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ARTHROSCOPY AND SPORTS MEDICINE

Intrarater reliability of goniometry and hand-held dynamometry for shoulder and elbow examinations in female team handball athletes and asymptomatic volunteers

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Abstract

Introduction To evaluate the intrarater reliability for examining active range of motion (ROM) and isometric strength of the shoulder and elbow among asymptomatic female team handball athletes and a control group using a manual goniometer and hand-held dynamometry (HHD).

Materials and methods 22 female team handball athletes (age: 21.0 ± 3.7 years) and 25 volunteers (13 female, 12 male, age: 21.9 ± 1.24 years) participated to determine bilateral ROM for shoulder rotation and elbow flexion/extension, as well as isometric shoulder rotation and elbow flexion/extension strength. Subjects were assessed on two separate test sessions with 7 days between sessions. Relative (intraclass correlation coefficients (ICC) and standard error of measurement (SEM) reliability were calculated.

Results Reliability for ROM and strength were good to excellent for both shoulders and groups (athletes: ICC = 0.94–0.97, SEM 1.07°–4.76 N, controls: ICC = 0.96–1.00, SEM = 0.00 N–4.48 N). Elbow measurements for both groups also showed good-to-excellent reliability (athletes: ICC = 0.79–0.97, SEM = 0.98°–5.94 N, controls: ICC = 0.87–1.00, SEM = 0.00 N–5.43 N).

Conclusions It is important to be able to reliably reproduce active ROM and isometric strength evaluations. Using a standardized testing position, goniometry and HHD are reliable instruments in the assessment of shoulder and elbow joint performance testing. We showed good-to-excellent reproducible results for male and female control subjects and female handball athletes, although the single parameters in ROM and strength were different for each group and between the shoulders and elbows.

Keywords Reliability · Hand-held dynamometry · Goniometry · Shoulder · Elbow · Range of motion · Strength

The investigation is part of the dissertation work by Thomas Molitor.

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Introduction

The assessment of mobility is an important part in clinical and physical examinations. The recognition of impairments in joint range of motion (ROM) assists clinicians in their diagnoses, measuring improvements or determining functional limitations [1]. Muscle strength testing is widely used by clinicians for both diagnostic purposes, as well as determining a patient’s joint function prior to, during and following an intervention [2, 3]. Muscle performance testing is used in a variety of patients to detect the presence of impairments and the ability to produce movements that are required for function [4]. In addition, the establishment of objective measurements of ROM and strength functions is a fundamental tool for identifying risk factors of joint disorders and pain, i.e. shoulder and elbow problems, particularly in an active and athletic population [5–11].

Therefore, it is necessary for clinicians and researchers to have reliable examination tools to accurately and objectively assess the functional status of a joint [1, 4, 6, 12, 13]. Methods in evaluation for shoulder and elbow ROM are the visual observation, linear measures, inclinometry and goniometry [14]. Goniometry has been used widely due to its portability and low cost [15]. As a limitation, the clinician is required to use both hands, making stabilization of the extremity more difficult and increasing the risk of error in reading the instrument. It also induces the need for a second person as an assistant [16]. The assessment of ROM and strength is considered to be integral components of outcome measures of shoulder and elbow function besides self-report outcome scores and subjective clinical examinations [6, 17–19].

Manual muscle testing is one of the most commonly used methods for assessing muscular strength [20]. Although isokinetic dynamometry is known as a criterion standard in measuring muscle strength, upper extremity muscles never generate isokinetic muscle actions in daily life [20]. Besides these physiological considerations, isokinetic testing is often not feasible because of the high costs and the laboratory setting required [21]. Hand-held dynamometry (HHD) has been described to be superior to manual muscle testing in identifying differences or impairments in muscle strength, such as those found after an injury [22, 23]. Stark et al. [21] concluded in their systematic review (19 studies) correlating the isokinetic dynamometer with the HHD that HHD for upper extremities was valid for measuring muscle strength. Limitations of HHD include tester strength [24, 25], lack of stabilization [24, 25] and inconsistency with testing procedures [25].

The purpose of this study was to examine the intrarater reliability for measuring shoulder and elbow active ROM using a clinical goniometer, as well as isometric strength using a portable HHD. Two testing sessions were completed with 7 days between sessions. We determined reliability (ICC, SEM) for the examination of asymptomatic female team handball athletes and an asymptomatic control group.

