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Upper limb functional testing: does age, gender, and sport influence performance?

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A R T I C L E I N F O

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Level of evidence: Basic Science Study; Validation of Performance Measures

Background: Musculoskeletal adaptations are common in overhead athletes. As they also are involved in injury prevention, there has been an increase in their evaluation through shoulder screening over the last years. However, for some evaluations, and especially for functional testing, there is a lack of normative values, which limits the interpretation of the values measured. Moreover, the influence of age, gender, and sport on upper limb functional tests remains underexplored.
Methods: Five hundred eighty seven athletes (handball players, rugby players, swimmers, tennis players, and volleyball players) performed a battery of upper limb functional tests between 2018 and 2023, including the Modified-Athletic Shoulder Test, the Single Arm Medicine Ball Throw, the Seated Single Arm Shot Put Test, the Upper Limb Rotation Test, the Upper Quarter Y Balance Test, the Modified Closed Kinetic Chain Upper Extremity Stability Test, and the Posterior Shoulder Endurance Test. In total, normative values as well as the influence of age, gender, and sport on upper limb functional performance were obtained for 496 of them.
Results: The Modified-Athletic Shoulder Test revealed sport-specific adaptations, with dominant arms significantly outperforming nondominant arms, notably in handball, rugby, and tennis. The Single Arm Medicine Ball Throw and Seated Single Arm Shot Put Test highlighted the influence of age and gender on upper limb power, with males consistently outperforming females. The Upper Limb Rotation Test demonstrated similar rotation in both arms across sports, while gender disparities were still observed. The Upper Quarter Y Balance Test exhibited surprising consistency in upper-quarter balance across sports and age groups ($P > .05$). The Modified Closed Kinetic Chain Upper Extremity Stability Test showed age-related improvements in stability, while the Posterior Shoulder Endurance Test demonstrated age-related differences in posterior shoulder endurance in swimmers.
Conclusion: This study contributes to advances in sports medicine by better understanding functional shoulder performances in upper limb athletes. The differences observed according to the sport, gender, or age underscore the importance of sport-specific assessments and interventions. Moreover, the normative values provided will be essential for primary prevention as well as for determining return-to-play capacity after an injury or surgery.

Shoulder musculoskeletal adaptations have been frequently described in overhead athletes following practice.[3,6,8,20,51,53] Indeed, changes in glenohumeral mobility, with an increase in external rotation range of motion at the expense of internal rotation, have been observed in upper limb athletes after just a few months of practice.[41,47] In addition, external rotator weakness and/or rotator cuff imbalances have been reported in overhead athletes with practice.[10,15,23] Structural changes have also been observed in overhead athletes' shoulders, such as tendons and cartilaginous structures such as the labrum.[1,24,34]

Following these observations, over the past years, shoulder screening has become more and more popular for clinicians with 3 different objectives: primary prevention, secondary prevention,

The study has been approved by the Medical Ethics Committee of University Hospital of Liège (Belgium).

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Table I
Characteristics of the athletes included in the study, classified by sports.

	Handball	Rugby	Swimming	Tennis	Volleyball
Adolescents					
Males					
Age (in y)	15.00 ± 0.92	15.81 ± 1.06	14.90 ± 1.00	15.58 ± 1.26	15.31 ± 1.49
Height (in cm)	176.80 ± 6.25	177.28 ± 8.20	174.15 ± 9.80	179.39 ± 6.49	181.13 ± 8.35
Weight (in kg)	67.80 ± 9.99	76.89 ± 13.77	61.25 ± 10.99	63.93 ± 9.46	65.00 ± 10.09
Number hours/practice	8.45 ± 2.92	6.05 ± 1.31	10.38 ± 3.32	6.76 ± 4.07	10.06 ± 2.09
Females					
Age (in y)	N.D.	N.D.	15.13 ± 0.83	15.25 ± 0.50	14.73 ± 1.03
Height (in meters)	N.D.	N.D.	166.50 ± 8.50	173.00 ± 5.48	170.70 ± 6.58
Weight (in kg)	N.D.	N.D.	57.00 ± 9.45	59.00 ± 7.26	59.72 ± 9.54
Number hours/practice	N.D.	N.D.	12.47 ± 3.85	7.25 ± 3.20	10.53 ± 2.10
Adults					
Males					
Age (in y)	19.90 ± 1.94	22.44 ± 3.96	26.10 ± 6.18	22.17 ± 2.57	24.51 ± 6.01
Height (in cm)	181.25 ± 7.57	180.22 ± 6.44	182.25 ± 8.19	183.02 ± 6.48	187.18 ± 6.55
Weight (in kg)	77.40 ± 12.69	81.84 ± 12.39	79.80 ± 10.04	73.63 ± 7.98	83.02 ± 12.34
Number hours/practice	8.45 ± 3.13	7.86 ± 1.39	7.75 ± 3.01	3.22 ± 1.38	7.05 ± 1.95
Females					
Age (in y)	N.D.	N.D.	23.58 ± 5.02	22.65 ± 3.17	17.32 ± 0.58
Height (in meters)	N.D.	N.D.	169.50 ± 6.96	167.75 ± 6.36	171.89 ± 7.27
Weight (in kg)	N.D.	N.D.	62.95 ± 7.36	62.25 ± 7.20	62.61 ± 7.78
Number hours/practice	N.D.	N.D.	10.00 ± 4.26	3.05 ± 1.00	9.83 ± 2.43

N.D., no data.

and performance.[42,54] Multiple tools and tests have been introduced into practice to assess shoulder kinetics, kinematics, mobility, strength, power, and endurance.[42,55] Besides laboratory/expertise center tools, functional testing has become an essential and valuable tool in assessing upper limb function and performance in various sports.[42,52] Its popularity is especially due to its reasonable cost, its speed of implementation, and its similarity with sport.[52]

A recent Delphi study done with 22 experts summarized the characteristics, the usefulness, and the advantages/disadvantages of the most popular upper limb functional tests.[52] However, this Delphi study also highlighted the lack of specific normative values that were available for those functional tests, which poses a challenge in their clinical use and interpretation.

