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Muscle strength measurements reflecting the extent of complete subscapularis tears: reliability in patients with rotator cuff tears

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Background: While several clinical tests for diagnosing subscapularis (SSC) tears have been reported, no quantitative method reflecting tear size has been established. This study investigated muscle strength measurements that best reflect the extent of SSC tears and clarified their reliability.

Methods: We analyzed 107 patients (111 shoulders) who underwent arthroscopic surgery for rotator cuff tears, assessing preoperative and postoperative muscle strength. Isometric internal rotation strength was measured by using a handheld dynamometer using three techniques: the belly-press, Napoleon, and bear-hug techniques. The correlation between the extent of complete SSC tears and preoperative strength for each technique was assessed using Spearman's rank correlation coefficient. Intrarater reliability was assessed using the intraclass correlation coefficient (ICC) (1, 3), minimal detectable change (MDC), and MDC% based on three preoperative measurements on the operated side. Test-retest reliability was evaluated using these parameters from measurements on the nonoperated side preoperatively and at 6- and 12-month postoperative intervals.

Results: The correlation coefficient between the extent of SSC tears and the strength of each muscle was approximately −0.45 for all techniques, indicating a weak negative correlation. The intrarater reliability for all techniques showed ICC (1, 3) >0.95, MDC <10 N, and MDC% of approximately 10%. The Napoleon technique demonstrated the highest test-retest reliability, with ICC (3, 1) of 0.87, MDC of 17 N, and MDC% of 21%.

Conclusion: The Napoleon technique provided more stable muscle exertion than the other methods. The results may aid in determining whether postoperative muscle strength recovery falls within the range of measurement error.

Rotator cuff tears are a major cause of shoulder disorders. While tears involving the supraspinatus muscle are the most common, subscapularis (SSC) muscle tears are also significant, given that they account for approximately 20%-30% of cases.[1,16,19] In patients with posterior superior rotator cuff tears, decreased muscle strength of the external rotators leads to a reduced active range of external rotation. This phenomenon is known as the external rotation lag sign[10] or Hornblower's sign.[25] However, in patients with anterior superior tears involving the SSC, the reduction in the muscle strength of the internal rotators may not substantially affect the range of motion, making it challenging to evaluate shoulder function. Poor clinical outcomes have been reported in cases of large SSC defects due to irreparable tears or retears after surgery.[15] Furthermore, shoulder strength has been shown to affect activities of daily living and return to work.[20,24] Therefore, accurate SSC strength measurement is crucial.

In many previous studies in healthy individuals or athletes, muscle strength of internal rotation is typically assessed through internal rotation in adducted and abducted positions.[5,6,11] Nevertheless, it has not been demonstrated whether internally rotated muscle strength measured during these movements accurately reflects the SSC muscle strength. Furthermore, the lift-off,[8] belly-press,[7] Napoleon,[4] and bear-hug tests[2] have been commonly employed to detect SSC tears. However, these qualitative clinical

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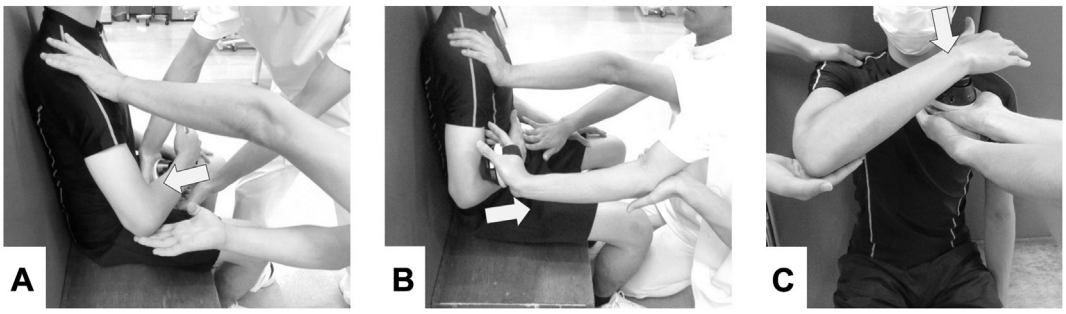

