8-1-2021

Establishing Age-calibrated Normative PROMIS Scores for Hand and Upper Extremity Clinic

Nikhil Yedulla

Carson T. Wilmouth

Sreten Franovic

Alaa A. Hazime

Jared T. Hudson

See next page for additional authors

Authors
Nikhil Yedulla, Carson T. Wilmouth, Sreten Franovic, Alaa A. Hazime, Jared T. Hudson, and Charles S. Day

OPEN

PRS GLOBAL OPEN

ORIGINAL ARTICLE

Hand/Peripheral Nerve

Establishing Age-calibrated Normative PROMIS Scores for Hand and Upper Extremity Clinic

Nikhil R. Yedulla, BS
Carson T. Wilmouth, BA
Sreten Franovic, BS, MS
Alaa A. Hazime, BS
Jared T. Hudson, BS
Charles S. Day, MD, MBA

Background: The purpose of our study is to investigate differences in normative PROMIS upper extremity function (PROMIS-UE), physical function (PROMIS-PF), and pain interference (PROMIS-PI) scores across age cohorts in individuals without upper extremity disability.
Methods: Individuals without upper extremity disability were prospectively enrolled. Subjects were administered PROMIS-UE, PROMIS-PF, and PROMIS-PI forms. Retrospective PROMIS data for eligible subjects were also utilized. The enrolled cohort was divided into age groups: 20–39, 40–59, and 60–79 years old. ANOVA, ceiling and floor effect analysis, and kurtosis and skewness statistics were performed to assess PROMIS scores trends with age.
Results: This study included 346 individuals. In the 20–39 age group, mean PROMIS scores were 56.2 ± 6.1, 59.8 ± 6.9, and 43.1 ± 6.7 for PROMIS-UE, PROMIS-PF, and PROMIS-PI, respectively. In the "40–59" age group, mean PROMIS computer adaptive test scores were 53.3 ± 7.5, 55.3 ± 7.6, and 46.6 ± 7.8 for PROMIS-UE, PROMIS-PF, and PROMIS-PI, respectively. In the 60–79 age group, mean PROMIS scores were 48.4 ± 7.6, 48.5 ± 5.6, and 48.7 ± 6.9 for PROMIS-UE, PROMIS-PF, and PROMIS-PI, respectively. Differences in mean PROMIS scores were significant across all PROMIS domains and age cohorts ($P < 0.001$).
Conclusion: Younger individuals without hand or upper extremity disability show higher normative PROMIS-UE and PROMIS-PF scores and lower PROMIS-PI scores, indicating greater function and less pain than older counterparts. A universal reference PROMIS score of 50 appears suboptimal for clinical assessment and decision-making in the hand and upper extremity clinic. *(Plast Reconstr Surg Glob Open 2021;9:e3768; doi: 10.1097/GOX.0000000000003768; Published online 17 August 2021.)*

INTRODUCTION

Patient-reported Outcomes Measurement Information System (PROMIS) is a patient-reported outcome measure (PROM) developed by the National Institutes of Health.[1] PROMIS has become widely utilized in clinical practices due to its increased precision and limited floor and ceiling effects.[2–5] PROMIS computer adaptive tests (CAT) apply computer-based algorithms to choose questions from an item bank, leading to shorter forms containing a select number of items.[1,6] PROMIS CAT forms encompass health domains such as upper extremity function (PROMIS-UE), physical function (PROMIS-PF), and pain interference (PROMIS-PI) and are commonly utilized in assessing hand and upper extremity patients.[7–10] PROMIS-UE has been shown to most effectively capture larger changes in upper extremity function, whereas PROMIS-PF also correlates with established upper extremity PROMs such as the Disabilities in Arm, Shoulder, and Hand (DASH) metric.[4,11,12] Moreover, the extent to which pain inhibits quality of life in hand and upper extremity patients is strongly represented by PROMIS-PI.[13]

Patients' preoperative or pretreatment PROMIS scores can be used in hand and upper extremity clinics to determine whether the minimal clinically important difference (MCID) is attained after surgeries such as carpal tunnel release or treatment of conditions such as distal radius fractures.[14,15] Achievement of MCID can serve as an indicator of the effectiveness of surgical and nonoperative interventions. For example, a patient who undergoes a carpal tunnel release who achieves a preoperative to postoperative PROMIS-UE score improvement of +5.0

From the Department of Orthopedic Surgery, Henry Ford Health System, Detroit, Mich.