Materials and methods

Participants

22 female handball athletes (age: 21.0 ± 3.7 years, body height: 1.7 ± 0.1 m, body mass: 69.1 ± 6.2 kg, body mass index 22.8 ± 1.6 kg m^{-2}) of a local 2nd-league team and 25 asymptomatic volunteers (13 women, 12 male; age: 21.9 ± 1.2 years, body height: 1.76 ± 0.1 m, body mass: 68.2 ± 14.1 kg, body mass index 21.7 ± 2.2 kg m^{-2}) participated following written informed consent. Each candidate underwent a bilateral clinical analysis for preexistent neck, shoulder and elbow pathologies. Subjects were excluded based on the following criteria: persistent or recurrent pain, subjective limitations in any ROM and discomfort which lead to interruptions for training or activity.

Instruments

Shoulder and elbow flexibility were measured with a standard baseline goniometer. Technical accuracy was provided with 1° discrimination and a range of 180°. Isometric muscle strength was determined with the IsoForceControl EVO2 hand-held dynamometer (Medical Device Solutions AG, Oberburg, Switzerland). This dynamometer is capable of measuring up to 400 N.

Procedures

After a supervised standardized warm-up consisting of multi-planar shoulder movements and bi-planar elbow exercises for 2 min, the participants completed all measurements bilaterally. Active shoulder ROM and isometric strength measurements consisted of internal rotation (IR) and external rotation (ER), while elbow ROM and strength measurements consisted of flexion (FLEX) and extension (EXT). All ROM and isometric strength measurements were conducted by one experienced examiner with support from an assistant familiar with the complete protocol. All assessments were performed bilaterally in the same order over three trials with 1 week between the two testing sessions. All participants refrained from performing any overhead throwing activities during the testing period [9].

For shoulder ROM measurements the participants were in a supine position with 90° of shoulder abduction, 90° of elbow flexion and a neutral wrist position. The assistant stabilized the test shoulder as described by Wilk et al. [16] to prevent any accessory movement [9, 16]. The goniometer was positioned with the fulcrum over the lateral humeral epicondyle, the stationary arm vertically and the moveable arm over the ulnar styloid process (Figs. 1, 2) [6].

Separate calculations were completed for glenohumeral internal rotation deficit (GIRD, difference between IR throwing arm and IR non-throwing arm, described in negative values) and external rotation gain (ERG, difference in ER between limbs, describes in positive values).

For assessment of elbow ROM, the subjects were also in a supine position with the humerus stabilized against the side of the subject's body. The goniometer was positioned with the fulcrum over the lateral humeral epicondyle, the stationary arm aligned with the midline of the humerus and

Fig. 1 Active shoulder external rotation ROM

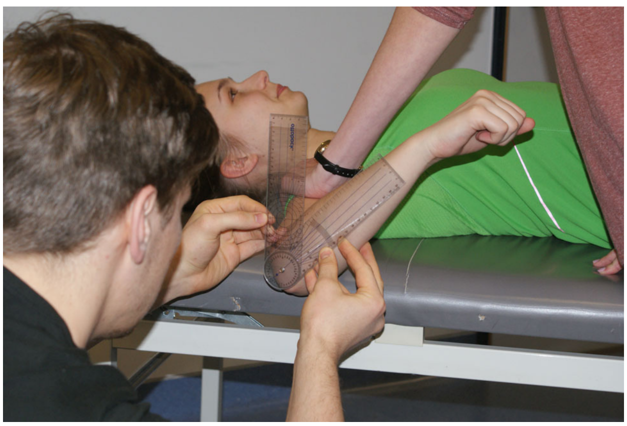

Fig. 2 Active shoulder internal rotation ROM

Fig. 3 Active elbow extension ROM

the moveable arm aligned with the radial styloid process (Figs. 3, 4).

