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Reliability, validity, and minimal detectable change of the push-off test scores in assessing upper extremity weight-bearing ability

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ABSTRACT

Study Design: Clinical measurement study.
Introduction: The push-off test (POT) was recently conceived and found to be reliable and valid for assessing weight bearing through injured wrist or elbow. However, further research with larger sample can lend credence to the preliminary findings supporting the use of the POT.
Purpose of the Study: This study examined the interrater reliability, construct validity, and measurement error for the POT in patients with wrist conditions.
Methods: Participants with musculoskeletal (MSK) wrist conditions were recruited. The performance on the POT, grip isometric strength of wrist extensors was assessed. The shortened version of the Disabilities of the Arm, Shoulder and Hand and numeric pain rating scale were completed. The intraclass correlation coefficient assessed interrater reliability of the POT. Pearson correlation coefficients (r) examined the concurrent relationships between the POT and other measures. The standard error of measurement and the minimal detectable change at 90% confidence interval were assessed as measurement error and index of true change for the POT.
Results: A total of 50 participants with different elbow or wrist conditions (age: 48.1 ± 16.6 years) were included in this study. The results of this study strongly supported the interrater reliability (intraclass correlation coefficient: 0.96 and 0.93 for the affected and unaffected sides, respectively) of the POT in patients with wrist MSK conditions. The POT showed convergent relationships with the grip strength on the injured side (r = 0.89) and the wrist extensor strength (r = 0.7). The POT showed smaller standard error of measurement (1.9 kg). The minimal detectable change at 90% confidence interval for the POT was 4.4 kg for the sample.
Conclusions: This study provides additional evidence to support the reliability and validity of the POT. This is the first study that provides the values for the measurement error and true change on the POT scores in patients with wrist MSK conditions. Further research should examine the responsiveness and discriminant validity of the POT in patients with wrist conditions.

Introduction

Wrist and elbow musculoskeletal (MSK) disorders such as nerve entrapments, tendinopathies, and fractures have negative effects on an individual's upper extremity functional ability. The point prevalence of wrist/elbow MSK disorders such as carpal tunnel syndrome (CTS), lateral epicondylitis (LE), and medial epicondylitis

(types of tendinopathies) remains high. The prevalence of CTS was 3.8% in a Swedish sample of 2466 individuals.[1] Similarly, the prevalence of LE and medial epicondylitis was 1.3% and 0.4% in a Finnish sample of 4783 individuals.[2] The financial implications of managing such injuries are often discordant with the expectations considering the pathology and anticipated clinical course. For instance, the direct medical costs related to CTS can be as high as $6,000 per patient as shown by the data for 7820 CTS-related claims handled between 1999 and 2004 by the Ohio Bureau of Workers' Compensation.[3] Claimants suffering from LE may miss as many as 66 days from their work due to pain and functional impairment resulting from the condition.[4]

Using reliable and valid tests and measures can precisely capture the impairments in wrist/hand functions, cater the rehabilitation interventions to manage these impairments, and potentially reduce the financial implications of wrist/hand conditions. Measurement properties of the self-reported as well as physical performance measures commonly used for assessing body structure/function, activity limitations, and participation restriction domains of the International Classification of Functioning, Disability and Health are well established in wrist/hand conditions.[5,6] Most self-reported measures provide perceived functional limitations across a broad spectrum of functional activities of daily living (ADL). However, the scope of assessment for some physical performance measures can be narrow and does not enhance our understanding of consequent ramifications on functional use of the hand. For example, measures such as wrist range of motion or wrist circumferential measurement are limited to assessing movement excursion and the swelling around the wrist joint, respectively, but offer no objective information regarding the functional use of the hand. Therefore, physical performance measures that provide assessment of functional abilities of the hand in patients with wrist/hand problems are useful.[7]

