The ExtRA Capacity Test: Reliability, validity and normative data of a new clinical tool for assessing shoulder muscle performance

Abstract

Objectives: Introduce The ExtRA Capacity Test, a measure for assessing shoulder muscle performance. Assess its reliability, validity and present normative scores in a large sample of asymptomatic adults.

Design: Cross-sectional observational study with test–retest

Setting: Community

Participants: Volunteers (*n*=344, age 20 to 90 years).

Interventions: The ExtRA Capacity Test involves two capacity tests completed to a 30 beats per minute metronome: maximal scapular plane lateral raises to 90° abduction with 2.5kg of external load, and maximal external rotations in unsupported prone lying with the shoulder at 90° abduction.

Reliability was assessed in 30 asymptomatic participants, tested by two raters over two sessions, one week apart, using Bland–Altman analysis to determine mean bias and 95% limits of agreement (LoA) as measures of error. Criterion validity was evaluated in 20 participants using Pearson correlation to examine the relationship between ExtRA and isokinetic dynamometry measures. A normative dataset was also established from 344 asymptomatic individuals across a range of ages, physical activity levels, and both sexes.

Results: The intra-rater and inter-rater agreement for the ExtRA Capacity Test was assessed in a sample of 30 participants. The 95% LoA for abduction and external rotation measurements ranged from 2.9 to 13.1 repetitions. In a sample of 20 participants, the abduction test showed good/moderate correlation with muscle strength measures but not with the external rotation test. Older age, female sex and not achieving the WHO activity guidelines have a negative impact on ExtRA performance.

Conclusions: Within the caveats discussed in this paper, ExtRA can be considered a reasonably reliable tool for assessing shoulder strength and control in a clinical setting. The normative database will help clinicians set rehabilitation or return-to-play targets based on sex, age, and physical activity level.

Contributions of Paper

- This study introduces the ExtRA Capacity Test as a reliable tool for assessing shoulder muscle performance in both sporting and non-sporting populations.
- The test demonstrates clinically acceptable intra- and inter-rater reliability, with the abduction component showing a strong correlation with strength measures from Isokinetic Dynamometry.
- The normative database established in this study facilitates the evaluation of shoulder performance relative to reference values stratified by age, sex, and physical activity level.
- Given its high reliability, the ExtRA Capacity Test can be used to monitor performance changes over time, providing valuable insights for clinical practice and rehabilitation planning.

Keywords

shoulder, capacity testing, strength, muscular control, isokinetic dynamometry

Introduction

Reduction in muscle performance may result from injury, trauma, disease, co-morbidities, immobilisation, kinesiophobia, or sedentary lifestyle [1,2]. Shoulder strength, range of motion (ROM), and functional outcome measures are used to guide safe return to activity or sport [3]. Current methods for measuring shoulder strength vary in cost and clinical utility. Isokinetic dynamometry (IKD) is the gold standard for assessing muscle strength and endurance through a specified ROM [4,5]. However, its high cost and time requirements limit clinical application.

Faster, cost-effective methods like handheld dynamometry (HHD) and manual muscle testing (MMT) are widely used [4,3,6,7]. HHD demonstrates excellent reliability for isometric strength measurement [6], but isometric tests may not reflect functional demands[3]. On the other hand, MMT lacks precision, detecting changes only when strength is reduced by 15-25% compared to the contralateral side [7]. Capacity testing, which measures the maximal number of repetitions before fatigue, may offer a more functional and practical alternative. It replicates real-world movements, provides objective outcomes, and avoids costly equipment or lengthy setup[8]. Open-chain capacity testing may also assess shoulder muscular control, a critical component for addressing shoulder pain [9,10,11]. Lower limb capacity tests with normative values already guide rehabilitation and return-to-play criteria [12,13].

Currently, upper limb capacity tests are limited to specific groups, such as elite athletes or those with neurological conditions, restricting their utility for broader musculoskeletal care [14,15,16]. The Shoulder Arm Return to Sports battery consists of 8 tests including push-up-claps, 5kg overhead snatch and line hold rotations, to determine readiness to return to sport after upper extremity injury [16]. These tests require a high level of strength, power and neuromuscular control and would be inappropriate for those with lower functional demands [17]. No upper limb capacity test exists for the general population [18,19,20].

The aim of this study was to introduce the ExtRA Capacity Test, a new measure for assessing shoulder muscle performance (strength and control) using a functional capacity approach [11,21,22]. Secondary objectives included evaluating the inter- and intra-rater reliability of the tests, assessing their criterion validity, and examining normative scores in a large asymptomatic adult sample, accounting for age, sex, and adherence to the World Health Organization (WHO) Physical Activity Guidelines[23].

Materials and Methods

Participants

The study was approved by the Institutional Research Ethics Committee 35944-LR-Mar/2022- 38654-1). The study sampling was carried out between April 2022- August 2025. Participants aged ≥20 years old with a QuickDASH score of <5 (indicating excellent upper limb function) were included [24]. Exclusions were systemic illness, cervical/shoulder pain at rest or movement, cervical/shoulder pain or treatment in the past 12 months, history of spinal/upper limb fractures or surgery, and pregnancy.

Written informed consent was obtained. Data from 344 participants were collected, 30 of whom took part in the reliability testing and 20 in the validity testing. A further 174 were rejected at initial sampling due to a QuickDASH score >5. At least 10 participants per decade (20s–80+), for both sexes, meeting/not meeting the World Health Organisation (WHO) activity guidelines, provided a heterogeneous sample for generalizable normative data [24]. Patients/public were not involved in the research design, conduct, or reporting.

Procedures

Baseline Measures

Height (m), weight (kg), age (years) and biological sex were recorded on the day of testing. Self-reported physical activity levels were assessed based on participants' adherence to the WHO Physical Activity Guidelines[23]. Participants indicated agreement or disagreement with two standardised statements: "*You complete at least 150–300 minutes of moderate-intensity aerobic physical activity; or at least 75–150 minutes of vigorous- intensity aerobic physical activity per week"* and *"you complete muscle-strengthening activities at moderate or greater intensity that involve all major muscle groups on 2 or more days a week"* [23]*.* Meeting activity guidelines, required agreement with both statements.

The ExtRA Capacity Test

The ExtRA (External Rotation/ Abduction) Capacity Test measures the maximum number of repetitions performed before fatigue or a loss of control of scapular plane shoulder abduction in standing and prone-lying external rotation.

