Relationship Between Seated Single-Arm Shot Put and Isokinetic Shoulder Flexion and Elbow Extension Strength

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Context: A recent report demonstrated moderate to strong relationships between seated single-arm shot-put (SSASP) test performance and isokinetic pushing forces at varying velocities, directly supporting the SSASP test as a reflection of multijoint upper-extremity strength. Yet, no previous work appears to have assessed whether the SSASP test is more reflective of shoulder flexion or elbow extension strength. **Objective:** To examine the relationship between isokinetic shoulder flexion and elbow extension strength and SSASP test performance and to compare limb symmetry indices (LSI) between the 2 tests. **Design:** Correlational design. **Setting:** Biomechanics laboratory. **Patients (or Other Participants):** A total of 30 healthy and physically active young adults. **Intervention(s):** Participants completed the SSASP test and concentric isokinetic (60°/s and 180°/s) shoulder flexion and elbow extension using their dominant and nondominant arms. **Main Outcome Measures:** SSASP test performance and isokinetic shoulder flexion and elbow extension peak torques as well as LSI between the 2 tests. **Results:** Strong relationships were observed between SSASP ranges and isokinetic peak torques at each velocity for both shoulder and elbow ($r \geq .804$, $P < .001$). While the Bland–Altman results on the LSI only demonstrated a significant bias for the shoulder (60°/s, $P = .009$), limits of agreement results demonstrated extremely wide intervals (32.5%–52.1%). **Conclusions:** The SSASP test is a multijoint upper-extremity functional performance test that is reflective of equal shoulder flexion and elbow extension contributions; however, there was large variability regarding the agreement between the SSASP LSI and isokinetic shoulder and elbow strength LSI.

Keywords: functional performance test, upper-extremity, limb symmetry index, biomechanics

The seated single-arm shot-put (SSASP) test is a unilateral, open kinetic chain upper-extremity (UE) functional performance test involving the pressing of a medicine ball for maximal horizontal distance. In addition to establishing reliability,¹ past works examining the SSASP test have also provided normative outcome data² and associated collected outcomes with overhead sport performance.³ Examination of SSASP projection mechanics revealed performance to be primarily influenced by medicine ball release velocity.⁴ A recent report demonstrating moderate to strong relationships between SSASP performance and isokinetic pushing forces at varying velocities⁵ directly supports the idea that the SSASP reflects multijoint UE strength.

Simultaneous shoulder flexion and elbow extension are utilized within both SSASP and isokinetic push testing techniques. No previous work appears to have assessed whether the SSASP test is more reflective of shoulder flexion or elbow extension strength. Understanding the degree to which elbow and shoulder strengths relate to SSASP performance is crucial to clinicians when determining appropriate application and interpretation of the SSASP test and its outcomes. In addition, synthesis of previous SSASP reports examining healthy young adults has noted performance favoring the dominant limb between 3% and 13%.^{1,2,4,5} Understanding limb symmetry in healthy populations is crucial information for clinical interpretation when tracking rehabilitation progression and making patient discharge decisions. While there have been previous investigations demonstrating the SSASP test asymmetry in healthy persons, it is unknown whether these natural SSASP asymmetries

are reflective of asymmetrical shoulder and/or elbow strength. Thus, the purpose of this study was to examine the relationship between isokinetic shoulder flexion and elbow extension strength and SSASP test performance. A secondary aim was to compare the limb symmetry index (LSI) of shoulder and elbow isokinetic strength with the SSASP test. The authors hypothesized that there would be strong correlations between both shoulder flexion and elbow extension strength and SSASP test performance along with compatibility between the isokinetic testing and SSASP test LSI.

Methods

Based on the relationships between SSASP and isokinetic pushing,⁵ 15 males (age = 25.0 [3.4] y, height = 1.82 [0.07] m, weight = 85.5 [11.0] kg) and 15 females (age = 22.7 [2.4] y, height = 1.64 [0.06] m, weight = 67.4 [10.0] kg) were recruited for participation. Individuals aged 18–35 years who were physically active for at least 3 sessions per week (30 min per session) for the past 3 months were included.⁶ Participants with preexisting cervical spine or UE injury, pain, or a surgical operation to those areas within the past 12 months were excluded. This study attained approval from the institutional review board of Georgia Southern University. Before participation, all potential participants completed a basic health questionnaire that included neuromuscular health history and signed an institutional review board-approved informed consent document. Entering $\rho = .6$ with power = .9, $\alpha = .05$, and 2-tailed test into an *a priori* power analysis yielded that a minimal sample size of 21 would be needed.