Figure 1 Muscle strength measurement methods. (**A**) Belly-press technique: The patient's shoulder and elbow are supported by one examiner, while the other examiner places the handheld dynamometer between the patient's palm and belly. The patient is instructed to push the palm towards the belly. (**B**) Napoleon technique: One examiner supports the patient's shoulder and palm while the other examiner places the handheld dynamometer on the patient's elbow. The patient is instructed to push the elbow forward. (**C**) Bear-hug technique: One examiner supports the patient's shoulder with flexion at 70° and holds the patient's shoulder and elbow. The other examiner places the handheld dynamometer between the patient's palm and the opposite shoulder. The patient is instructed to push the palm toward the opposite shoulder. Arrows indicate the direction in which the patient applies force.

assessments primarily focus on identifying the presence or absence of SSC tears, and it has also not been demonstrated whether muscle strength measured through internal rotation using these tests accurately reflects the SSC muscle strength. To address these questions, we previously conducted retrospective measurements of muscle strength during internal rotation at the side and using the belly-press and Napoleon techniques in patients with rotator cuff tears.[21] The results of our investigation into the correlation between the extent of SSC tears and muscle strength revealed no significant correlation with internal rotation at the side. Meanwhile, both the belly-press and Napoleon techniques showed nearly equivalent correlations. However, a notable limitation of this study was the variation in the timing of muscle strength measurements across the different techniques, leading to a lack of consistency among the study participants.

Therefore, in the current study, we prospectively measured muscle strength in patients with rotator cuff tears using three techniques: excluding internal rotation at the side and incorporating the belly-press, Napoleon, and bear-hug techniques. This study aimed to evaluate the correlation between muscle strength and the extent of SSC tears using three techniques and to investigate their reliability. We hypothesized that each technique would demonstrate comparable correlation and reliability.

Materials and methods

Study participants

This prospective study evaluated muscle strength using three measurement techniques in 110 patients (114 shoulders) who underwent arthroscopic surgery for rotator cuff tears at our institution from August 2019 to November 2023. Among these patients, 107 patients (111 shoulders; 62 males and 45 females) were enrolled in this study after excluding three patients (three shoulders) who lacked preoperative muscle strength measurements. The average age at the time of surgery was 63.4 ± 10.8 years (range: 24-83 years), with heights averaging 162 ± 9.1 cm (range: 140-182 cm) and weights averaging 65.5 ± 13.2 kg (range: 37-106 kg). The study was approved by the Institutional Review Board of the Academic Clinical Research Center of Osaka University (ID: 22548), and informed consent was obtained from all patients before surgery for the use of clinical data.

A power analysis was conducted to determine the sample size. Our previous retrospective study showed that the correlation coefficient between the extent of SSC tears and muscle strength ranged from 0.36 to 0.40.[21] Therefore, the sample size was calculated as 73, with a medium effect size of 0.36, power of 0.9, and significance level of 0.05.

Muscle strength measurements

Isometric muscle strength was measured by using a handheld dynamometer (microFET 2; Nihon Medix Co., Ltd., Chiba, Japan), which has the lowest threshold of approximately 4 Newtons (N), using three clinical assessment techniques—namely, the belly-press, Napoleon, and bear-hug techniques. Physical therapists with at least three years of experience in shoulder rehabilitation examined the patients. One examiner conducted the measurements, whereas the other assisted in maintaining the position of a patient's arm.

Muscle strength was measured as follows (Fig. 1):

(1) Belly-press technique: The patient was seated with the back against a wall and the palm against the belly. The examiner stabilized the shoulder against the wall and held the elbow at the anterior-posterior midpoint of the trunk to ensure adequate internal rotation of the shoulder. The other examiner placed the handheld dynamometer between the patient's palm and belly and instructed the patient to push the palm toward the belly.
(2) Napoleon technique: The patient assumed the same position as in the belly-press technique. The examiner stabilized the shoulder against a wall and secured the palm to the belly. The other examiner placed the handheld dynamometer on the lateral side of the elbow and instructed the patient to push the elbow forward.
(3) Bear-hug technique: The patient leaned against a wall and placed the palm in front of the opposite shoulder at approximately 70° of shoulder flexion. The examiner stabilized the shoulder against the wall and secured the elbow to maintain shoulder flexion. The other examiner placed the handheld dynamometer between the patient's palm and the opposite shoulder and instructed the patient to push the palm toward the opposite shoulder.