For the abduction capacity test, participants stood with their back against a wall, feet shoulder-width apart, with the elbow fully extended, abducting their arm to 90° in the scapular plane while holding a 2.5kg dumbbell. Pilot testing confirmed this weight was challenging yet tolerable across age groups. Movement rate was set at 30 beats per minute (bpm), with 2 seconds each for concentric and eccentric phase. Humeral rotation was controlled by keeping the thumb parallel to the floor [25]. The test ended if participants failed to: (1) reach 90° abduction; (2) maintain pace; or (3) stay within the required plane.

External rotation capacity was assessed in prone, lying with the arm positioned at 90° abduction, elbow at 90° flexion, and forearm pronated with the palm facing the floor. The examiner initially supported the

participant's arm, passively moving the shoulder into maximal passive shoulder external rotation, visually observing the point that medial side of the wrist reached in this position. The examiner passively moved the participant's arm through the required range twice. During testing, the examiner placed a finger at the point where the medial side of the wrist (overlying the ulnar head) would align at maximum external rotation. Another finger was positioned at the region overlaying the olecranon. The participant's upper arm remained unsupported on the treatment couch, during explanation, passive movements, and active testing.

Participants performed the movement actively from maximal external rotation. A repetition was counted each time the ulnar head touched the examiner's finger. Pace was controlled by a 30-bpm metronome, with 2 seconds for each the concentric and eccentric phase. The test ended if they failed to: (1) achieve full range (ulnar head did not reach the examiner's marker); (2) maintain the set pace; or (3) control the upper arm position (olecranon shifted by > 1cm) (FIGURE 1).

*****Insert FIGURE 1 here*****

Prior to testing, participants completed a 2-minute warmup including shoulder and cervical range of motion, resistance banded shoulder abductions, external rotation, and overhead press [26]. Following this, participants rested for 5 minutes before testing. Both dominant and non-dominant shoulders were tested. Arm dominance was assessed by participant self-report and defined as the limb primarily used to carry out common activities of daily living (e.g., brushing teeth or writing).

Reliability/ Validity

Thirty participants took part in the reliability study and 20 in the criterion validity study. Participants attended two testing sessions, separated by one week. During one session, each participant completed the ExtRA assessment (administered by the lead researcher) and isokinetic dynamometry (IKD) shoulder strength testing, with a 30-minute rest interval between assessments. In the other session, participants completed the ExtRA assessment twice—once evaluated by the lead researcher and once by an independent physiotherapist—with a 30-minute rest period between tests. To assess intra-rater reliability, the lead researcher's findings were compared across the two testing sessions. The order of testing was randomised, and results were withheld from all assessors until data collection was complete to minimise the risk of reporting bias.

When assessing the criterion validity of ExtRA, isokinetic testing was performed using a Biodex System 4 Isokinetic System [27]. The test was completed for scapular plane shoulder abduction capacity (from 0-90°abduction) and external rotation capacity at 90° abduction (from maximal external rotation-0° internal rotation). The Biodex System 4 used 'Passive Mode' at 30°/s for 20 repetitions [27]. For the external rotation capacity testing, participants were instructed to maximally push into external rotation and then to maximally resist the lever returning to the starting position. A similar instruction was given when monitoring abduction capacity: pull up as hard as possible and try to prevent the arm moving down. Prior to maximal testing, the participant was allowed to complete 5 practice repetitions. They were then given a 2-minute break between the practice repetitions and the maximal test, and a 5-minute rest between isokinetic testing in different positions [4].

Pearson correlation analyses examined the relationship between shoulder strength measures obtained by IKD (concentric/ eccentric values of peak torque, average peak torque, total work, work fatigue and average power) and ExtRA scores assessed by the lead researcher [4,28].

Inter- and intra-rater reliability were evaluated using Bland–Altman analysis. The mean bias (d) was calculated to assess systematic differences between paired measurements, and the 95% limits of agreement (LoA; $d \pm 1.96 \times SD$) were used to quantify random error. This approach quantifies both systematic bias and random error between raters or sessions.[29,30].

There is no universally accepted threshold for defining "acceptable" bias or limits of agreement in Bland–Altman analysis, as this depends on the scale of measurement and the clinical or functional implications of observed differences,[30] Previous studies of strength and functional performance testing have emphasised the importance of interpreting measurement error in absolute terms, relative to the typical range of scores, rather than as a fixed percentage. In this context, the limits of agreement should be considered in relation to the expected performance range to determine whether the observed differences are meaningful for practical or clinical interpretation.[31,32].

Normative Data

Data was screened following collection, this included checking the ExtRA scores for abduction and external rotation (dominant and non-dominant sides) for normal distribution using Shapiro-Wilk tests. Data was also screened using visual inspections of scatterplots to identify outliers, relationships between ExtRA scores and age (as a continuous variable).

The data was found to be non-normally distributed ($p<0.001$) with a positive skew due to a small number of participants scoring much higher than the means of the groups. Consequently, median values are used in reporting normative ranges for the subgroups. Similarly, the reported upper (90^{th}) and lower (10^{th}) bounds of confidence intervals are based on the group median.

Results:

Study Population

In the reliability study (n=30), 43% of the participants were female. The mean age was 37.2 (SD=17.6) years, ranging from 20-65. The mean weight was 75.5kg (SD=16.8kg) and mean height was 174.4cm (SD=10.4cm). Of the participants in the reliability study, 53% self-reported adherence to the WHO Activity Guidelines.[23].

In the criterion validity study (n=20), 40% of the participants were female. The mean age was 28 (SD=13.3) years, ranging from 20-58. The mean weight was 78.9kg (SD=18.1kg) and mean height was 173.9cm (SD=11.6cm). Among participants in the criterion validity study, 60% self-reported meeting the WHO Activity Guidelines.[23].

In the normative database study (n=344), 53% of the participants were female with a mean age of 53.5 (SD= 20.1) years, ranging from 20- 90. The mean weight was 74.5kg (SD= 16.1kg) and mean height was 170cm (SD= 9.8cm). Self-reported compliance with the WHO Activity Guidelines was noted in 54% of participants in the normative database study [23].

Reliability

Insert FIGURE 2 here

Bland–Altman analysis of inter-rater reliability demonstrated minimal bias between raters across all measures (Figure 2). In the abduction task, the mean bias between raters was 1.07 repetitions for the dominant arm and 0.82 repetitions for the non-dominant arm. The 95% limits of agreement showed that the second rater's measurements were within −9.56 to +11.69 repetitions of the first rater's for the dominant arm, and within −11.46 to +13.06 repetitions for the non-dominant arm. For the external rotation task, the limits of agreement ranged from −6.32 to +6.89 repetitions for the dominant arm and from −5.76 to +7.01 repetitions for the non-dominant arm, with mean biases of 0.28 and 0.63 repetitions, respectively.