Axial loading of upper extremity is crucial for ADL such as handling heavy doors, cutting food items, or using assistive devices for those who depend on them for mobility.[8,9] Understandably, the ability to transfer weight effectively through wrist/hand to proximal joints would be affected in case of painful or unstable wrist/hand in the presence of pathology. The push-off test (POT) was recently proposed as a simple tool to quantify weight-bearing capacity of the upper extremity using a grip dynamometer.[10] The preliminary study that examined the measurement properties of the POT showed excellent interrater reliability (intraclass correlation coefficient [ICC] > 0.9), but poor to moderate concurrent relationships with other measures assessing perceived functional limitations and participation restrictions in a sample consisting of patients with wrist or elbow pathology.[10] These results were attributed to smaller sample ($N = 22$) that was clearly underpowered to test the hypothesized relationships. The other possible explanation is the diversity of patient population within this smaller sample where 12 patients had wrist disorders and the other 10 had elbow disorders. The type of perceived limitations in ADL can differ between patients with wrist and elbow disorders. Finally, the scope of measurement properties assessed in this study was limited to testing the interrater reliability and concurrent relationships and the indices of measurement error (SEM) or true change which have greater relevance for using the POT in hand therapy practice were not examined.[10]

In summary, the POT is a promising new test for objectively assessing the impairment in weight bearing through upper extremity in the presence of wrist/hand pathology. However, advancing research to assess its measurement properties across diverse clinical settings using a larger sample is required to lend credence to the promising but preliminary results and support its integration in hand therapy practice.

Therefore, this study was aimed at expanding the evidence on the measurement properties of the POT. Specifically, we examined the interrater reliability, construct validity, SEM, and minimal detectable change at 90% confidence interval (MDC$_{90}$) for the POT in patients with wrist conditions. Our secondary objective was to examine the linear association of the POT scores with age, sex, body mass index (BMI), diagnosis on the dominant side, grip strength for the affected side (GS-A), and wrist extensor strength for the affected side (WES-A).

Methods

Ethical approval for this study was obtained from the Marshall University Institutional Review Board.

Participants

Convenient sample of English-speaking participants who were aged 18 years or older were recruited from the Hand Clinic at the Department of Orthopedic Surgery, Cabell Huntington Hospital, affiliated with Marshall University School of Medicine, Huntington, West Virginia, USA. No formal sample size estimations were performed. Participants with elbow or wrist MSK conditions were approached by a research nurse for their participation in this study during their visit with the orthopedic surgeon. If they agreed to participate, informed consent documents were completed. Individuals with concurrent peripheral neuropathy or preexisting neurological or MSK problems in the affected or unaffected upper extremity and those who still had restrictions on upper extremity weight bearing imposed by their surgeon due to the injury were excluded.

Outcome measures

"Push-off" test

A handheld dynamometer was set in the second rung (3.8 cm) in a reversed manner such that the convex side of the handle faces upward. The participant was positioned adjacent to a table that was 74-76 cm high with the buttocks leaning against but not sitting on the table. The test arm was positioned in approximately 10°-40° of shoulder extension and 10°-40° of elbow flexion. The hand/wrist and forearm were placed in a comfortable position that was determined by the participant. The assessor provided stabilizing support to the dynamometer, whereas the participant would bear weight through the dynamometer until their maximal tolerable load was applied. The test protocol is sufficiently described by Vincent et al.[10] for replication. The POT was administered on both the sides.

Isometric wrist extension strength

Isometric wrist extensor strength (WES) was assessed using a handheld dynamometer (Lafayette Instrument Company, Lafayette, IN). The participant was seated in a straight back chair with a table set in front and the hand/wrist placed over the edge of the table. The dynamometer was placed on the back of the hand. A "break test" method was used with the verbal instruction of "Hold, don't let me move you" while the assessor matched the force of the participant.[10,11] The system had 2 audible cues, the first cue indicated that the test had started and the second indicated that the test was over. The WES was assessed on both the sides.

