires over the 2017–2018 season and reported any overuse shoulder symptoms.
Results Decreased isometric and eccentric ER strength was identified as a risk factor for overuse shoulder injury, both for absolute (OR 10.70, 95% CI 1.2–95.6, $p = 0.034$) and normalised ER strength (OR 1.2, 95% CI 1.0–1.4, $p = 0.015$) and the ER:IR strength ratio (OR 1.2, 95% CI 1.1–1.5, $p = 0.012$). ER gain of more than 7.5° ($p = 0.025$) and GIRD of more than 7.5° ($p = 0.014$) were identified as risk factors for overuse shoulder injury in girls. Scapular dyskinesia (OR 1.1, n.s.) and maximum throwing velocity did not seem to contribute to injury risk. The average response rate was 63%.
Conclusion In elite youth handball, deficits in ER strength is a risk factor for overuse shoulder injury for both sexes; ER gain and GIRD are only risk factors for girls. Focused pre-season assessments may aid the identification of risk factors for shoulder overuse injuries and the application of specific programmes to reduce risk.
Level of evidence II.

Keywords Hand-held dynamometry · Goniometry · Scapular dyskinesia · Range of motion · Throwing · Overhead · GIRD · External rotation gain

Introduction

Handball is one of the most popular team sports worldwide, particularly in Europe. Thus, handball has increasingly become a focus of interest to sports physicians and orthopaedic surgeons. Handball is characterised by a multitude of repetitive and highly specific patterns of throwing movements. When such patterns are performed at high speed over a long period of time, these sports-specific motor stimuli evoke particular responses. During these responses, certain biological structures undergo adaptations that enable athletes to adequately process the load. These sports-specific adaptations are characterised by an asymmetrical distribution of load between the right and left side or the front and back of the body. Many of these adaptations cause changes in the muscular load and can sometimes lead to non-physiologic loading of certain musculoskeletal structures, exceed the stress tolerance of the structures and facilitate the development of overuse injuries.

During one season, up to 25% of youth handball players sustain overuse injuries of the shoulder [1, 7]. Prevalence is particularly high in female players [7, 31]. Prevalence rates

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of shoulder pain of over 60% have been reported for adolescent handball players [33]. However, research on youth athletes is only limited, despite the size and importance of this team handball population. Biological adaptations of the dominant shoulder, such as external rotation (ER) gain and glenohumeral internal rotation deficit (GIRD), have been described with conflicting results as risk factors for sustaining an overuse shoulder injury [5, 10, 22, 26].

Improved understanding of what physical factors may increase the risk of injury in this high risk group would enable better screening and injury prevention strategies. Thus, the purpose of this study was to identify risk factors for overuse shoulder injuries in youth handball players over the course of a full season. Based on previous findings, we hypothesised that increased external glenohumeral range of motion (ER gain), GIRD, decreased rotator cuff strength, scapular dyskinesia and high throwing velocity are risk factors for overuse shoulder injury in youth handball players. This study may help identify focus points for injury prevention programmes for overuse shoulder injury in this high-risk cohort at elite level.

Materials and methods

A prospective study including 138 (70 boys and 68 girls) elite youth handball players was conducted during the 2017–2018 season. Players were examined and screened for participation during the pre-season period. The inclusion criterion was being a youth handball athlete selected for the federal state at the time of assessment. Exclusion criteria were previous shoulder surgery, previous hospital admittance because of a shoulder injury or pain during the examination. One player experiencing pain during the examination of the range of motion was subsequently excluded, which resulted in 138 players included in the analysis.

Pre-season screening

At baseline testing, demographic data and standardised questionnaires were collected from all participating players. Demographic data included age, height, weight, handedness, player position, previous shoulder injuries, previous shoulder surgery and current shoulder symptoms. The study protocol included the evaluation of the glenohumeral ROM arc, external and internal rotation strength, scapular movement and throwing velocity.

To measure the glenohumeral ROM arc, two examiners evaluated internal rotation (IR) and external rotation (ER) using a manual goniometer. The total range of motion arc (TROM) was calculated by adding IR and ER for each side individually. Glenohumeral internal rotation deficit, ER gain and TROM gain were defined as difference in degree between the dominant and the non-dominant shoulder. For each player, the dominant shoulder was compared with the non-dominant shoulder to calculate glenohumeral internal rotation deficit (GIRD), TROM gain and ER gain.