The objective of this study was, first, to determine the influence of age, gender, and sport on the results of the most popular upper limb functional tests. Even if some concerns have been previously addressed in previous studies for some of the tests (Upper Quarter Y Balance Test [UQYBT], Seated Medicine Ball Throw, and Closed Kinetic Chain Upper Extremity Test),[5] none of these factors have been explored at the same time and in such a population before. The second objective was to provide normative data for these tests in different upper limb sports (rugby, handball, swimming, tennis, and volleyball). This way, we hope to help clinicians, coaches, and researchers to better interpret the results of those tests and identify potential deficits or areas for improvement for their athletes.

Methods

Participants

A total of 587 athletes (males and females), aged 14 to 35 years, practicing different popular upper limb sports (volleyball, handball, swimming, rugby, and tennis) in Belgium at least twice a week, were examined once between 2018 and 2023 by the research team. The chosen sports were selected due to their significant upper limb involvement, diverse movement patterns (cocking-throwing movements, closed-chain and open-chain, with and without contact), and high incidence of shoulder injuries (in a secondary prevention perspective). These sports provide a broad spectrum of functional adaptations, allowing for comprehensive assessment and the development of sport-specific normative values. Additionally, their popularity ensures a large and varied sample.

Among them, 18 were excluded because they had pain during the evaluation and 45 were excluded because they suffered from consequences of previous shoulder injuries. Twenty-six athletes were not retained because they practiced their sport at a professional level (or with a volume of more than 15 hours in a week) and 2 because they practiced their sport for less than 3 years. In total, the performance of 496 athletes was considered for analysis. The exclusion criteria were strictly applied to maintain homogeneity, acknowledging that extreme conditions (such as high-level professional athletes or those with less than 3 years of practice) could significantly skew the results due to their unique physical adaptations. Forty of them were handball players, 89 were rugby players, 96 were swimmers, 88 played tennis, and 183 played volleyball. The characteristics of the athletes included are specified in Table I.

The protocols have been validated by the Medical Ethics Committee of the University Hospital of Liège. All the participants were informed about the nature of the tests and the progress of the experimentations before the beginning of the tests.

Procedure

Standard personal data were first obtained from each participant (age, height, weight, sex, number of hours of practice, level of practice, and history of injury). Then, they performed different upper limb functional tests, according to their sport. The choice of the different tests was based on the parameters assessed by each test, their metrological qualities (validity, reliability, and sensitivity to change), and their potential links with sports performance or their ability to highlight risk factors of shoulder injuries. Furthermore, the rationale for choosing these tests included their relevance to sports-specific movements. From 2021 to 2023, the choice of the tests was also based on the sports-specific batteries of tests suggested by upper limb rehabilitation experts, summarized in a Delphi study performed by our research group.[52]

The following tests were included in the protocol: the Upper Limb Rotation Test (ULRT), the UQYBT, the Modified-Athletic Shoulder Test (M-AST), the Modified Closed Kinetic Chain Upper

Extremity Stability Test (MCKCUEST), the Single Arm Medicine Ball Throw (SAMBT), the Seated Single Arm Shot Put Test (SSASPT), and the Posterior Shoulder Endurance Test (PSET). All have been previously demonstrated as reliable in the literature. The way to perform the tests and the characteristics of them are described in Appendix A.

All the tests were performed by experimented assessors, who were using them regularly in practice and for whom the reliability had been measured before. As a warm-up, athletes had to perform 2 series of 10 shoulder internal rotations and external rotations at 0° and 90° of abduction (frontal plane with an elastic band), 15 shoulder circumductions, and 20 overhead medicine ball throws. Then, testing sequences were preceded by 2 familiarization trials with the different tests they had to perform. After that, each test was performed 3 times by the players (except for the PSET to limit fatigue) and only the best score was retained for analysis. All the tests were performed in a randomized order, except again for the PSET, since the fatigue induced by this test could have a significant impact on the results of the others. Therefore, the PSET was always performed at the end of the protocol. To avoid fatigue, a 1-minute rest time was provided between the different repetitions of a test and 5 minutes were given between the different tests. Fifteen minutes of recovery were provided before the PSET to limit the influence of fatigue on the results.

Data processing

The population was first classified into 2 groups: male and female athletes. Then, those 2 groups were split into 2 other groups, based on the age of the player at the moment of the tests. The first group included adolescents (in other words, pubertal players) and the second one included adult athletes. The relationship between timing of peak height velocity and pubertal staging in the US males and females was previously explored by Granados et al.[26] In this study, the majority of the girls had achieved their peak height velocity by Tanner stage 3, corresponding to a mean age of 12.8 years, and that the boys had achieved their peak height velocity by Tanner stage 4, corresponding to a mean age of 13.8 years. Puberty was considered as complete at the age of 16.8 years for girls and 17.8 years for boys.[29] Therefore, female players were assigned to the first group if they were aged between 13 and 16 years and to the second one if they were aged 17 years or more. Male players were assigned to the first group if they were aged between 14 and 17 years and to the second one if they were aged 18 years or more.

Maximal number of repetitions was considered for analysis for the ULRT as well as the MCKCUEST. The maximal distance (in meters) was considered for SAMBT and SSASPT. To obtain a normalized score for the UQYBT, the maximal distance (in cm) reached in the 3 directions was divided by the upper limb length (distance between C7 and the extremity of the middle finger). The maximal isometric strength values recorded by the handheld dynamometer in the 3 positions (I, Y, and T) were multiplied by upper limb length (measured between the acromion and the processus styloideus ulnae) to obtain the moment of force (expressed in Newton by meters) for the M-AST. A composite score was calculated for both the UQYBT and the M-AST values, which corresponded to the mean score of the 3 directions. Time to exhaustion was considered for the PSET. The participant was considered as exhausted when they stopped the movement and was not able to keep the rhythm anymore or to perform the movement without compensatory movements (such as excessive trunk rotation, shoulder elevation, or dropping the arm below the required level). The rhythm of 30 beats per minute was used to standardize the movement pace, with each beat indicating the cycle of elevating the arm to the horizontal position and returning to the starting position. A horizontal bar set at shoulder height was used as an external guide to ensure the arm was elevated to the same point each time, providing a standardized measure.