When considering intra-rater reliability for the abduction task, the mean bias was 0.17 repetitions for the dominant arm and −0.38 repetitions for the non-dominant arm. On 95% of occasions, repeated measurements by the same rater were within −7.46 to +7.79 repetitions for the dominant arm and −6.42 to +5.65 repetitions for the non-dominant arm. For the external rotation task, the limits of agreement ranged from −5.56 to +5.04 repetitions for the dominant arm and from −4.14 to +2.91 repetitions for the non-dominant arm, with small mean biases of −0.26 and −0.67 repetitions, respectively. This data is displayed in Supplementary Material 1.

Validity tests

ExtRA abduction measures correlated to 33 of 40 measurements obtained using IKD ($p<0.05$). Six IKD measures – concentric abduction total work and average concentric abduction power for the dominant and non-dominant arm, concentric average peak abduction torque for the non-dominant arm and dominant external rotation concentric peak torque – had a strong correlation with ExtRA abduction

scores (0.7-0.89). Twenty six of the 40 IKD strength measures demonstrated moderate correlation to the abduction strength measure (0.50-0.69) and one showed low correlation (0.26-0.49) [33].

For external rotation, only 2 of the 40 measurements of IKD correlated with ExtRA external rotation ($p<0.05$). The 2 measurements were non-dominant concentric abduction total work and non-dominant concentric external rotation peak torque. However, both demonstrated a low correlation (0.26-0.49) [33]. A table showing the results for all the correlational analyses for the validation study is available in the supplementary material (Supplementary Material 2).

Normative Values

Figure 3 and 4 demonstrates the median number of repetitions of the ExtRA Capacity Test by age group, dominant versus non- dominant arm, and WHO physical activity guideline compliance. This data is also available to view in Supplementary Materials 3 and 4.

*****Insert FIGURE 3 here*****

*****Insert FIGURE 4 here*****

Discussion:

The Bland–Altman analysis indicated that the 95% limits of agreement for the abduction measure were approximately ±13 repetitions for inter-rater reliability and ±8 repetitions for intra-rater reliability. According to this approach, the limits of agreement define the range within which most differences between repeated measures are expected to lie if no true change/difference has occurred. Therefore, only differences that exceed these limits can be interpreted as reflecting a real change in the underlying construct, rather than random error or variability inherent to the measurement process.

When this measurement error is interpreted in relation to the range of repetitions achieved, between 3 and 145, the inter-rater limits of agreement of 13 repetitions, indicate that for participants achieving fewer repetitions, the error could represent a substantial proportion of their performance. In contrast, among individuals with higher repetition counts, the relative impact of this measurement error would be less significant.

For the external rotation measure, the 95% limits of agreement were approximately ±7 repetitions for inter-rater reliability and ±5.5 repetitions for intra-rater reliability. Accordingly, changes exceeding 7 repetitions when assessed by two independent raters, or greater than 5.5 repetitions when assessed by the same rater, can be interpreted as representing a true change/difference, rather than variability attributable to measurement error. Again, interpreting this in light of the scores achieved (1-80 repetitions), for those with lower scores this error could be significant, although less so in those with higher scores. Previous studies investigating alternative shoulder assessment tools, such as hand-held dynamometry and the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST), have reported absolute reliability metrics comparable to those observed for the ExtRA measures[34,35]. Unlike ExtRA, these tests either do not provide functional measures of shoulder performance or are tailored for specific athletic cohorts. The normative database showed that ExtRA effectively captures differences in shoulder muscle performance across sex, activity levels, and age groups.

Measured agreement between the ExtRA and IKD assessed the criterion validity. The abduction component of ExtRA correlates closely to the strength values obtained using IKD, both for concentric and eccentric abduction and external rotation strength. Contrastingly, ExtRA external rotation poorly correlated to shoulder strength values obtained using IKD. The result may be because whilst IKD measured rotational strength using a supported upper arm, ExtRA external rotation is performed with an unsupported upper arm, which means that rotator cuff recruitment is likely to be different [36]. Poor

correlation may also be because ExtRA external rotation is limited by poor movement control of the shoulder rather than muscular fatigue. This may suggest that the test measures an aspect of shoulder function that is not currently captured by other measures or IKD. Muscular control training has been found to reduce pain and increase function for patients with shoulder pain and thus a measure of this aspect of muscle performance for the shoulder may be useful [9,10,36].

The results from the large cohort of asymptomatic participants provide population-based normative values, which can be used as a point of reference in a clinical setting when assessing the functional capacity of individuals. Older age, female sex, and not achieving WHO activity guidelines negatively impact ExtRA performance in both abduction and external rotation tests. Similar age-related patterns for the median number of repetitions for the abduction measure is seen for both sexes. Active individuals perform significantly better until ages 70-79, after which performance drops, aligning with previous findings of reduced shoulder strength above the age of 65 [37]. It is unclear why the abduction data demonstrate no significant change in performance in the active group compared to the inactive group over the age of 70. One possible explanation is that older adults are more likely to engage in submaximal or lower intensity resistance training. Thus, despite reporting that they meet the WHO activity guidelines, their activity level may not induce physiological adaptations for improved shoulder muscle performance during maximal testing.

Median scores in the external rotation capacity test show that men and women who meet WHO Activity Guidelines outperform those who do not, especially in younger age groups. Beyond ages 60-69 in men and 70-79 in women, achieving activity guidelines does not significantly impact performance. In both sexes, performance peaks in the active group in the 40-49 age group with a gradual decline observed from 20-29- 80+ in the inactive group (FIGURE 3, Supplementary Material 3/4). The peak in median

performance in the 40–49-year active groups is likely a result of high movement literacy in combination with minimal age-related decline in muscular performance [38]. By their 40s, physically active individuals likely accumulate experience that refines neuromuscular coordination. In older groups, performance is limited by gradual declines in muscle mass, strength, and neuromuscular control [38].

Limitations

One of the study limitations is that participants' activity prior to testing was not controlled. Therefore, the scores of some participants may have been affected by their engagement in strenuous exercise, potentially leading to fatigue. This nonetheless reflects a realistic scenario that a healthcare practitioner might encounter in a clinical setting.

Unlike other database studies which use an activity level scale [13,14], activity levels were classified into either 'achieves WHO activity Guidelines' or 'does not achieve WHO activity guidelines' in order to ensure resistance training was accounted for. The classification into subgroups based on these criteria results in considerable variance. For example, someone meeting the minimum WHO guidelines is grouped with an elite strength athlete doing daily resistance training. This leads to many high-performing outliers in the raw data, causing a positive skew in the active group.

