

Original Research

Normative Values of Isometric Shoulder Strength Among Healthy Adults

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Background

Normative data is useful for comparing measured values of strength with population norms and can avoid the issues associated with limb symmetry index. The available normative shoulder strength values are limited by constraints on research designs and variability in subject groups which prevents this data being successfully extrapolated to the greater population.

Purpose

The purpose of this study was to establish normative isometric strength values for various movements of the shoulder that are specific to function and rotator cuff strength. A secondary goal of this study was to analyze the effect of age, gender, weight, height, activity level and arm dominance on shoulder strength.

Design

Observational cohort study

Methods

Subjects in four age groups (20-29, 30-39, 40-49, 50-59) were included in this study—200 males (40.0 ± 11.6 years, 179.1 ± 6.5 cm, 81 ± 13.0 kg) and 200 females (40.1 ± 11.5 years, 165.3 ± 7.4sm, 64.4 ± 11.6 kg). Bilateral isometric strength measurements were taken with a handheld dynamometer testing seven shoulder movements. Tables of normative strength data were constructed. Multivariate analyses were performed to analyze the effects of age, gender, weight, height and activity level on isometric shoulder strength.

Results

Men were stronger than women ($p < 0.001$). Age was not associated with most strength measures with the exception of dominant arm abduction ($p < 0.004$), non-dominant arm abduction ($p < 0.028$) and non-dominant arm scapular plane abduction ($p < 0.004$) which had a negative association with strength. Weight was positively associated with strength ($p < 0.001$). Activity level was positively associated with all strength measures ($p < 0.05$) except dominant sided abduction ($p = 0.056$). There were no statistically significant differences between dominant and non-dominant sides.

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Conclusion

This normative data may be useful to the clinician, as it permits a standard against which to compare shoulder strength for various age groups. Clinicians can have confidence that the uninvolved limb, if symptom free, can be used as an adequate benchmark for strength measures.

Levels of Evidence

Level 3

INTRODUCTION

Strength of the shoulder complex musculature is necessary for activities of daily living, recreation and sport, and is an important physical parameter assessed by rehabilitation specialists.¹ Shoulder strength is often used as a benchmark for goal setting during rehabilitation, is helpful for evaluating progress, and is used to determine readiness to return to activity, work or sport.² The use of limb symmetry index (LSI) is often used in practice and is a beneficial way to compare limb strength, however it has several limitations including when an individual has bilateral pathologies or a limb dominance which can over- or underestimate strength values.³ Normative data can be useful for comparing measured values of strength with population norms. Previous researchers have reported normative values for shoulder strength however some of this has been restricted to specialized groups of individuals,^{3,4} conducted using small sample sizes or age ranges,⁵⁻⁷ and tested limited shoulder movements.⁷⁻⁹ Activity level of subjects was not considered in some studies^{6,10,11} which may influence strength. It is thought that an adequate balance in strength between ER (external rotators) and IR (internal rotators) helps maintain dynamic stabilization of the shoulder.¹² Studies that have investigated this metric typical involve throwing athletes with reported ER:IR ratios ranging from 0.72 to 1.42.¹³⁻¹⁶ In elite swimmers this ratio is approximately 0.70 bilaterally.¹⁷ There is a lack of information regarding what a normal ER:IR ratio is in a healthy population.

Differences in normative strength outcomes can be affected by the type of test used to measure strength. Some studies methods used a “break test” instead of a “make test”, which registers higher strength values than the make test.^{3,8} During the break test, the examiner pushes the hand held dynamometer (HHD) against the subject until the subject’s maximal muscular effort is overcome and the subject is unable to maintain an isometrically held position, while the make test is characterized by the examiner holding the dynamometer stationary while the subject exerts a maximal force against the dynamometer and examiner.¹⁸ Previous studies that have determined normative strength measurements of shoulder musculature included a limited number of testing positions, not testing all shoulder movements.⁷⁻⁹ In other studies, movements that optimize recruitment of specific muscles, such as the belly press movement to isolate the subscapularis muscle, were not included.¹⁹

Previous authors have reported normative values for shoulder strength using isokinetic equipment which provides valuable data but isokinetic dynamometers are not accessible for the majority of rehabilitation facilities.^{9,20} A

HHD is an inexpensive tool that offers clinicians a means of objectively assessing muscle force production (as a measure of strength). Previous authors have shown that hand-held dynamometry used to measure shoulder strength is a reliable and valid tool.²¹⁻²³

The purpose of this study is to establish normative isometric strength values for various movements of the shoulder that are specific to function and rotator cuff strength. A secondary goal of this study is to analyze the effect of age, gender, weight, height, activity level and arm dominance on shoulder strength.