Static grip strength

The grip strength was measured in accordance to the standardized methodology as described by the American Society of Hand Therapists.[12] The handle of the J-tech dynamometer was set to the second rung, and the participant was asked to exert maximal effort. The participant was given the standardized 30-second rest period, and the test was repeated 3 times.[13] The J-tech dynamometer has high accuracy.[14] The grip strength was assessed on both the sides. Grip strength ratio was derived as the function of GS-A divided by grip strength in the unaffected hand.[15]

Pain and functional assessments

The Quadruple Numeric Pain Rating Scale (QNPRS) and the shortened version of the Disabilities of Arm, Shoulder, and Hand (QuickDASH) were administered to assess pain and upper extremity disability resulting from wrist or elbow conditions. The 30-item DASH was designed to assess MSK disability in people with conditions affecting the upper extremity. The 11-item QuickDASH reduces administration time, can be administered verbally, and has excellent test-retest reliability and validity in patients with upper

extremity conditions.[16,17] The QNPRS measures the pain intensity on a 0-10 scale where 0 is no pain and 10 is the worst pain. The QNPRS assesses pain in 4 scenarios: pain intensity at present, pain intensity on an average, pain intensity when it is at its worst, and pain intensity when it is at its best. The numeric pain scale has been shown to be valid for assessing pain intensity in MSK conditions.[18,19]

Examiners

The assessments for each participant were performed by 2 of the 3 student examiners (H.R.G., C.A.G., and D.R.S.) enrolled in the second year of the doctor of physical therapy program. All the 3 students had successfully completed their first clinical rotation before collecting the data. The student examiners underwent a standardization session before starting the data collection to ensure consistency in providing instructions to the participants and measurement techniques for the POT, range of motion, WES, and grip strength testing. A pilot data were collected on 7 healthy volunteers for assessing interrater reliability for administering and assessing the results on the POT, WES, and grip strength for the 3 student examiners. The results of the pilot data showed excellent interrater reliability as revealed by the ICC values of >0.95 for all the measures.

Procedures

All the data were collected over a single visit. Once consent was obtained, demographic, health, and anthropometric data were collected through the "Participant Information Form" for each participant. Demographic variables of age, sex, education level, occupation, side dominance, height, and weight were collected. BMI was derived from the height and weight of the participant. Health- and disease-specific variables including medical diagnosis, side of diagnosis, duration of symptoms, and types/number of medical comorbidities were also collected. Following this, one of the student examiners obtained the first set of measurements for the physical performance tests of the POT, WES, and grip strength. An average of 3 trials was recorded for the POT, WES, and grip strength. The ratio of grip strength as the WES was derived by dividing the score for WES-A with that for the unaffected side. Finally, the second set of measurements was obtained for the POT by a different student examiner. Although the examiners were not randomized for obtaining the first vs second set of measurements, the order of administration for the physical performance tests was randomized. Participants completed the QuickDASH and QNPRS between the 2 sets of measurements for the physical performance tests.

Data analyses

Descriptive statistics were calculated for the demographic variable, health variables, physical performance tests, and self-reported measures of pain and functions. They were expressed as mean and standard deviations or frequency (%). Interrater reliability, which can also be conceptualized as reproducibility of POT scores between the 2 sets of measurements, was assessed using ICC. The ICC values of >0.75 and >0.90 were considered indicative of good and excellent interrater reliability, respectively.[20] The standard error of measurement (SEM) for the POT scores was calculated to express the error associated with a single measurement.[21] MDC$_{90}$ was calculated as the index of true change that is larger than random error associated with repeat measurements.[21] The Bland and Altman assessed the level of agreement between the POT scores obtained by 2 raters.[22] A graph of differences in the POT scores between the 2 raters was plotted against the average of the POT scores for both the raters. The agreement was assessed by calculating the mean difference between the POT scores for both the raters (random error in measurement) and limits of agreement (LOAs) (95% confidence interval) for the mean difference.[22] Before plotting the Bland and Altman graph, the normality of the mean differences was examined using the Shapiro-Wilk test, where $P > .05$ would indicate normal distribution.[23]