Table II
Normative values in handball players on the dominant (Dom) and nondominant (Ndom) sides.

	Males (N = 40)		*P* value (effect size)
	Adolescents (N = 20)	Adults (N = 20)	
ULRT Dom	17.85 ± 2.46	19.45 ± 3.33	.092 (0.07)
ULRT Ndom	18.20 ± 3.75	19.45 ± 2.96	.250 (0.03)
SAMBT	15.75 ± 2.39	18.28 ± 3.43	.010* (0.16)
M-AST I Dom	72.59 ± 16.03	88.41 ± 16.11	.004* (0.20)
M-AST Y Dom	60.47 ± 12.73	78.90 ± 19.17	.001* (0.25)
M-AST T Dom	58.65 ± 11.07	76.58 ± 20.16	.001* (0.24)
M-AST I Ndom	63.57 ± 12.77	82.53 ± 15.47	.000* (0.32)
M-AST Y Ndom	54.45 ± 12.69	69.04 ± 14.57	.002* (0.23)
M-AST T Ndom	52.24 ± 11.29	67.83 ± 16.70	.001* (0.24)
M-AST C Dom	63.90 ± 12.35	81.30 ± 17.30	.001* (0.26)
M-AST C Ndom	56.79 ± 11.42	73.13 ± 14.49	.000* (0.292)

ULRT, Upper Limb Rotation Test; *SAMBT*, Single Arm Medicine Ball Throw; *M-AST*, Modified-Athletic Shoulder Test; *I Dom*, 180° of abduction, dominant side; *Y Dom*, 135° of abduction, dominant side; *C Dom*, composite score; *T Dom*, 90° of abduction, dominant side
ULRT values are expressed in number of touches; M-AST values are expressed in N.m; SAMBT T values are expressed in meters.
*Indicates significant values ($P < .05$).

Statistical analysis

Statistical analysis was performed using SPSS Statistics 25 (IBM Corp., Armonk, NY, USA). The normality of the variables was assessed with a Shapiro-Wilk test. Since the variables were normally distributed, means and standard deviations (SDs) were expressed for the normative values. Dominant and nondominant side values inside a same population were compared using unpaired *t*-tests. Differences between age groups and gender were determined using an analysis of variance 2 for each sport to investigate not only the main effects of each factor but also the interaction effects between them. For the same test, a one-way analysis of variance was used to compare the results between sports as well as to highlight the specificities of the test, according to sport. In case of significant *P* values, the Bonferroni method was used to compare the differences between pairs (for sports). Effect size (ES) was expressed using eta-squared.[31] The ES was considered as low if inferior to 0.01, moderate if included between 0.01 and 0.06, and large if superior to 0.14. The level of significance was set at $P < .05$ for all the tests.[31]

Results

Influence of arm dominance, gender, and age on the results of the tests

Handball players

Only males were assessed in handball players. The results obtained in handball players are presented in Table II. Both adolescent and adult players obtained higher scores on the dominant side (between 7% and 12.5%) compared to the nondominant side for the M-AST, but those differences only reached significance when considering the I score of the adolescent players ($P = .048$). However, no bilateral difference was observed for the ULRT ($P = .808$).

When comparing adolescents to adults, a significant difference was observed for the SAMBT ($P = .010$) and the M-AST ($P = .000$-$.002$). A large ES was found for both tests (ES = 0.16 for SAMBT and

Table III
Normative values in rugby players on the dominant (Dom) and nondominant (Ndom) sides.

	Males (N = 89)		P value (effect size)
	Adolescents (N = 32)	Adults (N = 57)	
UQYBT M Dom	0.97 ± 0.08	1.01 ± 0.08	.093 (0.03)
UQYBT SL Dom	0.68 ± 0.09	0.68 ± 0.11	.819 (0.00)
UQYBT IL Dom	0.75 ± 0.08	0.75 ± 0.17	.927 (0.00)
UQYBT M Ndom	0.97 ± 0.07	1.00 ± 0.08	.134 (0.03)
UQYBT SL Ndom	0.69 ± 0.09	0.70 ± 0.12	.705 (0.00)
UQYBT IL Ndom	0.77 ± 0.08	0.78 ± 0.11	.770 (0.00)
UQYBT C Dom	0.80 ± 0.07	0.82 ± 0.08	.424 (0.01)
UQYBT C Ndom	0.81 ± 0.07	0.83 ± 0.09	.666 (0.00)
MCKCUEST	32.34 ± 5.25	37.91 ± 6.98	.007* (0.08)
M-AST I Dom	76.79 ± 19.42	98.61 ± 24.70	.000* (0.15)
M-AST Y Dom	69.20 ± 17.48	80.55 ± 19.99	.019* (0.06)
M-AST T Dom	67.46 ± 14.62	76.34 ± 19.46	.172 (0.02)
M-AST I Ndom	72.50 ± 19.61	93.74 ± 21.70	.000* (0.15)
M-AST Y Ndom	63.85 ± 16.12	75.29 ± 15.72	.022* (0.06)
M-AST T Ndom	62.14 ± 14.78	69.95 ± 17.72	.261 (0.015)
M-AST C Dom	71.15 ± 16.23	85.17.30 ± 19.38	.005* (0.09)
M-AST C Ndom	66.16 ± 15.94	79.66 ± 17.23	.008* (0.08)

UQYBT, Upper Quarter Y Balance Test; *MCKCUEST*, Modified Closed Kinetic Chain Upper Extremity Stability Test; *M-AST*, Modified-Athletic Shoulder Test; *I Dom*, 180° of abduction, dominant side; *Y Dom*, 135° of abduction, dominant side; *C Dom*, composite score, dominant side; M Dom, medial direction, dominant side; *SL Dom*, superolateral direction, dominant side; *IL Dom*, inferolateral direction, dominant side; *T Dom*, 90° of abduction, dominant side.
CKCUEST values are expressed in number of touches; M-AST values are expressed in N.m; UQYBT values are expressed in percentage of upper limb length.
*Indicates significant values ($P < .05$).