METHODS

This observational cohort study examined normative strength data using healthy subjects. Ethical approval was obtained from the Vail Health Institutional Review Board. Subjects were recruited using a convenience sample including hospital employees, local health fair participants, community events attendees, and via word of mouth. Subjects were included if they were free of any upper extremity impairments (discerned via health questionnaire and range of motion screen). They had to be able to stand for 30 minutes during testing and understand the instructions provided to them. They were excluded if they had prior history of shoulder surgery including clavicle, any radicular symptoms of the upper extremities, or pain in the shoulder, elbow or wrist in the preceding three months.

Subjects were recruited according to age group (20-29, 30-39, 40-49 and 50-59 years) with a total of 50 men and 50 women in each age group (400 subjects total). Each subject completed a health questionnaire, informed consent, and the Shoulder Activity Scale (SAS) to determine the subjects overall shoulder activity level and whether they participated in overhead or contact sports. Previous studies using the SAS have shown its reliability, validity and responsiveness.^{24,25}

Maximum isometric strength was collected using a calibrated, MicroFET 2[®] handheld dynamometer device (Hogan Health Industries). Seven movements were used to test isometric strength of the dominant and non-dominant shoulder musculature of each subject. These movements included, external rotation at the side (ERO), internal rotation at the side (IRO), abduction at 90° of shoulder abduction (ABD), external rotation at 90° of shoulder abduction (ER90), internal rotation at 90° abduction (IR90), belly press (BP) (the subject was asked to push his or her hand against a solid surface, such as a goniometer or clipboard, held at their abdomen) and scapular plane abduction (SCAP) measured at 90° of shoulder elevation in the scapu-

lar plane, with neutral rotation (see Appendix 1). Subjects were asked to produce a five second maximal isometric 'make' contraction against the HHD. Three trials were completed bilaterally in each position, the average of the trials was used for normative data and analysis. A five second break was given between each repetition, a 30 second break was given between movements and the testing order was randomized using a random number generator. Verbal encouragement was provided as the subject performed each isometric push.

Muscle force was normalized to body mass (Newtons of force/body mass in kg) for between subject comparisons of strength. Hurd and colleagues evaluated the effects of normalizing muscle strength using a spectrum of anthropometric parameters and concluded body weight was the most effective parameter.¹ The ratio of ER:IR was calculated for all subjects.

STATISTICAL METHODS

Interrater and intra-rater reliability were calculated for all the strength tests across two raters among a sample of five subjects (outside of the 400 subjects in this study), using a two-way random effects model and is reported as the intraclass correlation coefficient (ICC).²⁶ This was conducted to determine reliability of the testing protocol used in this study. Means with SD or 95% CI are presented along with 5th, 25th, 50th, 75th, and 95th percentiles stratified by age decade (20-29, 30-39, 40-49, 50-59), arm dominance, and gender. Numbers and percentages are presented for categorical variables. Independent t-tests or chi square analysis were used for comparisons between groups (e.g., gender). Paired t-tests were used for comparisons between subjects (e.g., dominant versus nondominant shoulder). Multiple linear regression was performed for each shoulder position with covariates of interest chosen *a priori*. Predictor variables for modeling of strength included age, gender, weight, height, and activity level. Effect modification between gender and age and activity level (e.g., does the relationship between age and strength depend on activity level?) was assessed via the inclusion of statistical interaction terms. Separate models were run for dominant (DOM) and non-dominant (ND) arms. R² values for each model are reported. Results were considered statistically significant at p<0.05 or if 95% CIs did not contain 1.00. All analysis was performed in SAS V 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Interrater reliability for strength measurements was good to excellent for most arm positions (ICC range 0.828-0.958) and moderate for ND ER90 (0.545), DOM ER90 (0.556), and DOM SCAP (0.694).²⁶ For Rater 1, intra-rater reliability was good to excellent for most arm positions (ICC range 0.762-0.990) with moderate reliability for ND ER90 (0.597) and poor for DOM ER90 (0.409). For Rater 2, most ICCs were also good to excellent (ICC range 0.766-0.974) with moderate agreement for DOM SCAP (0.624) and ND SCAP (0.532)