For shoulder strength, isometric internal and external rotation strength as well as eccentric external rotation were measured using a handheld dynamometer (microFET 2, Hoggan Health Industries, Salt Lake City, Utah, USA). IR strength, ER isometric and eccentric strength and the ratio of eccentric and isometric ER to IR were recorded and calculated. Both the absolute and relative ('normalised') value to the player's body weight were calculated in percent and used for analysis.

To assess scapular kinesia, male players were asked to remove their shirts and female players to wear halter tops to allow observation of the posterior thorax and scapula. After demonstration of the movement, players were instructed to lift their arms while holding a 2-kg dumbbell (1 kg for female players) as described in previous studies [5, 6, 10, 28]. Scapular movement was categorised into two scales (presence of dyskinesia: yes/no; and severity: absent/moderate/severe dyskinesia) by an experienced rater in accordance with previous studies [6, 24, 28, 31].

In each of the three tests, both the dominant and the non-dominant shoulder were assessed. Testers were blinded to the handedness of the athletes [34]. All tests were conducted as described in the Karolinska Handball Study Protocol (KHAST) [6]. Our protocol differed from that study in so far as glenohumeral ROM was measured with a manual goniometer attached to a 3-kg weight that helped align the goniometer vertically. In contrast, the KHAST protocol used a horizontally held goniometer.

For testing the maximum throwing velocity, players were asked to stand 7 m in front of the goal and to throw as hard as possible at a target in the middle of the goal (1 × 1 m). The 7-m line was blocked with a tilted wooden bench, typical for training halls. Players were allowed to touch the bench but not to overstep after the throw. Throwing velocity was measured using a stationary radar gun (PR1000 Traffic Advisor, Pocket Radar, Santa Rosa, CA, USA). Every player was allowed three attempts, and the best result based on the fastest velocity was used for analysis. Boys used a size 2 ball (325–375 g, 54–56 cm diameter) and girls a size 1 ball (290–330 g, 50–52 cm) according to the official handball rules in this age group.

Injury registration

Using online survey software, a standardised questionnaire was emailed to all study participants at five time points during the season: after baseline screening, before the start of the season, after the preseason period, in mid-season and at the end of the season. Players were therefore monitored five times during the 7-month season. Automatic reminders were sent to non-responders after 7 days. In addition, coaches were routinely contacted to remind the athletes to complete the questionnaires.

The online questionnaire assessed any overuse injury during a handball training session or match according to standardised and previously used study protocols [1, 19, 31]. The questionnaire addressed the severity of symptoms and the extent to which the injuries affected participation in handball. An injury was categorised as an overuse injury if no traumatic event could be identified and as re-injury if it was sustained at the same body site within 2 months after the first injury [19]. In addition to the questionnaire, the German version of the Western Ontario Shoulder Index (WOSI) was used to assess overuse shoulder symptoms [14, 31]. The individual average severity score of the WOSI was calculated by adding up the scores of each player and by dividing the number of questionnaire responses. The average severity scores for the standardised injury questionnaire and the WOSI were dichotomised using a cut-off value of 20% to distinguish players with an overuse shoulder injury from uninjured players. For example, a WOSI Score of 2100 points would result in a cut-off value of 420 points.

Informed written consent was obtained from all study participants and their parents. The study design was approved by the Ethics Committee of the University of Regensburg (ID 17-895-101).

Statistical analysis

Paired *t* tests were used to compare dominant and non-dominant shoulder ROM and strength. Logistic regression models were used to identify risk factors for an injury in the dominant shoulder. The best cut-off value for strength and ROM measurements to predict an injury were determined by means of receiver-operating characteristic (ROC) curves in combination with the Youden index. Further subgroup analyses regarding differences between the two sexes were also carried out.

No a priori sample size was calculated because this study included all elite youth players of the Southern German handball federations.

Results

The anthropometric differences between the two sexes are shown in Table 1.

