Original Research

Performance, Test-retest Reliability, and Measurement Error of the Upper Limb Seated Shot Put Test According to Different Positions of Execution

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BACKGROUND

The unilateral Seated Shot-Put Test (USSPT) is an easy to apply, inexpensive tool that can be used to assess shoulder performance unilaterally. Two different positions of execution have been described in previous studies, however, differences regarding reference values and psychometric properties were not assessed.

PURPOSE

To investigate the performance, test-retest reliability and measurement error of the USSPT according to different positions of execution (floor versus chair) in overhead athletes. The hypothesis was that both positions would present similar values, good to excellent test-retest reliability and clinically acceptable measures.

STUDY DESIGN

Test-retest reliability.

METHODS

Forty-four overhead athletes performed the USSPT on the floor (USSPT-F) and on a chair (USSPT-C). Normative values were established according to gender, age, and dominance. Test-retest reliability was determined using Intraclass Correlation Coefficient and measurement error through Standard Error of Measurement, Smallest Detectable Change, as well as Bland and Altman plots.

RESULTS

Reference values for both positions were provided. Women performed better on the USSPT-C than USSPT-F. Excellent test-retest reliability 0.97 (0.89 – 0.99) for dominant side and 0.95 (0.80 – 0.98) for non-dominant side was found for the USSPT-F. Moderate to excellent reliability 0.91 (0.67 – 0.98) for dominant side and 0.74 (0.01 – 0.93) for non-dominant side was found for the USSPT-C. Presence of systematic error (14.76 cm) was found only for USSPT-C dominant (p=0.011).

CONCLUSION

Differences were found only for women with better performance on the USSPT-C. The USSPT-F presented higher reliability values. Both tests presented clinically acceptable measures. Presence of systematic error was found only in the USSPT-C.

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LEVEL OF EVIDENCE

3

INTRODUCTION

Overhead sports involve the repetitive use of the shoulder with the hand above the head.[1] Baseball, lacrosse, volleyball, handball, and tennis can be highlighted as the most overhead sports studied. The overall incidence of injuries ranges from 2.6/1000 hours in volleyball athletes to 6.3/1000 hours in handball athletes. Overuse injuries should be highlighted, as the incidence ranges from 20% to 37%,[1] and the shoulder is one of the most injured joints with an incidence of 9-32%.[2] This high incidence is related to movements performed at high velocity and in extreme ranges of motion[3]; unfortunately, athletes who sustained a shoulder injury had a mean absence of participation of 6.2 weeks in overhead sports as handball or volleyball.[1]

Several extrinsic and intrinsic risk factors are connected to shoulder injuries in overhead sports.[1] Extrinsic factors include external loads sustained during match and training while intrinsic factors include gender, history of injury, level of play, shoulder range of motion, flexibility, and muscle strength.[1,3] An interaction between extrinsic (external load), and intrinsic (reduced external rotation or scapular dyskinesis) factors has been associated with higher shoulder injury rates in handball players.[4]

Among risk factors, muscle strength is one the most studied and important. The isometric strength of the internal rotators (IR) and external rotators (ER) was described as a protective factor in the development of rotator cuff tendinopathy in overhead athletes.[5] Isokinetic or isometric dynamometry can be used to assess athletes; however, they are not widely available measurement tools.[6] On the other hand, Physical Performance Tests (PPTs) are reliable, easy to apply, and inexpensive tools that can be used to assess shoulder performance, and previous studies have reported a strong relationship between the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) and the Upper Seated Shot Put Test (USSP-T) with IR and ER isokinetic strength.[7,8] Therefore, performance tests may be used in pre-season assessments as an alternative to a dynamometer.

The CKCUEST is a closed kinetic chain test with normative values for different populations[9] and that is capable of predicting shoulder injury,[10] however, is not possible to evaluate performance unilaterally. One alternative is the USSPT that can be performed on a chair (USSPT-C)[11] and on the floor (USSPT-F).[12] Normative values and psychometric properties for the USSPT have been reported for athletes from different sports,[11,13,14] healthy active adults,[11,15,16] and overhead athletes.[14] However, the differences in results for both positions have not been described in the literature in terms of measurement comparisons and reliablity. So, these comparison values would make it easier for clinicians to choose one of the tests to utilize.