Table 1. Inter-rater and intra-rater reliability coefficients (ICC)

Shoulder position	Interrater reliability	Intra-rater reliability	
		Rater 1	Rater 2
DOM ABD	0.955	0.762	0.480
ND ABD	0.970	0.984	0.954
DOM BP	0.908	0.986	0.848
ND BP	0.920	0.985	0.865
DOM ER0	0.943	0.901	0.843
ND ER0	0.921	0.910	0.824
DOM ER90	0.556	0.409	0.943
ND ER90	0.545	0.597	0.974
DOM SCAP	0.694	0.938	0.624
ND SCAP	0.897	0.941	0.532
DOM IR0	0.879	0.935	0.766
ND IR0	0.953	0.932	0.798
DOM IR90	0.828	0.899	0.907
ND IR90	0.958	0.990	0.890

ICC = intraclass correlation coefficient; DOM = dominant arm; ND = Non-dominant arm; ABD = abduction; BP = belly press; ER = external rotation; SCAP = scapular plane abduction; IR = internal rotation

and poor for DOM ABD (0.480). Inter-rater and intra-rater reliability coefficients are presented in [Table 1](#).

Participant demographics are shown in [Table 2](#). Males had significantly higher activity level scores compared to females (p<0.001) and were more likely to participate in contact sports at higher levels (p=0.002). BMI increased with age (p=0.01), and younger participants were more likely to participate in contact and overhand sports at higher levels (p=0.005 and 0.001, respectively). Ten point three percent of the subjects tested were left hand dominant.

[Table 3](#) displays normative data for mean shoulder strength for each of the movements, stratified by gender and arm dominance. For all muscle tests males had higher strength values than females (p<0.0001). Strength between DOM and ND limbs was not significantly different for most positions except for IR0 (p=0.03) and IR90 (p=0.04) for females and IR90 for males (p=0.05), in which the DOM arm was stronger.

The results of the general linear model showed that age, gender, weight, height and activity level explain 37-55% of the variation in shoulder strength (range of r² values in [Table 4](#)). Males were stronger than females. There was not a significant decline in strength with increasing age for most shoulder movements except ABD and SCAP.

Activity level was positively associated with strength such that those with higher activity scores had greater strength (p=0.000 to 0.056 depending on movement tested). Although interactions between gender and age were tested, they were not significant and therefore not included in the results. The interaction between age and activity level was significant for some arm positions (ER90 and IR0 both

