Shoulder Strength in Asymptomatic Individuals with Intact Compared with Torn Rotator Cuffs

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Background: Normative data are essential to the evaluation of shoulder function. The purposes of this study were to establish a normative database of isometric shoulder strength measured in asymptomatic individuals verified to have intact rotator cuffs and to determine the effect of asymptomatic rotator cuff tears on shoulder strength.

Methods: Two hundred and thirty-seven volunteers with no shoulder pain or history of shoulder injury were screened with ultrasonography bilaterally for rotator cuff tears and then underwent isometric strength measurements for abduction in the scapular plane and external rotation. Statistical analysis was performed to evaluate the effect of age, body habitus, hand dominance, and the presence of a rotator cuff tear on shoulder strength.

Results: Of the 237 volunteers, forty-one were found to have a torn rotator cuff in at least one shoulder. The prevalence of rotator cuff tears was 0% for the subjects between forty and forty-nine years old; 10%, between fifty and fifty-nine years old; 20%, between sixty and sixty-nine years old; and 40.7% for those seventy years old or older. Both abduction strength and external rotation strength in the male subjects showed an age-dependent decrease, whereas only abduction strength showed an age-dependent decrease in the female subjects. In multiple regression analysis, age and weight were the most important predictors of abduction strength and external rotation strength, respectively. In the shoulders with a large-to-massive full-thickness rotator cuff tear, abduction strength was significantly decreased ($p = 0.007$). Additionally, the ratio of abduction strength to external rotation strength was significantly decreased in the shoulders with a large-to-massive full-thickness tear compared with the shoulders with an intact rotator cuff ($p < 0.001$).

Conclusions: There is a high prevalence of rotator cuff tears in elderly asymptomatic individuals. Asymptomatic shoulders with a large-to-massive full-thickness rotator cuff tear have significantly decreased abduction strength. When there is a substantial decrease in abduction strength in relation to external rotation strength, the presence of an asymptomatic full-thickness tear should be suspected in that shoulder. Previous studies establishing normative values for isometric shoulder strength may have been skewed by the presence of asymptomatic rotator cuff tears in elderly subgroups.

Normative data are fundamental to the evaluation of shoulder strength, especially in patients with bilateral shoulder abnormalities. In previous studies¹⁻⁴, in which normative databases of shoulder strength were constructed, isometric shoulder strength was measured in individuals who were asymptomatic on the basis of a medical record review and/or interview. No imaging modalities were used to exclude asymptomatic rotator cuff tears in these studies. Rotator cuff tears are

often asymptomatic in elderly individuals⁵⁻⁹. The prevalence of rotator cuff tears has been reported to be as high as 50% in asymptomatic individuals older than sixty years and may increase to 80% in those older than eighty years⁵. Given the potentially high prevalence of rotator cuff tears in asymptomatic elderly individuals, the shoulder strength data reported in those studies are less likely to reflect the true strength of shoulders with an intact rotator cuff. The lack of accurate reference data may lead to

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an erroneous interpretation of shoulder strength. The purposes of this study were (1) to establish a normative database of the isometric shoulder strength by measuring shoulder strength in individuals whose rotator cuffs were verified to be intact by ultrasonography, (2) to determine the prevalence of asymptomatic rotator cuff tears, and (3) to determine the effect of a rotator cuff tear on the shoulder strength of asymptomatic individuals. We hypothesized that (1) isometric shoulder strength changes with age and body habitus, (2) there is a high, age-related prevalence of asymptomatic rotator cuff tears, and (3) shoulders with an asymptomatic rotator cuff tear have decreased shoulder strength compared with those with an intact rotator cuff.

Materials and Methods

Study Subjects

The study plan was approved by the institutional review board of our institution prior to recruiting the study subjects. Four age groups were designed and stratified by decade: Group A included subjects who were forty to forty-nine years old; Group B, subjects who were fifty to fifty-nine years old; Group C, subjects who were sixty to sixty-nine years old; and Group D, subjects who were seventy years old or older. The sample size was determined on the basis of a power analysis, in which the power was set at 0.8; standard deviations of the isometric strength in men and women were set at 24.5 Nm and 14.7 Nm, respectively; and the least meaningful clinical difference of strength to be detected was set at 20 Nm. A total of 136 subjects (100 men, with twenty-five subjects in each of the four age groups, and thirty-six women, with nine subjects in each of the four age groups) were suggested. The standard deviations were determined on the basis of a pilot study in which we measured the isometric shoulder strength in subjects with normal or torn rotator cuffs. In this pilot study, men were found to have a larger standard deviation than women, and thus more male subjects than female subjects were required for the power of the study.