The maximum value of isometric muscle contraction over a 3-second duration was recorded in newtons for each measurement. The measurements were repeated three times with an interval of at least 30 seconds between each measurement. Additionally, the degree of shoulder pain during measurement was recorded on a 3-point scale (1 = no pain or slight discomfort, 2 = pain present but able to exert full effort, 3 = too painful to exert full effort).

Bilateral muscle strength measurements were conducted preoperatively and at 6 and 12 months postoperatively. In this study, the results of muscle strength measurements on the nonoperated side were used to determine the test-retest reliability. A doctor with more than 15 years of experience in ultrasonography diagnosed the condition of the rotator cuff on the nonoperated side.

Assessment of the extent of SSC tears

The extent of SSC tears was assessed based on intraoperative findings. Under general anesthesia, patients underwent arthroscopic rotator cuff repair in the lateral decubitus position. Arthroscopic observation was performed through a standard posterior portal to identify the SSC tendon tears. The torn portion of the SSC tendon was carefully débrided using a standard shaver until the healthy tissue was exposed. Additionally, the torn portion was observed through an anterosuperior portal with bursoscopy. If the healthy tissue of the SSC was not visible, the transverse ligament was carefully dissected to observe the extent of SSC tears. Complete tears were defined as areas in which the SSC tendon was completely detached from the lesser tuberosity. The craniocaudal length of tears was measured using a probe with a 5-mm scale.

To standardize the extent of complete SSC tears, the proportion of the extent of complete tears relative to the entire SSC attachment was calculated as follows. The size of complete SSC tears was defined by the number of axial-view slices showing complete tears on preoperative magnetic resonance imaging with a 4-5-mm slice interval. These slices were selected by aligning the intraoperative craniocaudal length of the complete tears in the sagittal view, as they cannot be accurately determined based on just preoperative magnetic resonance imaging. Furthermore, the number of axial slices representing the anatomical attachment of the entire SSC was determined by referring to axial and sagittal views. The extent of complete SSC tears was calculated as a percentage by dividing the number of slices showing complete SSC tears by the number of slices representing the entire attachment of the SSC. Additionally, SSC tears were classified according to the Lafosse classification system.[17]

The condition of the rotator cuff on the nonoperated side was evaluated preoperatively using ultrasonography. Whenever a change in the patient's condition was possible, it was reassessed using ultrasonography. During follow-up, five shoulders with pain and muscle weakness on the nonoperated side were excluded.

Statistical analysis

Spearman's rank correlation coefficient was calculated to investigate the correlation between the extent of complete SSC tears and the muscle strength for each technique.

The intraclass correlation coefficient (ICC) was also calculated to evaluate relative reliability. The intrarater reliability of each technique was assessed by calculating the ICC (1, 3) based on three preoperative measurements on the operated side. Test-retest reliability was assessed by calculating the ICC (3, 1) based on measurements on the nonoperated side performed by the same examiner preoperatively and at 6 and 12 months postoperatively.

The standard error of measurement (SEM) and minimal detectable change (MDC) were calculated to assess the absolute reliability.[6] The SEM was determined using the following formula: $SEM = SD \times \sqrt{1 - ICC}$, where SD represents the standard deviation. The MDC represented the smallest change detectable by the measuring instrument, indicating the magnitude of measurement error.[6] Changes smaller than this value were considered to be within the range of measurement error. In contrast, changes exceeding this value were deemed to surpass the margin of error.

Table I
Demographic data.

	Operated side	Nonoperated side
Number of patients and shoulders	107/111	85/86
Age (y)	63.4 ± 10.8	62.5 ± 11.9
Male/female	62/45	48/37
Condition of rotator cuff		
No tear	-	46
Partial tear		
Only SSP	11	10
Only SSC	1	3
SSC-SSP	9	0
Complete tear		
Only SSP	39	20
Only SSC	5	0
SSC-SSP	11	1
SSP-ISP	19	2
SSC-SSP-ISP	16	4
After rotator cuff repair		9
Distribution of SSC tear (Lafosse classification)		
Normal	40 (8/15/13)	73
Partial lesion of superior one-third	37 (9/11/13)	8
Complete lesion of superior one-third	15 (3/3/3)	2
Complete lesion of superior two-thirds	12 (2/3/2)	3
Complete lesion of tendon but head centered and ≤ Goutalier stage 3	6 (2/2/3)	0
Complete lesion of tendon but eccentric head and ≥ Goutalier stage 3	1 (0/0/0)	0