Concurrent relationships between the POT and grip strength, WES, QNPRS, and QuickDASH were assessed by calculating the Pearson correlation coefficients (r). The relationship was considered strong if the coefficient was > 0.7, moderate if between 0.51 and 0.70, and low if ≤0.5.[24] Multivariate regression model was run with the POT scores on the affected side as the dependent variable and age, sex, BMI, diagnosis on the dominant side, the GS-A, and WES-A as independent variables. All the variables were entered into the model at once, and results were only provided for the variables that had significant associations with the POT scores. The SPSS, version 22 (Armonk, NY) was used for all the analyses.

Results

A total of 50 participants, 15 men and 35 women, were included in this study. The demographic and disease characteristics as well as the scores on the outcome measures for the participants are shown in Table 1. Twelve participants had diagnoses affecting the elbow joint, which included LE, cubital tunnel syndrome, and nonspecific elbow pain. Thirty-eight participants had diagnoses affecting the wrist joint, which included fractures involving wrist area, CTS, and nonspecific wrist pain.

Reliability

The results of interrater reliability for the POT scores are shown in Table 2. The results showed that the interrater reliability was excellent for the POT scores obtained for the affected and the unaffected side (ICC of 0.96 and 0.93, respectively). The SEM value for the POT scores was 1.9 kg, whereas the MDC$_{90}$ value was 4.4 kg.

Table 1
Demographic, health, and injury characteristics of participants ($N = 50$)

Variable	Mean ± SD or frequency (%)
Age	48.1 ± 16.6
Sex	
Men	15 (30)
Women	35 (15)
BMI	
Normal (≤24.9)	8 (16)
Overweight (25-29.9)	17 (34)
Obese (≥30)	25 (50)
Involved joint	
Elbow	12 (24)
Wrist	38 (76)
Diagnosis on the dominant side	
Yes	29 (58)
No	21 (42)
Affected side	
Right	30 (60)
Left	20 (40)
Duration of symptoms (mo)	28.2 ± 38.7
Grip strength ratio	0.73 ± 0.28
POT ratio	0.86 ± 0.2
WES ratio	0.89 ± 0.25
Q-NPRS	3.5 ± 2.3
QuickDASH	37.5 ± 20.6

BMI = body mass index; POT = push-off test; Q-NPRS = quadruple numeric rating scale; QuickDASH = shorter version of the Disabilities of Arm, Shoulder, and Hand Questionnaire; SD = standard deviation; WES ratio = wrist extensor strength ratio.

Table 2
Reproducibility of POT measurements ($N = 60$)

Tests	ICC (95% CI)	SEM (95% CI) kg	MDC$_{90}$ (95% CI) kg
Interrater reliability: affected side	0.96 (0.93-0.98)	1.9 (1.3-2.5)	4.4 (3-5.8)
Interrater reliability: unaffected side	0.93 (0.89-0.96)		

CI = confidence interval; ICC = intraclass correlation coefficient; Kg = kilograms; MDC$_{90}$ = minimal detectable change at 90% confidence interval; POT = push-off test; SEM = standard error of measurement.

Figure 1 shows the Bland-Altman plot with the differences in the POT scores between the 2 raters on the Y-axis and the mean for these scores on X-axis. The differences in the POT scores between the 2 raters followed normal distributions ($P = .1$). The mean difference was 0.36 with LOA at between −2.31 and 3.02. This suggests that the measurement error in assessing the POT scores between the 2 raters was very small (0.36 kg).

Concurrent validity

The correlations between the POT, GS-A, WES-A, QNPRS, and QuickDASH are shown in Table 3. The POT scores showed high correlations with the GS-A ($r = 0.88$) and WES-A ($r = 0.70$) but had low correlations with the QuickDASH ($r = −0.34$) and the QNPRS ($r = −0.17$).

