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Does grip strength correlate with rotator cuff strength in patients with atraumatic shoulder instability?

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Abstract

Aim: To investigate if there is a correlation between grip strength (GS) and rotator cuff (RC) strength in patients with atraumatic shoulder instability (ASI) and to compare the relationship between these two measures with that previously published for a healthy population. Moreover, to determine if testing GS could be incorporated as a surrogate clinical assessment for RC strength in these patients.

Methods: A total of 20 subjects with ASI were included. Out of the 20 patients, eight presented with bilateral instability, which constituted a total of 28 atraumatic unstable shoulders ($N = 28$). GS was measured using a Jamar hand-dynamometer. External rotation (ER) and internal rotation (IR) strength was tested in inner and outer ranges using a hand-held dynamometer (HHD). Pearson's correlation test was computed to investigate the relationship. Multiple linear regression was conducted to predict GS based on RC strength.

Results: Significant and strong positive correlations were found between GS and inner-range IR ($r = 0.764$, $P < 0.001$), inner-range ER ($r = 0.611$, $P = 0.001$), outer-range IR ($r = 0.817$, $P < 0.001$), and outer-range ER ($r = 0.736$, $P < 0.001$). A significant regression equation was found (F (4, 23) $= 13.254$, $P < 0.001$), with an R^2 of 0.697 indicating that RC strength explained 69.7% of the variance in GS.

Conclusions: The results support the hypothesis showing that GS is strongly associated with RC strength in ASI patients. The simplicity of handgrip testing allows it to be used in clinical scenarios where sophisticated assessment tools are not available. GS is a convenient means to monitor patient progress during shoulder rehabilitation programs.

Keywords: Grip strength, Rotator cuff strength, Atraumatic shoulder instability, Rotator cuff, Shoulder instability, Shoulder

Introduction

Rotator cuff (RC) muscles (supraspinatus, infraspinatus, subscapularis, and teres minor) are considered to be the key dynamic muscles in shoulder stabilization since they contribute significantly to shoulder stability in a number of different ways [1]. They work not only as a dynamic stabilizer but also as static stabilizers because of their orientation and location around the shoulder joint [2]. While stabilizing the joint, they also allow a wide range of shoulder movement through rotational moments [3]. The RC muscles are required to counterbalance the forces produced by surrounding muscles and soft tissues [3] and along with scapulothoracic muscles play crucial roles in the functional optimization of the GHJ to produce efficient movements as they co-contract to stabilize the joint by compressing the humeral head into the glenoid fossa [2]. Rotator cuff muscles form attachments with the joint capsule, which contribute to the increased capsular tension during shoulder active range of motion [2] further stabilizing the joint.

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The shoulder joint is one of the most commonly dislocated joints. The majority of cases (95%) are due to a traumatic instability, which results from a direct, forceful collision, or falling on outstretched arms [4]. An estimated 5% of shoulder instability however is classed as atraumatic instability and this refers to a dislocation or subluxation that occurs following a minor injury and/or overuse [5] or sometimes no apparent incident at all. The main etiology of atraumatic instability is poor muscular control and this may also be associated with capsular-labral pathology [6, 7]. Atraumatic shoulder instability is therefore related to muscular imbalances rather than structural causes and this can affect both athletes and non-athletic individuals. Atraumatic shoulder instability results in significant disability not only in sporting pursuits but also in activities of daily living [2].

Rotator cuff weakness is a recognized cause for symptoms in atraumatic shoulder instability patients [8] and improving muscle strength is the focus of rehabilitation programs. Assessing the strength of these muscles is therefore imperative for diagnostic, preventive, and rehabilitative purposes in patients with shoulder diseases [9]. However, in the clinical setting, these muscles are not always objectively measured due to time constraints, patient's limitation, or difficulty in accessing the equipment. Incorporating a new quick and simple assessment test such as testing grip strength to indicate rotator cuff strength would be beneficial.