SSC, subscapularis; *SSP*, supraspinatus; *ISP*, infraspinatus.
The condition of the rotator cuff was diagnosed based on preoperative magnetic resonance imaging (MRI) and intraoperative findings on the operated side. On the nonoperative side, a diagnosis was made based on preoperative ultrasonography. The numbers in parentheses under the Distribution of SSC Tear section indicate the number of shoulders excluded due to a pain level of 3 in the belly-press, Napoleon, and bear-hug techniques.

The MDC with a 95% confidence interval was calculated using the following formula: $MDC = SEM \times 1.96 \times \sqrt{2}$. The percentage of MDC (MDC%) was calculated as the ratio of MDC to the mean value, with a lower MDC% indicating higher reliability.

For the preoperative measurements on the operated side, each parameter (the correlation coefficient, ICC (1, 3), SEM, MDC, and MDC%) was first calculated by excluding only the patients for whom muscle strength could not be measured three times. Each parameter was then recalculated by excluding patients with a pain level of 3 due to the potential risk of failing to achieve the maximum strength in patients with severe pain.

Power analysis was performed using G*Power version 3.1 (Heinrich Heine University Düsseldorf, Germany), whereas ICC and MDC calculations were conducted using IBM SPSS Statistics version 21 (IBM Corp., Armonk, NY, USA). Spearman's rank correlation coefficient was computed using JMP Pro version 17 (SAS Institute, Cary, NC, USA), with the significance level set at $P < .05$.

Results

Demographic data

Regarding the operated side, 107 patients (111 shoulders) were included. The condition of the SSC tendon was as follows: 40 normal shoulders, 37 shoulders with partial tears, 15 shoulders with complete tears in less than one-third of the SSC, 12 shoulders with complete tears in less than two-thirds of the SSC, and seven shoulders with complete tears in more than two-thirds of the SSC (Table I). The number of shoulders in which the measurements could not be completed three times was follows: 1 shoulder for the

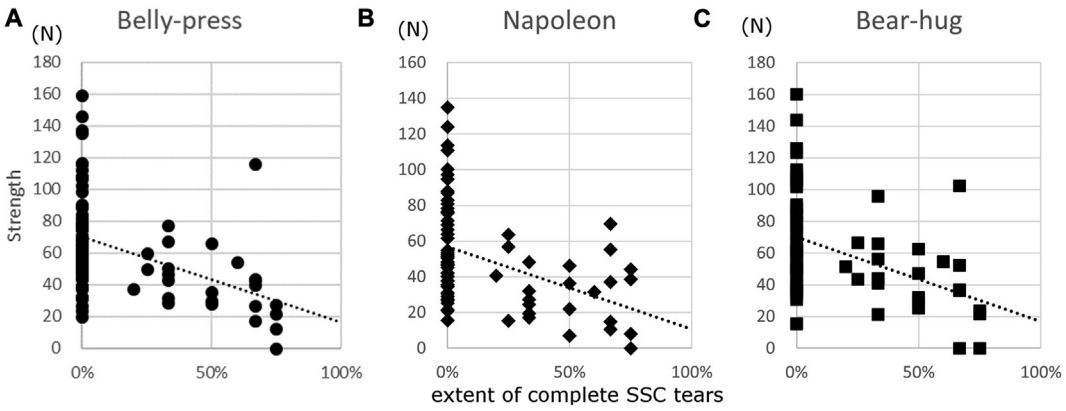

Figure 2 Correlation between the muscle strength for each technique and the extent of complete SSC tears. The correlation was calculated after excluding cases with severe pain. Scatterplots and regression lines depict each technique's muscle strength measurement values (newtons, y-axis) against the extent of SSC tears (%, x-axis). The correlation coefficient between the extent of SSC tears and the muscle strength for each technique was −0.47 for the belly-press technique (**A**), −0.45 for the Napoleon technique (**B**), and −0.42 for the bear-hug technique (**C**). *SSC*, subscapularis.