Inclusion and Exclusion Criteria

The eligible subjects for the study were those who (1) were forty years old or older, (2) were verified on the basis of an interview to be asymptomatic in both shoulders, and (3) were verified to have healthy and normally functioning shoulders by a basic physical examination consisting of observation of elevation and external rotation. The exclusion criteria were (1) current or past symptoms (for example, pain, limited range of motion, weakness, or instability) in either shoulder; (2) a history of trauma or surgery in either shoulder; (3) inflammatory arthritis; (4) a history of any intervention for cervical spine or thoracic disease; (5) neuromuscular disorders; (6) chronic debilitating medical conditions (such as diabetes mellitus, chronic renal failure, or chronic alcoholism); (7) the use of the upper extremities for weight-bearing; and (8) difficulty standing or walking independently. All participants were asked to provide their age, weight, height, and hand dominance.

After an interview, 237 subjects (144 men and ninety-three women) who met the selection criteria were identified and were included in the study. The mean age (and standard

TABLE I Age and Sex Distribution of the Study Subjects

	Group A (40-49 yr)	Group B (50-59 yr)	Group C (60-69 yr)	Group D (≥70 yr)	Total
Men	29	41	37	37	144
Women	24	29	23	17	93
Total	53	70	60	54	237

deviation) was 59.6 ± 11.3 years (range, forty to eighty-six years). Table I illustrates the age and sex distribution of the study subjects. The mean height was 172.6 ± 11.2 cm, and the mean weight was 83 ± 17.9 kg. The group included twenty-eight patients who visited the orthopaedic surgery clinic in our institution for non-shoulder-related problems, 188 family members who accompanied patients, eight volunteers from a local church, six volunteers from a volunteer program for research in our institution, and seven employees of our institution. More subjects (237) were enrolled in the study than the initial power analysis had suggested (136) in an attempt to increase the power of the study and to find more subjects with an asymptomatic rotator cuff tear.

Screening Ultrasonography

Screening ultrasonography of both shoulders was performed by a single orthopaedic surgeon (H.M.K.) who had been extensively trained in shoulder ultrasonography. The diagnostic accuracy of ultrasonography in our institution has been validated for both full-thickness and partial-thickness tears of the rotator cuff¹⁰⁻¹².

All ultrasonography examinations were performed in real time with use of a scanner (Zonare Medical Systems, Mountain View, California) and a variable high-frequency linear array transducer (5 to 10 MHz). All study subjects had standardized bilateral ultrasonography of the shoulder as previously described^{11,13}. In brief, the subject was seated on a stool with the forearms resting on the thighs and the examiner was positioned behind him or her. First, the biceps tendon was examined in the transverse plane from the level of the acromion inferiorly to the point where the tendon merged with the biceps muscle. The transducer then was rotated 90° in order to examine the tendon longitudinally. Next, images of the subscapularis tendon were made with the subject's arm externally rotated; the transducer was placed in the transverse anatomical orientation of the subscapularis at the level of the lesser tuberosity and was moved medially. Longitudinal images of the subscapularis were also made by placing the transducer parallel with the subscapularis muscle direction. Images of the supraspinatus tendon were made with the shoulder extended, the elbow flexed, and the hand placed on the iliac wing. The transducer was oriented parallel to the tendon in order to visualize the fibers in a longitudinal plane and was moved in an anterior-to-posterior direction in order to visualize the supraspinatus and infraspinatus tendons. The transducer was then rotated 90° in order to examine the tendons in the transverse plane.

