

[Sports Physical Therapy]



Isometric Shoulder Strength Reference Values for Physically Active Collegiate Males and Females

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Background: It is common clinical practice to assess muscle strength during examination of patients following shoulder injury or surgery. Strength comparisons are often made between the patient's injured and uninjured shoulders, with the uninjured side used as a reference without regard to upper extremity dominance. Despite the importance of strength measurements, little is known about expected normal baselines of the uninjured shoulder. The purpose of this study was to report normative values for isometric shoulder strength for physically active college-age men and women without history of shoulder injury.

Methods: University students—546 males (18.8 ± 1.0 years, 75.3 ± 12.2 kg) and 73 females (18.7 ± 0.9 years, 62.6 ± 7.0 kg)—underwent thorough shoulder evaluations by an orthopaedic surgeon and completed bilateral isometric strength measurements with a handheld dynamometer. Variables measured included internal rotation, external rotation, abduction, supine internal rotation and external rotation at 45° , and prone flexion (lower trapezius).

Results: Significant differences were found between the dominant and nondominant shoulder for internal rotation, internal rotation at 45° , abduction, and prone flexion in males and in internal rotation at 45° and prone flexion for females ($P \leq 0.01$).

Keywords: isometric; shoulder; strength; normative data

Strength assessment of the glenohumeral and scapulothoracic muscles is an essential component of the shoulder examination. The rotator cuff muscles function primarily to stabilize and center the head of the humerus on the glenoid during upper extremity movements.³⁰ The lower trapezius serves an equally important role, contributing to shoulder function primarily in scapular upward rotation, external rotation, and posterior tilt.²² When weakness is detected, strengthening exercises serve as a primary component of rehabilitation. Throughout the recovery process, strength assessments are repeated to evaluate progress, to adjust resistance for rehabilitation exercises, and to determine readiness to return to activity or sport. Despite the importance of postinjury strength assessment, little is known about expected baseline isometric strength in the uninjured shoulder in college athletes.

It is generally accepted that optimal shoulder function requires “normal” shoulder strength. A strain or tear of the rotator cuff muscles often leads to abnormal function because of inadequate secondary dynamic stabilization of the glenohumeral joint. Even in the absence of injury, rotator cuff muscle weakness may predict shoulder injury and may contribute to shoulder instability.^{5,17,31} Because muscle strength is a potential modifiable risk factor for shoulder injury, it is important to implement effective and proper techniques for strengthening the glenohumeral and scapulothoracic musculature. If the goal, however, is to reach “normal” shoulder strength, knowledge of muscle strength normative values may be useful.

While the most commonly performed clinical assessment of strength is the gross manual muscle test, this method lacks objectivity and presents reliability concerns.^{3,8,26} In contrast, because isokinetic testing provides easily interpreted

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The views and opinions expressed in this manuscript are those of the author(s) and do not reflect the official policy of the Department of the Army, the Department of Defense, or the U.S. Government.

One or more of the authors has declared a potential conflict of interest: This project was aided by a grant from the Orthopaedic Research and Education Foundation.

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DOI: 10.1177/1941738112456280

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objective data, it is often recognized as the gold standard for strength testing. Unfortunately, this method is costly and time-consuming, and the equipment is not readily available for many clinicians. Additionally, patients with pathology or those who are postoperative may not be able to tolerate isokinetic testing.²¹ Isometric strength testing with a handheld dynamometer is a relatively inexpensive and efficient way for clinicians to assess strength, and these devices have been shown to produce reliable objective data.^{12,15,23,25} The concurrent validity of handheld dynamometry and isokinetic dynamometry has been reported in several studies.^{7,14,28}

Age-related changes in normal isometric shoulder strength indicate that meaningful differences likely exist between subjects in their second decade and those in their third and fourth decades.⁹ Riemann and colleagues reported normative data for shoulder internal and external rotator musculature on subjects 20 to 40 years old; however, they did not report a comparison between those in their twenties versus those in their thirties.²³ Furthermore, their sample was not specifically athletic college students, as it included faculty members as well as other community members.²³ Turner and colleagues also reported normative data on subjects 13 to 60 years old, stratified by activity level rather than age.²⁹