Table II
Intrarater reliability.

	Number	ICC (1, 3)	Mean (N)	SD (N)	SEM (N)	MDC(N)	MDC%
Belly-press	110/1	0.964	58.0	8.7	1.66	4.59	7.9
Napoleon	111/0	0.968	43.9	6.8	1.22	3.37	7.7
Bear-hug	106/5	0.961	53.1	10.0	1.98	5.49	10.3

ICC, intraclass correlation coefficient; *SD*, standard deviation; *SEM*, standard error of measurement; *MDC*, minimal detectable change.
Intrarater reliability was assessed by measuring the muscle strength of the operated shoulder three times preoperatively after excluding cases where measurements could not be performed three times. The ICC was >0.95 for all techniques, indicating almost perfect reliability, and the MDC% was approximately 10%, indicating good reliability.

Table III
Intrarater reliability after excluding cases with severe pain.

	Number	ICC (1, 3)	Mean (N)	SD (N)	SEM (N)	MDC(N)	MDC%
Belly-press	87/24	0.966	62.4	8.6	1.64	4.53	7.3
Napoleon	77/34	0.97	49.8	6.9	1.20	3.31	6.7
Bear-hug	77/34	0.951	62.1	10.3	2.28	6.31	10.2

ICC, intraclass correlation coefficient; *SD*, standard deviation; *SEM*, standard error of measurement; *MDC*, minimal detectable change.
Intrarater reliability was recalculated after excluding cases with a pain level of 3. The cases excluded due to severe pain included 24 shoulders for the Belly-press technique and 34 shoulders each for the Napoleon and Bear-hug techniques. The ICC was >0.95 for all techniques, indicating almost perfect reliability, and the MDC% was approximately 10%, indicating good reliability.

belly-press technique, 0 shoulder for the Napoleon technique, and 5 shoulders for the bear-hug technique. The number of shoulders with a pain level of 3 was as follows: 24 shoulders overall for the belly-press technique, of which 7 had complete tears; and 34 shoulders overall for the Napoleon and bear-hug techniques, with 8 shoulders having complete tears (Table I).

Concerning the nonoperated side, 85 patients (86 shoulders) were included. The condition of the SSC tendon was as follows: 73 normal shoulders, 8 shoulders with partial tears, 2 shoulders with complete tears in less than one-third of the SSC, and 3 shoulders with complete tears in less than two-thirds of the attachment (Table I). SSC tears on the nonoperated side were less severe than those on the operated side.

Correlation between the extent of complete SSC tears and the muscle strength for each technique

Excluding cases where measurements could not be performed three times, the correlation coefficient between the extent of complete SSC tears and muscle strength for each technique was −0.37 ($P < .0001$) for the belly-press technique, −0.27 ($P = .0042$) for the Napoleon technique, and −0.28 ($P = .004$) for the bear-hug technique. After excluding cases with a pain level of 3, the correlation coefficients were −0.47 ($P < .0001$), −0.45 ($P < .0001$), and −0.42 ($P = .0002$), respectively (Fig. 2).

Intrarater reliability

The results after excluding cases where measurements could not be performed three times are shown in Table II, and the results after excluding cases with a pain level of 3 are shown in Table III. The intrarater reliability assessed by ICC (1, 3) exceeded 0.95 for all techniques, indicating excellent reliability regardless of the presence or absence of severe pain. The MDC and MDC% were smallest for the Napoleon technique, regardless of the presence or absence of severe pain. The MDC% was less than about 10% for all techniques.

Test-retest reliability

The test-retest reliability assessed by ICC (3, 1) was 0.78 for the belly-press technique, 0.87 for the Napoleon technique, and 0.76 for the bear-hug technique. Although all were considered good, the Napoleon technique demonstrated the highest reliability among

Table IV
Test-retest reliability.