Conclusion

This study introduces ExtRA, an external rotation and abduction capacity test for the shoulder. The test is devised for use in clinical settings and can provide a functional insight into shoulder muscle performance specific to a real world or sporting environment. The normative database, derived from a large sample of asymptomatic individuals, enables clinicians to assess shoulder muscle performance by comparing individual results to reference values matched for age, sex, and physical activity level. An

estimate of the error of measurement has been given, and within the caveats given, has reasonable reliability. It can therefore be useful in monitoring performance over time whereby changes in ExtRA performance are likely to indicate changes in functional capacity.

Ethical Approval:

Ethical approval was granted by the [Blinded] College of Health, Medicine and Life Sciences Research Ethics Committee. (31585-LR-Oct/2021- 34399-2).

Funding:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest:

There are no potential conflicts of interest (such as personal associations or roles as a director, officer, or expert witness) relevant to this manuscript.

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FIGURE 1. Step by step instructions on how to complete The ExtRA Capacity Test for abduction and external rotation testing

FIGURE 2. Bland-Altman plots illustrating inter-rater and intra-rater reliability for the ExtRA Abduction and External Rotation Tests. The dark solid line represents the bias (mean difference) in measurements, while the dashed lines indicate the limits of agreement.

FIGURE 3. Histogram displaying median repetitions of the Abduction ExtRA Capacity Test by Sex, Age Group, Arm Dominance, and whether they do/ do not meet the WHO Physical Activity Guidelines

FIGURE 4. Histogram displaying median repetitions of the External Rotation ExtRA Capacity Test by Sex, Age Group, Arm Dominance, and whether they do/ do not meet the WHO Physical Activity Guidelines

Supplementary Material 1. Bland–Altman analysis showing mean bias and 95% limits of agreement (LoA) between and within raters for The ExtRA Capacity Test

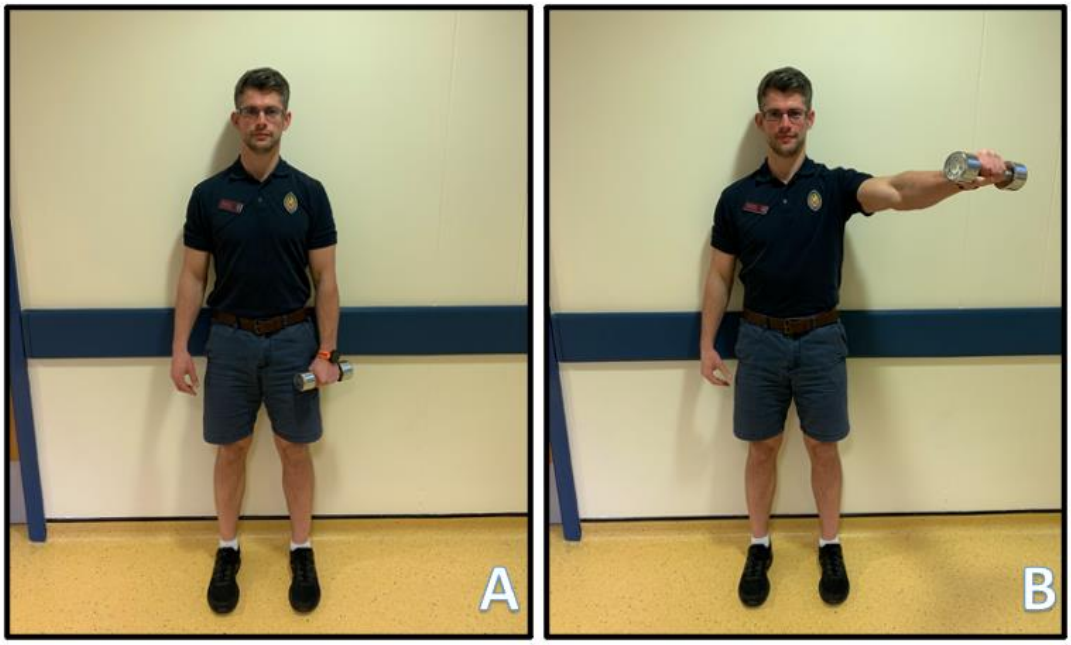
Supplementary Material 2. Table demonstrating the correlation between the ExtRA Capacity Test and strength measured obtained by Isokinetic Dynamometry

Supplementary Material 3. Normative median (50th), lower (10th) and upper (90th) percentile values of the median for ExtRA scores, presented by sex for each decade of life (i.e.,20 to 80+ years) and for the two physical activity groups.

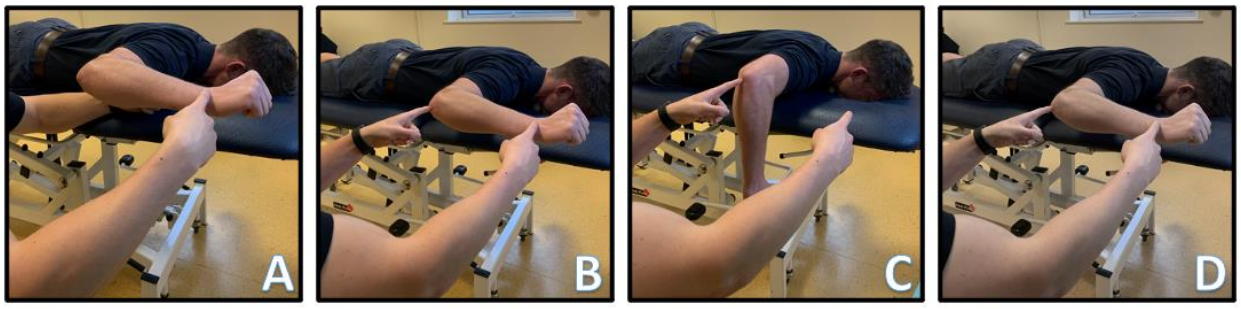
Supplementary Material 4. Distribution of Normative ExtRA Capacity Test Scores for the Dominant Side Across Age Groups in Males and Females: A Violin Plot

511
512

ExtRA Abduction Capacity Test
A: Starting position of capacity test
B: Participant raised 2.5kg dumbbell to 90° abduction in scapular plane