Grip strength has been widely used in clinical practice for assessing diseases and rehabilitation progression [10]. The handgrip is a physiology-related variable that can be affected by a wide range of factors such as age, gender, and body mass index (BMI) [11]. It is frequently used in rehabilitation centers to compare patient grip strength with normative data or to compare the force generated by dominant and nondominant arms [12]. The handgrip is evaluated not only as an element of hand function but also as an objective index of upper limb functional integrity [11]. For example, grip strength was found to be a predictor for wrist, hand, and forearm performance [13]. Furthermore, grip strength was found to be a predictor for total muscle strength in children and adolescents [14] and upper and lower body strength in racquet players [15]. Grip strength has also been used as an index to assess nutritional status [16].

Several studies have investigated this relationship between grip strength and rotator cuff strength further. Sporrong et al. [17] found positive correlations between handgrip strength and increased activity of rotator cuff muscles in nine subjects using electromyography (EMG). Mandalidis and O'Brien [18] concluded that the isometric grip strength could be used to monitor the isokinetic strength of shoulder stabilizers in eighteen collegiate-level male athletes. In 27 subjects, Horsley et al. [12] suggested using handgrip strength as a monitor for rotator cuff recruitment function. Sathya et al. [11] studied 75 intercollegiate cricket players and concluded that grip strength testing could be used as a predictor for shoulder power. Although these studies reported the presence of the relationship, all were limited to healthy active populations and athletes with asymptomatic shoulders. To the best of our knowledge, no study has investigated the relationship between isometric grip strength and rotator cuff strength in pathological shoulders, especially atraumatic unstable shoulders.

The purpose of this study was to investigate if there is a correlation between grip strength and rotator cuff function in patients with atraumatic shoulder instability and to compare the relationship between these two measures with that previously published for a healthy population.

Materials and methods

Participants and setting

Adult patients ($\geq$ 18 years, 13 females and 7 males), with an age range of 18 to 48 years (mean age $\pm$ SD $=$ 30 $\pm$ 9.392) with atraumatic shoulder instability attending outpatient clinics or physiotherapy treatment at a specialist hospital in the UK, were invited to participate in the study. Patients with neurological disorders or wrist and hand pathology were excluded. Patients were given the participant information sheet and the procedure explained to them. If they were willing to participate and fully understood what was involved, they were asked to sign the written informed consent form. The raw data were taken for healthy participants ($N = 27$, mean age 19.8 $\pm$ 5.7 years, range 18 to 23 years) from the study by Horsley et al. [12] and compared to the data collected in this study.

Instrumentation

Grip strength was measured using a calibrated Jamar Hydraulic Hand Dynamometer (Model 60440, Sammons Preston, Bolingbrook, Illinois). The dynamometer is the most widely used method in the literature and it is considered to be the gold standard for measuring handgrip strength [19]. The excellent intra-rater and inter-rater reliability, as well as the validity of Jamar hydraulic hand dynamometer for measuring handgrip strength have been reported in several studies [20–24].

Shoulder range of motion (ROM) was measured in degrees using a universal plastic goniometer (EZ Read Jamar Goniometer, Patterson Medical, Warrenville, Illinois). A hand-held dynamometer (HHD) (Manual Muscle Tester, model 01163, Lafayette Instruments Company, Lafayette, Indiana, USA) was used to measure the isometric strength of shoulder external and internal rotation. The readings from both the Jamar hydraulic dynamometer and the hand-held dynamometer were taken in kilograms.

Grip strength assessment

Grip strength was measured with the patient in a sitting position (with 90° knee flexion and the feet in contact with the floor) and with the arm in a neutral position with 90° elbow flexion (Fig. 1). This position is recommended by the American Society of Hand Therapists (ASHT) to avoid unwanted compensation or overflow of impulses [25]. The patient was asked to squeeze as hard as he/she could and then to relax for about 30 s before taking the next measurement to allow sufficient recovery time between contractions and to avoid muscle fatigue [12]. The measures were taken three times, and the highest score was taken for statistical analysis [26].