Received for publication May 17, 2021; accepted June 22, 2021.

Presented at the American Society for Surgery of the Hand (ASSH) Annual Meeting 2020 (Online).

DOI: 10.1097/GOX.0000000000003768

Disclosure: *The authors have no financial interest to declare in relation to the content of this article.*

that exceeds the established MCID of 3.6 for PROMIS-UE can be said to have achieved MCID and significant clinical improvement.[14] Commonly, many hand and upper extremity surgeons identify patients with initial PROMIS scores deviating from 50 for surgery or treatment, as this score is assumed to be the "normative" value of a healthy reference population.[8] However, previous research indicates that PROMIS and other comparable metrics such as the DASH and Knee Injury and Osteoarthritis Outcomes Score differ by age, so this reference score presents potential limitations.[16–19] Determining age-calibrated PROMIS reference scores is therefore important in evaluating patient candidacy for surgical procedures and better interpreting MCID.

Normative PROMIS scores have previously been shown to deviate from 50 for healthy, asymptomatic individuals both above and below 40 years of age.[8] Although this is a significant finding, a considerable portion of hand and upper extremity diagnoses tend to affect patients above the age of 40.[20–25] Thus, improved determination of normative PROMIS scores across more specific age ranges within this increasingly afflicted over 40 cohort is merited, as these individuals are more frequently seen by hand and upper extremity clinicians and likely to undergo surgery. Clarification of age-calibrated PROMIS scores can optimize the utility and accuracy of PROMIS in assessing and treating this disproportionately affected older population.

The purpose of our study is to investigate differences in normative PROMIS-UE, PROMIS-PF, and PROMIS-PI scores across age cohorts in individuals without upper extremity disability. We hypothesize that younger individuals will have higher PROMIS-UE and PROMIS-PF scores representative of increased function and lower PROMIS-PI scores indicative of decreased pain levels in comparison to older counterparts.

MATERIALS AND METHODS

Institutional review board approval was attained before commencing this study, and no grant support or research funding was provided. Participants were prospectively recruited from October 20, 2020, to November 15, 2020. Subjects meeting inclusion criteria (20 years of age or older, without any stated symptoms of pain or disability in the upper extremity) and exclusion criteria (under 20 years of age, exhibiting upper extremity complaint or disability, refusal to complete all PROMIS CAT forms) were contacted for enrollment in the study by the authors through in-person requests at public spaces as well as phone, e-mail, and in-person solicitation of peers and colleagues. Retrospective PROMIS data for subjects meeting inclusion and exclusion criteria stored on an institution-wide Research Electronic Data Capture (REDcap) registry was also utilized in analysis. REDcap is a web-based HIPAA-compliant data management and collection application maintained by Vanderbilt University (Nashville, Tenn.).[26]

PROMIS CAT forms for the domains of upper extremity function (PROMIS-UE), physical function (PROMIS-PF), and pain interference (PROMIS-PI) were e-mailed or administered in-person on an electronic device using REDCap to enrolled subjects. Participants were also asked about their age in years, and up to two reminders were sent via repeat e-mail message. All PROMIS instruments were calibrated to a mean score of 50 and an SD of 10. Higher scores on PROMIS-UE and PROMIS-PF forms signify greater physical function, whereas higher scores on the PROMIS-PI form indicate that pain has a greater detriment on quality of life. The enrolled cohort was divided into age groups: 20–39 years old, 40–59 years old, and 60–79 years old. Prior research regarding normative PROMIS scores only assessed subjects in two groups above 40 years and below 40 years.[8] With consideration to this previous work, we deemed that classifying subjects in 20-year age brackets between the ages of 20 and 79 years would be the most optimal methodology for evaluating normative PROMIS scores with respect to life expectancy.