Table 1 Anthropometric and handball-specific data

Anthropometric data	Male players ($n=70$), mean ± SD	Female players ($n=68$), mean ± SD	Total ($n=138$), mean ± SD
Age (years)	14.7 ± 0.4	13.5 ± 0.6	14.1 ± 0.8
Height (cm)	181.2 ± 5.9	169.8 ± 5.9	175.2 ± 8.2
Weight (kg)	70.4 ± 8.5	58.5 ± 6.7	64.0 ± 9.6
BMI (kg/m^2)	21.7 ± 2.1	20.5 ± 2.0	21.1 ± 2.0
Team handball experience (years)	8.7 ± 2.3	7.9 ± 2.1	8.2 ± 2.2

SD standard deviation

Pre-season screening

The range of motion arc significantly differed between the two sexes (Tables 2, 3; Fig. 1).

The two sexes also differed in absolute and normalised shoulder muscle strength (Table 4; Figs. 2, 3).

Overall, 34 (25%) players (18 boys and 16 girls) showed signs of scapular dyskinesia, of whom 29 players (85%) had moderate scapular dyskinesia and five players (15%) severe scapular dyskinesia. No differences between the two sexes were found regarding the presence or severity of scapular dyskinesia. The mean maximum throwing velocity was 79.4 ± 12.2 km/h (boys 87.4 ± 7.7, girls 71.1 ± 10.4).

Injury questionnaires

Five questionnaires were distributed over the course of the season, and the total response rate was 63%. All 138 youth elite players (100%) answered the first questionnaire. The complete data of all five questionnaires were collected from 61 (44%) players. The last three questionnaires did not show any strong differences in response rates. There were no associations between shoulder pain or a player's injury history and data completeness.

Pain or overuse symptoms in the dominant shoulder was experienced by 36 (26%) players (17 boys and 19 girls) during the season. The average score of the Western Ontario Shoulder Index was 414 ± 310 points (462 ± 272 points for boys and 370 ± 344 points for girls). Sixteen players (12%, 9 boys and 7 girls) had a score of over 420, which is 20% of the maximum WOSI Score.

Fifteen (11%) players had sustained an injury to their shoulder prior to the investigated season. These injuries included three (sub-)dislocations, six rotator cuff injuries, one labral injury and one clavicular injury. For four players, the cause of injury was unknown.

Table 2 Total, internal and external glenohumeral range of motion for both sexes

	Male players ($n=70$)		Female players ($n=68$)		Total ($n=138$)	
	Dominant side, mean ± SD	Nondominant side, mean ± SD	Dominant side, mean ± SD	Nondominant side, mean ± SD	Dominant side, mean ± SD	Nondominant side, mean ± SD
Total ROM (°)	112 ± 29[a]	107 ± 28	120 ± 19[a]	116 ± 20[a]	116 ± 25[b]	112 ± 24
Internal ROM (°)	29 ± 9[a]	33 ± 10	38 ± 10[a]	41 ± 10	33 ± 11[b]	37 ± 11
External ROM (°)	88 ± 13[a]	79 ± 13	82 ± 16[a]	75 ± 16	85 ± 15[b]	77 ± 15

[a]Significantly different from the other sex

[b]Significantly different from the other shoulder

Table 3 External rotation gain, glenohumeral internal rotation deficit and gain in total range of motion in the dominant arm for both sexes

	Male players ($n=70$), mean ± SD	Female players ($n=68$), mean ± SD	Total ($n=138$), mean ± SD
TROM gain (°)	5 ± 18	4 ± 17	4 ± 18
GIRD (°)	4 ± 11	3 ± 11	4 ± 11
ER gain (°)	9 ± 14	7 ± 14	8 ± 14

Risk for overuse shoulder injury

Shoulder strength deficits were identified as a risk factor for overuse shoulder injury (Table 5). The risk factor passive range of motion also differed between the two sexes (Table 6).

Scapular dyskinesia was not found to be a risk factor for overuse shoulder injury (OR 1.1, 95% CI 0.75–1.60, n.s.). Throwing velocity did not differ between players with (75.4 km/h) and without (79.8 km/h, n.s.) overuse shoulder symptoms.

Discussion

The most important finding of this study was that ER strength deficits were associated with an increased risk of overuse shoulder injury in youth elite handball players. Higher than normal rotational arc adaptations, such as GIRD and ER gain, were associated with an increased risk of overuse shoulder injury, and male players seem to be susceptible at lower degrees of range adaptations.