	Number	ICC (3, 1)	Mean (N)	SD (N)	SEM (N)	MDC(N)	MDC%
Belly-press	86	0.781	76.0	20.1	9.43	26.1	34.4
Napoleon	86	0.874	79.0	16.9	5.99	16.6	21.0
Bear-hug	86	0.757	83.1	23.2	11.41	31.6	38.1

ICC, intraclass correlation coefficient; *SD*, standard deviation; *SEM*, standard error of measurement; *MDC*, minimal detectable change.
Test-retest reliability was calculated by measuring the muscle strength of the nonoperated shoulder preoperatively and at 6 and 12 months postoperatively. The Napoleon technique yielded the highest ICC and smallest MDC values.

the three techniques (Table IV). The MDC was 26.1 N for the belly-press technique, 16.6 N for the Napoleon technique, and 31.6 N for the bear-hug technique, with corresponding MDC% values of 34.4%, 21.0%, and 38.1%, respectively. The Napoleon technique showed the smallest MDC and MDC% values among the techniques.

Discussion

This study was the first report to measure internally rotated muscle strength using three techniques—belly-press, Napoleon, and bear-hug techniques—in patients with rotator cuff tears. The primary aim was to identify the muscle strength measurement method that best correlates with the extent of SSC muscle tear. The correlations between the extent of complete SSC tears and muscle strength were low, ranging from −0.27 to −0.37 for all techniques. However, when cases with severe pain were excluded, the correlations improved to approximately −0.45 for all techniques, indicating a similar level of correlation across each technique. This finding is consistent with our hypothesis. Another aim was to determine the intrarater reliability and test-retest reliability of these techniques. This study showed that the intrarater reliability among the techniques was comparable and excellent, regardless of the presence or absence of severe pain. The test-retest reliability for each technique remained satisfactory, although lower than the intrarater reliability. Among them, the Napoleon technique exhibited the highest reliability, with an ICC (3, 1) of 0.87. The indices of measurement error, MDC, and MDC% were the smallest for all three techniques, measuring 16.6 N and 21.0%, respectively. Contrary to our hypothesis, the Napoleon technique showed the best test-retest reliability.

The SSC muscle has the largest volume among the muscles constituting the rotator cuff and functions as the internal rotator of the shoulder. Shoulder muscle strength evaluation commonly measures muscle strength during internal rotation in the abducted and adducted positions. However, little is known about whether the muscle strength during internal rotation in these positions accurately reflects the muscle strength of the SSC. Greis et al[9] suggested that internal rotation in the adducted position may not accurately reflect SSC muscle strength because of compensation from the pectoralis major. In our previous study investigating muscle strength measurements, which included internal rotation in the adducted position, the belly-press technique, and the Napoleon technique among patients with rotator cuff tears, we found a low correlation coefficient of −0.1 between the muscle strength during internal rotation and the extent of complete SSC tears, indicating no significant correlation.[21] Therefore, this study excluded muscle strength measurement during internal rotation in the adducted position.

Furthermore, some clinical tests such as the lift-off, belly-press, Napoleon, and bear-hug tests have widely been used to detect SSC tears.[2,4,7,8] While each clinical test exhibited specificity exceeding 85% in all reports, their sensitivity varied widely, ranging from 12% to 40% for the lift-off test, 28%-57% for the belly-press test, 19%-74% for the Napoleon test, and 25%-80% for the bear-hug test.[3,13,26] The significant variability in the sensitivity of clinical tests may be attributed to whether partial tears are included or excluded in the tears to be detected. Kappe et al[13] and Yoon et al[26] suggested that excluding partial tears could lead to a higher sensitivity, as partial tears might not significantly affect muscle strength unless accompanied by severe pain. Therefore, in this study, we decided to focus on the correlation between muscle strength and the extent of complete tears, excluding partial tears.

Another issue with muscle strength measurement is the influence of pain. Patients with severe pain are unable to exert maximum muscle strength regardless of the extent of the tear. In this study, there were 24 shoulders in the belly-press technique and 34 shoulders in both the Napoleon and bear-hug techniques where pain during muscle strength measurement was too severe for the participants to exert their full strength. The presence or absence of pain did not affect intrarater reliability. However, the correlation coefficients between the extent of complete tears and muscle strength improved for all techniques after excluding cases with severe pain. These findings suggest that a more accurate measurement of the remaining SSC muscle strength can be achieved by excluding cases with severe pain.