Power analysis was additionally performed for the study. Assuming an ANOVA F-test with a 0.05 alpha and an effect size of 0.25, no fewer than 207 subjects in total (69 subjects in each age group) must be tested to detect a significant difference in PROMIS scores among the three age groups with a power of 80%.

Statistical Methods

Descriptive statistics were calculated and reported. One-way analysis of variance (ANOVA) was used to identify significant differences in PROMIS domain scores among the three age groups. Despite PROMIS being designed to be normally distributed, intragroup correlations between PROMIS instruments were determined using Spearman rho (r). Similar to previous studies, Spearman correlation strengths were categorized as excellent (>0.7), excellent-good (0.61 to 0.70), good (0.4 to 0.6), or poor (<0.4).[27] Histograms were visually analyzed, as frequency polygons, for floor and ceiling effects, which measure the ability of a questionnaire to differentiate amongst those respondents at both extremes of the scale.

Additionally, ceiling and floor effects for all three age group PROMIS CAT forms were determined by calculating the number of individuals who had PROMIS scores toward the maximum and minimum scores possible and dividing it by the total number of individuals in the study cohort. As previously reported, a true floor or ceiling effect was considered present if 15% or more of subjects were at either of the extremes.[8] Kurtosis and skewness test statistics were also obtained and divided by their respective standard errors of measurement to determine normality, respective to each statistic. Values outside the range of −1.96 to 1.96 were considered nonnormal.

For all analyses, significance was set a priori at a P value less than 0.05. Statistical analyses were conducted using SPSS software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, N.Y.)

RESULTS

This study included 346 participants that completed all the necessary PROMIS questionnaires. Of this cohort, 176 were between the age of 20 and 39 (mean age = 25.5), 96 were between the age of 40 and 59 (mean age = 49.9), and 74 were between the age of 60 and 79 (mean age = 68.6). In the 20–39 age group, mean PROMIS CAT scores were 56.2 ± 6.1, 59.8 ± 6.9, and 43.1 ± 6.7 for PROMIS-UE, PROMIS-PF, and PROMIS-PI, respectively (Table 1). In the 40–59 age group, mean PROMIS CAT scores were 53.3 ± 7.5, 55.3 ± 7.6, and 46.6 ± 7.8 for PROMIS-UE, PROMIS-PF, and PROMIS-PI, respectively (Table 1). In the 60–79 age group, mean PROMIS CAT scores were 48.4 ± 7.6, 48.5 ± 5.6, and 48.7 ± 6.9 for PROMIS-UE, PROMIS-PF, and PROMIS-PI, respectively (Table 1). Differences in mean PROMIS scores were statistically significant across all PROMIS domains and age cohorts ($P < 0.001$). Median scores and interquartile ranges (IQRs) for PROMIS CAT scores by age group can also be found in Table 1.

Floor and ceiling effects and score distributions of each cohort were visualized with histogram analysis (Figs. 1–3). PROMIS-UE showed significant ceiling effects in all age cohorts while PROMIS-PI showed strong floor effects in all cohorts (Table 2). Both findings were most prominent in the 40–59 cohort (35.5% and 40.9%, respectively) when compared to the 20–39 and 60–79 cohorts (Table 2). Distribution analysis identified normality for PROMIS-UE, PROMIS-PF, and PROMIS-PI in the 60–79 cohort when assessed by skewness and kurtosis (Table 2). Normality was also observed for PROMIS-PF in the 20–39 and 40–59 age cohorts when assessed by skewness and kurtosis (Table 2).