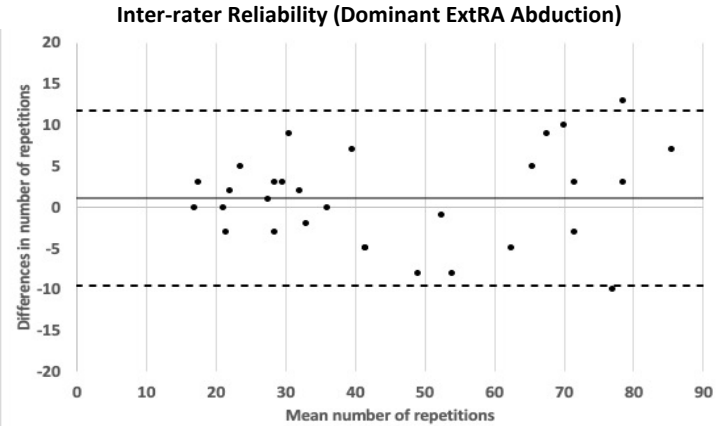


ExtRA External Rotation Capacity Test
A: Examiner to support participant's upper arm so it is in line with their upper back and noting position of the head of the ulnar when in maximal external rotation
B: Examiner to mark olecranon
C: Participant internally rotates arm around point marked on olecranon until fingers point to the floor
D: Participant rotates arm back up until head of ulnar makes contact with examiner's hand

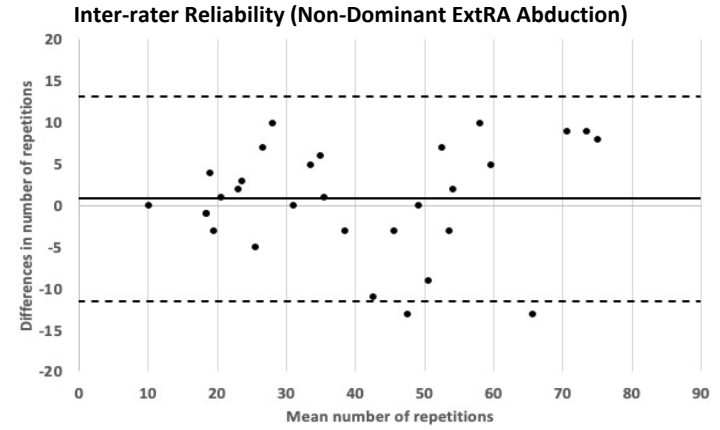


Demonstration of the area that the researcher's index finger, marking the olecranon, should remain in during the ExtRA External Rotation Capacity Test

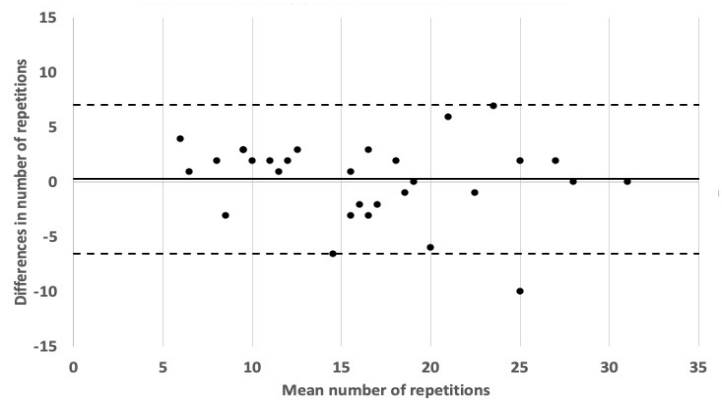
Inter-rater Reliability (Dominant ExtRA Abduction)



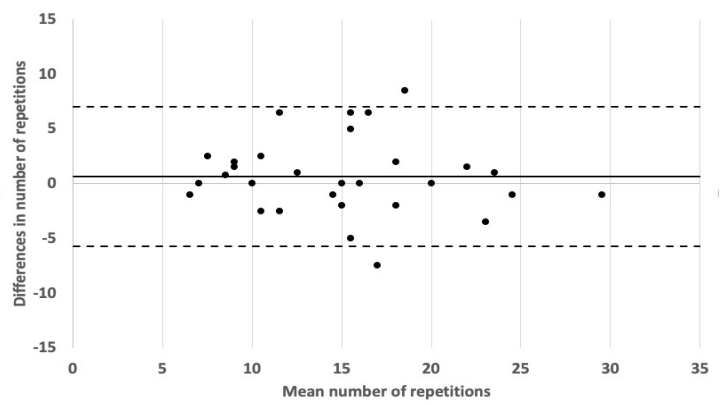
Inter-rater Reliability (Non-Dominant ExtRA Abduction)



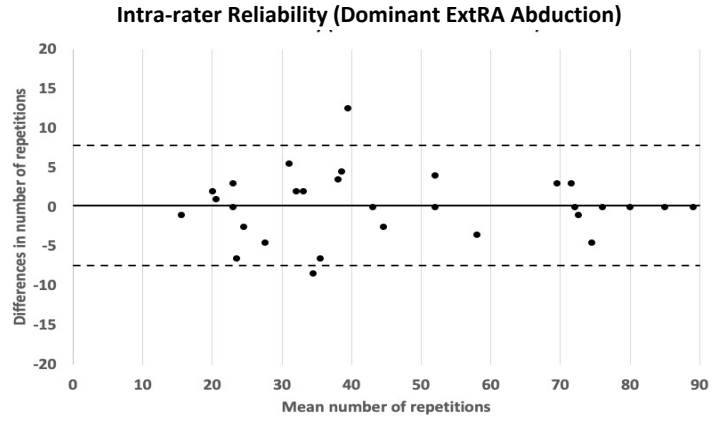
Inter-rater Reliability (Dominant ExtRA External Rotation)



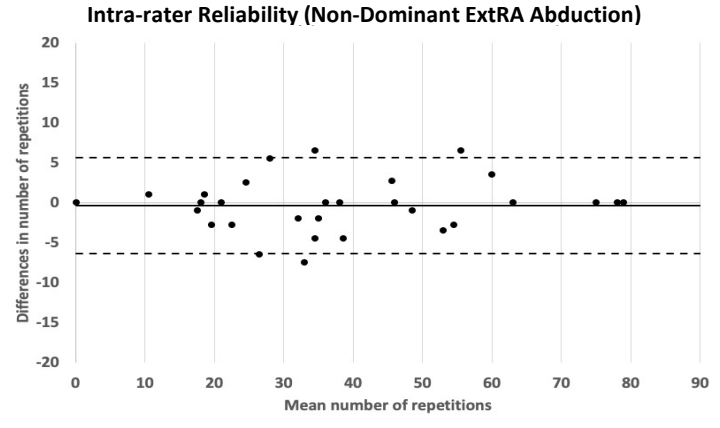
Inter-rater Reliability (Non-Dominant ExtRA External Rotation)