Table 4 Absolute and normalised shoulder rotator muscle strength

	Male players ($n=70$)		Female players ($n=68$)		Total ($n=138$)	
	D, mean ± SD	ND, mean ± SD	*D*, mean ± SD	ND, mean ± SD	*D*, mean ± SD	ND, mean ± SD
Absolute rotator muscle strength						
Isometric external rotation (N)	143 ± 29[a]	162 ± 41	120 ± 28	136 ± 36	132 ± 30[b]	149 ± 40
Eccentric external rotation (N)	242 ± 47[a]	244 ± 37	195 ± 31	192 ± 33	219 ± 46	219 ± 44
Isometric internal rotation (N)	187 ± 27[a]	181 ± 28	139 ± 25	135 ± 26	163 ± 34[b]	158 ± 34
Normalised rotator muscle strength						
Isometric external rotation (N/kg)	2.1 ± 0.5[a]	2.3 ± 0.5	2.1 ± 0.5	2.4 ± 0.6	2.1 ± 0.5[b]	2.3 ± 0.6
Eccentric external rotation (N/kg)	3.5 ± 0.7[b]	3.5 ± 0.4	3.4 ± 0.5	3.3 ± 0.5	3.4 ± 0.6	3.4 ± 0.5
Isometric internal rotation (N/kg)	2.7 ± 0.4	2.6 ± 0.3	2.4 ± 0.4	2.6 ± 0.3	2.5 ± 0.4	2.5 ± 0.4
Ratio external: internal rotator muscle strength						
Ratio isometric external: isometric internal rotation	0.78 ± 0.16		0.88 ± 0.21		0.83 ± 0.19	
Ratio eccentric external: isometric internal rotation	1.30 ± 0.21		1.42 ± 0.21		1.37 ± 0.22	