ES = 0.20-0.32 for M-AST). However, no significant difference was reported for the ULRT, even if adult players seemed to have better scores than adolescent ones (P = .092-.250), with an ES of 0.07 on the dominant side.

Rugby players

Our recruitment included only male players in rugby. The results obtained in rugby players are presented in Table III. Comparing dominant to nondominant side, significant and higher values were obtained for the M-AST (from 5% to 8.5%) on the dominant side but this didn't reached significance (P = .171-.363). No significant bilateral difference was highlighted for UQYBT, no matter the direction considered (P = .507-.995).

For the MCKCUEST, adult players reached significantly better performance than adolescents (P = .007). The ES was considered as moderate (0.08). The same observation was made for the M-AST (P = .000-.022), except for the T position, where the difference did not reach significance, both on the dominant and nondominant sides (P = .172-.261). A large ES was found for the "I position" (ES = 0.148-0.151), while a moderate one was found for the "Y position" (ES = 0.06) as well as for the composite score (0.08-0.09). However, no significant difference was found between adolescents and adults for the UQYBT score, no matter the directions considered (P = .093-.927).

Swimmers

The present study included both male and female swimmers for all the tests considered. The results obtained in swimmers are presented in Table IV. An increase of 9% was found for M-AST score on dominant side and in "I position" in adult male swimmers (P = .044). No significant bilateral difference was found for the M-AST when considering female swimmers or male adolescents ($P > .05$). No significant difference was found for ULRT (P = .284-.799) or PSET (P = .284-.904).

Considering age and gender, none of these variables significantly influenced the results of the ULRT (P = .124-.250 for age and P = .419-.630 for gender) or the PSET results (P = .200-.296 for age and P = .195-.750 for gender). However, the opposite was found for M-AST performances. An interaction effect was also found for age and gender when considering the results of this test. This was the case for Y position on both sides (P = .028-.034 and ES = 0.05), the I position on the nondominant side (P = .044 and ES = 0.05), and the composite score on the nondominant side (P = .033 and ES = 0.05), even if the ESs were quite low.

Tennis players

The sample included both male and female players for tennis, except for the UQYBT, where only male players were included. The results obtained in tennis players are presented in Table V.

Comparing dominant to nondominant side, significant bilateral differences were found for some of the positions of the M-AST in male players. In adolescent male players, a significant difference of 17% was found (P = .047), in favor of the dominant side, while in adult male players, highest scores (from 14% to 21%) were obtained on the dominant side in all the positions, except the "T position" (P = .003-.049). No bilateral difference was observed for M-AST in female players ($P > .05$) as well as for the other tests performed (ULRT and UQYBT) ($P > .05$).

The results of ULRT are significantly influenced by gender (with male players performing better then female ones). A large ES was found for this variable (ES = 0.19-0.21). However, the influence of the age on the score of this test did not reach statistical significance (P = .358-.578). The same observation was made for the SAMBT and the M-AST, with a significant effect of gender on the results, with large ESs (P = .000 and ES = 0.30 for SAMBT; P = .000 and ES = 0.26-0.38 for M-AST). Moreover, the SSASPT score was significantly influenced by age (P = .002; ES = 0.18) and gender (P = .002; ES = 0.17). No significant effect of age was found for the UQYBT (P = .291-.902), no matter the direction considered for analysis. Finally, no interaction effect of age and gender combined was found for all those tests ($P > .05$).

Volleyball players

Both male and female players were included in the sample. The results obtained in volleyball players are presented in Table VI. No significant bilateral difference was observed for all the tests and groups considered ($P > .05$).

Table IV
Normative values in swimmers on the dominant (Dom) and nondominant (Ndom) sides.

	Males (N = 58)		Females (N = 38)		P value age (effect size)	P value gender (effect size)	Age*gender (effect size)
	Adolescents (N = 21)	Adults (N = 37)	Adolescents (N = 15)	Adults (N = 23)			
ULRT Dom	13.00 ± 3.85	14.95 ± 3.44	13.75 ± 4.27	16.00 ± 3.19	.124 (0.03)	.419 (0.01)	.971 (0.00)
ULRT Ndom	13.30 ± 3.54	14.15 ± 2.80	13.00 ± 3.93	15.27 ± 3.69	.250 (0.01)	.630 (0.00)	.404 (0.01)
M-AST I Dom	68.38 ± 25.92	98.77 ± 22.14	48.23 ± 12.95	59.93 ± 20.54	.002* (0.11)	.000* (0.24)	.201 (0.02)
M-AST Y Dom	51.81 ± 13.30	73.50 ± 18.60	42.15 ± 12.79	47.06 ± 12.13	.002* (0.11)	.000* (0.23)	.034* (0.05)
M-AST T Dom	45.19 ± 15.47	64.29 ± 17.91	36.82 ± 11.60	44.97 ± 9.63	.000* (0.14)	.000* (0.14)	.170 (0.02)
M-AST I Ndom	62.42 ± 17.01	90.10 ± 20.83	51.01 ± 16.63	56.04 ± 13.14	.003* (0.10)	.000* (0.21)	.044* (0.05)
M-AST Y Ndom	48.54 ± 13.86	67.21 ± 14.16	43.20 ± 13.58	48.88 ± 11.46	.001* (0.12)	.000* (0.15)	.028* (0.05)
M-AST T Ndom	43.14 ± 12.50	59.35 ± 15.72	37.78 ± 12.64	43.12 ± 8.10	.000* (0.14)	.001* (0.13)	.081 (0.03)
M-AST C Dom	58.18 ± 16.69	78.85 ± 17.27	42.40 ± 12.17	50.65 ± 13.25	.000* (0.14)	.000* (0.24)	.092 (0.03)
M-AST C Ndom	51.37 ± 13.90	72.22 ± 15.49	44.00 ± 13.90	49.35 ± 10.51	.001* (0.13)	.000* (0.19)	.033* (0.05)
PSET Dom	195.45 ± 68.99	190.05 ± 65.25	166.50 ± 66.83	168.78 ± 110.00	.200 (0.02)	.750 (0.00)	.212 (0.02)
PSET Ndom	181.95 ± 70.22	204.50 ± 66.45	155.83 ± 66.77	133.89 ± 46.58	.296 (0.01)	.195 (0.02)	.750 (0.00)