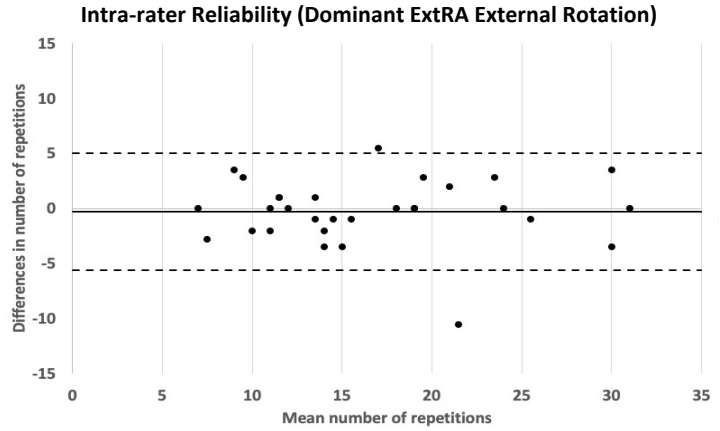
Intra-rater Reliability (Dominant ExtRA Abduction)



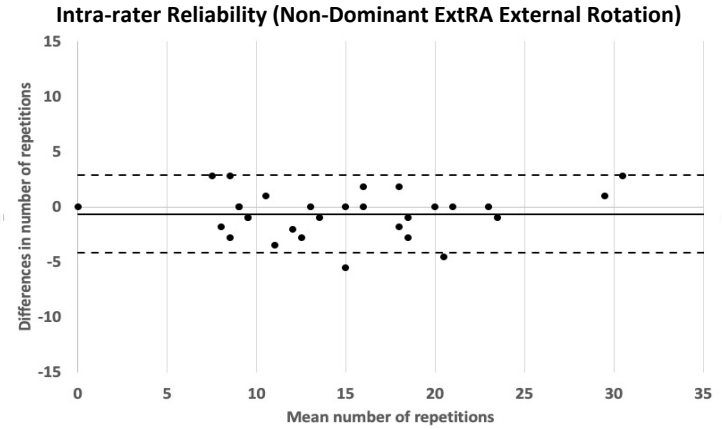
Intra-rater Reliability (Non-Dominant ExtRA Abduction)



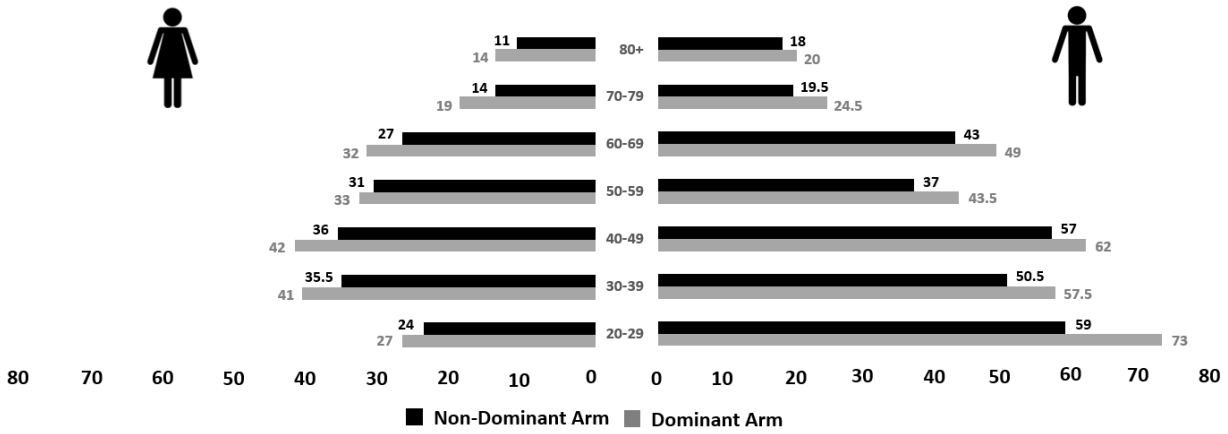
Intra-rater Reliability (Dominant ExtRA External Rotation)



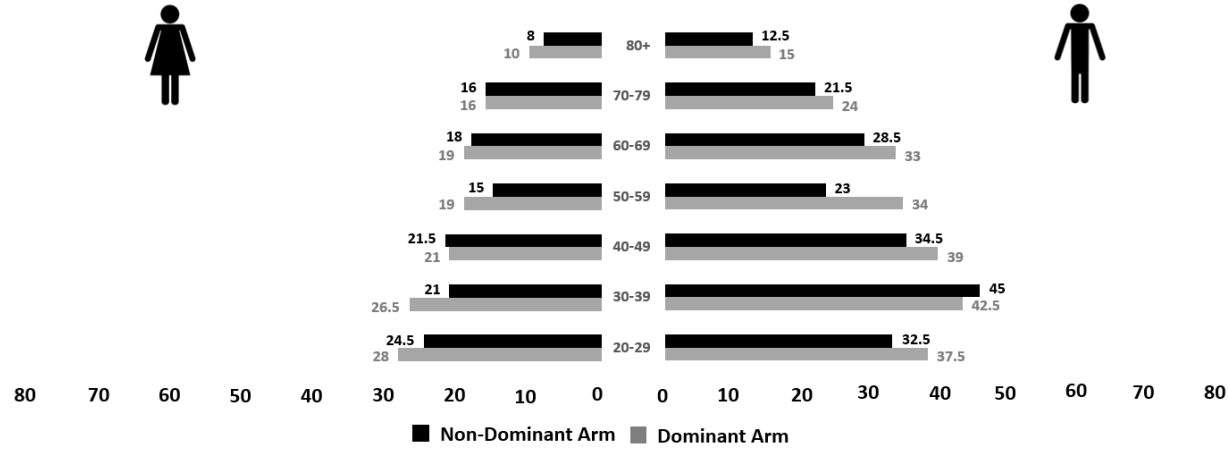
Intra-rater Reliability (Non-Dominant ExtRA External Rotation)