Ultrasonographic Criteria

The ultrasonographic criteria used to identify the abnormalities of the rotator cuff were strictly based on the criteria used in the previous study¹¹. Briefly, a full-thickness tear was diagnosed when the rotator cuff could not be visualized or when there was a focal defect in the rotator cuff created by retraction of the torn tendon ends. A partial-thickness tear was diagnosed when there was focal flattening or loss of convexity at the bursal side of the rotator cuff (a bursal-side partial-thickness tear) or a distinct hypoechoic or mixed hyperechoic and hypoechoic defect visualized in both the longitudinal and the transverse plane at the articular side of the rotator cuff (an articular-side partial-thickness tear). Compression force was applied to the deltoid muscle with the transducer in order to separate the torn tendon ends at the site of a nonretracted tear and, thus, to facilitate the identification. The size of the rotator cuff tear was measured at the level of the anatomic neck on the transverse dimension. Tears of <1 cm in width were considered small. Tears of ≥ 1 cm and <3 cm were considered medium. Tears of ≥ 3 cm and <5 cm were considered large, and tears of ≥ 5 cm were considered massive¹⁴. The rotator cuffs considered to have tendinopathy or normal anisotropy without a frank defect were classified as being intact.

Measurement of Isometric Shoulder Strength

An Isobex dynamometer (Cursor AG, Bern, Switzerland) was used to measure the isometric shoulder strength. The dynamometer was fixed onto a stable table with use of a built-in vacuum apparatus. The strap of the dynamometer was applied to the wrist of the subject, and the subject was asked to pull the strap with his or her full exertion in a designated direction for five seconds. Two different tasks were performed by each subject: (1) isometric elevation at 90° of abduction in the scapular plane (i.e., 30° of horizontal flexion anterior to the coronal plane) with neutral humeral rotation as specified by the Constant and Murley shoulder assessment protocol¹⁵ (Fig. 1-A) and (2) isometric external rotation at 0° of abduction with 45° of internal rotation of the humerus as specified by Kelly et al.¹⁶ (Fig. 1-B). The subject was asked to perform abduction in the scapular plane in a standing position and to perform external rotation in a sitting position on a stable chair. When performing the external rotation task, the subject was asked to externally rotate only the forearm with the elbow kept at the side to prevent compensation from motion of the torso or extension-abduction of the humerus. Each task was repeated three times for each shoulder with at least thirty seconds of resting time between measurements to avoid the effect of muscle fatigue. When the subject did not follow the testing method correctly, the measurements were discarded and testing was repeated following the correct method. The mean strength value of the three trials was obtained for each task and was used for analysis. No subject experienced pain during the strength testing.

Statistical Methods

Data from each subject were entered into a Microsoft Excel spreadsheet and then were transferred to the data table of a

statistical software program for analysis. To compare shoulder strength between the age groups, one-way analysis of variance tests and the Tukey honestly significant difference post hoc tests were performed. To compare the shoulder strength between sexes and between the dominant and nondominant sides, unpaired t tests and paired t tests, respectively, were performed. To investigate the association of shoulder strength with body habitus and age, Pearson correlation coefficients were obtained. To determine important predictors of shoulder strength, stepwise multiple linear regression analyses were performed. Tests for normality of the shoulder strength values were performed with Kolmogorov-Smirnov tests and Shapiro-Wilk tests. To compare strength between the shoulder with a rotator cuff tear and the contralateral shoulder with an intact rotator cuff within each subject, either paired t tests or Wilcoxon signed-rank tests were performed. To compare the strength of the shoulders with a rotator cuff tear and that of the shoulders with an intact rotator cuff, either unpaired t tests or Mann-Whitney tests were performed. All of the data were reported as the mean and the standard deviation.