ULRT, Upper Limb Rotation Test; *M-AST*, Modified-Athletic Shoulder Test; *PSET*, Posterior Shoulder Endurance Test; *I Dom*, 180° of abduction, dominant side; *Y Dom*, 135° of abduction, dominant side; *C Dom*, composite score; *T Dom*, 90° of abduction, dominant side.
ULRT values are expressed in number of touches; M-AST values are expressed in N.m; PSET values are expressed in seconds.
*Indicates significant values ($P < .05$).

Table V
Normative values in tennis players on the dominant (Dom) and nondominant (Ndom) sides.

	Males (N = 65)		Females (N = 23)		P value age (effect size)	P value gender (effect size)	Age*gender (effect size)
	Adolescents (N = 19)	Adults (N = 46)	Adolescents (N = 4)	Adults (N = 19)			
ULRT Dom	16.69 ± 2.10	14.05 ± 2.46	11.75 ± 1.71	12.75 ± 3.31	.358 (0.02)	.001* (0.19)	.045* (0.07)
ULRT Ndom	15.92 ± 1.98	14.26 ± 2.88	10.25 ± 3.30	12.95 ± 3.15	.578 (0.01)	.000* (0.21)	.023* (0.10)
SAMBT	11.79 ± 3.02	12.28 ± 2.21	9.55 ± 2.32	8.07 ± 1.29	.492 (0.01)	.000* (0.30)	.171 (0.04)
SSASPT	5.18 ± 0.70	5.06 ± 0.49	5.08 ± 0.88	3.85 ± 0.60	.002* (0.18)	.002* (0.17)	.009* (0.13)
UQYBT M Dom	1.05 ± 0.17	1.06 ± 0.13	N.D.	N.D.	.830 (0.00)	N.D.	N.D.
UQYBT SL Dom	0.72 ± 0.06	0.73 ± 0.09	N.D.	N.D.	.902 (0.00)	N.D.	N.D.
UQYBT IL Dom	0.91 ± 0.05	0.87 ± 0.10	N.D.	N.D.	.286 (0.04)	N.D.	N.D.
UQYBT M Ndom	0.94 ± 0.16	0.99 ± 0.11	N.D.	N.D.	.291 (0.04)	N.D.	N.D.
UQYBT SL Ndom	0.74 ± 0.05	0.76 ± 0.12	N.D.	N.D.	.754 (0.00)	N.D.	N.D.
UQYBT IL Ndom	0.87 ± 0.06	0.88 ± 0.10	N.D.	N.D.	.838 (0.00)	N.D.	N.D.
UQYBT C Dom	0.87 ± 0.05	0.86 ± 0.09	N.D.	N.D.	.801 (0.00)	N.D.	N.D.
UQYBT C Ndom	0.85 ± 0.08	0.88 ± 0.09	N.D.	N.D.	.480 (0.02)	N.D.	N.D.
M-AST I Dom	59.07 ± 20.70	74.88 ± 19.32	40.06 ± 12.40	41.34 ± 9.56	.119 (0.05)	.000* (0.31)	.183 (0.03)
M-AST Y Dom	53.03 ± 13.04	59.02 ± 11.36	36.18 ± 14.40	36.18 ± 9.45	.424 (0.01)	.000* (0.35)	.423 (0.01)
M-AST T Dom	50.95 ± 12.72	48.01 ± 13.62	32.99 ± 9.66	32.37 ± 8.66	.939 (0.00)	.000* (0.33)	.392 (0.01)
M-AST I Ndom	49.11 ± 14.81	59.06 ± 14.06	32.25 ± 8.86	37.52 ± 10.08	.073 (0.06)	.000* (0.29)	.575 (0.01)
M-AST Y Ndom	44.11 ± 10.43	50.05 ± 12.02	32.80 ± 6.67	31.75 ± 9.59	.482 (0.01)	.000* (0.26)	.316 (0.02)
M-AST T Ndom	43.34 ± 10.62	46.19 ± 11.01	28.86 ± 3.42	28.33 ± 7.03	.896 (0.00)	.000* (0.29)	.180 (0.03)
M-AST C Dom	54.35 ± 14.32	60.64 ± 13.07	35.03 ± 9.28	36.63 ± 8.55	.311 (0.02)	.000* (0.38)	.545 (0.01)
M-AST C Ndom	45.52 ± 10.66	52.10 ± 11.21	32.68 ± 7.50	32.53 ± 8.15	.325 (0.02)	.000* (0.33)	.302 (0.02)

ULRT, Upper Limb Rotation Test; *M-AST*, Modified-Athletic Shoulder Test; *UQYBT*, Upper Quarter Y Balance Test; *SAMBT*, Single Arm Medicine Ball Throw; *SSASPT*, Seated Single Arm Shot Put Test; *N.D.*, no data; *I Dom*, 180° of abduction, dominant side; *Y Dom*, 135° of abduction, dominant side; *C Dom*, composite score, dominant side; *M Dom*, medial direction, dominant side; *SL Dom*, superolateral direction, dominant side; *IL Dom*, inferolateral direction, dominant side; *T Dom*, 90° of abduction, dominant side.
ULRT values are expressed in number of touches; M-AST values are expressed in N.m; UQYBT values are expressed in percentage of upper limb length; SAMBT and SSASPT values are expressed in meters.
*Indicates significant values ($P < .05$).