D dominant shoulder; *ND* nondominant shoulder

[a]Significantly different from the other sex

[b]Significantly different from the other shoulder

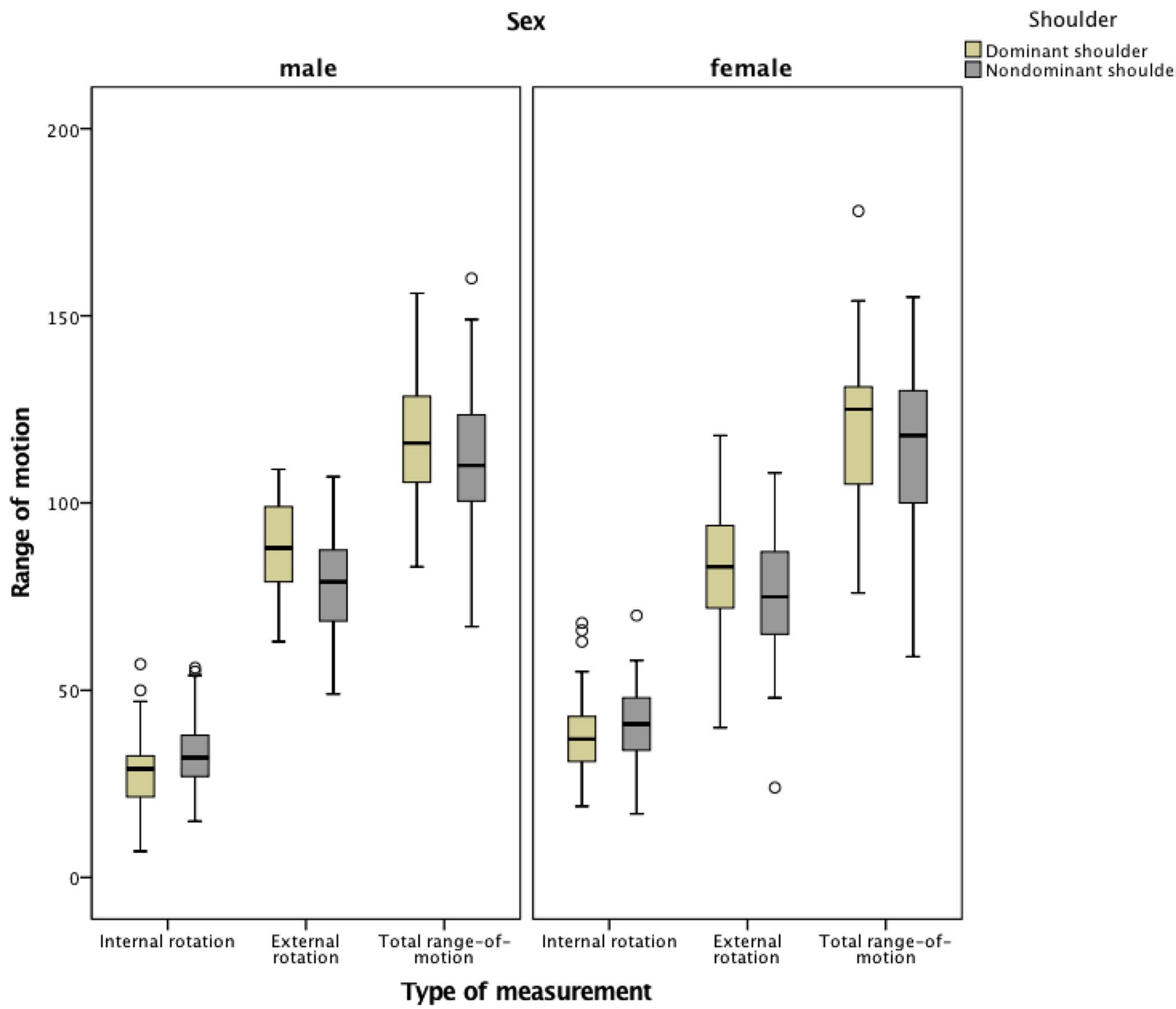

Fig. 1 Boxplots representing the glenohumeral range of motion between the two sexes. Range of motion was measured (°) for the dominant and non-dominant shoulder for internal rotation (IR), external rotation (ER) and total range of motion (TROM). Male players showed higher ER but lower IR and TROM

In total, 26% of handball players at a mean age of 14 years had pain or overuse symptoms in their throwing shoulder. This rate highlights the importance of studies focusing on the shoulders in youth handball. The prevalence of overuse shoulder injuries was comparable to that in the literature [5, 7, 20, 27, 31]. The current study showed that sports-specific adaptations of the throwing shoulder, such as shoulder ER gain and GIRD, are already developed at this age. Further studies should evaluate if players at a younger age and other levels of play, such as youth amateur players, show similar patterns of adaptation at this age.

Although adaptations in the passive glenohumeral range of motion arc in the dominant shoulder have been previously described in adult handball players, the current study was the first to examine the effects of handball in boys and girls [7, 9, 25, 31, 35]. Male players had a higher ER gain and a higher internal rotation deficit than female players. This finding may be explained by longer handball exposure, because male players were on average 1 year older and had therefore also played handball 1 year longer. Considerable changes in the passive range of motion arc were found to be only a risk factor for girls, especially in the case of adaptations of more than 7.5°. Interestingly, male players with overuse injury symptoms were susceptible at a lower degree of GIRD than female players, which may be explained by different pathomechanics and injury mechanisms. Future studies should investigate potential differences in overuse injury

Table 5 Shoulder strength as a risk of overuse injury in the dominant shoulder

	Group with symptoms of overuse injury ($n=16$)	Uninjured group ($n=122$)	Odds ratio (95% confidence interval)	p
Absolute muscle strength				
Isometric ER (Newton, N)	119 ± 32	133 ± 30	10.70 (1.2–95.6) per 10 N	0.034
Eccentric ER (Newton, N)	219 ± 52	219 ± 46	1.00 (0.9–1.1)	n.s.
Normalised muscle strength				
Isometric ER (N/kg)	1.8 ± 0.4	2.1 ± 0.5	1.2 (1.0–1.4) per 0.1 N/kg	0.015
Eccentric ER (N/kg)	3.2 ± 0.7	3.4 ± 0.6	0.56 (0.2–1.6)	n.s.
Eccentric ER < 2.90 N/kg	6 (38%)	17 (14%)	Both sexes: 3.53 (1.1–11.8) Men: 5.89 (1.2–27.9) Women: 1.38 (0.1–13.3)	0.047 0.034 n.s.
Ratio of ER:IR muscle strength				
Isometric ER:isometric IR	0.70 ± 0.15	0.84 ± 0.19	1.20 (1.1–1.5) (per 0.1)	0.012
Isometric ER:isometric IR < 0.75	11 (69%)	45 (37%)	4.29 (1.3–14.5)	0.019
Eccentric ER:isometric IR	1.32 ± 0.22	1.38 ± 0.22	1.22 (0.8–1.9)	n.s.
Eccentric ER:isometric IR < 1.30	10 (63%)	44 (36%)	3.20 (1.0–10.1)	0.047