Therefore, the primary objective of this study was to investigate the performance, test-retest reliability and measurement error of the USSPT according to different positions of execution (chair versus floor) in overhead athletes. The secondary objective was to investigate the relationship between results from both test positions. The hypothesis was that both positions would present similar values, good to excellent test-retest reliability and clinically acceptable measures. Also, we expected that both positions would be highly correlated.

METHODS

TYPE OF STUDY

A test-retest design was carried out according to the recommendations of STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) and COSMIN (Consensus-based Standards for the selection of health Measurement Instruments). The order of the tests were randomized for all participants. Before testing, all participants signed an informed consent form and the rights of the subjects were protected. The study was approved by the Ethical Committee of the University of State of São Paulo (UNESP – Campus Botucatu) under protocol number 44561421.7.0000.5411. Informed consent was obtained in accordance with the Helsinki Declaration and local resolution.

PARTICIPANTS

A convenience sample of healthy male and female overhead athletes was recruited for the study. They were later divided according to sex and age category for analyses. The mean age was used to dichotomize participants. The inclusion criteria were: (I) age between 18 and 40 years; (II) overhead athletes with a frequency of three times / week during one hour / day. The exclusion criteria were: (I) history of shoulder pain or surgeries in the trunk, upper or lower limbs in the prior year; (II) presence of shoulder pain during arm elevation in the frontal plane. Any subject that trained for competitive purposes, that was affiliated with an gym, club or sports institution, and that competed in the prior year was considered as an athlete.[17]

OUTCOME MEASURES

The comparison of the average distance in the USSPT-F and USSPT-C according to gender and age category was the primary outcome of the study. The test-retest reliability, measurement error, and correlation between the USSPT-F and USSPT-C were the secondary outcomes of the study. Normative data and the relationship between both tests were described considering the total sample (n=44), while the test-retest reliability and measurement error were calculated with part of the sample (n=10).

STUDY PROTOCOL

Data collection began with subjects completing an adapted questionnaire[18] to obtain identification data and general information such as age, height, body mass, body mass index, limb dominance, training characteristics, and injury history. Limb dominance was determined as the arm used to throw a ball. Next, the tests were performed. Before the tests were executed, the participants received information about how they were to be performed. The participants performed both versions of the USSPT with one examiner who was previously trained to apply the tests. After seven days, both tests were performed in the same conditions to assess test-retest reliability.

For the USSPT-F, participants were seated on the floor with their backs supported against a wall. The knees remained flexed and the feet flat on the floor. The non-tested arm was positioned close to the trunk with medial rotation of the shoulder and ninety degree of elbow flexion. A measuring tape was placed on the floor and extended at a distance of 10 meters. A 3 kg medicine ball was then delivered to the participants, and they were instructed to hold it with the throwing hand at shoulder height, and then push the ball as far as possible in relation to the tape measure placed on the floor. (Figure 1) Three attempts throwing with an interval of one minute between them. The average of three repetitions was considered for analyses. If the participant moved their back off the wall or launched the ball in a non-horizontal trajectory, the repetition was not valid and a new one was performed. The mean (to account for variability) distance (centimeters) covered by the ball was marked with the same measuring tape.[12]

For the USSPT-C, participants were seated on a standard 45 cm chair without armrests. The subjects were seated in the chair with their feet and lower legs placed on another 45 cm chair, positioned just in front of their chair. The non-tested arm was positioned across the chest. A measuring tape was placed in front of the chair and extended at a distance of 10m. A 3 kg medicine ball was then delivered to the participants and they were instructed to hold it with the throwing hand at shoulder height, and then push the ball as far as possible in relation to the tape measure placed on the floor. Also, they were instructed to keep their head, scapula on the non-tested side, and back in contact with the wall. Three attempts throwing with an interval of one minute between them. The average of three repetitions was considered for analyses. Similarly, if the participant moved their back off the chair or launched the ball in a non-horizontal trajectory, the repetition was not valid and a new one was performed. The mean (to account for variability) distance (centimeters) covered by the ball was marked with the same measuring tape.[11] (Figure 1)