Fig. 1 The subject position while measuring grip strength

Shoulder range of motion and isometric strength assessment

Patients lay supine with hips flexed at 45° and shoulder of measurement abducted to 90°, or as close to 90° as tolerated with no stabilization. Active range of motion (ROM) in external rotation (ER) and internal rotation (IR) was measured in degrees with a universal goniometer. Following ROM measurement, ER and IR isometric strength in the inner and outer range were measured in kilograms using a hand-held dynamometer (HHD) (Fig. 2). The patient position and the measurement procedure used in this study were similar to that used in previous studies [27, 28]. Universal goniometer is portable, easy to use and inexpensive; moreover, it has an excellent inter-rater and intera-rater reliability of when assessing upper extremity ROM [29]. HHD has shown an excellent inter-rater and intra-rater reliability in testing shoulder strength [9].

Statistical analysis

Statistical Package for the Social Sciences (SPSS) for Windows version 25.0 was used (SPSS, Chicago, IL, USA). The means and standard deviations (SD) were calculated for all variables of interest: grip strength in kilograms, the range of motion of the ER and IR in degrees, and the isometric shoulder ER and IR strength in kilograms.

Data were found to be normally distributed and therefore a Pearson's correlation test was used to investigate the association between grip strength and rotator cuff strength in the four different ranges (inner-range IR, inner-range ER, outer-range IR, and outer-range ER). A multiple linear regression analysis was conducted to predict grip strength based on rotator cuff strength. Rotator cuff strength (in all the ranges) served as the predictor variable, and the grip strength served as a criterion variable. For further analysis, a paired t test was carried out to compare external and internal rotator strength in the inner and outer range. Significance level was set at $p \leq 0.05$. To compare the relationship between grip strength and rotator cuff strength with that of healthy subjects, a plot of external rotation strength against grip strength was overlaid with data from the healthy participants. Statistical comparison of these data was deemed inappropriate as the measurements were made under different conditions.

Results

Descriptive statistics

A total of 20 patients with atraumatic shoulder instability participated in this study. Out of the 20 subjects, eight patients presented with bilateral instability, which constituted a total of 28 atraumatic unstable shoulders ($N =$

Fig. 2 Subject's position while applying the resistance by the HHD when assessing the isometric rotator cuff strength. **A** External rotation (inner range). **B** Internal rotation (outer range). **C** Internal rotation (inner range). **D** External rotation (outer range)

28). In this study, 65% of the patients were females ($N = 13$), and 35% were males ($N = 7$).

The mean and the standard deviation for grip strength, isometric inner range internal and external rotations, isometric outer range external and internal rotations, and the ROM of external and internal rotation for patient with atraumatic shoulder instability are given in Table 1. Table 2 shows the mean and SD for healthy participants taken from Horsley et al. [12].

Rotator cuff isometric strength

The paired *t* test indicated no significant difference between the strength of the inner-range IR and outer-range IR, and no significant difference between the strength of the outer-range IR and outer-range ER. The outer-range ER was significantly stronger than the inner-range ER ($P = 0.001$). A significant difference was found between the strength of the inner-range ER and inner-range IR ($P = 0.001$).

Relationship between grip strength and shoulder strength

When using Pearson's correlation test (*r*), a number of significant and positive correlations were observed between grip strength and rotator cuff strength (two-tailed) (Table 3). A significant and strong positive correlation was found between grip strength and shoulder internal rotation in the inner range ($r = 0.764$, $P < 0.001$). A significant and strong positive correlation was found between grip strength and shoulder external rotation in the inner range ($r = 0.611$, $P = 0.001$). A significant and

Table 1 Presentation of the mean and SD for grip strength, isometric inner range internal and external rotations, isometric outer range external and internal rotations, and the ROM of external and internal rotation for patient with atraumatic shoulder instability. $N = 20$