To measure shoulder strength, each subject was again placed supine with their shoulder in 90° of abduction, elbow in 90° of flexion and neutral wrist position, with an

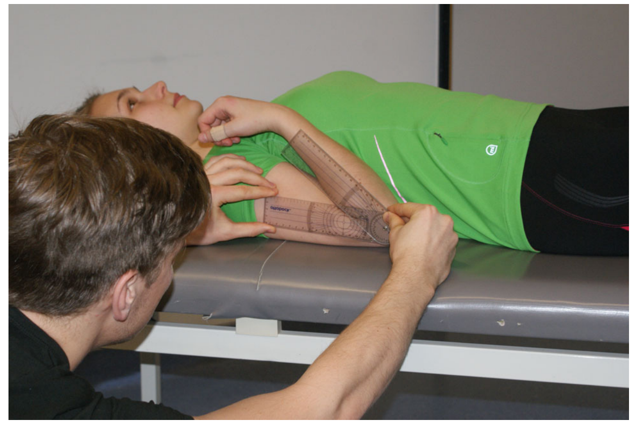

Fig. 4 Active elbow flexion ROM

Fig. 5 Examination for isometric shoulder strength in external rotation

assistant stabilizing the shoulder. The strap of the HHD was then held by the test hand of each subject as they isometrically contracted into either internal or external rotation against the counter force applied by the investigator holding the HHD (Figs. 5, 6).

Determination of the isometric elbow strength was made with the subject seated and their humerus resting at 90° of forward flexion and stabilized against the examination table by the assistant (Figs. 7, 8).

The strap of the HHD was held by the test hand of each subject as they isometrically contracted into either flexion or extension. All contractions lasted for 10 s for a total of three trials per movement. These trials were then averaged and used for analysis.

Statistical analysis

Descriptive statistics were calculated across participants for the dependent variables (active ROM and absolute isometric strength). Differences between groups (control vs. handball) were tested using a general linear model and

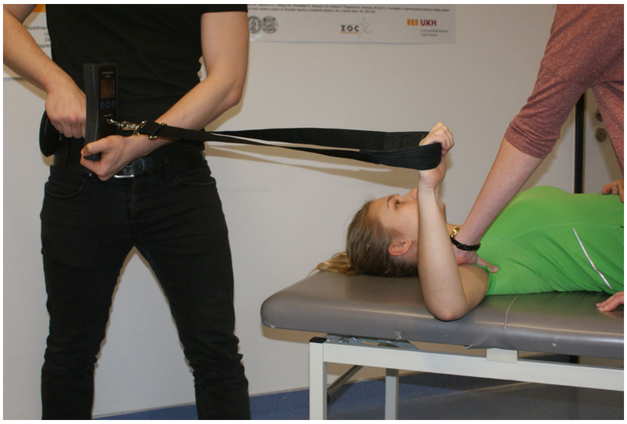

Fig. 6 Examination for isometric shoulder strength in internal rotation

Fig. 7 Examination for isometric elbow strength in flexion

Fig. 8 Examination for isometric elbow strength in extension

were considered statistically significant at p values <0.05. Partial eta-squared (η^2) values were also provided to represent the level of clinical significance, if $\eta^2 > 0.10$.

Intraclass correlation coefficient (ICC) and standard error of measurement (SEM) were used to describe test–retest reliability [20]. Interpretation of ICC values was based on guidelines provided by Portney and Watkins, where a value above 0.75 was classified as good or excellent reliability [26]. ICC values may be influenced by inter-subject variability of scores, because a large ICC may be reported despite poor trial-to-trial consistency if the inter-subject variability is too high [26, 27]. However, the SEM is not affected by inter-subject variability [27]. Therefore, SEM was reported in conjunction with the ICC's using the formula: $\mathrm{SEM} = \mathrm{SD}\sqrt{1 - r}$ [26].

95 % limits of agreement (LOA) were calculated using the formula:

95 % limits of agreement = mean difference ± 2 SD [28].

Finally, one-way ANOVAs were conducted to determine if significant differences existed between test sessions.

All statistical analyses were performed using SPSS version 22.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

There were no significant differences between groups for any anthropometric data. Reliability data are shown (Tables 1, 2).