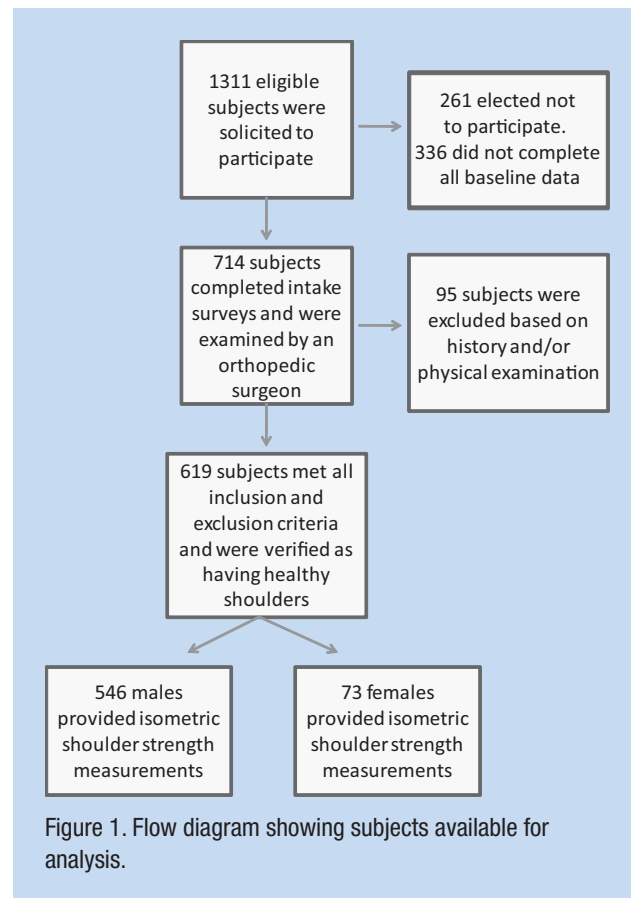
When normative strength values are reported for a “healthy” population, it is important to first verify that the population is healthy. Previous research has demonstrated a high prevalence of rotator cuff pathology in asymptomatic individuals, which increases with age.¹² A physical examination could identify asymptomatic subjects with shoulder pathology. Previous studies of normative shoulder strength have measured individuals who were asymptomatic solely on the basis of patient-reported screening questionnaires or medical record review and/or interview.^{9,12,23,29} Turner et al did not report any form of physical evaluation; some subjects in their study were in age ranges that could have asymptomatic rotator cuff pathology.^{12,29}

Baseline strength comparisons between injured and uninjured shoulders are commonly performed following injury under the assumption that the uninjured limb is an appropriate reference regardless of hand dominance. Furthermore, it is common to encounter patients with bilateral shoulder symptoms, which inhibit side-to-side strength comparisons.⁹ The purpose of this study was to describe isometric shoulder strength values for healthy, physically active university students (17–21 years of age) without a history of shoulder injury. A secondary objective was to evaluate differences in strength measures by arm dominance and sex.

METHODS

Design and Setting

Subjects were freshmen between the ages of 17 and 21 years entering a 4-year collegiate-level military academy in June 2006. As part of the baseline assessment within this cohort, all subjects completed bilateral strength testing for the muscles of



the shoulder and rotator cuff. The Institutional Review Board at Keller Army Community Hospital reviewed and approved this study prior to initiation.

Participants

The majority of students at the United States Military Academy are highly active and participate in athletics and physical activities to a greater extent than their counterparts at civilian universities.¹⁶ Exclusion criteria for this study included current shoulder symptoms (pain, weakness, instability), history of shoulder surgery, shoulder instability or trauma, neurological disease, and current cervical or thoracic spine pain or injury.

Of the 1311 potential subjects solicited to participate in the study, 714 provided informed consent and completed all baseline assessments (Figure 1). Of those, 619 met all inclusion/exclusion criteria and were verified as having “normal” shoulders based on physical examination by an orthopaedic surgeon. As a result, the final study population consisted of 546 males (18.8 ± 1.0 years, 75.3 ± 12.2 kg) and 73 females (18.7 ± 0.9 years, 62.6 ± 7.0 kg), which is reflective of the sex distribution of the United States Military Academy at matriculation (85% male, 15% female).