	Grip strength (kg)	IR inner range (kg)	ER inner range (kg)	IR outer range (kg)	ER outer range (kg)	IR ROM (°)	ER ROM (°)
Mean and SD	30 ± 13.48	5.7 ± 2.5	4.7 ± 1.8	6.06 ± 2.7	6.05 ± 2.4	63 ± 19.9	51 ± 22.5

Table 2 Presentation of the mean and SD for grip strength and isometric strength external rotations for healthy participants (n = 27)

	Grip strength (kg)	External rotation (kg)
Mean and SD	36 ± 9.4	5.59 ± 1.7

very strong positive correlation was found between grip strength and shoulder internal rotation in the outer range ($r = 0.817$, $P < 0.001$). A significant and strong positive correlation was found between grip strength and shoulder external rotation in the outer range ($r = 0.736$, $P < 0.001$). Therefore, the null hypothesis of the absence of the correlation between grip strength and rotator cuff strength is rejected.

Table 3 Pearson correlation coefficients (r) between grip strength and rotator cuff strength of the internal and external rotation in the inner and outer range ($N = 28$)

	Isometric IR (inner range)	Isometric ER (inner range)	Isometric IR (outer range)	Isometric ER (outer range)
Grip strength	r (28) = .746**	r (28) = .611**	r (28) = .817**	r (28) = .736**

**$P \leq 0.001$ (2-tailed)

Regression analysis

A multiple linear regression was computed to predict the grip strength based on rotator cuff strength (IR and ER in the inner and outer range). A significant regression equation was found (F (4, 23) = 13.254, $P < 0.001$), with an R^2 of 0.697 indicating that 69.7% of the variance of grip strength could be explained by rotator cuff strength (Fig. 3). While the internal rotation in the outer range contributed significantly to the grip strength ($B = 2.992$, $P < 0.05$), the internal rotation in the inner range ($B = 0.171$, $P = 0.898$), the external rotation in the inner range ($B = 1.249$, $P = 0.295$), and the external rotation in the outer range ($B = 0.506$, $P = 0.681$) did not. The final predictive model was: Grip strength = 2.064 + (0.171 × inner-range IR) + (1.249 × inner-range ER) + (2.992 × outer-range IR) + (0.506 × outer-range ER).

Atraumatic shoulder instability versus healthy shoulders

When comparing the raw data of healthy participants from the study by Horsley et al. [12] to the data collected in this study, unpaired t test showed no significant difference in grip strength ($P = 0.068$) or external