The intrarater reliability varied from 0.94 to 0.97 (SEM 1.07 N–4.76 N) for the shoulder joint samples from the handball athletes and 0.96–1.00 (SEM 0 N–4.48 N) from the control group. The ICC and SEM for the elbow joint samples differed between 0.79 and 0.97 (SEM 0.98°–5.94 N) for the athletes and 0.87–1.00 (SEM 0 N–5.43 N) for the volunteer subjects. The test–retest results were highly reliable for both samples. Based on the recommendation (ICC > 0.75) of Portney and Watkins [20], all parameters showed good reliability. The SEM differed in similar ranges in both groups. For female handball players, we found the lowest SEM with 0.98° in elbow ROM extension (throwing arm). In contrast, the highest SEM was calculated in elbow strength extension (non-throwing arm) with 5.94 N. Comparable results were observed for the control subjects. The lowest SEM was 0° and 0 N for five different parameters (Table 1); in contrast, elbow flexion strength of the throwing arm had the highest SEM (5.43 N). There were no significant differences between testing sessions (Tables 1, 2). 75 % of the parameters (12/16) showed larger limits of agreement in the handball sample than in the control sample (Tables 1, 2).

Overall (about all parameters), we could not find a group effect regarding intrarater reliability. For comparing absolute numbers concerning ROM and strength at the shoulder and elbow joint for athletes and control subjects, we

Table 1 Comparison of measurements [° and N] obtained from the two testing sessions for healthy subjects

control subjects ($n = 25$; 13 women, 12 male)									
Elbow or Shoulder action	Session one, mean ± SD	Session two, mean ± SD	ICC (95 % CI)	ANOVA, *p*	SEM	Difference			
						Mean	2 SD	Limits of agreement (LOA)	
								Upper limit, mean + 2 SD	Lower limit, mean – 2 SD
Throwing arm									
Flex elbow, N	165.7 ± 55.8	163.2 ± 52.7	0.99 (0.99–1.00)	0.143	5.43	2.50	16.5	19.0	−14.0
Ext elbow, N	121.5 ± 48.8	121.5 ± 48.3	1.00 (0.99–1.00)	0.999	0	0.00	13.4	13.4	−13.4
Flex elbow,°	140.6 ± 5.90	140.8 ± 5.78	0.96 (0.92–0.98)	0.681	1.17	−0.19	4.48	4.29	−4.67
Ext elbow,°	8.47 ± 4.48	8.34 ± 4.35	0.87 (0.70–0.94)	0.838	1.59	0.13	6.14	6.27	−6.01
IR shoulder, N	96.1 ± 35.8	95.8 ± 36.0	0.99 (0.99–1.00)	0.802	3.59	0.28	11.2	11.4	−10.9
ER shoulder, N	120.0 ± 46.3	115.6 ± 43.3	0.99 (0.97–1.00)	0.001	4.48	4.33	11.1	15.4	−6.77
IR shoulder,°	44.1 ± 7.72	43.8 ± 6.76	0.96 (0.91–0.98)	0.631	1.45	0.28	5.74	6.02	−5.46
ER shoulder,°	94.3 ± 10.5	92.8 ± 10.3	0.98 (0.94–0.99)	0.010	1.47	1.51	5.40	6.91	−3.89
Non-throwing arm									
Flex elbow, N	154.9 ± 55.4	154.4 ± 52.0	1.00 (0.99–1.00)	0.767	0	0.45	14.9	15.4	−14.5
Ext elbow, N	114.1 ± 51.0	113.8 ± 48.1	1.00 (0.99–1.00)	0.840	0	0.27	13.2	13.4	−12.9
Flex elbow,°	141.3 ± 5.21	140.6 ± 4.62	0.95 (0.88–0.98)	0.169	1.10	0.63	4.42	5.05	−3.79
Ext elbow,°	8.43 ± 3.44	8.55 ± 4.59	0.88 (0.72–0.95)	0.829	1.39	−0.12	5.48	5.36	−5.60
IR shoulder, N	83.4 ± 30.7	81.9 ± 28.7	1.00 (0.99–1.00)	0.073	0	1.53	8.16	9.69	−6.63
ER shoulder, N	110.0 ± 39.7	110.1 ± 38.0	1.00 (0.99–1.00)	0.905	0	−0.14	11.7	11.6	−11.8
IR shoulder,°	43.0 ± 7.86	43.9 ± 7.86	0.98 (0.94–0.99)	0.055	1.11	−0.92	4.56	3.64	−5.48
ER shoulder,°	90.8 ± 11.1	90.9 ± 10.9	0.98 (0.96–0.99)	0.840	1.56	−0.12	5.88	5.76	−6.00

Descriptive statistics (mean ± SD) and reliability analysis calculated for each parameter based on means of three trials

Flex flexion, *Ext* extension, *IR* internal rotation, *ER* external rotation

separated the sample of volunteers into males and females and analysed the female data as shown in Table 3.