Data are presented as mean ± SD or absolute frequencies (%)

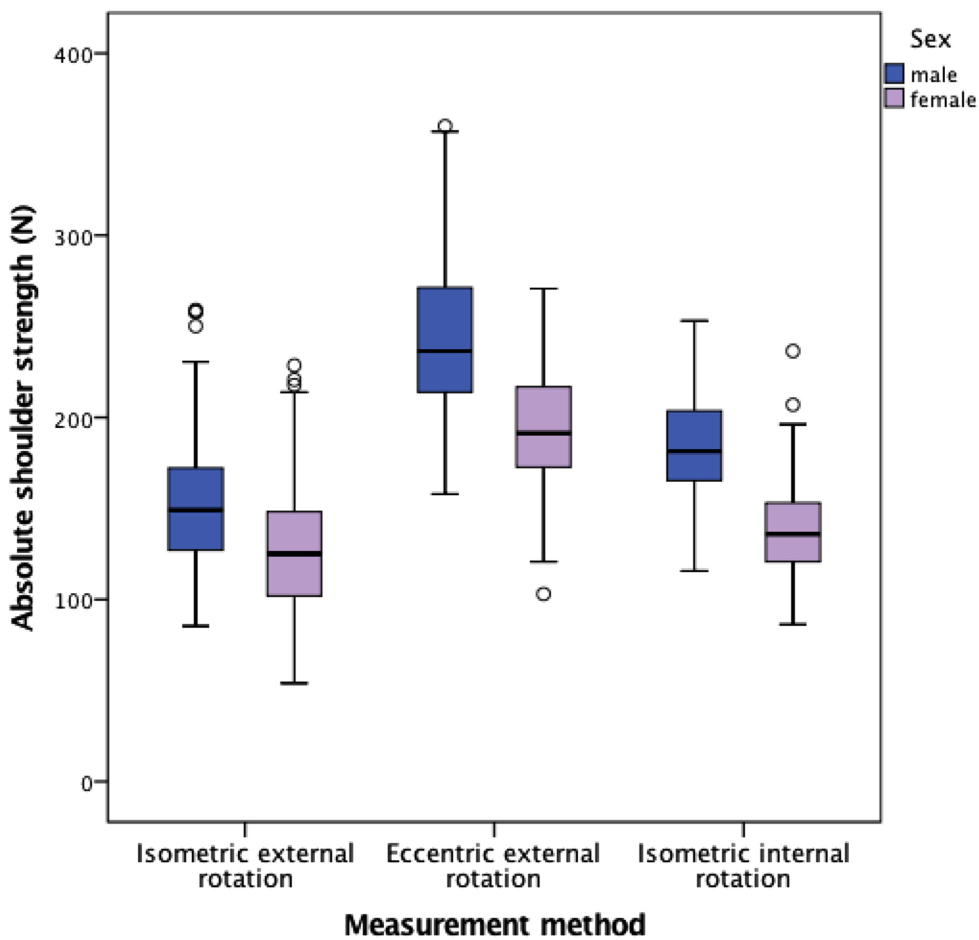

Fig. 2 Box plots representing the absolute shoulder strength for different measurement methods between the two sexes. Shoulder strength was measured (Newton, N) with a hand-held dynamometer. Male players showed higher internal and external rotator strength

mechanisms between the two sexes, such as throwing mechanics and potential influences of ROM and joint laxity.