DATA ANALYSIS

Data were analyzed using SPSS software (version 23.0; SPSS, Chicago, IL, USA). Data normality and homogeneity of variance were tested using the Shapiro Wilk and Levene's tests, respectively. Mean and standard deviation were calculated for the anthropometric data, and for the results of the USSPT-F and USSPT-C. For the anthropometric data, a linear regression model was applied considering "sex" (male or female), and "age category" (18-25 or 26-40) as fixed factors in order to determine significant differences between these aspects. Additionally, side (dominant or non-dominant), and position differences (floor x chair) were also examined for the USSPT using a linear mixed model by adding the fixed factors "side" and "position". The anthropometric data that were different across the subgroups were included in the model as covariates. For all variables, only the highest significant interaction-effect (or mean effect in absence of an interaction effect) was used in the model for interpreting the results.[19] Sidak's post hoc test was used to make pairwise comparisons. Effect sizes were determined using partial eta-squared (η_p^2). Values of $\eta_p^2 > 0.01$ were defined as small, $\eta_p^2 > 0.06$ as medium, and $\eta_p^2 > 0.14$ as large. The test-retest reliability of the USSPT performed on the floor and on a chair was assessed using the Intraclass Correlation Coefficient (ICC) with a random two-way model, evaluation using the same examiner at different times (k = 2), and absolute agreement. ICC values below 0.50 were considered as poor reliability, between 0.51 and 0.75 moderate reliability, 0.76 and 0.90 good reliability, and above 0.91 excellent reliability.[20] Standard error of measurement was calculated using the following formula: $SEM = SD \times \sqrt{1 - ICC}$ where SEM = Standard Error of Measurement; SD = Pooled Standard deviation of the variable; ICC = Intraclass Correlation Coefficient. Smallest Detectable Change was calculated as follows: $SDC = SEM \times 1.96 \times \sqrt{2}$ where SDC = Smallest Detectable Change; SEM = Standard Error of Measurement. In addition, Bland-Altman Plots (BAPs) were used to verify the absolute agreement between assessments from the scatter plot between the difference of the two assessments and the average of the two evaluations. Bias and 95% limits of agreement were used to determine the accuracy of these measures. Also, a linear regression analysis was conducted to test the null hypothesis. Correlations between the USSPT performed on the floor and on a chair were assessed across the subgroups of the study using Pearson's Correlation Coefficient (r). Associations were classified as negligible (0.0 - 0.3), low (0.31 - 0.5), moderate (0.51 - 0.7), good (0.71 - 0.9), or excellent (0.91 - 1.0).[21] A significance level of $p < 0.05$ was used.

RESULTS

The 44 participants (24=male versus 20=female) had a mean age of 25 (6.33) years, a body mass of 75.72 (16.51) kg, a height of 1.73 (0.07) m, and a Body Mass Index of 25.31 (4.78) kg/m². Based upon mean age, subjects were divided into two groups, 26 in the 18–25 year group and 18 in the 26–40 year old group. No significant effect of the interaction between sex and age was found for the anthropometric characteristics, however, an effect of sex was found for body mass ($F = 6.39$; $p = 0.016$), and height ($F = 18.36$; $p < 0.001$), with men presenting greater values. These comparisons presented medium to large effect sizes respectively ($\eta_p^2 = 0.138$; $\eta_p^2 = 0.315$).