We found significant differences in the throwing arm elbow isometric strength between the handball athletes (flexion 150.0 ± 19.3 N, extension 116.2 ± 21.3 N) and control subjects (flexion 117.0 ± 24.3 N, extension 82.3 ± 18.2 N). There was also a significantly higher amount of throwing arm isometric strength for shoulder external and internal among the athletes (athletes IR 92.6° ± 20.0°, ER 105.9° ± 19.2°; controls IR 71.9° ± 16.4°, ER 82.8° ± 16.5°) (Table 3). For the non-throwing arm, we determined significant differences in all parameters except for ER ROM at the shoulder between the groups. Although only elbow extension and elbow ROM were significantly larger in the control group (Table 3). There were no significant differences for the calculated parameters GIRD, ERG, or total ROM in either arm between groups (Table 3). We found significant differences for all strength parameters between groups. The largest difference ($\eta^2 = 0.533$) was observed for elbow extension strength (controls: 72.5 ± 14.5 N vs. handball: 112.1 ± 20.4 N). In contrast, only 50 % (4/8) of flexibility parameters showed significant differences. 75 % (3/4) of these parameters were found in the throwing arm.

Discussion

This study investigated the parameters for intrarater reliability of measuring active ROM and strength in the shoulder and elbow using standardized positions among female handball athletes and a group of controls. The study revealed good-to-excellent reliability for active shoulder internal and external ROM as well as elbow flexion and extension ROM, measured with a goniometer. The study also established good-to-excellent reliability for isometric shoulder IR and ER strength as well as elbow flexion and extension strength, using a HHD.

Cools et al. [6] measured reliability in shoulder external/internal rotation strength and passive ROM among asymptomatic individuals with two examiners at a single time evaluation. They concluded that different patient's positions and technical equipment might influence the outcome measures of the assessment for shoulder external

Table 2 Comparison of measurements [° and N] obtained from the two testing sessions for team handball players

Female team handball players ($n = 22$)									
Elbow or Shoulder action	Session one, mean ± SD	Session two, mean ± SD	ICC (95 % CI)	ANOVA, p	SEM	Difference			
						Mean	2 SD	Limits of agreement (LOA)	
								Upper limit, mean + 2 SD	Lower limit, mean − 2 SD
Throwing arm									
Flex elbow, N	150.0 ± 19.3	148.7 ± 17.6	0.95 (0.87–0.98)	0.476	4.13	1.31	16.9	18.2	−15.6
Ext elbow, N	116.2 ± 21.3	117,1 ± 18.4	0.93 (0.83–0.97)	0.709	5.25	−0.84	20.8	20.0	−21.6
Flex elbow,°	139.2 ± 3.23	139.4 ± 3.52	0.82 (0.57–0.93)	0.675	1.43	−0.24	5.34	5.10	−5.58
Ext elbow,°	8.11 ± 2.34	8.05 ± 2.29	0.82 (0.57–0.93)	0.878	0.98	0.06	3.66	3.72	−3.60
IR shoulder, N	92.6 ± 20.0	91.4 ± 18.9	0.94 (0.87–0.98)	0.546	4.76	1.19	18.2	19.4	−17.0
ER shoulder, N	105.9 ± 19.2	107.4 ± 19.0	0.95 (0.89–0.98)	0.401	4.27	−1.51	16.5	15.0	−18.0
IR shoulder,°	49.8 ± 6.44	50.7 ± 5.93	0.97 (0.93–0.99)	0.043	1.07	−0.85	3.7	2.85	−4.55
ER shoulder,°	94.2 ± 9.87	93.8 ± 9.41	0.95 (0.88–0.98)	0.705	2.16	0.35	8.5	8.85	−8.15
Non-throwing arm									
Flex elbow, N	141.1 ± 19.0	141.0 ± 18.4	0.97 (0.93–0.99)	0.929	3.24	0.13	12.9	13.0	−12.8
Ext elbow, N	112.1 ± 20.4	112.6 ± 19.2	0.91 (0.79–0.96)	0.859	5.94	−0.44	22.8	22.4	−23.2
Flex elbow,°	140.3 ± 3.68	140.7 ± 3.20	0.79 (0.49–0.91)	0.563	1.58	−0.36	5.80	5.44	−6.16
Ext elbow,°	7.58 ± 3.02	8.08 ± 2.34	0.80 (0.52–0.92)	0.301	1.20	−0.50	4.42	3.92	−4.92
IR shoulder, N	84.4 ± 16.7	84.5 ± 15.8	0.95 (0.89–0.98)	0.969	3.63	−0.06	14.1	14.0	−14.2
ER shoulder,N	105.9 ± 22.1	108.1 ± 20.8	0.96 (0.91–0.98)	0.224	4.29	−2.18	16.3	14.1	−18.5
IR shoulder,°	51.1 ± 6.85	51.3 ± 6.30	0.97 (0.92–0.99)	0.605	1.14	−0.27	4.88	4.61	−5.15
ER shoulder,°	85.8 ± 10.9	86.6 ± 9.85	0.96 (0.90–0.98)	0.398	2.08	−0.76	8.24	7.48	−9.00