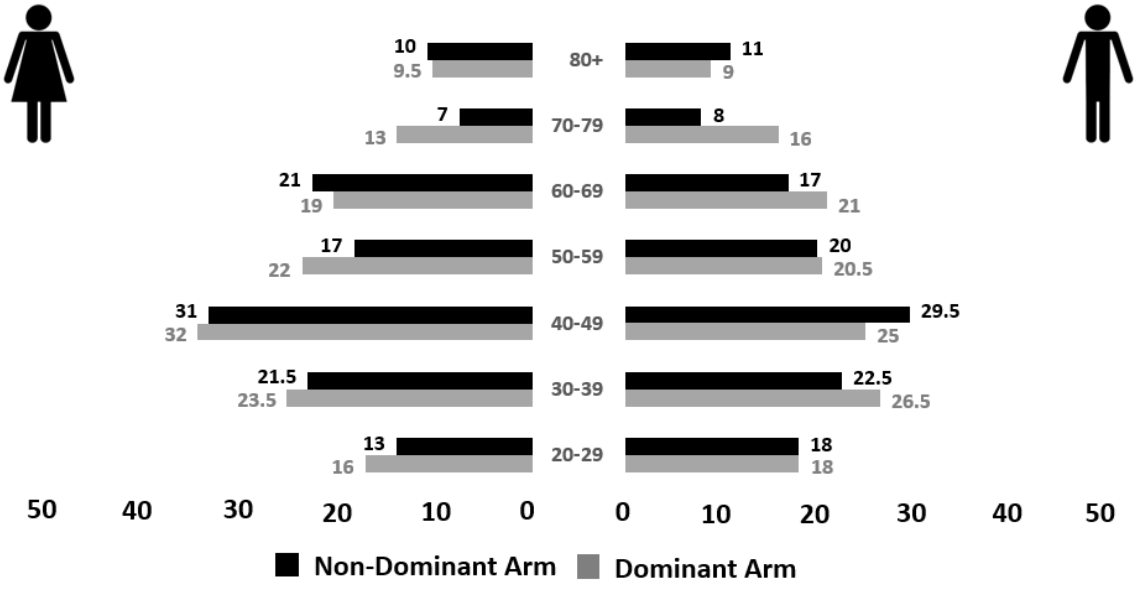
ExtRA Abduction- Active



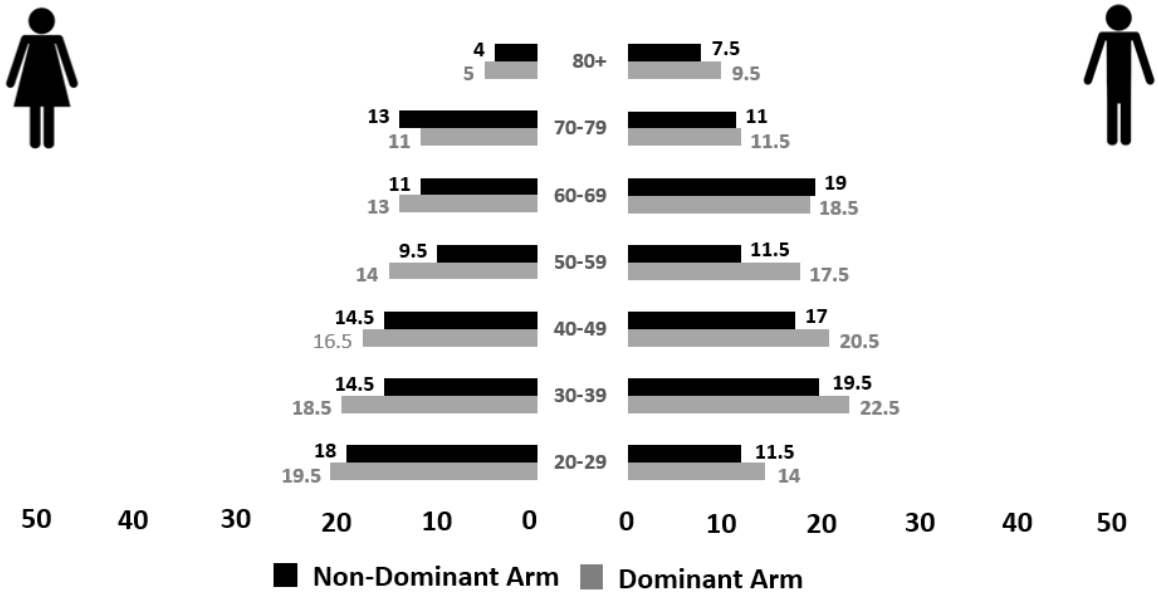
ExtRA Abduction- Inactive



ExtRA External Rotation- Active



ExtRA External Rotation- Inactive



Supplementary Material 1. Bland–Altman analysis showing mean bias and 95% limits of agreement (LoA) between and within raters for The ExtRA Capacity Test

	Variable	**Mean Bias**	**Lower LoA**	**Upper LoA**
Inter-rater	Dominant Abduction	1.07	-9.56	11.69
	Non-Dominant Abduction	0.82	-11.46	13.06
	Dominant External Rotation	0.28	-6.32	6.89
	Non-Dominant External Rotation	0.63	-5.76	7.01
Intra-rater	Dominant Abduction	0.17	-7.46	7.79
	Non-Dominant Abduction	-0.38	-6.42	5.65
	Dominant External Rotation	-0.26	-5.56	5.04
	Non-Dominant External Rotation	-0.67	-4.14	2.91

Supplementary Material 2: Table demonstrating the correlation between the ExtRA Capacity Test and strength measured obtained by Isokinetic Dynamometry

		Concentric Peak Torque	Concentric Average Peak Torque	Concentric Total Work	Concentric Work Fatigue	Concentric Average Power	Eccentric Peak Torque	Eccentric Average Peak Torque	Eccentric Total Work	Eccentric Work Fatigue	Eccentric Average Power
Abduction Capacity Test											
		Isokinetic Dynamometry Measure: Abduction									
Dominant	Pearson Correlation	0.616	0.607	0.817	0.268	0.752	0.556	0.533	0.576	0.135	0.514
	p-value (2-tailed)	0.004	0.005	<0.001	0.254	<0.001	0.011	0.016	0.008	0.570	0.020
Non-Dominant	Pearson Correlation	0.616	0.718	0.797	0.338	0.739	0.584	0.542	0.601	0.351	0.533
	p-value (2-tailed)	0.005	0.001	<0.001	0.157	<0.001	0.009	0.017	0.007	0.140	0.019
		Isokinetic Dynamometry Measure: External Rotation									
Dominant	Pearson Correlation	0.764	0.69	0.661	0.413	0.689	0.698	0.68	0.531	-0.070	0.583
	p-value (2-tailed)	0	0.001	0.002	0.07	0.001	0.001	0.001	0.016	0.768	0.007
Non-Dominant	Pearson Correlation	0.692	0.679	0.623	0.487	0.615	0.596	0.509	0.514	0.263	0.519
	p-value (2-tailed)	0.001	0.001	0.004	0.034	0.005	0.007	0.026	0.024	0.277	0.023
External Rotation Capacity Test											
		Isokinetic Dynamometry Measure: Abduction									
Dominant	Pearson Correlation	0.108	0.074	0.234	0.342	0.211	-0.026	-0.038	0.186	0.206	0.107
	p-value (2-tailed)	0.652	0.756	0.321	0.140	0.373	0.914	0.874	0.432	0.383	0.653
Non-Dominant	Pearson Correlation	0.309	0.373	0.476	0.199	0.403	0.268	0.245	0.334	0.253	0.236
	p-value (2-tailed)	0.197	0.116	0.040	0.415	0.087	0.267	0.312	0.163	0.295	0.331
		Isokinetic Dynamometry Measure: External Rotation									
Dominant	Pearson Correlation	0.346	0.290	0.204	0.350	0.171	0.207	0.159	0.193	0.285	0.159
	p-value (2-tailed)	0.135	0.214	0.388	0.130	0.470	0.382	0.504	0.415	0.223	0.502
Non-Dominant	Pearson Correlation	0.482	0.393	0.328	0.324	0.316	0.322	0.260	0.268	0.153	0.259
	p-value (2-tailed)	0.037	0.096	0.170	0.177	0.188	0.179	0.282	0.267	0.531	0.285