Participants began the single 45-minute testing session with a 5-minute standardized upper body ergometer and arm swing warm-up⁵ before the SSASP and isokinetic testing. The test order (SSASP

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and isokinetics), limb (dominant [DOM], nondominant [NDOM]), and joint (elbow and shoulder isokinetics only) were randomized between participants. The SSASP testing protocol replicated previous procedures.^{2,4,5} Following a progressive gradient SSASP warm-up,^{2,4,5} the participants were instructed to “press the medicine ball as far as possible” while maintaining proper form (Figure 1). Three maximal effort repetitions using a 2.0-kg, 11.3-cm circumference ball (TheraBand; Performance Health, Warrenville, IL) were completed with each limb. Bilateral concentric shoulder flexion and elbow extension strength were assessed isokinetically (System 4; Biodex Medical System, Inc., Shirley, NY) at 60°/s (5 repetitions) and 180°/s (10 repetitions) velocities, respectively, reflective of maximal voluntary contraction and coordinated muscle activation.⁷ Isokinetic shoulder flexion testing (140° range of motion) was conducted (Figure 2) using the participant positioning described by Wang et al.⁸ Elbow extension (130° range of motion) positioning duplicated the procedures described by Ekstrand et al.⁹ with the exception that the forearm was in a pronated position (Figure 3). Recorded isokinetic test trials for each joint and velocity were preceded by a progressive 4 trial gradient warm-up (25%, 50%, 75%, and 100% maximum effort).⁵ Cues were given to the participants before each test set to move through the full range of motion “as hard and fast as possible.” Thirty seconds of rest was given between velocities, and 3 minutes were given between each joint and limb. The peak torque registered during each set was recorded for data analysis.

Following exploratory analysis, normality within each sex was confirmed through Shapiro–Wilk tests and linearity was confirmed through scatterplots. Pearson correlation coefficients, separate for each limb, were computed between the SSASP ranges and isokinetic data. Correlation coefficient magnitudes were interpreted as >.8 very strong and .6 to .8 moderately strong.¹⁰ Bland–Altman¹¹ analysis between the LSI ($LSI = DOM/NDOM \times 100$) for the SSASP and isokinetic peak torques was conducted to determine

bias and the 95% limits of agreement (LOA). Prior to computing the LOA, normality and heteroscedasticity were examined. Statistical analyses were conducted using SPSS (version 25.0; IBM, Inc, Armonk, NY) and Excel (version 1908, Microsoft, Inc, Redmond, WA) with statistical significance considered at $\alpha = .05$.

Results

Descriptive statistics are presented in Table 1. Very strong relationships were revealed between the SSASP ranges and isokinetic peak torques for both the shoulder and elbow (Table 2). While the Bland–Altman results (Table 3) only demonstrated a significant bias for the shoulder (60°/s), the LOA results demonstrated extremely wide intervals (32.5%–52.1%).

Discussion

Consistent with the hypothesis, the authors observed strong associations between SSASP performance and shoulder flexion and elbow extension strength. The coefficient magnitudes were similar between the elbow and shoulder joints, suggesting that across the sample both joints contributed equally to SSASP performance. Based upon the observance that neither joint related more strongly to SSASP performance than the other, coupled with the very strong

Figure 1 — The seated single-arm shot-put test began with the ball held in the hand while keeping the elbow tucked against the torso and as far back to the backrest as possible. Participants were then verbally instructed to “put the medicine ball as hard as you can to obtain the greatest distance.”

Figure 2 — Isokinetic shoulder flexion testing was conducted with the forearm in neutral.

relationships previously reported between SSASP performance and isokinetic pushing strength,⁵ the authors concluded that the SSASP test may be best considered to reflect multijoint total arm strength versus strength of an individual UE joint.

Figure 3 — Isokinetic elbow extension testing was conducted with the forearm in pronation.