Table 2. Participant demographics and characteristics by gender and age decade

Overall Sample					20 -29 years		30-39 years		40-49 years		50-59 years		
Variable	Total (n=400)	M (n=200)	F n=200	p value**	M (n=50)	F (n=50)	M (n=50)	F (n=50)	M (n=50)	F (n=50)	M (n=50)	F (n=50)	p value†
Age, years [mean (SD)]	40.0 (11.5)	40.0 (11.6)	40.1 (11.5)	0.88	25.5 (2.4)	25.6 (2.6)	34.6 (3.1)	34.5 (3.0)	44.6 (4.1)	45.3 (2.9)	55.2 (3.1)	55.1 (3.0)	<0.001
Height, cm [mean (SD)]	172.2 (9.8)	179.1 (6.5)	165.3 (7.4)	<0.001	180.6 (7.7)	165.8 (8.4)	179.1 (6.3)	167.3 (6.6)	178.5 (5.7)	164.6 (6.4)	178.1 (6.0)	163.7 (7.7)	0.23
Weight , kg [mean (SD)]	72.7 (14.8)	81.0 (13.0)	64.4 (11.6)	<0.001	77.8 (8.0)	63.3 (11.4)	80.3 (14.4)	65.8 (11.1)	82.3 (14.2)	63.7 (11.9)	83.6 (14.0)	64.8 (12.2)	0.37
BMI, m/kg2 [mean (SD)]	24.4 (4.1)	25.3 (3.8)	23.4 (4.3)	<0.001	23.9 (2.2)	23.0 (3.9)	25.0 (3.8)	23.5 (3.9)	25.8 (4.1)	23.5 (4.1)	26.4 (4.3)	24.3 (5.2)	0.01
Arm length, cm [mean (SD)]*	31.5 (2.8)	32.7 (2.5)	30.4 (2.6)	<0.001	33.4 (4.4)	30.0 (3.3)	32.7 (2.4)	30.1 (2.3)	32.6 (2.1)	30.4 (2.1)	32.7 (2.8)	31.4 (4.3)	0.54
Activity Score [mean (SD)]	12.4 (4.1)	13.5 (4.1)	11.4 (3.8)	<0.001	13.8 (3.9)	10.6 (3.5)	14.3 (4.4)	12.1 (4.1)	12.9 (4.4)	11.8 (3.4)	13.0 (3.7)	10.9 (4.0)	0.17
Dominant hand (n, % left)	41 (10.3)	25 (6.3)	16 (4.0)	0.14									
Participated in contact sports [n (%)]													
No	3 (0.8)	1 (0.5)	2 (1.0)	0.002	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (4.0)	1 (2.0)	0 (0.0)	0.005
Unorganized	303 (75.8)	137 (68.5)	166 (83.0)		30 (60.0)	38 (76.0)	27 (54.0)	40 (80.0)	38 (76.0)	42 (84.0)	42 (84.0)	46 (92.0)	
Organized	48 (12.0)	29 (14.5)	19 (9.5)		10 (20.0)	7 (14.0)	10 (20.0)	6 (12.0)	5 (10.0)	3 (6.0)	4 (8.0)	3 (6.0)	
Professional	46 (11.5)	33 (16.5)	13 (6.5)		10 (20.0)	5 (10.0)	13 (26.0)	4 (8.0)	7 (14.0)	3 (6.0)	3 (6.0)	1 (2.0)	
Participated in overhand throwing/serving/swimming sports [n (%)]													
No	3 (0.8)	1 (0.5)	2 (1.0)	0.2	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (4.0)	1 (2.0)	0 (0.0)	0.001
Unorganized	273 (68.3)	128 (64.0)	145 (72.5)		30 (60.0)	32 (64.0)	27 (54.0)	34 (68.0)	35 (70.0)	38 (76.0)	36 (72.0)	41 (82.0)	
Organized	90 (22.5)	53 (26.5)	37 (18.5)		14 (28.0)	15 (30.0)	16 (32.0)	6 (12.0)	12 (24.0)	8 (16.0)	11 (22.0)	8 (16.0)	
Professional	34 (8.5)	18 (9.0)	16 (8.0)		6 (12.0)	3 (6.0)	12 (24.0)	10 (20.0)	3 (6.0)	2 (4.0)	2 (4.0)	1 (2.0)	

*arm length missing for 7 subjects (1F, 6M)

** p value compares males and females

¥ p value corresponds to change in demographic or survey response with age category, accounting for sex.

Table 3. Strength (Newtons) normalized to body weight (kg) by sex and arm dominance

	Female		Male		
Strength measurement	Mean	SD	Mean	SD	*p-value
DOM ABD	1.76	0.44	2.18	0.55	<0.001
ND ABD	1.78	0.44	2.18	0.56	<0.001
**p-value	0.19		0.69		
DOM BP	0.87	0.21	1.12	0.29	<0.001
ND BP	0.86	0.2	1.12	0.27	<0.001
**p-value	0.64		0.78		
DOM ER 0°	1.31	0.28	1.53	0.31	<0.001
ND ER 0°	1.32	0.28	1.55	0.31	<0.001
**p-value	0.58		0.13		
DOM ER 90°	0.92	0.25	1.04	0.29	<0.001
ND ER 90°	0.91	0.24	1.04	0.29	<0.001
**p-value	0.16		0.4		
DOM SCAP	1.81	0.46	2.2	0.58	<0.001
ND SCAP	1.79	0.45	2.18	0.59	<0.001
**p-value	0.35		0.27		
DOM IR 0°	1.47	0.36	1.76	0.49	<0.001
ND IR 0°	1.44	0.4	1.78	0.54	<0.001
**p-value	0.03 ^a		0.22		
DOM IR 90°	1.18	0.3	1.43	0.37	<0.001
ND IR 90°	1.16	0.31	1.4	0.37	<0.001
**p-value	0.04 ^a		0.05 ^a		

SD = standard deviation; DOM=dominant arm; ND = Non-dominant arm; ABD = abduction; BP = belly press; ER = external rotation; SCAP = scapular plane abduction; IR = internal rotation *Row p-values compare dominant to non-dominant arms within sex, **column p-values compare males and females for each strength measurements.