PROMIS-UE showed a good correlation with PROMIS-PF in the 20–39 age cohort ($r = 0.402$, $P < 0.01$). In this same cohort, poor correlations were observed when comparing PROMIS-PI with PROMIS-UE and PROMIS-PF ($r = -0.364$, $P < 0.01$; $r = -0.388$, $P < 0.01$, respectively) (Table 3). In the 40–59 age cohort, good correlations were observed when comparing PROMIS-UE with PROMIS-PF and PROMIS-PI ($r = -0.550$, $P < 0.01$; $r = 0.535$, $P < 0.01$, respectively). In this same cohort, good-excellent correlations were found when comparing PROMIS-PF with PROMIS-PI ($r = -0.607$, $P < 0.01$) (Table 3). In the 60–79 age cohort, a good correlation was observed when comparing PROMIS-PI with PROMIS-UE and PROMIS-PF ($r = -0.438$, $P < 0.01$; $r = -0.499$, $P < 0.01$, respectively). In this same cohort, excellent correlations were found between PROMIS-UE and PROMIS-PF ($r = 0.701$, $P < 0.01$) (Table 3). No significant correlations were found between age and any PROMIS domain for any of the three age cohorts analyzed.

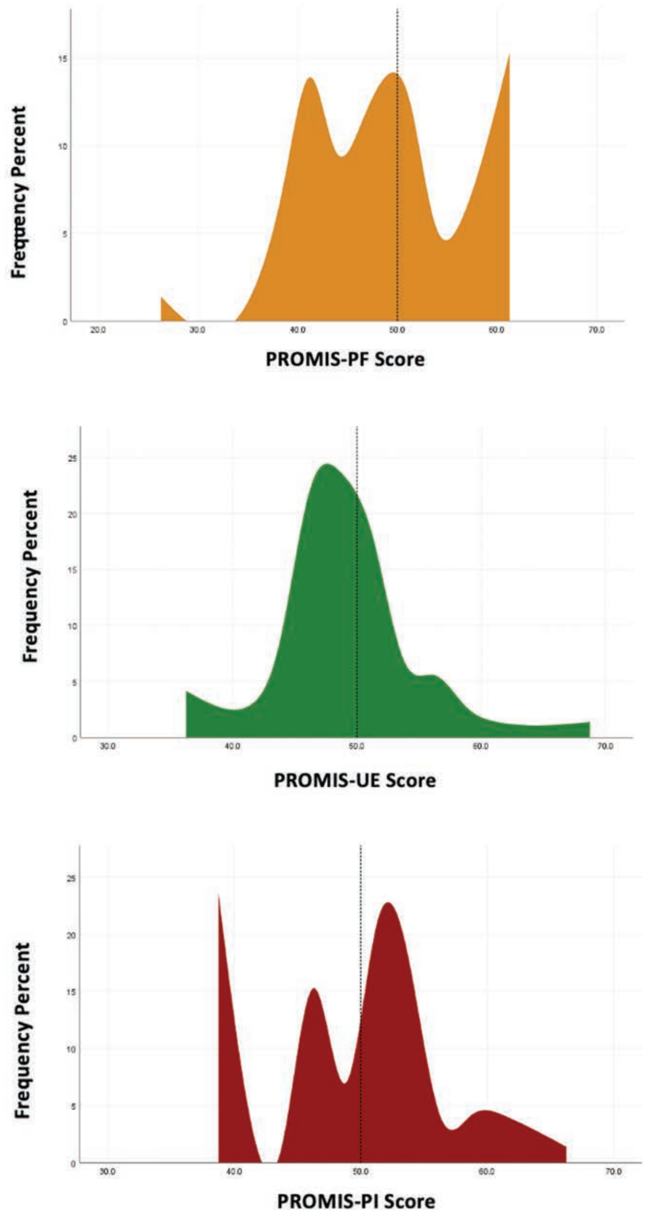

Fig. 1. PROMIS score distribution of individuals 20–39 with no upper extremity disability or pain. Percentage frequency of PROMIS-UE, PROMIS-PF, and PROMIS-PI scores in the enrolled 20–39 age cohort (n = 176) are displayed.