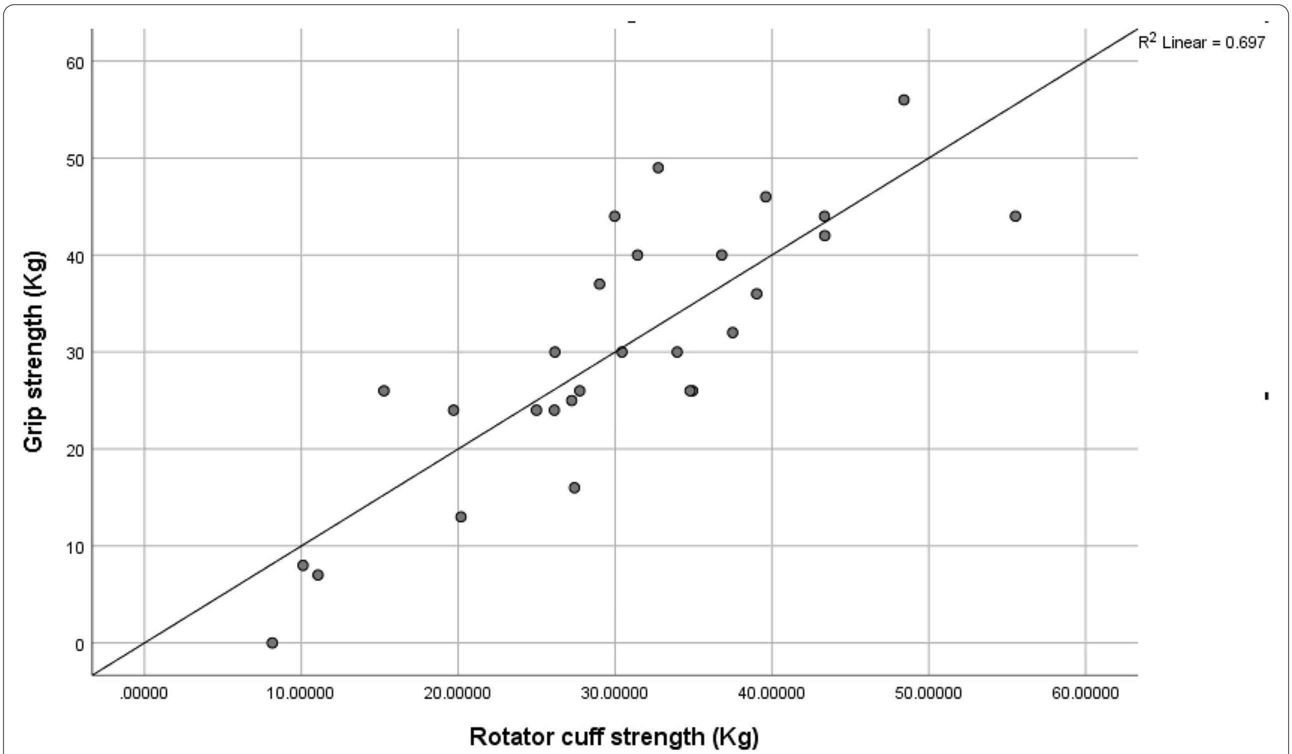

Fig. 3 Linear regression of handgrip strength and rotator cuff strength

rotation isometric strength ($P = 0.084$) between healthy participants and ASI patients. Moreover, the relationship between grip strength and RC external rotation strength appears to be similar (Fig. 4). Interestingly, although the ASI group had some of the lowest strength values, the majority of values overlaid those of the healthy population.

Discussion

The primary purpose of this study was to investigate if there is a correlation between grip strength and rotator cuff strength in atraumatic shoulder instability patients. Grip strength and rotator cuff strength were examined isometrically across 20 patients with 28 unstable shoulders. The results of this study support the hypothesis showing strong positive correlations between grip strength and rotator cuff strength in the inner and outer range.

The scores of grip strength were compared with the normative reference values of the healthy population. In the literature, grip strength was found to be significantly higher with the elbow in extension or during standing than with elbow flexion due to the overflow of impulses [25]; therefore, we focused only on the articles that involved Jamar hydraulic hand dynamometer as an outcome measure and the same position as in our study (sitting with the arm in a neutral position and 90° elbow flexion). In line with many studies, this study found that males have a stronger grip strength as well as internal and external rotation strength when compared with females of the same age group [23, 30].

The scores of shoulder external and internal rotation strength were also compared against the normative data for healthy population. There was no significant difference between the results of healthy active population and patients with atraumatic shoulder instability.

In rehabilitation, it is widely accepted that effective muscle action on distal joints can be achieved when proximal joints are efficiently stabilized by the surrounding structures [18]. Therefore, the link between proximal stability and distal mobility could explain the relationship between handgrip strength and rotator cuff strength [31]. Several interventional studies supported this link and reported a significant increase in grip strength with increased shoulder stability [31, 32].