^aStatistically significant difference, $p \leq 0.05$

DOM and ND) (see [Table 4](#)). ER:IR strength ratios were higher in females compared to males (DOM $p=0.002$; ND $p=0.001$) and ER:IR ratio significantly declined with age (DOM $p=0.015$; ND $p=0.002$). Ratios are presented in [Table 5](#). Gender based percentiles for shoulder strength are presented for each decade in Appendix 2.

DISCUSSION

The primary purpose of this study was to establish normative strength data for relevant shoulder movements, across a broad age range, in individuals with healthy shoulders. Variables including age, gender, weight, height, activity level and limb dominance were evaluated to see how they related to shoulder strength. The most important findings of the present study were that gender and activity level were significantly associated with strength measures. Age and limb dominance were not associated with most strength measures.

SHOULDER STRENGTH AND GENDER

The outcome that shoulder strength is affected by gender is in agreement with other studies.^{3,5,6,9,10,27} Specifically, males exhibited greater muscle strength than females in all

tested shoulder positions even when normalized to body weight. Comparisons of muscle strength between individuals necessitates data to be normalized in order for valid comparisons to occur.¹ Hurd et al.¹ showed body weight was the most effective scaling factor in terms of reducing variability. It is suspected that the findings of the current study are due to differences in muscle morphology (men have larger muscle fibers and longer fascicles than women) and differences in muscle mass distribution between males and females (men have a greater total skeletal muscle mass in the upper body compared to females).^{28,29}

SHOULDER STRENGTH BETWEEN LIMBS

Across all strength measures, male and female subjects demonstrated no significant difference between sides except in IR0 and IR90, with the DOM limb being significantly stronger. Westrick et al.³ also found similar differences between DOM and ND strength of IR while Riemann et al.⁸ reported stronger dominant IR in healthy subjects aged 20-40 years. The results from these studies^{3,8} differ with findings from normative strength studies which have shown a difference between limb dominance and strength.^{5,6,11,27} Those studies also used healthy volunteers, but had fewer subjects per age group which could explain the differences in data. The current study showed isometric strength mea-

Table 4. Results of the multivariate linear regression modelling shoulder strength.

Strength measurement (Newtons)	Beta Coefficients for Model Covariates*							R ^b
	Intercept	SAS	Sex (Female vs male)	Age (years)	Height (cm)	Weight (kg)	Age x activity level	
DOM ABD	38.004	0.827	-43.005	-0.437	0.491	0.671	-	0.500
p value	0.414	0.056	0.000 ^b	0.004 ^a	0.062	0.000 ^b	-	
ND ABD	31.749	1.645	-40.095	-0.338	0.403	0.766	-	0.490
p value	0.499	0.000 ^b	0.000 ^b	0.028 ^a	0.129	0.000 ^b	-	
DOM BP	49.171	0.629	-25.745	-0.016	-0.035	0.482	-	0.500
p value	0.051	0.007 ^a	0.000 ^b	0.843	0.805	0.000 ^b	-	
ND BP	67.888	0.519	-26.693	0.013	-0.170	0.551	-	0.550
p value	0.004 ^a	0.017 ^a	0.000 ^b	0.862	0.195	0.000 ^b	-	
DOM ER0	26.792	0.732	-24.492	-0.051	0.194	0.660	-	0.540
p value	0.335	0.005 ^a	0.000 ^b	0.577	0.217	0.000 ^b	-	
ND ER0	22.943	0.885	-25.086	-0.059	0.229	0.626	-	0.550
p value	0.403	0.001 ^b	0.000 ^b	0.514	0.141	0.000 ^b	-	
DOM ER90	44.554	0.675	-15.573	-0.131	-0.043	0.531	0.044	0.370
p value	0.091	0.006 ^a	0.000 ^b	0.127	0.775	0.000 ^b	0.035 ^a	
ND ER90	22.064	0.706	-13.963	-0.061	0.052	0.552	0.046	0.373
p value	0.407	0.005 ^a	0.000 ^b	0.485	0.729	0.000 ^b	0.031 ^a	
DOM SCAP	-6.310	1.410	-38.672	-0.318	0.672	0.690	-	0.470
p value	0.899	0.002 ^a	0.000 ^b	0.051	0.017 ^a	0.000 ^b	-	
ND SCAP	-7.828	1.484	-36.679	-0.324	0.622	0.790	-	0.460
p value	0.877	0.002 ^a	0.000 ^b	0.049 ^a	0.029 ^a	0.000 ^b	-	
DOM IRO	-47.536	1.386	-21.413	0.065	0.488	0.991	0.068	0.442
p value	0.276	0.001 ^b	0.000 ^b	0.646	0.048 ^a	0.000 ^b	0.049 ^a	
ND IRO	-40.936	1.495	-27.756	0.227	0.476	0.855	0.074	0.429
p value	0.382	0.001 ^b	0.000 ^b	0.138	0.072	0.000 ^b	0.048 ^a	
DOM IR90	-18.351	0.981	-18.658	0.098	0.198	1.004	-	0.480
p value	0.595	0.002 ^a	0.000 ^b	0.383	0.311	0.000 ^b	-	
ND IR90	-33.133	0.941	-17.404	0.198	0.263	0.969	-	0.480
p value	0.331	0.003 ^a	0.000 ^b	0.076	0.172	0.000 ^b	-	