ULRT values were significantly influenced by gender (with males performing better than females) (P = .009-.022), with a moderate to large ES (ES = 0.08-0.11). No significant effect of age was found for this test (P = .943-.952). Considering the SAMBT, a significant interaction was found for the interaction of age and gender (P = .000). A large ES was found for this interaction (ES = 0.14). Finally, UQYBT results were not significantly influenced by age (P = .059-.792) or gender (P = .071-.897), no matter the direction or the side considered.

Between-sport comparison

ULRT scores were significantly influenced by the sport practiced. In male players, significantly higher scores were obtained in handball and volleyball players (P = .000; ES = 0.36-0.39). In male adolescents, tennis players performed higher than swimmers, while scores were quite similar between those 2 sports in male adults. For female players, volleyball players had significantly better scores than tennis players (P = .007-.022; ES = 0.13-0.21). No

Table VI
Normative values in volleyball players on the dominant (Dom) and nondominant (Ndom) sides (mean, standard deviation, *P* value, and effect size).

	Males (N = 109)		Females (N = 74)		*P* value age (effect size)	*P* value gender (effect size	Age*gender (effect size)
	Adolescents (N = 32)	Adults (N = 77)	Adolescents (N = 55)	Adults (N = 19)			
ULRT Dom	18.43 ± 0.79	19.50 ± 2.12	16.72 ± 3.07	15.81 ± 2.14	.943 (0.00)	.022* (0.08)	.394 (0.01)
ULRT Ndom	19.00 ± 2.60	19.50 ± 2.12	16.51 ± 2.86	15.88 ± 2.42	.952 (0.00)	.009* (0.11)	.617 (0.00)
SAMBT	13.91 ± 3.55	18.99 ± 3.44	9.68 ± 1.91	9.17 ± 1.26	.000* (0.10)	.000* (0.51)	.000* (0.14)
UQBYT M Dom	0.96 ± 0.20	0.98 ± 0.10	0.97 ± 0.10	0.96 ± 0.11	.789 (0.00)	.897 (0.00)	.371 (0.00)
UQBYT SL Dom	0.70 ± 0.17	0.71 ± 0.12	0.72 ± 0.12	0.69 ± 0.13	.686 (0.00)	.943 (0.00)	.324 (0.01)
UQBYT IL Dom	0.89 ± 0.23	0.82 ± 0.13	0.92 ± 0.12	0.88 ± 0.14	.047* (0.02)	.071 (0.02)	.498 (0.00)
UQBYT M Ndom	0.95 ± 0.21	0.99 ± 0.10	0.97 ± 0.10	0.99 ± 0.08	.243 (0.01)	.544 (0.00)	.749 (0.00)
UQBYT SL Ndom	0.70 ± 0.17	0.70 ± 0.12	0.73 ± 0.13	0.75 ± 0.13	.746 (0.00)	.075 (0.02)	.672 (0.00)
UQBYT IL Ndom	0.90 ± 0.23	0.82 ± 0.12	0.91 ± 0.13	0.89 ± 0.13	.059 (0.02)	.135 (0.01)	.302 (0.01)
UQBYT C Dom	0.85 ± 0.19	0.84 ± 0.10	0.87 ± 0.09	0.84 ± 0.11	.375 (0.00)	.494 (0.00)	.698 (0.00)
UQBYT C Ndom	0.85 ± 0.19	0.83 ± 0.10	0.87 ± 0.10	0.87 ± 0.10	.792 (0.00)	.132 (0.01)	.632 (0.00)

ULRT, Upper Limb Rotation Test; *SAMBT*, Single Arm Medicine Ball Throw; *UQYBT*, Upper Quarter Y Balance Test; *C Dom*, composite score, dominant side; *M Dom*, medial direction, dominant side; *SL Dom*, superolateral direction, dominant side; *IL Dom*, inferolateral direction, dominant side.
ULRT values are expressed in number of touches; UQYBT values are expressed in percentage of upper limb length; SAMBT values are expressed in meters.
*Indicates significant values ($P < .05$).

significant difference was observed between swimmers' and volleyball players' scores as well as between swimmers' and tennis players' scores ($P > .05$) (Appendix B).

SAMBT performance was also significantly influenced by the sport ($P = .000$-$.015$; ES = 0.16-0.38), except for female adolescents ($P = .896$). Volleyball players had better scores than tennis players. This difference was significant in all the adults. In male athletes, handball players had also significantly better performances than tennis players (Appendix B).

UQYBT was, in majority, performed by male players. Despite some observed differences, no significant increase or decrease was observed between sports, no matter the age category considered ($P = .052$-$.297$) (Appendix B).

M-AST scores were influenced by the sport practiced for the whole of the observed population, except for female adolescents ($P = .078$-$.241$). In male adolescents, rugby players reached better scores than swimmers and tennis players in the "Y position" ($P = .000$; ES = 0.21), the "T position" ($P = .000$; ES = 0.30), and the "composite score" ($P = .001$; ES = 0.19), while no significant difference was observed in comparison to handball players ($P > .05$). Moreover, handball and tennis players reached better scores than swimmers in the "T position". In male adults, tennis players had smaller scores in the "Y position" ($P = .000$; ES = 0.170) and the "composite score" ($P = .000$; ES = 0.18) than handball players, volleyball players, or swimmers. In the "I position," rugby players and swimmers significantly performed better than tennis players ($P = .006$; ES = 0.09), while in the "T position," rugby and handball players had better scores than swimmers and tennis players ($P = .000$; ES = 025). Finally, in female adults, swimmers reached significant and better scores than tennis players, no matter the position considered ($P = .002$-$.015$; ES = 0.14-0.23) (Appendix B).