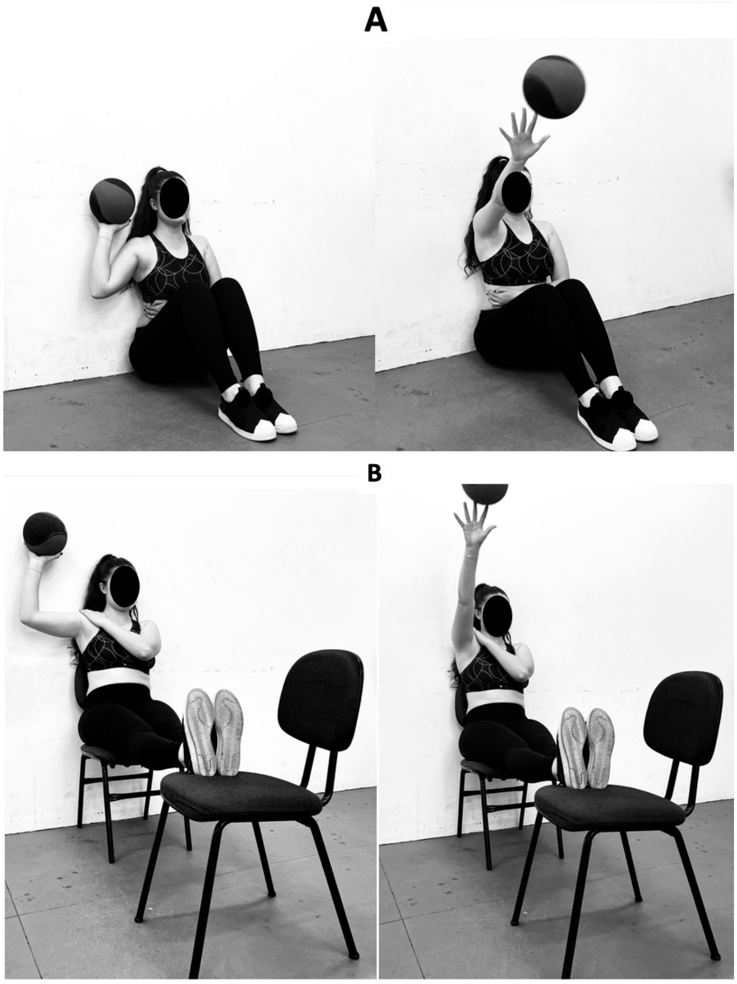

Figure 1. Upper Limb Seated Shot-Put Test.

A. Floor version, B. Chair version.

PERFORMANCE OF THE USSPT ON THE FLOOR AND ON A CHAIR

Due to the influence of body mass and height on the scores of the USSPT, these variables were considered in the final statistical models as covariates. An effect of the interaction between sex and position was found for the USSPT [$F = 6.39$; $p = 0.012$]. Post hoc testing showed that only female participants had a difference in the performance between the two positions with greater scores obtained when the test was performed on the chair ($p<0.001$). This comparison presented a medium effect size ($\eta_p^2 = 0.084$). Also, males had a better performance than females on the USSPT-F ($p<0.001$) and USSPT-C ($p<0.001$). These comparisons presented large effect sizes respectively ($\eta_p^2 = 0.474$; $\eta_p^2 = 0.326$). Reference values for both positions according to gender, age, and dominance are provided (Table 1).

RELIABILITY AND MEASUREMENT ERROR OF THE USSPT PERFORMED ON THE FLOOR AND ON A CHAIR

Excellent test-retest reliability was found for the USSPT when performed on the floor for both limbs (ICC = 0.95 – 0.97), while excellent test-retest reliability was found for the test performed on the chair with the dominant limb (ICC = 0.97), and moderate reliability with the non-dominant limb (ICC = 0.74). In the USSPT-F, the SEM values ranged from 8 to 11 cm, and the SDC ranged from 23 to 30 cm, while in the USSPT-C, the SEM values ranged from 8 – 19 cm, and the SDC ranged from 22.53 to 52.49 cm (Table 2). In addition, according to the Bland-Altman Plots and the regression analysis performed, it is possible to observe the absence of systematic error between assessments ($p > 0.05$) for the USSPT-F (dominant – $p = 0.731$; non-dominant – $p = 0.250$), and for the USSPT-C (non-dominant – $p = 0.443$). Presence of systematic error was found for the USSPT-C for the dominant arm ($p = 0.011$) (Figure 2).

Table 1. Mean and standard deviation for the Upper Seated Shot-Put Test performed on the floor and on a chair according to gender, age category, and dominance (n=44)

	Total (n=44)		Women (n=20)		Men (n=24)	
USSPT-F	D	ND	D	ND	D	ND
18 – 25 years	377.88 (97.87)	353.34 (110.58)	266.10 (34.60)	235.40 (29.54)	447.75 (41.35)	427.06 (69.19)
26 – 40 years	349.77 (106.55)	312.22 (107.82)	269.70 (34.65)	240.90 (29.59)	449.87 (73.61)	401.37 (103.73)
USSPT-C						
18 – 25 years	393.26 (80.90)	366.46 (96.19)	306.70 (42.47)	269.50 (27.32)	447.37 (41.34)	427.06 (69.19)
26 – 40 years	371.16 (93.56)	345.16 (92.13)	304.80 (48.72)	293.40 (53.96)	454.12 (63.64)	409.87 (90.88)

USSPT-F = Upper Seated Shot-Put Test performed on the Floor; USSPT-C= Upper Seated Shot Put Test performed on the Chair; D = Dominant; ND = Non-Dominant.