Since the correlation has been established, a multiple linear regression analysis was conducted to investigate if handgrip strength can be predicted based on rotator

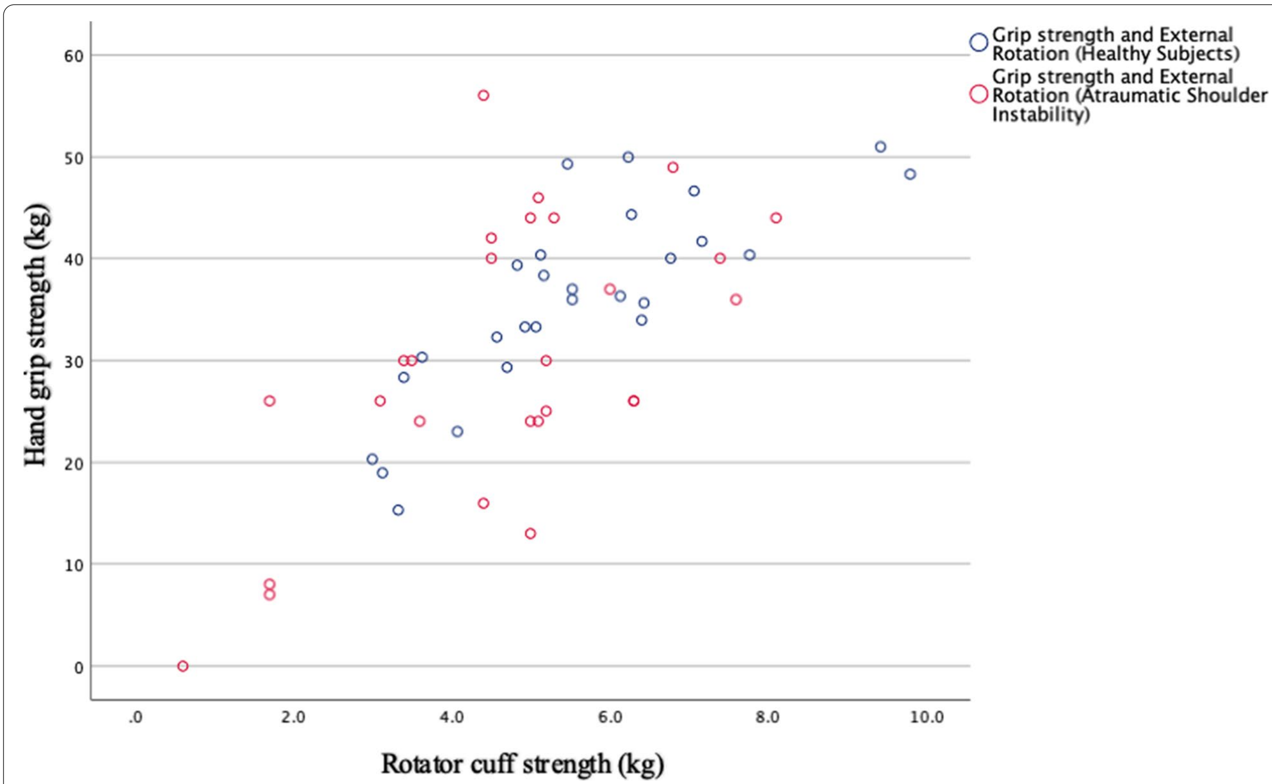

Fig. 4 A representation of the correlation between grip strength and external rotation in both healthy subjects and atraumatic shoulder instability patients

cuff strength and was found to be significant. The results indicated that 69.7% of the variance in the grip strength is explained by rotator cuff strength. Mandalidis and O'Brien [18] suggested that the relationship between the handgrip and rotator cuff could be explained based on the overflow principle, which is mediated by the neural circuits in the central nervous system (CNS) leading to the co-activation of the agonists and synergists muscle groups that are responsible for a specific task. The presence of the co-activation was supported by EMG studies, which reported that gripping increases the activities within some muscles around the shoulder joint and decreases others [17, 33]. Sporrong et al. [17] found that rotator cuff muscles are the most activated by handgrip. Therefore, these findings suggest that grip strength could be used as an indicator of rotator cuff strength.