Table 1. Median Scores and IQRs of PROMIS CAT Domains by Age Group

PROMIS CAT Domain	Age Group (y)	Mean *t* Score ± SD (Min–Max)	Median *t* Score ± IQR
PROMIS-UE			
	20–39	56.2 ± 6.1 (14.7–61.0)	61.0 ± 9.1
	40–59	53.3 ± 7.5 (27.1–61.0)	54.5 ± 12.4
	60–79	48.4 ± 7.6 (27.1–61.0)	47.5 ± 11.3
PROMIS-PF			
	20–39	59.8 ± 6.9 (14.7–75.6)	60.4 ± 8.5
	40–59	55.3 ± 7.6 (37.2–75.6)	54.8 ± 10.7
	60–79	48.5 ± 5.6 (35.5–68.5)	48.5 ± 5.6
PROMIS-PI			
	20–39	43.1 ± 6.7 (38.7–83.8)	38.7 ± 11.2
	40–59	46.6 ± 7.8 (38.7–76.4)	46.6 ± 13.9
	60–79	48.7 ± 6.9 (38.7—67.0)	50.1 ± 7.4

DISCUSSION

As hypothesized, this study demonstrates how younger individuals show higher normative PROMIS-UE and PROMIS-PF scores as well as lower PROMIS-PI scores, indicating higher function and less pain when compared to older counterparts. PROMIS-PF and PROMIS-UE scores in individuals without upper extremity disability are the highest in the 20–39 cohort, followed by the 40–59 and then 60–79 cohort. Mean PROMIS-PF and PROMIS-UE scores

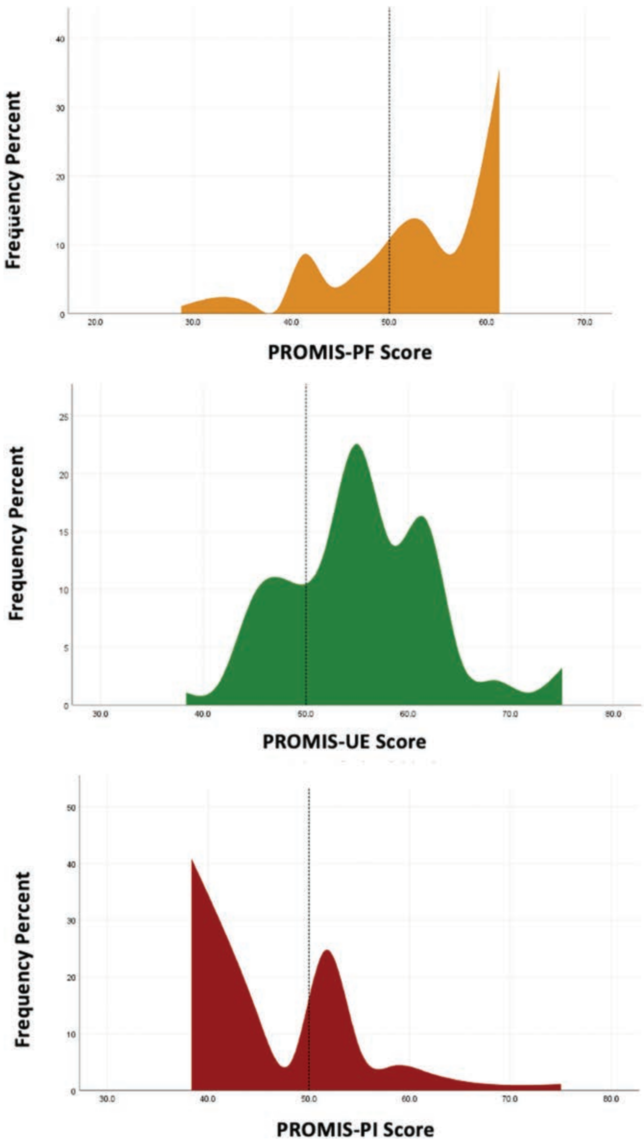

Fig. 2. PROMIS score distribution of individuals 40–59 with no upper extremity disability or pain. Percentage frequency of PROMIS-UE, PROMIS-PF, and PROMIS-PI scores in the enrolled 40–59 age cohort (n = 96) are shown.