Table 2. Test-retest reliability: Intraclass Correlation Coefficient with 95% Confidence Intervals, Standard Error of Measurement, and Smallest Detectable Change for the Upper Seated Shot-Put Test performed on the floor and on a chair (n=10).

	ICC (95%)		SEM		SDC	
	D	ND	D	ND	D	ND
USSPT-F	0.97 (0.89 – 0.99)	0.95 (0.80 – 0.98)	8.13	10.89	22.53	30.18
USSPT-C	0.91 (0.67 – 0.98)	0.74 (0.01 – 0.93)	14.76	18.94	40.79	52.49

ICC 95%= Intraclass Correlation Coefficient with 95% Confidence Interval; SEM= Standard Error of Measurement; SDC= Smallest Detectable Change; USSPT-F = Upper Seated Shot-Put Test performed on the Floor; USSPT-C = Upper Seated Shot-Put Test performed on the Chair; D = Dominant; ND = Non-Dominant; ICC = (0.0 - 0.50) - poor; (0.51 - 0.75) - moderate; (0.76 - 0.90) - good; (0.91 - 1.0) - excellent

Table 3. Pearson's Correlation Coefficient (r) for the relationship between the Upper Seated Shot-Put Test performed on the floor and on a chair (n=44).

USSPT-F	Total (n=44)		Women (n=20)		Men (n=24)	
	D	ND	D	ND	D	ND
18 – 25 years	r = 0.975; p < 0.001	r = 0.990; p < 0.001	r = 0.812; p = 0.004	r = 0.778; p = 0.007	r = 0.990; p < 0.001	r = 1; p < 0.001;
26 – 40 years	r = 0.923; p < 0.001	r = 0.915; p < 0.001	r = 0.614; p = 0.059	r = 0.761; p = 0.011	r = 0.947; p < 0.001	r = 0.986 P < 0.001

USSPT-F = Upper Seated Shot-Put Test performed on the Floor; USSPT-C = Upper Seated Shot-Put Test performed on the Chair; D = Dominant; ND = Non-Dominant; R = (0.0 - 0.30) - negligible; (0.31 - 0.50) - low; (0.51 - 0.70) - moderate; (0.71 - 0.90) - good; (0.91 - 1.0) - excellent. Significance level for $p < 0.05$.

CORRELATION BETWEEN THE USSPT PERFORMED ON THE FLOOR AND ON A CHAIR

Significant, positive good to excellent correlations were found between the USSPT performed on the floor and on a chair for both upper limbs according to gender and age categories pre-specified (all, $r > 0.70$; $p < 0.05$), except for the dominant limb in women 26 to 40 years old, where a positive, moderate, and non-significant relationship was found ($r = 0.614$; $p = 0.059$) (Table 3).

DISCUSSION

Differences between the positions of execution of the USSPT were found only for the female participants, where a greater distance of throwing was found for the USSPT-C. One hypothesis for this difference could be the stabilization provided by the non-throwing limb positioned in the glenohumeral joint during the execution of the USSPT-C.

Excellent test-retest reliability was found for the USSPT-F with SEM and SDC values for the whole sample ranging from 8 - 11 cm and 23 - 30 cm respectively. Moderate to excellent test-retest reliability was found for the USSPT-C with SEM and SDC values ranging from 15 - 19 cm and 41 - 52 cm respectively. Presence of systematic error was found only for the USSPT-C dominant. The authors are unsure why this was the only test in which systematic error was detected.