Absolute and normalised strength values as well as ER:IR ratios were higher than the values reported for elite athletes of the same age class [11, 21]. However, it is important to

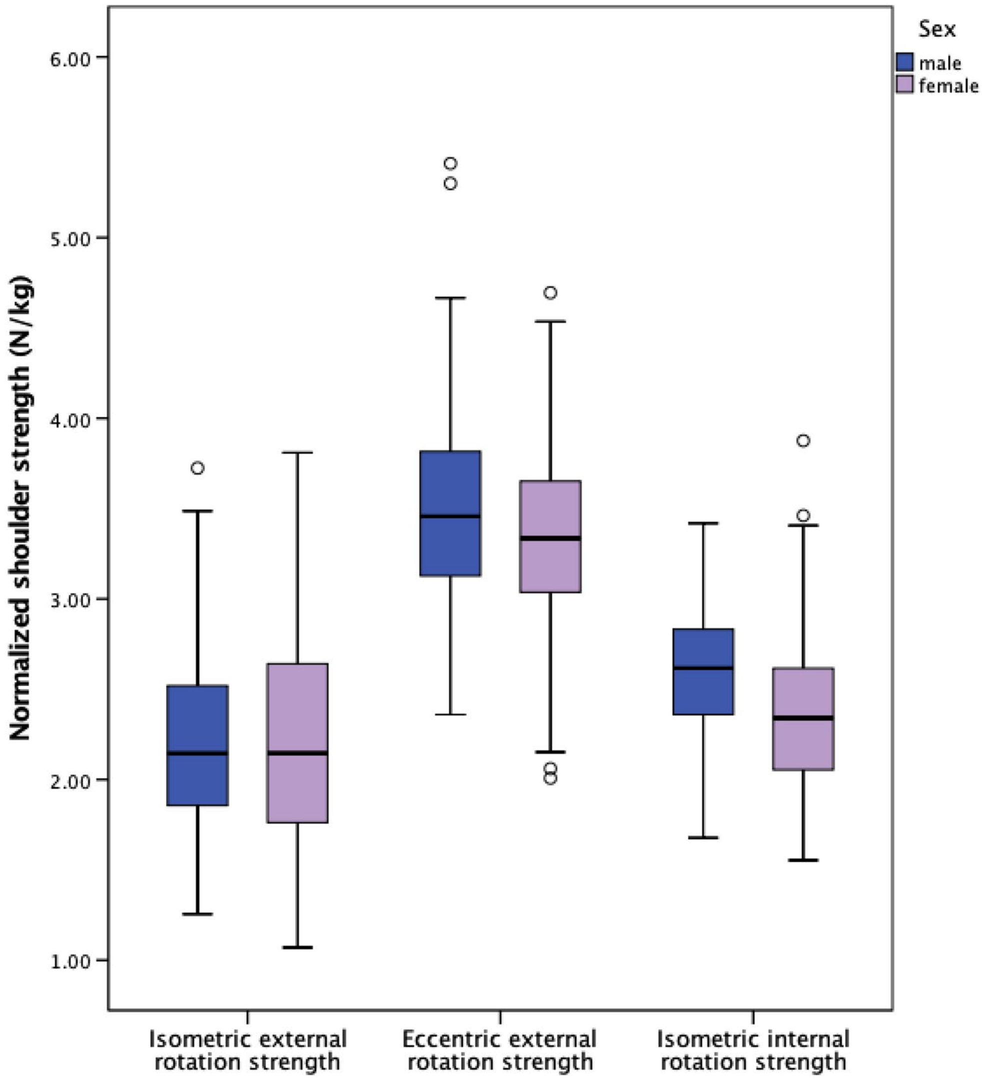

Fig. 3 Box plots representing normalised shoulder strength for different measurement methods between the two sexes. Male players showed higher eccentric external and internal rotator strength. Absolute shoulder strength was measured (Newton, N) with a hand-held dynamometer and calculated to the relative (normalised) value of the player's body weight

Table 6 Passive glenohumeral rotational range of motion as a risk of overuse injury in the dominant shoulder

	Group with symptoms of overuse injury ($n=16$)	Uninjured group ($n=122$)	Odds ratio (95% confidence interval)	p
Passive glenohumeral range of motion				
ER gain (°)	12 ± 8	8 ± 14	Both sexes: 1.0 (1.0–1.1)	n.s.
ER gain > 7.5°	13 (81%)	58 (47%)	Both sexes: 4.1 (1.1–15.4) Men: 1.78 (0.4–8.1) Women: 15.20 (1.1–185.3)	0.045 n.s. 0.025
GIRD (°)	3 ± 6	4 ± 11	Both sexes: 1.00 (0.9–1.1)	n.s.
GIRD > 7.5°	6 (38%)	41 (33%)	Both sexes: 1.00 (0.4–3.5) Men: 0.61 (0.5–0.8) Women: 12.50 (1.4–114.6)	n.s. 0.044 0.014
TROM gain (°)	8 ± 9	4 ± 18	Both sexes: 0.99 (1.0–1.0)	n.s.