SAS = Shoulder Activity Scale; DOM = dominant arm; ND = non-dominant arm; ABD = abduction; BP = belly press; ER = External Rotation; SCAP = scapular plane abduction; IR = internal rotation.

*All models were statistically significant (p-value for F statistic <0.01).

P-values listed in table correspond to the beta coefficient for each variable. The interaction term of age x activity level was only included when the interaction term was significant (p<0.05). Non-normalized strength was used as the dependent variable since weight was included as a predictor. For continuous variables, a positive Beta coefficient indicates a positive association between the variable and strength. For sex, a negative Beta coefficient indicates that females have lower strength than males. The interaction term indicates that the relationship between age and strength depends on activity level, such that higher levels of activity show higher levels of strength at older ages.

^a Statistically significant difference p<0.05

^b Statistically significant difference p<0.001

Table 5. External rotation/internal rotation ratios by gender and age

Age	20-29		30-39		40-49		50-59	
Gender	Female	Male	Female	Male	Female	Male	Female	Male
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
DOM ER:IR 90	0.810.16	0.770.15	0.810.19	0.780.18	0.790.18	0.730.16	0.770.16	0.710.18
ND ER:IR 90	0.860.16	0.760.18	0.810.15	0.780.16	0.790.19	0.760.17	0.760.17	0.740.28

DOM = dominant arm; ND = non-dominant arm; ER:IR90 = external rotation:internal rotation at 90° abduction

*DOM arm p-value: Gender 0.002; Age 0.015; ND arm p-value: Gender 0.001; Age 0.002

tures were not statistically significantly different between limbs for most movements. Therefore, clinicians can have some confidence that the uninvolved limb, if symptom free, can be used as an adequate benchmark for strength measures, and the utilization of LSI may be of benefit when comparing shoulder strength, with the exception of IR.

Additionally, strengthening interventions for the musculature surrounding the shoulder joint should continue to focus on symmetrical strength performance.

ER:IR RATIO

An adequate balance between the strength of the ER's and IR's helps maintain dynamic stabilization of the shoulder.¹² Ratios varied from 0.71 to 0.86 which are similar to those seen in other studies and provide good reference values for a healthy, active population.^{4,6,8} With age this ratio decreased, either due to a decreasing ER strength or increasing IR strength. The data from this study does not allow determination of which of these changes caused the decline, but it is suspected that a combination of changes may have occurred.

SHOULDER STRENGTH AND AGE

In this healthy population, age was not a predictor of strength for most muscle groups surrounding the shoulder, except for ABD (DOM $p=0.004$ and ND $p=0.028$) and SCAP (ND $p=0.049$). These were negative correlations, indicating older individuals were less strong in these movement patterns. Standing elevation in the scapular plane has been shown to be an optimal position to recruit the supraspinatus muscle for strength testing.³⁰ Wickham et al.³¹ confirmed that the position for supraspinatus to reach peak muscle activity was 89° shoulder ABD. Given the positive association between asymptomatic rotator cuff tears and age,³² especially in individuals over 50 years,³³ this outcome could be related to asymptomatic rotator cuff pathology. Further research is needed to confirm this possibility.