Good to excellent correlations were found between USSPT-F and USSPT-C for both upper limbs. This correlation is expected due to the standard position of movement between the two versions of the test, testing the same movement construct. The non-dominant limb presented a lower reliability coefficient, which may be explained by the

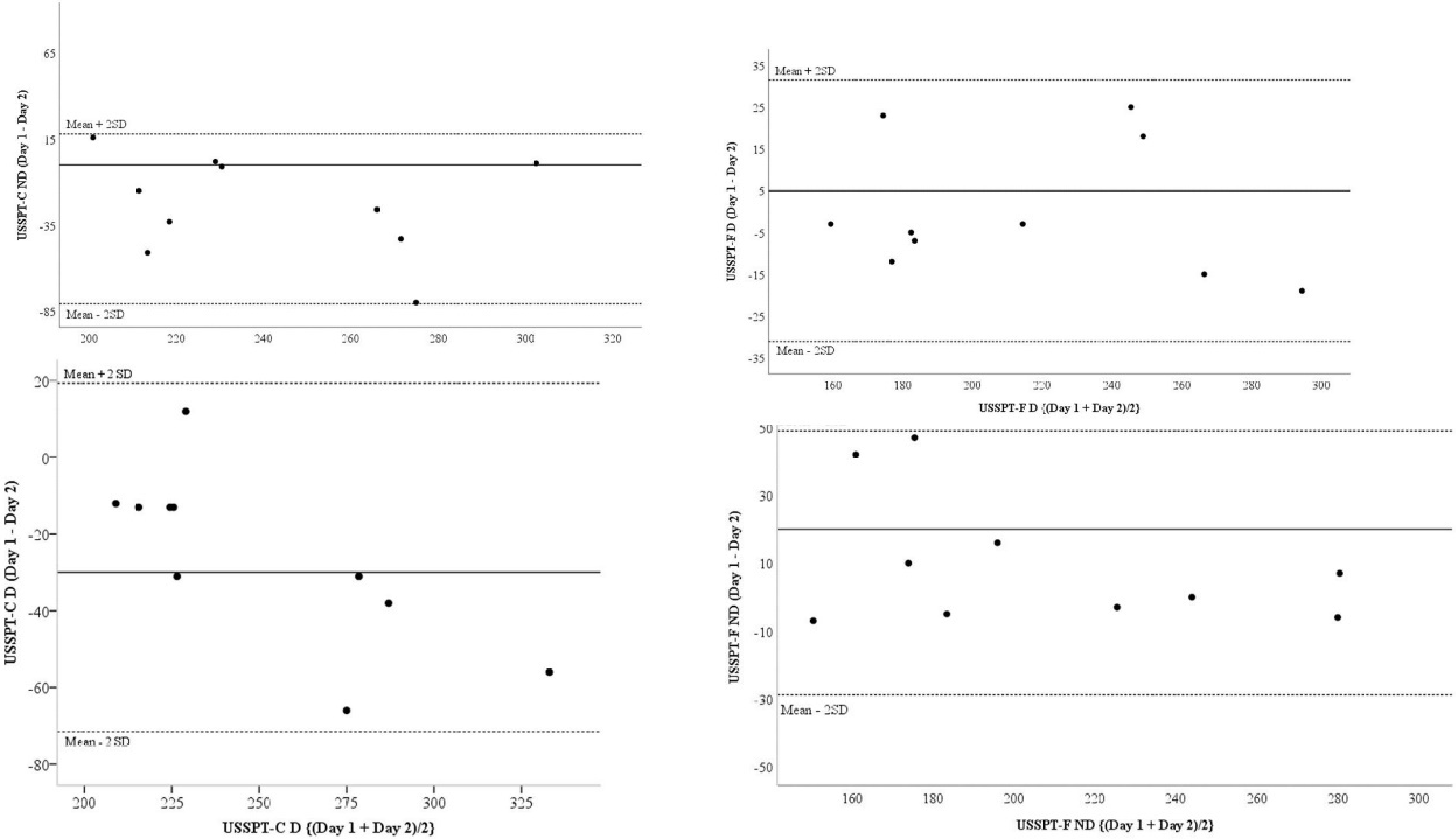

Figure 2. Bland-Altman Plot for the USSPT performed on the floor, and on a chair.

A. USSPT-C non-dominant limb; B. USSPT-F dominant limb; C. USSPT-C dominant limb; D. USSPT-F non-dominant limb. Straight line represents bias and dotted lines 95% limits of agreement. USSPT-F = Upper Seated Shot Put Test performed on the Floor; USSPT-C = Upper Seated Shot Put Test performed on the Chair; D = Dominant; ND = Non-Dominant.

fact that this limb would not the extremity of choice for the athlete to perform the shotput movement. Further, athletes may have less strength, coordination and control in the non-dominant limb explaining the higher variability during testing.