The SSASP LSI was consistent with previously reported SSASP LSI ranges.^{1,2,4,5} As there is a void of previous research examining LSI for concentric isokinetic shoulder flexion and elbow extension, the current data are relevant to clinicians using UE isokinetic testing. Surprisingly, the average isokinetic LSIs were all slightly above, yet very close to, 100%, illustrating symmetrical peak torque production between the limbs for these 2 movement patterns. If both the SSASP and isokinetic tests had yielded similar LSIs, the mean differences (eg, mean bias) would be 0. Rather than 0 differences, all of the LSI differences were slightly negative, indicative of more prevalent limb asymmetry, favoring the DOM limb, for the SSASP compared with the isokinetic tests. Although only slightly larger, the mean bias between SSASP and isokinetic shoulder flexion at 60°/s reached statistical significance. Despite small LSI mean biases between SSASP performance and shoulder and elbow isokinetic strength, the LOA were extremely large. Likely explaining the large LOA is that the SSASP test requires simultaneous shoulder flexion and elbow extension, whereas the shoulder and elbow isokinetic testing isolated each joint. The concurrent shoulder and elbow movement patterns associated with the SSASP test allow for variation in the degree of respective joint contribution between individuals, presumably eliciting the wide LOA. Although small biases, favoring the DOM limb, were revealed for the LSI computed for both the SSASP and isokinetic tests, the wide LOA intervals preclude using SSASP-derived LSI interchangeably with isokinetic shoulder and elbow strength.

It is important to recognize that this study used a young adult, healthy, recreationally active cohort. Although none of the participants were currently involved with organized sport participation, the authors did not control for history of unilateral overhead athletic activity. In addition, the authors did not control for the types of physical activities (ie, running, weightlifting, etc) the participants routinely completed. Both factors, previous unilateral history and current activities, may have contributed to the variability in LSI between participants.

In conclusion, the SSASP test is a multijoint UE functional performance test that is reflective of equal shoulder flexion and

Table 1 Descriptive Statistics (Mean [SD]) for the SSASP Ranges, Isokinetic Peak Torques, and LSI

Limb	SSASP ranges, m	Isokinetic peak torques, N·m			
		Shoulder		Elbow	
		60°/s	180°/s	60°/s	180°/s
DOM	3.67 (10)	55.2 (22.2)	45.3 (19.9)	45.8 (17.8)	34.8 (14.2)
NDOM	3.62 (9.78)	55.3 (22.1)	44.5 (19.3)	45.6 (18.2)	34.5 (13.7)
LSI	104.5 (7.2)	100.3 (8.9)	102.1 (10.3)	101.8 (9.9)	100.9 (9.5)

Abbreviations: DOM, dominant; LSI, limb symmetry indices; NDOM, nondominant; SSASP, seated single-arm shot put.

Table 2 Pearson Correlation Coefficients Between Seated Single-Arm Shot-Put Distances and Isokinetic Peak Torques

Limb	Isokinetic peak torques			
	Shoulder		Elbow	
	60°/s	180°/s	60°/s	180°/s
DOM	.832	.832	.817	.850
NDOM	.834	.846	.804	.812

Abbreviations: DOM, dominant; NDOM, nondominant. Note: All coefficients were statistically significant ($P < .001$).

Table 3 Results of the Bland–Altman Analysis for the Limb Symmetry Indexes

Joint	Isokinetic velocity	Systematic bias					
		$\bar{X}_{\text{diff}}$ (SD _{diff})	Bias <i>P</i> value	95% CI bias		95% LOA	
				Lower bound	Upper bound	Lower bound	Upper bound
Shoulder	60°/s	−4.2 (8.3)	.009	−7.3	−1.1	−20.4	12.0
	180°/s	−2.4 (9.8)	.194	−6.0	1.3	−21.6	16.8
Elbow	60°/s	−2.7 (13.3)	.279	−7.6	2.3	−28.7	23.4
	180°/s	−3.6 (12.0)	.113	−8.1	0.9	−27.1	19.9

Abbreviations: $\bar{X}_{\text{Diff}}$, mean difference; CI, confidence interval; LOA, limits of agreement; SD_{diff}, standard deviation of differences. Note: Negative values indicate larger limb symmetry indexes for the seated single-arm shot-put ranges than the isokinetic peak torques.

elbow extension contributions and, therefore, clinicians can consider it to represent overall UE strength. The large individual variance among the agreement between LSI computed for the SSASP and isokinetic shoulder and elbow strength preclude clinicians from interpreting the SSASP LSI as indicative of isokinetic strength test LSI.

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