Data are presented as mean ± SD or absolute frequencies (%)

note that different testing positions were chosen, which may explain the differences and highlights the need for standardised test settings and sports-specific and age-specific values for the better comparability of test results.

Weak external rotation strength as well as a low ER:IR ratio were identified as risk factors with higher susceptibility of male players, especially for normalised eccentric ER. Similar findings have been described in previous studies on handball and other sports [8, 10, 15, 18]. Increases in the handball load of more than 20% further reduced ER strength and its association with shoulder injury in senior handball players [29]. So far, only one injury prevention programme has focused on overuse shoulder injury in handball. Exercises implemented to increase external rotation strength in the dominant shoulder decreased the rate of shoulder injury by 28% [4].

One of four players in the current study presented with signs of scapular dyskinesia. Although scapular dyskinesia has previously been described as a risk factor for overuse shoulder injuries, this study showed only a weak non-significant correlation [10, 22, 29]. This discrepancy could be explained by the nature of overuse shoulder injury and the study design. Overuse shoulder symptoms are not constant but rather vary over time [7, 29]. Five questionnaires may have been insufficient to gather data from all injured players.

The prevalence of overuse shoulder injury warrants further studies on risk factors and the development and implementation of prevention exercises [3, 13, 32]. The high prevalence of shoulder injury in this young age group suggests that prevention strategies should be implemented at an early stage of the players' development, hence at a young age. This implementation should not only be considered in handball, but also in variants of this sport, such as beach handball [2]. Injury prevention should thus focus on addressing and reducing risk factors, such as increasing external rotator strength and decreasing harmful adaptations of the glenohumeral rotational arc by means of neuromuscular and strength training programmes [13]. Such exercises have been shown to be effective in reducing overuse shoulder injury in senior handball players [4].

Pre-season assessment of the shoulders as part of general medical screening may identify players at high risk. As youth elite teams rarely have a medical staff regularly working with them, a single pre-season examination may be feasible and sufficient for this age group. In this setting, on-field tests showed valid, reliable and useful possibilities. Satisfactory reliability was identified using a three-rating scapular classification system of normal, subtle or obvious dyskinesia in overhead throwing athletes [16, 30]. Using hand-held dynamometers, scapular control and ROM can be assessed with acceptable reliability in a field-based setting due to the high threshold for reliable measurements of isometric strength [12, 30]. The difference in glenohumeral ROM should be more than 5° to ensure high reliability, which was the case in this study.

The strengths of this study were its prospective design, its adherence to the highly standardised tests described in the literature, the sports specificity at this young age due to the elite athletic setting and the comparison of male and female players for the first time.

However, this prospective cohort study has some limitations. Assessing scapular control, glenohumeral range of motion and shoulder strength in an on-field test setting differs in reliability and validity, especially for shoulder strength measured by a hand-held dynamometer [30]. However, this test setting allows a more practical clinical setting and thus has high clinical relevance. Scapular kinesia and on-field analysis was assessed by only one rater, but no video analysis with repeatability of tests was carried out. However, a recent study by Moller et al. has validated the on-field assessment of scapular motion as a reliable diagnostic test [30]. Also, muscle strength was only assessed by one rater, which increased the quality of this study due to high intra-rater reliability but may decrease the comparability with other studies [17, 23].

Conclusion

Elite youth handball players of both sexes showed a high prevalence of overuse shoulder injury. Risk factors for overuse shoulder injury in elite youth handball for both sexes are weakness in glenohumeral external rotation strength and, for girls, higher than normal adaptations in the glenohumeral range of motion arc. Pre-season assessments may aid the identification of risk factors for shoulder overuse injuries in this population.

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Compliance with ethical standards

Conflict of interest All authors declare no conflict of interest for this study.

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Ethical approval Institutional Review Board (IRB) approval was obtained from the IRB (ID 17-895-101) prior to the initiation of this study.

Informed consent Informed written consent was obtained from all study participants and their parents.

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