Discussion

Musculoskeletal adaptations in overhead athletes have long been a subject of interest, and concern, among clinicians and researchers. These adaptations encompass a wide range of changes, from alterations in glenohumeral joint mobility and muscle balance to structural changes to the shoulder.[6,20,39,48] To highlight and address these concerns, shoulder screening has gained in popularity over the last years, providing important data for primary and secondary prevention as well as for performance optimization.[51,56] This surge in interest has led to the development of various tools and tests to assess shoulder kinetics, kinematics, mobility, strength, power, and endurance.[40,42,43] Functional testing has become a part of this evaluation.[52] Despite the popularity of upper limb functional testing, a critical issue arises: the lack of specific normative values for these tests, presenting a challenge in clinical interpretation and application.[42,52] The influence of sports, age, and gender on the results of these tests has also not been extensively explored in the past and needs to be better understood if we want to use them more efficiently in practice. By comparing the performance test results across different sports and age categories, we aim to identify specific adaptations and understand how different physical activities and development influence upper limb function. Providing normative values for these tests across multiple sports enhances the utility of the tests in clinical and sports settings. Coaches, trainers, and clinicians can use these data to benchmark performance, identify deficits, and tailor training or rehabilitation programs specific to each sport. The diverse nature of the selected sports, ranging from symmetrical (eg, swimming) to asymmetrical (eg, tennis), overhead (eg, volleyball) to contact-based (eg, rugby), offers a comprehensive overview and a more complete understanding of upper limb functional performance.

First, the results of the M-AST provided valuable insights into the shoulder musculature and its correlation with specific age groups and gender. Across various sports, the M-AST scores showed significant differences between the dominant and nondominant arms. In male handballers, the dominant arm exhibited higher M-AST scores by 7% to 12.5%, emphasizing the dominance of shoulder musculature in the arm primarily used in their sport. Significant side-to-side differences have previously been observed for shoulder rotator strength in handball players.[14,22,57] Even if we consider a nonrotational plane of movement in this test,[2,50,52] we can easily understand a similar increase of strength on the dominant side. This observation underscores the sport-specific nature of shoulder development and the demands placed on these athletes' shoulders, potentially due to repetitive overhead motions and ball-handling requirements.[19,22,32,38] On the other hand, unlike in male adults, the M-AST did not reveal significant bilateral differences in female swimmers. This suggests that the demands of swimming may lead to more balanced shoulder muscle development in female athletes, reducing the dominance of one arm over the other.[4,12] Since this sport is symmetrical, this affirmation appears quite logical.[12] The same observation was made for tennis players, where significant bilateral differences were only found in male players. Next to gender specificities, the unilateral movements and forceful strokes (especially for serve and forehand) required in tennis likely contribute to these differences in male players.[28,33,44,49] It is noteworthy that male tennis players outperformed female tennis players in M-AST scores, further illustrating the gender-specific impact on shoulder musculature development.[27,49] This impact, which is not only observed in tennis, can be attributed to testosterone, which is more produced and expressed in males than in females when puberty begins.[27] Moreover, the present study observed a significant influence of age on M-AST scores. Adult athletes generally outperformed adolescents, with substantial ESs observed in both handball and rugby players as well as swimmers. This indicates that shoulder musculature continues to develop and strengthen with age, potentially due to increased training and competitive experience.[3,9] Surprisingly, despite an increase in male players, a significant effect of age was not found in tennis players for the M-AST, even if the effect of age on absolute shoulder rotator strength (and especially shoulder internal rotator strength) of tennis players had been observed in literature before.[16,18,49] In our sample, this difference can be attributed to the number of hours of practice, which was higher in adolescents than in adults. Indeed, adults with an important volume of practice were professional athletes (and therefore were excluded), while the other athletes had often to combine their sport practice with studies, with, as consequence, a decrease in the number of hours of practice.

The SAMBT and the SSASPT assessed upper limb power in our athletes. While the SAMBT was significantly correlated with javelin throw distance previously in the literature, the SSASPT score was significantly associated with softball throw, which highlights the link between these tests and upper limb field performance.[21,37] In the present study, adult athletes outperformed adolescents, emphasizing the potential influence of age on shoulder and arm muscle balance.[16,18,36,38,49] Since sports performance is also influenced by age, this affirmation is not surprising. This may be attributed to the greater experience, training, and muscle development of adult athletes. Moreover, a relationship between the SAMBT and shoulder rotator strength was previously reported in the literature.[21] This emphasizes the link between strength and sports performance. Furthermore, gender played a significant role, with males consistently achieving higher scores in the SAMBT across different sports. The observed gender disparities underscore the need for tailored training programs that consider these differences in shoulder and arm muscle balance.

The ULRT provided insights into the rotational capacities, shoulder proprioception, shoulder stability during rotational movements, and coordination of the athletes.[13,52] Notably, in the present study, the ULRT did not reveal significant differences between the dominant and nondominant arms for the majority of athlete groups. This suggests that, in general, upper limb rotation is relatively consistent between the dominant and nondominant arms in athletes regardless of age or gender. In rugby and swimming, for example, this may be attributed to the diverse movements and techniques used, which engage both arms similarly.[12,46] Gender appeared to influence ULRT performance, with, except for swimmers, males consistently outperforming females across all athlete groups. One explanation for such results can be the fact that atraumatic shoulder instability is mostly observed in female than in male athletes.[7,11,35] This instability, mostly reported in women, could be reflected by a lesser performance in the ULRT since this test requires to stay stable on the lowering arm when executing the trunk rotations. However, another explanation, and probably the most important one, may also be related to upper body strength, which is influenced by gender issues.[18,49] Age had minimal influence on the results of the test, which means that rotational capacities as well as shoulder stability are not particularly influenced by puberty or by the years of practice.

For the UQYBT, designed to assess upper quarter balance and stability in a static position,[52] no significant bilateral differences were observed for any sports discipline or age group, highlighting a surprising consistency in this aspect of shoulder performance despite important differences in sports. These results are consistent with those of previous studies.[5,59] Moreover, the fact that the results were not influenced by age suggests that the ability to maintain upper body balance remains relatively steady throughout an athlete's development. As for gender, while Borms et al[5] observed significant differences between male and female athletes from different disciplines, the results of our study were closer to those of Gorman et al[25] which showed no effect of gender on the results. This difference between studies can be explained by the fact that the measurements were not normalized by upper limb length in Borms et al's study,[5] which did not take the height of the subject (often more important in males than in females) into account.