Significance > 0.05	Very Low Correlation (0-0.25)	Low correlation (0.26-0.49)	Moderate correlation (0.5-0.69)	Strong correlation (0.7-0.89)	Very strong correlation (0.9-1.0)

Supplementary Material 3. Normative median (50th), lower (10th) and upper (90th) percentile values of the median for ExtRA scores, presented by sex for each decade of life (i.e.,20 to 80+ years) and for the two physical activity groups.

Age	Arm Dominance	Male		Female	
		Achieves activity guidelines	Do not achieve activity guidelines	Achieves activity guidelines	Do not achieve activity guidelines
Abduction					
20-29	Dominant	73 (41.8, 95.8)	37.5 (22.6, 81.5)	27 (20.6, 53.6)	28 (14.0, 53.1)
	Non-Dominant	59 (30.8, 85.6)	32.5 (15.7, 57.9)	24 (16.0, 48.4)	24.5 (17.2, 41.0)
30-39	Dominant	57.5 (35.7, 101.1)	42.5 (38.2, 85.7)	41 (21.6, 69.0)	26.5 (9.3, 49.2)
	Non-Dominant	50.5 (31.7, 94.5)	45 (31.2, 73.2)	35.5 (17.4, 63.4)	21 (8.1, 32.9)
40-49	Dominant	62 (42.0, 120.5)	39 (14.0, 67.6)	42 (27.2, 100.6)	21 (14.3, 30.9)
	Non-Dominant	57 (29.0, 113.0)	34.5 (13.8, 64.6)	36 (23.4, 86.6)	21.5 (12.5, 34.4)
50-59	Dominant	43.5 (13.7, 139)	34 (18.5, 65.3)	33 (21.2, 58.6)	19 (8.7, 36.6)
	Non-Dominant	37 (12.0, 113.8)	23 (12.7, 54.4)	31 (19.6, 54.4)	15 (5.0, 28.8)
60-69	Dominant	49 (14.6, 137.6)	33 (15.5, 52.7)	32 (20.0, 65.0)	19 (6.0, 35.2)
	Non-Dominant	43 (17.8, 108.4)	28.5 (15.8, 44.6)	27 (16.0, 37.0)	18 (4.8, 26.8)
70-79	Dominant	24.5 (15.1, 71)	24 (12.0, 35.9)	19 (8.4, 27.6)	16 (8.6, 29.0)
	Non-Dominant	19.5 (9.3, 50.8)	21.5 (8.1, 38.8)	14 (5.8, 31.2)	16 (7.2, 23.8)
80+	Dominant	20 (10.4, 36.4)	15 (9.2, 18.9)	14 (5.6, 26.6)	10 (3.6, 12.9)
	Non-Dominant	18 (7.8, 36.8)	12.5 (5.5, 19.8)	11 (4.6, 25.4)	8 (4.1, 10)
External Rotation					
20-29	Dominant	18 (10.2, 40.6)	14 (10.1, 32.9)	16 (8.6, 46.6)	19.5 (12.1, 62.8)
	Non-Dominant	18 (8.6, 39.2)	11.5 (5.3, 26)	13 (8.4, 31.2)	18 (9.4, 52.7)
30-39	Dominant	26.5 (15.4, 56.5)	22.5 (8.4, 43.9)	23.5 (13.1, 42.5)	18.5 (8.1, 32.9)
	Non-Dominant	22.5 (13.1, 49.5)	19.5 (7.0, 41.7)	21.5 (11.1, 34.8)	14.5 (8.1, 32)
40-49	Dominant	25 (11.0, 79.0)	20.5 (11.1, 50.9)	32 (8.4, 68.4)	16.5 (6.3, 24.7)
	Non-Dominant	29.5 (12.5, 81.5)	17 (9.1, 60.5)	31 (6.2, 56.2)	14.5 (5.3, 24.6)
50-59	Dominant	20.5 (7.4, 62.0)	17.5 (5.6, 36.7)	22 (12.8, 35.6)	14 (6.0, 35.5)
	Non-Dominant	20 (6.3, 61.0)	11.5 (8.0, 36.2)	17 (10.2, 30.8)	9.5 (4.0, 22.5)
60-69	Dominant	21 (15.0, 41.8)	18.5 (8.6, 34.2)	19 (8.0, 41.0)	13 (3.6, 21.0)

	Non-Dominant	17 (8.2, 30.0)	19 (5.8, 39.6)	21 (6.0, 47.0)	11 (4.2, 20.8)
70-79	Dominant	16 (6.0, 35.9)	11.5 (4.0, 43.5)	13 (4.6, 29.4)	11 (3.6, 26.2)
	Non-Dominant	8 (5.1, 33.0)	11 (2.1, 35.4)	7 (3.6, 26.8)	13 (2.6, 19.4)
80+	Dominant	9 (1.8, 34.0)	9.5 (5.3, 13.9)	9.5 (3.1, 16.9)	5 (2.2, 9.7)
	Non-Dominant	11 (1.2, 29.8)	7.5 (6.0, 13.8)	10 (1.1, 12.0)	4 (2.1, 19.9)

Supplementary Material 4: Distribution of Normative ExtRA Capacity Test Scores for the Dominant Side Across Age Groups in Males and Females: A Violin Plot