The regression findings also indicated that the outer-range IR strength contributed significantly to the grip strength, and the grip strength increased 2.2992 kg for each 1 kg of the outer-range IR strength. Anatomically, when the origin is fixed, latissimus dorsi and pectoralis major both act to adduct and internally rotate the humerus (along with subscapularis) [34]. Since it is widely accepted that hand flexors, shoulder adductors, and internal rotators are among the upper limb synergists; we could speculate that the co-activation of these synergistic muscles might be a reason behind the increased contribution of internal rotators toward grip strength.

Despite the difference with regards to the chosen sample (healthy population), the examined muscle groups (external rotators), and the mode of examination (isometric or isokinetic), the positive correlation between grip strength and rotator cuff strength in this study is in agreement with those reported in the literature [12, 18]. Isometric grip strength testing is simple, easy to perform, less time consuming than measuring shoulder internal and external rotation, and strongly associated with the rotator cuff strength; therefore, it could be used as an outcome measure to monitor the patient's progression during shoulder rehabilitation programs. The simplicity of handgrip measurement allows it to be used in clinical scenarios where sophisticated assessment tools are not available.

Special tests such as belly-press as well as infraspinatus retraction tests are used to examine the rotator cuff muscles in their inner range [35]; nonetheless, it is necessary to examine these muscles in the full range including the outer range [36]. Therefore, this study investigated the isometric rotator cuff strength in both inner and outer ranges. The findings indicated that both the ER and IR were stronger in the outer range than in the inner range. The increased strength in the outer range could be explained by the length-tension relationship.

The length-tension relationship is related to the sarcomere and the sliding filament theory. It states that the maximum force production happens when the muscle is at resting length where they are not in extreme shortened or lengthened position [3]. It is widely accepted that the normal ROM of internal and external rotation (from 90° abduction and 90° elbow flexion) is between 80 and 90° [37]. Since the patients had instability, they were not able to bring their shoulders to maximum internal and external rotation. This enables muscles to stay in their resting position contributing to maximum force production. When the muscle stretches beyond its resting length, the actin slides apart from the myosin where the passive tension (from the Titin protein (Connectin)) increases and the active tension decreases, contributing to decreased force production [38].

The weakness of the external rotators in recurrent anterior shoulder instability patients was reported in different studies [39, 40]. Similarly, the results indicated that the inner-range ER is significantly weaker than inner-range IR and the outer-range ER. A possible reason for the weakness is the patient's apprehension to move their arms toward the external rotation from 90° abduction since this position is the most common cause of anterior dislocation [40].

This study has some limitations. The direction of instability and factors such as weight and height were not taken into consideration. This study was not able to investigate the correlation between grip strength and rotator cuff strength pre- and post-intervention.

Future studies are suggested to investigate the relationship between grip strength and rotator cuff strength while considering the direction of shoulder instability and to investigate the correlation between the strength of handgrip and rotator cuff before and after shoulder rehabilitation in this group.

Conclusion

The results of this study demonstrate that grip strength is strongly associated with rotator cuff strength in patients with ASI. Isometric handgrip strength is quick and easy to test, and therefore could provide a convenient means to provide an objective measure of rotator cuff strength; however, low strength alone is not an indicator of ASI.

Authors' contributions
Ruqayyah Turabi carried out the study as part of Masters Project, collected the data, analyzed the data, and wrote it. Ian Horsely provided us with data of healthy population to compare our data with. Helen Birch supervised the study. Anju Jaggi supervised the study and provided us with the patients to collect the data from. The authors read and approved the final manuscript.

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Availability of data and materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the research governance framework, EU and UK legislation, and the applicable UK acts. It was approved by London-Stanmore Research Ethics Committee and by Health Research Authority (HRA) and Health and Care Research Wales (HCRW) with a reference number of (18/LO/0901). If patients were happy to participate and fully understood what was involved, they were asked to sign the participant consent form. All queries were answered prior to the measurement, and the patients were given a copy of their signed consent form.

Consent for publication
We confirm that all authors have approved the manuscript and agree with its submission to this journal.

Competing interests
The authors declare that they have no competing interests.

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