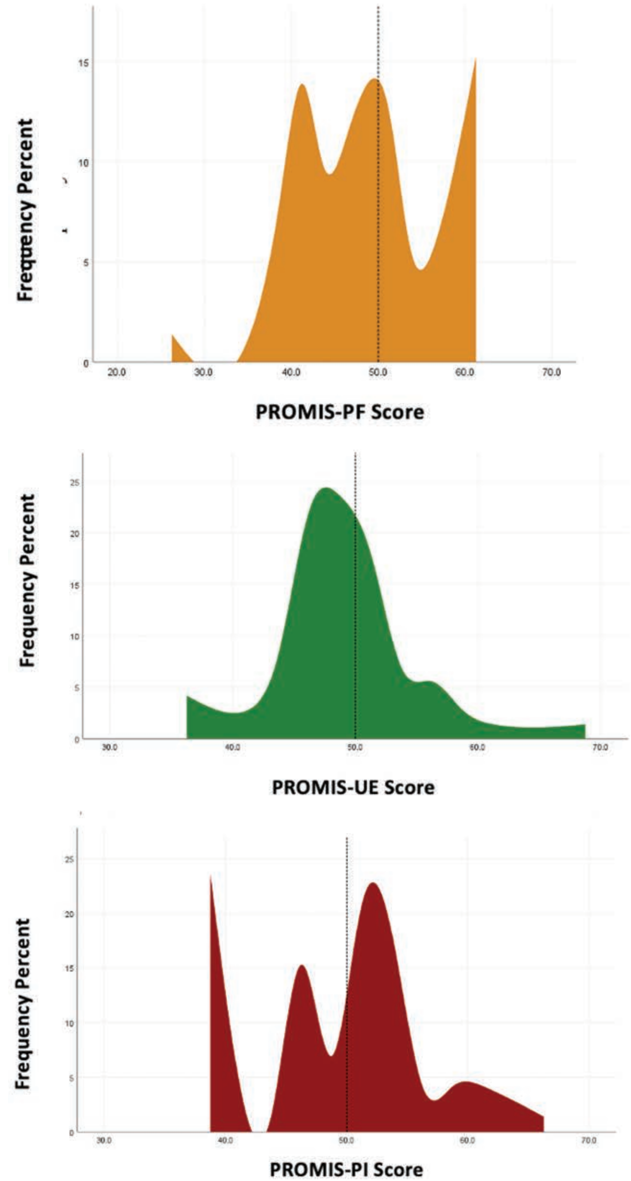

Fig. 3. PROMIS score distribution of individuals 60–79 with no upper extremity disability or pain. Percentage frequency of PROMIS-UE, PROMIS-PF, and PROMIS-PI scores in the enrolled 60–79 age cohort (n = 74) are visualized.

in both the 20–39 cohort (56.2 and 59.8, respectively) as well as the 40–59 cohort (53.3 and 55.3) exceeded the reference PROMIS score of 50, whereas those in the 60–79 cohort (48.4 and 48.5) were lower than 50. PROMIS-PI scores in individuals without upper extremity disability are highest in the 60–79 cohort, followed by the 40–59 and then 20–39 cohorts. Mean PROMIS-PI scores in the 20–39, 40–59, and 60–79 cohorts were all below the reference PROMIS score of 50 (43.1, 46.6, and 48.7, respectively).

Given the significant age-based differences in pain and function in healthy individuals without upper extremity disability, a universal reference PROMIS score of 50 may not be accurate for clinical comparison in the hand and upper extremity clinic, especially when evaluating the need for surgery. For example, a 58-year-old patient with carpal tunnel syndrome and an initial PROMIS-PF score of 53.0 may not be deemed a candidate for a carpal tunnel release because the patient already exceeds the currently established reference score of 50. When looking at age-calibrated PROMIS-UE reference scores determined in our study, however, this patient does not meet the reference score of 55.3 for the 40–59 cohort and thus could potentially be considered for surgery based on this interpretation. Age-calibrated PROMIS scores can also better contextualize how MCID relates to clinical improvement in patients. For instance, a 35-year-old patient who undergoes a carpal tunnel release and achieves a preoperative to postoperative PROMIS-UE score change of 46.0–51.0 can be said to have achieved MCID because the improvement of +5.0 exceeds the established MCID of 3.6 for PROMIS-UE.[14] Though this patient has met the