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Results

Normative Isometric Strength of Shoulders with an Intact Rotator Cuff

In the male subjects verified to have intact rotator cuffs by ultrasonography, the mean external rotation strength of the shoulders on the dominant side and those on the nondominant side was 107.9 ± 28.4 Nm and 107.9 ± 31.4 Nm, respectively, and the mean abduction strength of the dominant shoulders and the nondominant shoulders was 92.2 ± 21.6 Nm and 92.2 ± 24.5 Nm, respectively. In the female subjects verified to have intact rotator cuffs by ultrasonography, the mean external rotation strength of the dominant and nondominant shoulders was 61.8 ± 14.7 Nm and 58.8 ± 13.7 Nm, respectively, and the mean abduction strength of the dominant and nondominant shoulders was 52.0 ± 12.8 Nm and 50.0 ± 11.8 Nm, respectively (Table II). The strength was not significantly different between the dominant and nondominant side in the male subjects, whereas the shoulder on the dominant side was significantly stronger than the shoulder on the nondominant side in the female subjects ($p = 0.015$ for external rotation strength, and $p = 0.005$ for abduction strength). The male subjects were significantly stronger than the age-matched female subjects in both tasks ($p < 0.0001$ for both tasks in all age groups).

In a comparison between the age groups of the male subjects, there was a trend for both decreased external rotation and abduction strength in the older age groups, and a significant difference was found between Group A and Group C ($p = 0.024$ for external rotation strength, and $p = 0.019$ for abduction strength), between Group A and Group D ($p = 0.003$ and $p = 0.001$, respectively), and between Group B and Group

Fig 1-A

Figs. 1-A and 1-B Isometric shoulder strength measurement with use of an Isobex dynamometer. **Fig. 1-A** Isometric elevation at 90° of abduction in the scapular plane (i.e., 30° of horizontal flexion anterior to the coronal plane) with neutral humeral rotation. **Fig. 1-B** Isometric external rotation at 0° of abduction with 45° of internal rotation of the humerus.

Fig. 1-B

D ($p = 0.029$ and $p = 0.003$, respectively) (see Appendix). In the female subjects, only the abduction strength was significantly decreased in Group D compared with Group A ($p = 0.002$) and Group B ($p < 0.001$) (see Appendix).

Age, weight, height, and body mass index all had a significant correlation with both external rotation and abduction strength in the male subjects ($p < 0.05$) (see Appendix). In the female subjects, weight and body mass index had a significant

TABLE II Isometric Shoulder Strength of Subjects with Intact Rotator Cuff

	Group A (40-49 yr)	Group B (50-59 yr)	Group C (60-69 yr)	Group D (≥70 yr)	Overall
Men	29	38	27	21	
External rotation* (Nm)					
Dominant side	120.6 ± 33.3	112.8 ± 22.6	99.0 ± 24.6	92.2 ± 25.5	107.9 ± 28.4
Nondominant side	121.6 ± 36.3	110.8 ± 28.4	100.0 ± 31.4	94.1 ± 21.6	107.9 ± 31.4
Abduction* (Nm)					
Dominant side	102.0 ± 27.5	97.1 ± 16.7	85.3 ± 18.6	77.5 ± 16.7	92.2 ± 21.6
Nondominant side	103.0 ± 27.5	99.1 ± 16.7	84.3 ± 23.5	73.6 ± 19.6	92.2 ± 24.5
Women	24	25	21	11	
External rotation* (Nm)					
Dominant side	62.8 ± 15.7	65.7 ± 14.7	61.8 ± 12.8	52.0 ± 12.7	61.8 ± 14.7
Nondominant side	58.8 ± 12.8	61.8 ± 14.7	60.8 ± 12.8	49.0 ± 9.8	58.8 ± 13.7
Abduction* (Nm)					
Dominant side	54.9 ± 10.8	56.9 ± 12.8	49.0 ± 10.8	40.2 ± 9.8	52.0 ± 12.8
Nondominant side	54.0 ± 10.8	53.9 ± 11.8	46.1 ± 10.8	38.3 ± 8.8	50.0 ± 11.8

*The values are given as the mean and the standard deviation.

correlation only with external rotation strength ($p < 0.05$). On the other hand, age had a significant correlation with abduction strength ($p < 0.01$). Height had a slightly negative effect on shoulder strength although the relationship did not reach the level of significance.