The ICC is commonly used as an indicator of relative reliability, with values above 0.8 signifying almost perfect agreement and values above 0.6 indicating substantial agreement.[18] The interrater reliability for the preoperative assessment on the operated side showed almost perfect agreement for all techniques, exceeding 0.95, regardless of the presence or absence of severe pain. Moreover, the test-retest reliability exceeded 0.8 for the Napoleon technique, whereas the belly-press and bear-hug techniques were approximately 0.75. Recently, the MDC has been utilized as an indicator of absolute reliability. Changes exceeding the MDC were interpreted as surpassing the measurement errors, indicating that methods with smaller MDC values were superior. In this study, the intrarater reliability for all techniques showed MDC% values less than 10%, indicating excellent reliability. However, the MDC% for test-retest reliability was 21% for the Napoleon technique and exceeded 30% for the belly-press and bear-hug techniques. Previous studies on muscle strength during internal rotation in the adducted position using a handheld dynamometer in healthy individuals reported MDCs of approximately 30N and MDC% ranging from 13.3% to 23.7%.[6,11] Sørensen et al[22] conducted a literature review on shoulder muscle strength evaluation using the handheld dynamometer. They reported that while the ICC was satisfied at 0.70 or higher, the MDC% ranged from 0% to 51.0%, indicating the need for caution in determining treatment effects. Based on this, it can be concluded that the Napoleon technique exhibits high intrarater and test-retest reliabilities, making it a reliable assessment technique for regular postoperative muscle strength evaluations.

Two reasons can be cited for the highest test-retest reliability demonstrated by the Napoleon technique. Firstly, it can be attributed to better stability of the upper limb. It is considered that the stabilization of the shoulder and wrist joints, as in the Napoleon technique, provides better stability of the upper limb

compared to the stabilization of the shoulder and elbow joints, as in the other two techniques. Secondly, this outcome can be attributed to the simplicity of the movement direction. The instruction to push the elbow forward in the Napoleon technique is simpler and easier to understand, especially for elderly individuals, compared to internal rotation in shoulder flexion or slight abduction positions. Several authors have also used the Napoleon technique for postoperative muscle strength assessment in patients with rotator cuff tears, although it is called the "modified belly-press test."[14,17,23,27] However, their approaches may lack quantitative evaluation or merely compare the values between the operated and nonoperated sides. The MDC obtained in this study could be a crucial indicator for assessing postoperative muscle recovery in patients with SSC tears.

The strength of this study lies in its focus on patients with rotator cuff tears rather than on healthy individuals, marking a departure from previous investigations. Additionally, this study examined muscle strength and explored its correlation with the extent of SSC tears, making this the first report of its kind. Previous studies on the reliability of shoulder muscle strength measurements predominantly involved relatively young, healthy individuals, with sample sizes typically limited to 30 or fewer participants.[6,12] Clinical evaluations often target elderly individuals who may have difficulty following exercise instructions compared to healthy individuals. Thus, the present study's findings have valuable implications for clinical practice, particularly in assessing patients with rotator cuff tears.

Nonetheless, the current study had some limitations, including the assessment of test-retest reliability on the nonoperated side and an extended measurement period of six months. Test-retest reliability is commonly evaluated within a few days to two weeks after the initial measurement. However, calling patients for multiple measurements before surgery was not feasible. Therefore, test-retest reliability was determined using data obtained from the nonoperated side. The patients' nonoperated sides included those with asymptomatic rotator cuff tears. Although the condition of the rotator cuff tears probably changed during the 1-year evaluation period, patients in whom pain clearly emerged during the evaluation period were excluded. Furthermore, at the 2-year postoperative follow-up, the condition of the rotator cuff on the nonoperated side was assessed using ultrasonography. Therefore, it can be considered that the condition of the rotator cuff tears did not change significantly.

Conclusions

This study evaluated the muscle strength of patients with rotator cuff tears using the belly-press, Napoleon, and bear-hug techniques. While all techniques exhibited similar correlations between the extent of SSC tears and muscle strength as well as comparable intrarater reliability, the Napoleon technique demonstrated the highest test-retest reliability. Based on these results, the assessment of SSC muscle strength is best recommended using the Napoleon technique. Furthermore, the MDC of 16.6 N for this technique would serve as a useful indicator for assessing changes in muscle strength, such as postoperative muscle recovery.

Disclaimers:

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