Table 2. Distribution Analysis of PROMIS CAT Domains by Age Group

PROMIS CAT Domain	Statistic	Age 20 to 39			Age 40 to 59			Age 60 to 79		
		Value	SEM	Normality	Value	SEM	Normality	Value	SEM	Normality
PROMIS-UE										
	Kurtosis	0.314	0.359	**0.875**	−0.759	0.250	−3.036	0.106	0.283	**0.375**
	Skewness	−1.110	0.181	−6.133	0.133	0.495	**0.269**	−0.302	0.559	**−0.540**
	Floor effect, n (%)		1 (0.3%)			0 (0.0%)			1 (0.3%)	
	Ceiling effect, n (%)		96 (**26.5%**)			33 (**35.5%**)			11 (**15.3%**)	
PROMIS-PF										
	Kurtosis	0.370	0.359	**1.031**	0.433	0.250	**1.732**	0.414	0.283	**1.463**
	Skewness	−0.219	0.181	**−1.210**	0.302	0.495	**0.610**	1.902	0.559	**3.403**
	Floor effect, n (%)		1 (0.3%)			0 (0.0%)			0 (0.0%)	
	Ceiling effect, n (%)		6 (1.7%)			3 (3.2%)			0 (0.0%)	
PROMIS-PI										
	Kurtosis	−0.185	0.359	**−0.515**	0.711	0.250	2.844	0.039	0.283	**0.137**
	Skewness	1.137	0.181	6.282	0.693	0.495	**1.400**	−0.365	0.559	**−0.653**
	Floor effect, n (%)		121 (**33.4%**)			38 (**40.9%**)			17 (**23.6%**)	
	Ceiling effect, n (%)		0 (0.0%)			1 (0.3%)			0 (0.0%)	

PF, physical function; SEM, standard error of measurement.
Boldface values indicate statistical test values within normal distribution assumption (−1.96 to 1.96).

technical definition for attaining MCID and has a postoperative PROMIS-UE score above 50, the score of 51.0 is still lower than the age-calibrated PROMIS-UE reference score of 56.2 determined in our study. Essentially, this patient has a lower level of function compared to healthy individuals in the same age cohort despite achievement of MCID suggesting otherwise. These scenarios emphasize the value of utilizing age-calibrated PROMIS scores in clinical decision-making and evaluation of outcomes.

A previous study at a Midwest academic medical center also looked at normative PROMIS scores in asymptomatic subjects.[8] This study enrolled 294 individuals and compared normative PROMIS scores in those under 40 years or aged 40 years and above, revealing how average PROMIS-UE (55.9 versus 51.2) and PROMIS-PF (59.7 versus 52.9) scores were significantly higher in younger subjects while PROMIS-PI scores were significantly higher in older counterparts (49.0 versus 43.6). Our study finds similarly decreasing trends of PROMIS-UE and PROMIS-PF with age and an increase in PROMIS-PI with age. For individuals over 60 years, mean PROMIS-UE, -PF, and -PI scores were, respectively, 48.4, 48.5, and 48.7, whereas scores for those below 40 years were 56.2, 59.8, and 43.1. Our study supports previous findings regarding how younger individuals have increased function and less pain in comparison to older counterparts. Moreover, our study better discerns differences in normative PROMIS scores across age cohorts. By looking at more specific 20-year-age intervals instead of broader 40-year intervals, we provide detailed insights into specific normative PROMIS scores that can be better utilized in clinic settings.

Though not entirely similar to our investigation, previous research at a tertiary care upper extremity clinic in St. Louis assessed the relationship between PROMIS scores and age in outpatients.[3] In this study, advancing age demonstrated a weak negative correlation with PROMIS-PF and PROMIS-UE in upper extremity patients. Likewise, another study at an academic medical center in Utah analyzed correlations between PROMIS domains in hand and upper extremity patients.[10] Findings show how PROMIS-PF and PROMIS-UE were strongly negatively correlated with PROMIS-PI in upper extremity patients. Like both of the aforementioned studies, we also analyze PROMIS trends related to age and correlations between different