The finding that age did not affect strength measures, contradicts the study by Hughes et al.⁶ who showed age was negatively associated with all strength measures. Participants in their study were aged between 20-78 years. The current study evaluated strength in individuals up to 59 years, which may not have been an age that demonstrates significant age-related declines. Andrews et al.⁵ collected normative data on five movements of the shoulder in patients between the ages of 50-79 years old. Moderate to high correlations were found between isometric strength and height, weight and gender, and a weak but significant negative correlation between age. Studies of age and strength have reported conflicting results which could be related to how active the population involved in the study is.^{6,10,27} Age-related decreases in muscle mass from 30-50% have been described in both males and females between the ages of 40-80 years.^{34,35} The decrease in muscle mass is accompanied by at least an equal decrease in strength.³⁶ However, there is evidence that age-associated atrophy and weakness can be slowed by staying active and exercising as is seen in Master athletes.^{37,38}

SHOULDER STRENGTH AND ACTIVITY LEVEL

There was a significant association between activity level and strength in all movements tested except dominant ABD. The fact that there were no significant differences in activity level between age groups (Table 2) could explain why minimal associations between strength and age were seen in the data. People who stay active as they age are able to maintain good shoulder strength into later life. Harlinger et al.²⁷ saw no significant difference in strength in subjects of 20-64 years (except for a decline in external rotators in men). They interviewed participants to assess activity level and noted the majority of people tested did participate in regular exercise including swimming, weightlifting and physically demanding employment. In comparison when authors examined shoulder strength, age, and activity level, a weak or inconsistent relationship between activity level and strength and a significant regression of strength has been found with advancing age.^{5,9} These studies evaluated activity level by recording metabolic equivalent (MET) over a 24-hour period⁹ or getting subjects to grade their work and leisure activity level according to a four point ordinal activity scale.⁵ Neither measure was specific to the shoulder. The current study, which utilized the SAS, revealed that over 99% of individuals reported participating in contact sports and overhand, serving or swimming activities, indicating a very active population. The SAS has been validated in a healthy population.²⁴ Studies have evaluated the SAS and age and shown that among subjects with no history of shoulder symptoms or treatment for a shoulder condition, the SAS decreases with age and is lower in women than men.^{39,40} The SAS was lower in women compared to men in this study, supporting previous studies, however decreases with age were not observed. This suggests the cohort used in the current study were more active than individuals seen in the general population.

SHOULDER STRENGTH, AGE AND ACTIVITY LEVEL

Older adults who were active showed less decline in strength across two arm positions (ER90 and IR0 both DOM and ND) compared to older adults who were not as active. This may indicate that staying active is important for maintaining strength, although this observation was not present in all shoulder movements. This may be due to the relatively active population comprising the study or indicate that this relationship was also movement-dependent.

LIMITATIONS

The primary limitation of this study was the potential for selection bias of the subjects. The subject population was drawn primarily from Colorado. Based on analysis of Center for Disease Control health data, Colorado is ranked highly for individuals who participate in physical activity so extrapolating this normative data to other regions that are less active could be difficult.⁴¹ Future studies should include recruitment of a wider range of subjects who are less physically active to reflect the population at large. The upper age range measured in this study was 50-59

years and this does not represent a senior demographic age group. Inclusion of individuals of 60 years and over would have added more information about strength changes with age. Additionally, this study used pain and a subject reported health history questionnaire to determine if an individual had a healthy shoulder. A physical examination which could identify asymptomatic rotator cuff pathology was not undertaken and could have helped verify that the study population was healthy prior to collecting normative strength values.

CONCLUSION

The findings of this study provide normative data regarding shoulder strength for a healthy, active population across four decades. Clinically this provides preliminary evidence that healthy individuals without injury have relatively symmetrical isometric strength regardless of limb dominance. This suggests that following shoulder injury or surgery, clinicians can have some confidence that the uninvolved limb can be used as an adequate benchmark for strength measures if the uninvolved arm is healthy. The normative data presented provides data regarding shoulder strength measures which are gender and age specific. It may assist

in setting rehabilitation goals, monitoring progress in patients with shoulder injuries and allow clinicians to make better informed return to sport decisions. The data also highlights the positive association between activity level and strength; the more active an individual, the stronger they are, regardless of age.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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SUPPLEMENTARY MATERIALS

Appendix 2

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Appendix 1

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