Table 1. Intrarater and interrater reliability.

Position	Rater 1 ^a	Rater 2 ^a	Rater 3 ^a	Interrater ^b
External rotation	0.725	0.631	0.808	0.792
Internal rotation	0.896	0.862	0.935	0.897
Abduction	0.905	0.887	0.662	0.827
External rotation, 45°	0.894	0.924	0.776	0.850
Internal rotation, 45°	0.985	0.969	0.957	0.905
Prone flexion	0.948	0.885	0.860	0.829

^an = 12.^bIntraclass correlation coefficient.

Procedures

Baseline questionnaires established demographics: injury and physical activity. All subjects underwent a standardized shoulder evaluation by an orthopaedic surgeon, including active range of motion, joint stability, and shoulder impingement.¹⁹

Handheld Dynamometer Isometric Strength Testing

Bilateral isometric strength was assessed using a handheld dynamometer (model 01163, Lafayette Instrument Company, Lafayette, Indiana).^{10,12,32} Intraclass correlation coefficients were calculated along with inter- and intrarater reliability for all 3 researchers (Table 1).¹

The strength measures included internal and external rotation and abduction in the neutral position, supine internal rotation and external rotation at 45° abduction, and flexion in the prone position. The dynamometer was placed just proximal to the elbow for the abduction measurement and just proximal to the styloid process of the wrist joint for all other measurements. Subjects were asked to produce a 5-second maximal contraction rather than a “break test.”^{23,29} Two trials were completed for each side in each position; the greatest force produced was used as a measure of muscular strength.⁴

Internal rotation at 45° and external rotation at 45° were measured with subjects in the supine and seated position with the shoulder abducted to 45° with 0° of flexion/extension. A bolster was used to maintain neutral flexion/extension. The supine internal rotation at 45° and external rotation at 45° positions have been described as optimal positions associated with reduced coefficient of variation and were selected to stabilize the scapulothoracic joint with the shoulder abducted to the scapular plane.^{6,11}

Prone flexion measurements were obtained for the lower trapezius with the arm extended overhead (full flexion up to 180°) and abducted 135° with the elbow fully extended and thumb directed upward.^{11,13,20}

Table 2. Participant demographics.

	Men (n = 546)	Women (n = 73)
Age, y	18.8 ± 1.0	18.7 ± 0.9
Mass, kg ^a	75.3 ± 12.2	62.6 ± 7.0
Height, cm ^a	178.5 ± 7.5	165.4 ± 7.0

^a

Statistical Analysis

Strength means and standard deviations were normalized by body mass (strength/body mass) and analyzed by sex and hand dominance. Paired *t* tests were performed to identify significant differences between dominant and nondominant sides. Independent *t* tests were performed to identify differences between sex. Gender-based percentile cut points were calculated for all strength measures. All statistical analyses were performed using SPSS 11.5.

RESULTS

Participant demographics were normally distributed (Table 2). The dominant shoulder was significantly stronger than the nondominant shoulder ($P \leq 0.01$) for internal rotation, internal rotation at 45°, abduction, and prone flexion in males and in internal rotation at 45° and prone flexion in females (Table 3). Males were significantly stronger ($P \leq 0.01$) than females in all measures (Table 3). Gender based percentile cut points are presented in Table 4.