Weight, height, and age were entered into multiple linear regression models in a backward stepwise method. There was a significant collinearity between weight and body mass index (correlation coefficient = 0.865), which precluded simultaneous inclusion of both factors in regression models. Weight was chosen over body mass index for a predictor because weight was thought to be a more direct measurement of the body habitus of a subject than was body mass index and because height did not show a significant correlation with shoulder strength in the female subjects. In the male subjects, weight was the most important predictor of external rotation strength for

either side (standardized coefficient, $\beta = 0.341$ and 0.331 for the dominant and nondominant side, respectively), followed by age (Table III), and, in contrast, age was the most important predictor of abduction strength for either side ($\beta = -0.364$ and -0.378 for the dominant and nondominant side, respectively), followed by weight. In the female subjects, weight was the only important predictor of external rotation strength for either side ($\beta = 0.282$ and 0.331 for the dominant and nondominant side, respectively), and age was the only important predictor of abduction strength for either side ($\beta = -0.401$ and -0.411 for the dominant and nondominant side, respectively) (Table III).

Prevalence of Asymptomatic Rotator Cuff Tears

With screening ultrasonography, forty-one (17.3%) of the 237 subjects were found to have a torn rotator cuff in at least one

TABLE III Multiple Regression Analysis to Determine Important Predictors of Shoulder Strength

Predictors	External Rotation Strength*		Abduction Strength*	
	Dominant Side	Nondominant Side	Dominant Side	Nondominant Side
Male subjects				
Age	-0.338 (0.000)†	-0.283 (0.001)†	-0.364 (0.000)†	-0.378 (0.000)†
Weight	0.341 (0.000)†	0.331 (0.000)†	0.251 (0.004)†	0.284 (0.001)†
Height	0.127 (0.146)	0.136 (0.130)	0.164 (0.059)	0.120 (0.163)
Female subjects				
Age	-0.198 (0.075)	-0.154 (0.164)	-0.401 (0.000)†	-0.411 (0.000)†
Weight	0.282 (0.014)†	0.331 (0.004)†	0.145 (0.171)	0.236 (0.024)†
Height	-0.137 (0.228)	-0.113 (0.317)	-0.203 (0.057)	-0.202 (0.053)

*The values are given as the standardized coefficient of each predictor (the greater the absolute value of the coefficient of a predictor, the greater the predictor contributes to strength determination), with the p value in parentheses. †The correlation was significant ($p < 0.05$).

TABLE IV Distribution of Rotator Cuff Tears Across Age Groups

	Group A (40-49 yr)	Group B (50-59 yr)	Group C (60-69 yr)	Group D (≥70 yr)	Total	Mean Age (yr)
No. of subjects	53	70	60	54	237	59.6
Intact rotator cuff (<i>no. of subjects</i>)	53	63	48	32	196	57.9
Bilateral full-thickness tear (<i>no. of subjects</i>)	0	0	1	3	4	73.8
Unilateral full-thickness tear (<i>no. of subjects</i>)	0	4	4	9	17	68.2
Full-thickness tear in one shoulder and partial-thickness tear in the other shoulder (<i>no. of subjects</i>)	0	1	0	4	5	72.8
Unilateral partial-thickness tear (<i>no. of subjects</i>)	0	2	6	5	13	67.4
Bilateral partial-thickness tear (<i>no. of subjects</i>)	0	0	1	1	2	70.5
Prevalence of cuff tear in each age group	0%	10%	20%	40.7%	17.3%	

shoulder. The prevalence of rotator cuff tear for each age group was 0% for Group A, 10% for Group B, 20% for Group C, and 40.7% for Group D (Table IV). The mean age of the subjects with an intact rotator cuff was 57.9 ± 10.7 years, and the mean age of the subjects with a rotator cuff tear was 69.2 ± 9.1 years ($p < 0.05$). The thirty subjects with a unilateral rotator cuff tear had a mean age of 67.8 ± 9.3 years, and the eleven subjects with bilateral tears were all men with a mean age of 72.8 ± 7.8 years. A unilateral full-thickness tear was the most common pattern (seventeen [41%] of forty-one subjects) among the rotator cuff tears, followed by unilateral partial-thickness tear (thirteen [32%] of forty-one subjects). Four subjects (mean age, 73.8 ± 6.2 years) had bilateral full-thickness tears, and three of them were more than seventy years old. Among the thirty subjects with a unilateral tear, nineteen (63%) had the tear in the dominant shoulder, and eleven had the tear in the nondominant shoulder.