Adjusted relationships between the POT and grip strength test

Table 4 shows the results of multivariate regression analyses. Age, sex, and the GS-A were the only variables that were significantly associated with the POT scores on the affected side and therefore retained in the model ($P < .05$). Older age, female sex, and weaker grip strength on the affected side were all associated with lower POT scores. The model accounted for 83% of the variance in the POT scores. Age, sex, and grip strength of the unaffected side also showed significant associations ($P < .05$) with the POT scores on the unaffected side (results not shown in the table).
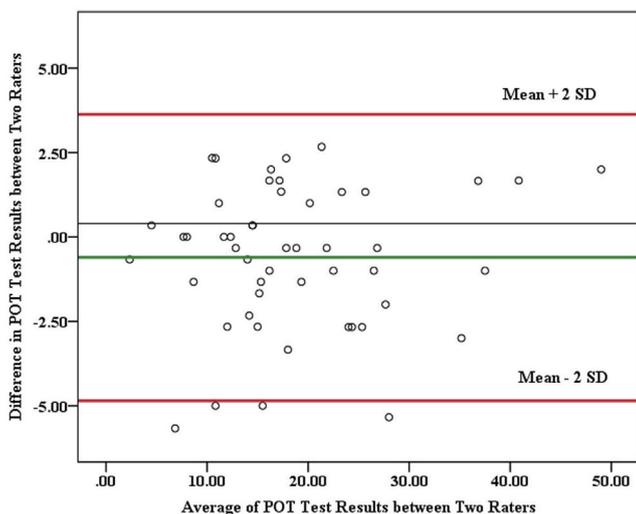

Fig. 1. The Bland-Altman plot showing the agreement in the POT scores between 2 raters is shown in this figure. The limits of agreement (*red lines*) and the mean difference (*green line*) are also shown. POT = push-off test. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 3
Concurrent construct validity of the push-off test ($N = 50$)

Measures	Grip strength: affected side	WES: affected side	QuickDASH	QNPRS
POT	**0.89**[a]	**0.7**[a]	**−0.34**	−0.17
Grip strength–affected side		**−0.67**[a]	**−0.36**	−0.1
WES-affected side			−0.28	−0.06
QuickDASH				**0.73**[a]

POT = push-off test; QuickDASH = shorter version of the Disabilities of Arm, Shoulder, and Hand Questionnaire; Q-NPRS = quadruple numeric pain rating scale; WES = wrist extensor strength.
Correlation in bold are significant at the 0.05 level (2 tailed).
[a] Correlation is significant at the 0.01 level (2 tailed).

Discussion

The key objective of this study was to validate the preliminary findings suggesting that the POT provides reliable and valid assessment of the ability to axially load the upper extremity through painful wrist/hand or elbow.[10] Our results concur with these findings, build further evidence for the measurement properties of the POT by providing the values for the SEM and MDC$_{90}$ for the POT scores in patients with wrist or elbow conditions, and identify the demographic variables that are associated with the performance on the POT. Recruiting relatively larger sample size and using quality research methods to assess the measurement properties of the POT scores render credence to our results. However, the readers are cautioned about the generalizability of the results of our study, especially since the recruited cohort included patients with the spectrum of diagnoses involving wrist and elbow conditions vs a specific diagnosis. Secondarily, the comprehensive evidence to integrate the POT in clinical practice to assess impairment level is still lacking. Especially, the age and gender matched normative values for the POT scores which have not yet been defined, making it difficult to determine the impairment level using the POT score for a given patient.