Descriptive statistics (mean ± SD) and reliability analysis calculated for each parameter based on means of three trials

Flex flexion, *Ext* extension, *IR* internal rotation, *ER* external rotation

and internal rotation [6]. Kolber et al. [1] described interchangeable results when using goniometry and a digital inclinometer. Kolber et al. [4] also reported a high range of reliability for evaluating healthy male and female, using a HHD. Most previous studies have been focused on shoulder passive ROM. However, our results show similar reliability to those of Kolber et al. [29] and Fieseler et al. [9] for measuring active shoulder ROM. Our reliability is also consistent with other studies using passive motion [1, 4, 6]. Because different subject positions have been shown to influence ROM during evaluation, we attempted to standardize our tests using a supine position for shoulder ROM and strength, and elbow ROM as well as sitting for elbow strength. According to the work from Cools et al. [6], we kept the subject's position constant for practical utility, which has been an important condition to reveal reproducible results. Owing to technical difficulties of requiring both hands for goniometry and HHD, we conducted the whole study with one examiner and an assistant, who only needs to be familiar with the purpose of the study and the stabilization techniques. According to Wilk et al. [16] and based on our good reliability, the positioning and stabilization techniques we used should be considered in the prevention and evaluation of various shoulder and elbow pathologies among athletes and non-athletes alike. There is no research available that has used a time interval similar to ours of 7 days in between test sessions. Although previous research has investigated male team handball players [9], this is the first study to investigate the reliability in shoulder and elbow joint active ROM and isometric strength among female handball athletes.

There is a similar lack of research investigating the reliability of shoulder and elbow strength measurements using a HHD. Gajdosik et al. [30] showed fair-to-excellent reliability when measuring very young children (age 28–50 months). Similarly, Rex Wong et al. [31] and Vermeulen et al. [32] reported good reliability, but tested a non-throwing adult population. Therefore, our results are the first to show that using HHD can produce reliable results for isometric strength among female athletes.

In summary, Schrama et al. [20] concluded in a recent review article that intrarater reliability of muscle strength testing with HHD was only acceptable for elbow measurements in asymptomatic individuals. There has been a

Table 3 Descriptive statistics (mean ± SD; 95 % confidence interval) calculated for each sample