Isometric Shoulder Strength in Asymptomatic Subjects with a Torn Rotator Cuff

In the thirteen subjects with a unilateral partial-thickness rotator cuff tear, no significant strength difference was seen between shoulders with respect to external rotation ($p = 0.564$) and abduction ($p = 0.974$) strength. In the seventeen subjects with a unilateral full-thickness tear, no significant strength difference was seen between shoulders with regard to external rotation ($p = 0.406$) and abduction ($p = 0.159$) strength. However, the abduction strength was found to be significantly decreased ($p = 0.007$) in the six shoulders with a large-to-massive full-thickness tear compared with the contralateral shoulders with an intact rotator cuff, a partial-thickness tear, or a small or medium full-thickness tear. External rotation strength was also decreased in the shoulders with a large-to-massive tear, but this decrease was not significant ($p = 0.126$). In the male subjects who were seventy years old or more, the fifteen shoulders with a full-thickness tear showed significantly decreased abduction strength compared with the intact shoulders ($p = 0.004$ for the dominant side, and $p = 0.003$ for the non-dominant side). Meaningful statistical tests were not possible in

any other groups because of the small number of shoulders with a tear in those groups. The mean ratio of abduction strength to external rotation strength in the shoulders with an intact rotator cuff was 0.86 ± 0.18 . In the shoulders with a full-thickness tear, this ratio was significantly decreased to 0.70 ± 0.24 ($p < 0.001$). This ratio was further decreased to 0.48 ± 0.21 ($p < 0.001$) in the shoulders with a large or massive full-thickness tear.

Discussion

It is not known how rotator cuff tears affect the shoulder strength in asymptomatic subjects. In a recent study, Yamaguchi et al.¹⁷ showed that there is a 56.3% chance of a rotator cuff tear in the contralateral, asymptomatic shoulder if a patient presents with a painful full-thickness tear in one shoulder. In the evaluation of shoulder function in patients with bilateral rotator cuff tears, neither shoulder can serve as a reliable internal reference for the other because the biomechanics may have been altered by the presence of the tear¹⁸. Thus, for an accurate and objective evaluation of shoulder function, it is important to compare with a normative database of healthy subjects with intact rotator cuffs. In this study, we developed an age and sex-stratified normative database that represents the actual isometric strength of the shoulders with an intact rotator cuff by eliminating individuals with an asymptomatic rotator cuff tear. The results may be particularly helpful when the popular Constant and Murley scoring system¹⁵ is used for the assessment of shoulder function.

This study shows that isometric shoulder strength changes with age and body habitus. In men, shoulder strength decreased with increasing age and increased with increasing weight, height, and body mass index. In the multiple regression analysis, age was the most important predictor of abduction strength, whereas weight was the most important predictor of the external rotation strength. Likewise, shoulder strength decreased with increasing age in women. However, the age-dependent decrease in external rotation strength in women did not reach the level of significance. In the multiple regression analysis, weight was found to be the only significant predictor of external rotation strength in women. This finding is consistent

with the study by Lannersten et al.¹⁹ who found no age-related decrease in shoulder strength in women. However, this finding does not support other reports^{1,20-24} that have shown an age-related decrease in upper extremity strength in both sexes. We also confirmed by our stepwise multiple regression analyses the finding in the study by Andrews et al.²⁰ that height is not an independent predictor of shoulder strength in either sex.

In the present study, men did not demonstrate a significant difference in shoulder strength between the dominant and nondominant sides, but women did. This result supports the finding of Cahalan et al.²⁵ who measured isokinetic strength during shoulder flexion-extension and abduction-adduction in fifty healthy volunteers and found that strength on the dominant side was substantially greater than that on the nondominant side only for shoulder flexion and adduction in male subjects, whereas substantial differences between the two sides were observed for all testing directions in female subjects. The finding of significant strength differences between men and women observed in our study is not surprising and is in agreement with many other studies in the literature^{1-3,19-22,24,25}. In the present study, women were noted to have between 48.3% (external rotation strength of the nondominant shoulder in Group A) and 62.4% (external rotation strength of the dominant shoulder in Group C) of the shoulder strength of men in the corresponding age groups.