The POT is a relatively newer measure; therefore, even experienced clinicians will be required to become familiar with the administration of the POT in a consistent manner. One advantage of the POT is that it requires using grip dynamometer, which is an extremely familiar equipment for all the hand therapists. Conversely, the precise technique for administering the POT which includes reversing the grip handle, placing the dynamometer on a solid supporting surface, positioning the participant to optimize the axial loading through the upper extremity is likely new for most hand therapists. This requires creating robust evidence for the reliability of administering and scoring the POT assessed across multiple novice learners.

The interrater reliability of the POT scores, assessed by 2 entry-level physical therapy students, was excellent for the affected hand (ICC = 0.96) in the recruited sample. Our findings are concordant to those observed by Vincent et al.[10] for the similar patient population (ICC = 0.97). The interrater reliability observed by Vincent et al.[10] for assessing the POT scores on the unaffected side was lower (ICC = 0.85) compared to our study (ICC = 0.93) and below the

Table 4
Relationships between the demographic and injury variables with the POT score

Variable	Parameter estimate	*P* value	95% confidence limits for the parameter
Constant	−0.69	—	−5.45 to 4.1
Age	0.08	.028	0.009 to 0.154
Sex (men vs women)	4.09	.006	1.261 to 6.917
Grip strength–affected	0.67	<.0001	0.551 to 0.783

Adjusted R^2 = 83%.

hypothesized benchmark for "excellent" reliability (ICC> 0.90).[20] There are 2 plausible rationale for this lower ICC value in the previous study. First, the ICC values are lower in instances when the performance on a given measure is less variable across the recruited sample, that is, when the between-participant variance for the scores of that measure is low. It would be logical to infer that the POT scores obtained for the unaffected side would be less variable between the participants in the absence of pain in the wrist/hand or elbow joint, which could have resulted in lower ICC value for the interrater reliability for the POT scores for the unaffected side.[10] Second, Vincent et al.[10] assessed the interrater reliability on a relatively smaller sample ($N = 22$). This likely resulted in higher error variance (within-participant) further impacting the ICC value. Nonetheless, the interrater reliability of the POT scores was still excellent for the affected side across both the studies. Moreover, the Bland-Altman plot showed very narrow mean difference in the POT scores between the 2 raters (0.36 lbs) with smaller LOA (-2.31 to 3.06 lbs). The high interrater reliability and smaller random error in the POT scores assessed by 2 different raters substantiates the use of the POT in hand therapy practice while assessing impairments in patients with wrist/elbow conditions.

A novel finding of our study is that we provide the SEM and MDC_{90} values for the POT scores in patients with wrist/hand or elbow conditions. These values were not defined in the previous study.[10] Though the values are derived from a sample with extremely heterogeneous diagnostic subgroups, they provide preliminary evidence to determine the true change in patient's POT scores (4.4 lbs) should hand therapists adopt the POT in their assessment of patients with wrist/hand or elbow condition. It is highly suggested that the SEM and MDC_{90} values should be validated in future using a narrow diagnostic subgroup with wrist/hand or elbow condition.

The POT scores showed expected direction of relationship (inverse) but low correlations with the self-reported measures of QuickDASH ($r = -0.34$) and the QNPRS ($r = -0.17$). Vincent et al.[10] examined the relationship of the POT scores with the full-length DASH and also found lower correlation but of a somewhat larger magnitude ($r = -0.47$). Though the 11-item QuickDASH provides reliable and valid assessment of upper extremity disability,[17] the 30-item full DASH provides a much broader assessment of disability construct. Therefore, minor variations in the magnitude of the correlations between the POT scores and 2 versions of the DASH can be expected. Relationships between objective measures of functional performance and self-reported assessments of pain and functions tend to be moderate to poor in individuals with upper extremity impairments[25,26]; therefore, it is not surprising to find moderate to poor correlations between the POT scores and self-reported measures. An interesting but expected finding is very high correlation between the POT scores and the GS-A ($r = 0.89$, R^2 of 0.79). Grip strength provides an estimate of the force produced by the intrinsic hand muscles which can be impaired by pain and poor stability of the wrist/hand joints. Similarly, the axial loading of the upper extremity assessed by the POT can also be impaired in the presence of pain, weakness, and poor stability of the wrist/hand or elbow joints. Therefore, our result indicating strong relationships between these 2 measures is not surprising. Furthermore, the assessment of grip strength may have greater relevance in the earlier stages of hand rehabilitation when patient's wrist/hand impairment may be severe, and such assessment can provide grounds for selecting optimal functional training that involves handling different objects using the affected hand. Conversely, the POT score can provide indications about the patient's readiness to engage in high-level functional activities that involve handling heavier objects with the affected hand as well as transmitting force through the affected wrist/hand. In summary, the GS-A and POT provide mutually exclusive summary of wrist/hand or elbow impairment that can be utilized to select types of hand therapy interventions.