DISCUSSION

Isometric testing offers a practical, reliable,^{8,23,25} and cost-effective alternative to more costly and time-consuming

Table 3. Isometric shoulder strength normative data computed relative to body weight for healthy male and female subjects (mean $\pm$ SD).^a

		Dominant	Nondominant
External rotation	Males	0.20 $\pm$ 0.04	0.19 $\pm$ 0.05
	Females	0.16 $\pm$ 0.04	0.15 $\pm$ 0.04
Internal rotation	Males	0.27 $\pm$ 0.06 ^b	0.27 $\pm$ 0.06
	Females	0.21 $\pm$ 0.05	0.21 $\pm$ 0.06
Abduction	Males	0.35 $\pm$ 0.08	0.35 $\pm$ 0.08
	Females	0.29 $\pm$ 0.10	0.29 $\pm$ 0.10
External rotation, 45° abduction	Males	0.22 $\pm$ 0.05	0.22 $\pm$ 0.05
	Females	0.18 $\pm$ 0.04	0.18 $\pm$ 0.04
Internal rotation, 45° abduction	Males	0.26 $\pm$ 0.05 ^b	0.25 $\pm$ 0.05
	Females	0.21 $\pm$ 0.05 ^b	0.20 $\pm$ 0.05
Prone flexion	Males	0.12 $\pm$ 0.03 ^b	0.11 $\pm$ 0.03
	Females	0.10 $\pm$ 0.03 ^b	0.10 $\pm$ 0.03

^ap $\leq$ 0.001 Each difference between males and females significant at $P < 0.001$.

^bStatistically significant side-to-side difference at $P \leq 0.01$.

Table 4. Isometric shoulder strength percentiles computed relative to body weight by hand dominance for male and female subjects.

	Dominant											
	External Rotation		Internal Rotation		Abduction		External Rotation 45°		Internal Rotation 45°		Prone Flexion	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
5th	0.14	0.11	0.18	0.13	0.23	0.18	0.15	0.11	0.17	0.15	0.07	0.05
25th	0.17	0.14	0.24	0.18	0.30	0.23	0.19	0.15	0.22	0.18	0.10	0.08
50th	0.19	0.16	0.27	0.21	0.35	0.29	0.22	0.17	0.26	0.21	0.11	0.10
75th	0.22	0.18	0.32	0.24	0.40	0.34	0.24	0.20	0.29	0.23	0.14	0.12
95th	0.26	0.23	0.37	0.31	0.49	0.44	0.30	0.25	0.35	0.31	0.18	0.17
	Nondominant											
5th	0.13	0.10	0.18	0.13	0.23	0.17	0.15	0.12	0.17	0.13	0.06	0.06
25th	0.16	0.13	0.23	0.18	0.29	0.21	0.19	0.15	0.22	0.17	0.09	0.08
50th	0.19	0.15	0.27	0.20	0.34	0.28	0.21	0.17	0.25	0.20	0.11	0.09
75th	0.22	0.18	0.30	0.24	0.40	0.34	0.24	0.20	0.29	0.22	0.13	0.11
95th	0.27	0.20	0.36	0.33	0.47	0.47	0.29	0.26	0.34	0.30	0.17	0.16

isokinetic testing when evaluating strength. Handheld dynamometry strength measures have demonstrated high concurrent validity when compared with the established

standard, isokinetic measurements.¹⁴ Clinicians frequently gauge strength by deficiency in the affected side.^{9,10,32} These data indicate that there may be an underlying difference in

side-to-side strength measures in some positions with the dominant side being stronger than the nondominant side. Riemann et al reported dominant internal rotation is stronger in healthy subjects aged 20 to 40 years.²³ The differences in the current study were small (0.01%-0.02% body weight). Work and leisure activities can contribute to unilateral strength discrepancies.^{2,23}

Shoulder strength assessments are a valuable component of the physical examination. In adolescent female volleyball athletes, shoulder dysfunction was related to strength ratio deficits, suggesting that preventive shoulder eccentric strengthening programs focused on correcting imbalances between medial and lateral rotators may be warranted.²⁷ Similar conclusions are seen in young tennis players^{18,24} and in female athletes in general.¹⁷ The relationship between strength and the risk of shoulder injury is unknown.⁵ Prospective studies are needed to determine if shoulder strength measures are associated with the subsequent risk of shoulder instability.

An important limitation in the current investigation is the generalizability of the relatively homogeneous male dominance in the study population. The study has several strengths, including strength measurements bilaterally on 619 physically active, healthy university students. Nearly 75% participated in high school athletics, and all met the baseline medical and physical fitness standards for military service. As a result, the findings of the current study are probably most comparable with young athletic high school or college-age populations.

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