	Female control ($n = 13$)	Handball ($n = 22$)	Control vs. handball	
	Mean ± SD (95 % CI)	Mean ± SD (95 % CI)	p	η^2
Throwing arm				
Flex elbow, N	117.0 ± 24.3 (105.0 to 129.0)	150.0 ± 19.3 (140.8 to 159.2)	**<0.001**	**0.374**
Ext elbow, N	82.3 ± 18.2 (70.9 to 93.7)	116.2 ± 21.3 (107.5 to 125.0)	**<0.001**	**0.411**
Flex elbow,°	143.7 ± 4.88 (141.5 to 145.9)	139.2 ± 3.23 (137.5 to 140.9)	**0.002**	**0.246**
Ext elbow,°	10.5 ± 4.69 (8.60 to 12.4)	8.11 ± 2.34 (6.64 to 9.58)	0.050	0.111
IR shoulder, N	71.9 ± 16.4 (61.3 to 82.2)	92.6 ± 20.0 (84.5 to 100.37)	**0.003**	**0.231**
ER shoulder, N	82.8 ± 16.5 (72.5 to 93.2)	105.9 ± 19.2 (97.9 to 113.8)	**0.001**	**0.282**
IR shoulder,°	44.9 ± 8.52 (40.8 to 49.0)	49.8 ± 6.44 (46.7 to 53.0)	0.060	0.103
ER shoulder,°	96.8 ± 9.70 (91.2 to 102.3)	94.2 ± 9.87 (89.9 to 98.4)	0.453	0.017
Non-throwing arm				
Flex elbow, N	107.3 ± 22.4 (95.9 to 118.8)	141.1 ± 19.0 (132.3 to 149.9)	**<0.001**	**0.406**
Ext elbow, N	72.5 ± 14.5 (62.1 to 82.9)	112.1 ± 20.4 (104.1 to 120.1)	**<0.001**	**0.533**
Flex elbow,°	141.6 ± 5.24 (141.2 to 146.1)	140.3 ± 3.68 (138.4 to 142.2)	**0.034**	**0.128**
Ext elbow,°	10.2 ± 2.34 (8.58 to 11.7)	7.58 ± 3.02 (6.36 to 8.79)	**0.013**	**0.174**
IR shoulder, N	59.2 ± 12.5 (50.5 to 67.8)	84.4 ± 16.7 (77.8 to 91.1)	**<0.001**	**0.411**
ER shoulder, N	79.4 ± 19.3 (67.5 to 91.3)	105.9 ± 22.1 (96.8 to 115.1)	**0.001**	**0.281**
IR shoulder,°	43.8 ± 7.68 (39.7 to 47.8)	51.1 ± 6.85 (47.9 to 54.2)	**0.007**	**0.204**
ER shoulder,°	92.4 ± 11.2 (86.2 to 98.6)	85.8 ± 10.9 (81.0 to 90.6)	0.094	0.083
Calculated scores				
GIRD,°	1.10 ± 6.00 (−2.28 to 4.48)	−1.23 ± 5.98 (−3.82 to 1.37)	0.274	0.036
ERG,°	4.33 ± 4.36 (−0.81 to 8.75)	8.36 ± 9.24 (4.97 to 11.8)	0.150	0.062
ROM-TA,°	141.6 ± 14.8 (133.9 to 149.4)	144.0 ± 13.2 (138.0 to 150.0)	0.630	0.007
ROM-NTA,°	136.2 ± 14.0 (129.2 to 143.2)	136.9 ± 11.4 (131.5 to 142.2)	0.883	0.001

Analysis of variance between groups (female control vs. handball). Statistical significance was set at $p < 0.05$ and $\eta^2 > 0.10$ and marked in bold

SD standard deviation, *IR* internal rotation, *ER* external rotation, *GIRD* glenohumeral internal rotation deficit, *ERG* external rotation gain, *ROM* internal rotation shoulder + external rotation shoulder, *TA* throwing arm, *NTA* non-throwing arm

wide range of grades of ICCs for shoulder strength among different studies, especially for athletes or patients with pain [20]. These authors have also recommended future research and pointed out that clinicians should not rely on HHD measurements for evaluation of treatment effects in patients with upper extremity disorders [20]. The results of our study prove that reliable measurements for shoulder and elbow ROM and strength among female athletes and asymptomatic non-throwing individuals can be conducted. Our results also underscore the need for consistent conditions during evaluation like standardizing subject's position, proper stabilization techniques and defined time intervals between measurement sessions.

As a limitation, we know that the end ROM measurements taken during our flexibility tests were determined by subjective criteria. Future studies should also examine the reliability and validity of ROM and isometric strength testing among populations with joint disorders, pain or under high demands, such as athletes during competitive seasons.

Conclusion

We demonstrated a clinically applicable and standardized protocol for determining ROM and isometric strength in the shoulder and elbow. We revealed good-to-excellent reliability for shoulder and elbow ROM and strength in female team handball athletes and control subjects using a standard goniometer and HHD. Measurements for ROM and strength are recommended in the supine position for the shoulder and sitting for elbow strength because of the practical applicability and trunk stabilization [6].

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Compliance with ethical standards

The study has been performed without any source of support in the form of grants, financial donations or other items.
All participants provided written consent.
The work is part of a study that was approved by the Research Ethics

Committee of the University of Medicine of the Federal University of Halle—Wittenberg, Germany (study 2013–13).

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