The MCKCUEST assesses the stability of the shoulder, the kinetic chain, and coordination.[52] However, this test is performed bilaterally. Therefore, this is one of the main disadvantages of this test;[52] the impact of the dominance on the results obtained cannot be appreciated, and in individuals, one side could even work more to compensate a deficit of stability on the other side. In the present study, adult athletes achieved significantly better performance compared to adolescents for this test. Coordination tends to increase with age until adulthood,[30] which can be one hypothesis to explain the observed results. An increase of shoulder and/or kinetic chain stability with age could be another explanation since these factors are evaluated by the MCKCUEST. This hypothesis will have to be confirmed by future studies.

Finally, the results for the PSET, dedicated to assesses the endurance of shoulder posterior muscles (posterior deltoid, infraspinatus and middle trapezius mainly),[17] indicated a significant difference in performance between adults and adolescents in swimmers. Indeed, adults achieved significantly better scores than adolescents. This suggests that posterior shoulder endurance may vary with age, with adults demonstrating superior endurance in maintaining posterior shoulder performance across time. These results could be attributed to a higher level of experience in swimming (and number of years of practice), with as consequence, an increase in global shoulder muscles endurance. Regarding dominance, no bilateral difference was found between dominant and nondominant arms, which can be explained by the bilateral gesture performed in the different swimming strokes.[12] It is worth noting that the PSET was only performed in swimmers, and other factors could impact posterior shoulder endurance in different sports.

Another part of this study was aimed at exploring the influence of the sport on upper limb functional testing performance. The findings from this study highlighted the substantial influence of the specific sport practiced on the results of the tests, revealing the intricate relationship between discipline and musculoskeletal outcomes.

The normative values provided by this study constitute the most important database currently in literature. This database as well as the findings will have implications for primary and secondary prevention as well as for enhancing performance.

For example, in rugby, tackles and physical contact are an essential part of the sport. Players tackle using their shoulder to stop or knock down an opponent carrying the ball. These movements, combined with scrums and rucks, exert pressure on the shoulder and the neck and require strength and stability to avoid injuries, especially dislocations.[45,46] Our results showed that rugby players excelled in multiple positions in the M-AST, outperforming swimmers and tennis players. First described by Ashworth et al,[2] the Athletic Shoulder Test (and its modified version)[50] was designed to assess the ability to produce and transfer force across the shoulder girdle, which appears essential to cope with high speeds, high collision forces, and unstable positions in rugby. The positions of the tests as well as the isometric contractions appear to be quite close to the solicitations applied to the shoulder during tackles or scrums. For these reasons, we can easily understand that rugby players outperformed the other athletes in this test. Since the I position seems to be close to the entry of water in crawl swimming, and that swimming can be considered as a closed chain sport,[12] we could also have imagined that swimmers would have exhibited better performances for the M-AST than the other athletes. This was the case in adults, where swimmers significantly outperformed tennis players in all the positions of the test. These results reinforce the specificity of this test according to the sport practiced.

Volleyball players achieved better scores than tennis players for the SAMBT. Additionally, male handballers outperformed tennis players for this test, further underscoring the impact of the sport on shoulder and upper limb performance. In handball and volleyball, the hand is directly in contact with the ball.[58] In tennis, the kinetic energy produced at upper limb level is transferred to the ball by the racket.[33,58] Therefore, the SAMBT seems to be closer to handball and volleyball gestures than to tennis gestures, which can maybe explain the lowest scores obtained in this population.

The only exception was the UQYBT score, which did not exhibit significant variations between sports regardless of the age category considered. Therefore, upper quarter balance and stability appears to be relatively consistent among athletes from different sport disciplines. Opposite results were found by Borms et al[5] a few years ago, for the medial direction of this test. However, the significant difference was found between handball and volleyball players in their study, while the handball players of the present study did not perform this as it was not recommended by a Delphi study[52] and did not appear to be appropriate for this sport.

This study has still limitations. The first one is the nature of the tests practiced in our athletes. As previously explained, the choice of the tests was first based on their characteristics, and metrological qualities and only then, on the Delphi study performed by our research team.[52] However, the Delphi study was performed in 2020-2021. Therefore, the first tests performed before these dates included the most popular tests but were not always specific to the sport concerned. This is the case for the UQYBT, which was performed in male tennis players as well as in volleyball players, while this test was not recommended in the Delphi study for those sports. These 2 samples were the first to be included in our protocol, while rugby and handball players or swimmers were included later in the study. However, we still chose to present all the data in the current article as it might be helpful for clinicians in the context of secondary prevention and return-to-sport. The second limitation concerns the percentage of women in our population. Indeed, only males were recruited in handball and rugby. In tennis, only 23 females were tested, while 65 males were evaluated. Therefore, this population, which has very specific needs and adaptions, will have to be further investigated in future studies. The last limitation concerns the physical capacity of the athletes included. While all the athletes performed their sport at least twice a week and not more than 15 hours a week, their level of performance can be highly variable among the sample included. Even if this variable can be difficult to appreciate, the influence of this parameter on upper limb functional performance could be explored in the future too.

Conclusion

These results emphasize the complex interaction among sport discipline, age, gender, and musculoskeletal performance. The normative values provided by this study constitute the most important database currently in literature. This database as well as the findings will have implications for primary and secondary prevention as well as for enhancing performance. In practice, using the mean and the SDs presented in the tables, the 2 following equations will be recommended to be used if we want to determine if an athlete differs highly from the normative values: mean $\pm$ 1.28 SD (10% cut-off) or mean $\pm$ 1.04 SD (15% cut-off). The observed differences among sports, genders, and age groups highlight the importance of tailoring training and adapting programs to the specific needs of athletes in each sport. Clinicians, coaches, and researchers can use these insights to develop targeted interventions that optimize athletes' performance and reduce the risk of injuries based on their sport, age, and gender. Further research will be required to uncover the underlying mechanisms contributing to these differences and to provide normative values for other sports or specific populations (eg, female athletes).

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Supplementary Data

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