In relation to the performance in the USSPT-F, the current results were similar with those reported in studies that assessed healthy/physically active participants,[15,16] and athletes from different sports.[13,22] Lower scores were found compared to Division I collegiate athletes.[10,12] In relation to the performance in the USSPT-C, in general, the current scores were greater (377.88 cm for USSPT-F) and (393.26 cm for USSPT-C) than those from a study performed with healthy active adults (92 inches = 223.00cm).[11] Previous studies found correlations between strength tests and the performance tests such as the USSPT,[16] which can be explained due to the overlap of some of the variables examined in the two forms of evaluations, including strength, power and speed. Thus, because of the current reliability findings, clinicians may have an option of an accessible and cheaper test than instrumented strength testing.[15] It is expected that the performance in the USSPT is influenced by the population assessed, therefore, clinicians must be aware that the current study was performed with handball players.

Excellent test-retest reliability was found for the USSPT-F, while moderate to excellent test-retest reliability was found for the USSPT-C. These results corroborate with previous data that found good to excellent test-retest reliability 0.94 (0.88–0.97) for the USSPT-F,[13] and excellent test-retest reliability 0.98 (0.97–0.99) for the USSPT-C[11] in active/physically adults. In relation to SEM and MDC, Pinheiro et al.[13] reported values of 16.27 cm and 45.11 cm for the USSPT-F, while Negrete et al.[11] reported 17.78 – 20.32 cm and 43.18 – 45.72 cm for the USSPT-C. The current results were similar for both positions. It is recommended that clinicians use the mean of three repetitions with the rest time of one minute between them to get the most stable and accurate measure in the USSPT.[13,22]

The current results showed good to excellent correlations between the USSPT-F and USSPT-C. In previous studies, performance in the USSPT-F presented strong correlation with shoulder flexor and elbow extensor strength,[14-16] strong correlations with IR and ER isokinetic strength,[8] and moderate to strong correlations with pushing force assessed through isokinetic dynamometry[15] in active/physically adults. Also, the isometric strength of the serratus anterior was correlated with USSPT-F performance.[14] Because shoulder muscle weakness may be a risk factor for overuse shoulder injuries[3] and rotator cuff tendinopathy[23] in overhead athletes, it is suggested that clinicians might consider the use of the USSPT-F and USSPT-C as an indirect measure of shoulder and elbow strength in this population. Future studies need to assess the direct correlation between the USSPT-C with isokinetic shoulder and elbow strength.

This is the first study to assess performance of the USSPT in different positions. Normative values according to sex, age and limb dominance, as well as test-retest reliability and measurement error for both positions in handball players are presented. Studies that present normative values and psychometric properties of the upper extremity physical performance tests in different populations are necessary.[24] In this context, the current adds to the literature. The USSPT is a reliable tool to assess strength and power unilaterally in the absence of an isokinetic dynamometer[15]; and because this test reproduces a similar position of the arm during sports movements, the authors recommend its implementation in the assessment of overhead athletes. The USSPT-F may be preferred considering the reliability values and the absence of systematic error found in both limbs. Further, the SEM and MDC values provided can be used to guide the rehabilitation programs.

The limitations of this study should be noted. All assessments were performed during the season, so, the results might be influenced by training. The sample consisted of healthy handball athletes; therefore, interpretation of the results regarding participants with shoulder pain or that practice other overhead sport (i.e. baseball, tennis, volleyball, badminton, basketball, and swimming) must be performed with caution. In the same way, interpretation of the results in relation to participants older than 40 years old is not recommended due to the mean age of the sample. Finally, the current sample size prevented some comparisons with others sports from being powered adequately. Future studies that present normative values of the USSPT in other overhead sports and those that investigate the ability of the test to predict shoulder injuries are necessary.

CONCLUSION

The results of the current study highlight differences in the performance of the USSPT according to the position of execution in women where greater scores were obtained in the USSPT-C. Excellent test-retest reliability was found for the USSPT-F, and moderate to excellent test-retest reliability was found for the USSPT-C. SEM and MDC were established. Presence of systematic error was found only in the USSPT-C for the dominant extremity. Good to excellent correlations were found between both positions.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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