Contrary to our hypothesis, not all of the shoulders with an asymptomatic rotator cuff tear were weaker than the shoulders with an intact rotator cuff. However, when there was a large or massive full-thickness tear in a shoulder, abduction strength was significantly decreased compared with the contralateral shoulder with an intact cuff, a partial-thickness tear, or a small or medium full-thickness tear. This finding was not observed in the external rotation strength measurement. We also noted that in individuals who were seventy years of age and older, the shoulders with a full-thickness tear had significantly decreased abduction strength compared with normal shoulders regardless of the size of the tear. Again, this finding was not observed in the external rotation strength measurement.

This study shows that the strength of abduction in the scapular plane is approximately 86% of external rotation strength in normal shoulders with an intact rotator cuff. We noted that, in the shoulders with a full-thickness tear of any size, abduction strength decreased to 70% of external rotation strength. When we included only the shoulders with a large or massive full-thickness tear, the abduction strength was found to be further decreased to 48% of external rotation strength. From these results, one may conclude that if a shoulder has substantially decreased abduction strength compared with external rotation strength, the presence of a large full-thickness rotator cuff tear should be suspected in that shoulder.

It is unclear why abduction weakness was more pronounced than external rotation weakness in shoulders with a full-thickness rotator cuff tear. The phenomenon can most likely be explained by the fact that the majority of cuff tears involve the supraspinatus tendon with variable but progressive involvement of the infraspinatus tendon as the tear size increases.

We observed that the prevalence of asymptomatic rotator cuff tears increased with age as has been reported in previous studies^{5-9,17}. The prevalence of rotator cuff tears in asymptomatic subjects in this study is slightly lower than that reported by some investigators. Rotator cuff tears were found in 30.7% of the study subjects over sixty years old in our study. Sher et al.⁸ reported a 54% prevalence of rotator cuff tears in subjects older than sixty years. Milgrom et al.⁵ reported a 50% rate, and Tempelhof et al.⁹ reported a 30.3% rate in this age group.

Although various methods have been used by other investigators to measure shoulder strength, measuring isometric strength with an Isobex dynamometer was chosen for this study for a few reasons. Measuring isometric strength has been reported to be more tolerable and easier for patients with rotator cuff tears to complete than isokinetic strength testing^{1,26}. The Isobex dynamometer is portable and easy to use. It is the most commonly reported strength measurement device for the shoulder, and its accuracy and reliability have been validated by other investigators^{2,4,27,28}.

This study has a few limitations. First, we collected weight and height data solely on the basis of information provided by the subjects, introducing the possibility of inaccurate data collection compared with actual measuring for each subject. Second, the Isobex dynamometer was positioned parallel to the coronal plane of the subject during the external rotation strength measurement rather than perpendicular to the direction of forearm pulling (i.e., at a 45° angle to the coronal plane). This positioning should be reproduced if our results are to be compared in future studies.

Considering the high prevalence of asymptomatic rotator cuff tears in elderly individuals, one may question whether the strength data of this study obtained from individuals with intact rotator cuffs represent the normative strength of the population. The purpose of this study was to establish a database for the strength of shoulders that were anatomically and physiologically normal so that the shoulder strength of a patient can be compared with a reference value even in the presence of bilateral rotator cuff disease.

In summary, we developed a normative database of isometric shoulder strength, which may be useful to many clinicians in evaluating shoulder strength in patients. Age is the most important predictor of strength of abduction in the scapular plane, whereas body weight is the most important predictor of external rotation strength. There is a high prevalence of rotator cuff tears in asymptomatic individuals, especially those over sixty years old. The strength of abduction in the scapular plane in individuals with a large-to-massive full-thickness rotator cuff tear is substantially decreased. When there is a substantial decrease in the strength of abduction in the scapular plane in relation to the strength in external rotation, the possibility of an asymptomatic full-thickness rotator cuff tear should be suspected. Previous studies establishing the normative values for isometric shoulder strength may have been skewed by the presence of asymptomatic rotator cuff tears in elderly subgroups.

Appendix

eA Figures showing comparisons of isometric shoulder strength between age groups and a table showing correlations between isometric shoulder strength and subject descriptors are available with the electronic versions of this article, on our web site at jbsj.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD). ■

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