The grip strength ratio in the present study (0.73 ± 0.28) was considerably lower than the normative ranges of 0.97[15] or 0.95.[27] described earlier. While the ratio of POT scores (affected side vs unaffected side) was also lower (0.86 ± 0.2), no inferences can be made regarding the magnitude of its impairment due to unavailability of the data for the normal POT ratio. Furthermore, the normative values for the grip strength have been adequately described in healthy adults[27-29] and even for individuals with rheumatoid arthritis affecting wrist/hand.[30] Such normative values need to be determined for the POT scores. Our finding that the age and sex of an individual have strong associations with the POT score on the affected and the unaffected side clearly suggests that the POT scores will be different for different age/sex subgroups. Without the age/sex-expected normative values for the POT scores, it is not feasible to draw any conclusions about the level of impairment in the POT scores found in this study or any future studies.

Despite its important messages to inform hand therapy practice, this study has several limitations. Most importantly, the study did not examine the responsiveness of the POT scores in assessing change in patient's status. Our data collection protocol limited us to collect the data cross-sectionally vs longitudinally which limited the scope of measurement properties. Future studies should examine whether the POT scores are sensitive to assessing change in patient's wrist/hand impairment. Second, the generalizability of the findings has limitations since the recruited sample consisted of wide range of wrist/hand elbow diagnoses. Given that the present study is still one of the earlier works to examine the spectrum of measurement properties of the POT scores, future studies that build on this work can recruit patients with more homogenous diagnoses (eg, wrist fractures, ligament injuries and so on) while expanding the scope of measurement properties of the POT scores. Finally, we did not perform a priori sample size calculation to guide recruitment of participants. Though the recruited sample size ($N = 50$) is still large, it is not clear whether it was sufficient to assess the stated study objectives.

Conclusion

In conclusion, this study provides further evidence that the POT is a reliable and valid tool to assess impairment in the ability to axially load the upper extremity in the presence of diagnoses involving these areas. The SEM and MDC_{90} values should facilitate decision-making for hand therapists for assessing the error associated with a single POT score (1.9 kg) or assessing true change (4.4 kg) in patient's ability to transfer weight through upper extremity. Nonetheless, it should be clear that the POT is a newer test and requires substantial work to establish its reliability, validity, and responsiveness across different wrist/hand and elbow conditions. More importantly, the immediate research priority is to establish the normative values for the POT scores for different age and sex subgroups.

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Quiz: # 596

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\# 1. The study looked at the _____ for the POT
   a. measurement error
   b. reliability
   c. validity
   d. all of the above
\# 2. The POT was first described by
   a. Linscheid et al
   b. Osterman et al
   c. Vincent et al
   d. Wolfe et al

\# 3. The POT was originally designed to assess the weight bearing ability of the
   a. wrist
   b. elbow
   c. shoulder
   d. none of the above
\# 4. Forces were measured with a
   a. tensiometer
   b. dynamometer
   c. miniature, custom made bathroom scale
   d. digital pressure plate
\# 5. The study provides additional support for the validity and reliability of the POT
   a. false
   b. true

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