Table 3. Correlations of PROMIS CAT Domains by Age Group

PROMIS CAT Domain	Comparative Measure	Total Cohort			Age 20–49			Age 40–59			Age 60–79		
		R Value	*P*	Correlation Strength	R Value	*P*	Correlation Strength	R Value	*P*	Correlation Strength	R Value	*P*	Correlation Strength
PROMIS-UE													
	PROMIS-PF	0.582	**<0.01**	Good	0.402	**<0.01**	Good	0.535	**<0.01**	Good	0.701	**<0.01**	Excellent
	PROMIS-PI	−0.464	**<0.01**	Good	−0.364	**<0.01**	Poor	−0.550	**<0.01**	Good	−0.438	**<0.01**	Good
	Age	−0.388	**<0.01**	Poor	0.017	0.817	Poor	−0.129	0.218	Poor	−0.257	0.029	Poor
PROMIS-PF													
	PROMIS-UE	0.582	**<0.01**	Good	0.402	**<0.01**	Good	0.535	**<0.01**	Good	0.702	**<0.01**	Excellent
	PROMIS-PI	−0.549	**<0.01**	Good	−0.388	**<0.01**	Poor	−0.607	**<0.01**	Excellent-Good	−0.499	**<0.01**	Good
	Age	−0.544	**<0.01**	Good	−0.062	0.406	Poor	−0.24	0.821	Poor	−0.139	0.246	Poor
PROMIS-PI													
	PROMIS-UE	−0.464	**<0.01**	Good	−0.364	**<0.01**	Poor	−0.550	**<0.01**	Good	−0.438	**<0.01**	Good
	PROMIS-PF	−0.549	**<0.01**	Good	−0.388	**<0.01**	Poor	−0.607	**<0.01**	Excellent-Good	−0.499	**<0.01**	Good
	Age	0.318	**<0.01**	Poor	0.120	0.109	Poor	−0.115	0.272	Poor	−0.151	0.204	Poor

PF, physical function.
Boldface values indicate statistically significant values ($p < 0.05$).

PROMIS domains. However, we evaluate these relationships in healthy individuals instead of patients with hand and upper extremity diagnoses as the other two studies do. Though our research has a similar direction, drawing comparisons between our findings and the St. Louis and Utah studies is not feasible given the fundamental differences in the health of our enrolled cohorts.

This investigation has multiple limitations. First, our study does not evaluate differences in demographics across the enrolled cohort other than age. Such analysis would have allowed for deeper insights into the variance in normative PROMIS according to additional relevant factors such as race and gender. Regardless, age is still an important criterion for calibrating normative PROMIS scores with clinical applications, even in the absence of other comparisons. Second, some enrolled individuals may not have entirely met inclusion criteria, thereby skewing responses. For example, certain subjects may have perceived themselves as having no upper extremity disability and thus completed PROMIS CAT forms, even though their actual physical condition reflected otherwise. However, enrolled subjects were explained eligibility criteria in great detail by researchers and allowed to ask questions, which likely limits the degree of improper form completion. Third, our study presents a limited diversity of enrolled individuals. The majority of participants were from a specific metropolitan area, leading to homogeneity in the data that limits the external validity. However, many contacts located in different geographic regions were also enrolled, which improves this potential lack of generalizability.

Our study better clarifies age-calibrated PROMIS scores of clinical relevance to hand and upper extremity patients. We show how these normative PROMIS scores range between 43.1 and 59.8 across all age cohorts and PROMIS domains, which is notable given how MCID for many conditions in this patient population is often below 5.0.[14,15] Thus, age-calibrated PROMIS scores are critical to better assessing and treating patients in the hand and upper extremity clinic.

Charles S. Day, MD, MBA
Department of Orthopedic Surgery
Henry Ford Health System
2799 W. Grand Blvd., CFP-6
Detroit, MI 48202
E-mail: cday9@hfhs.org

REFERENCES

1. Cella D, Yount S, Rothrock N, et al; PROMIS Cooperative Group. The Patient-Reported Outcomes Measurement Information System (PROMIS): progress of an NIH Roadmap cooperative group during its first two years. *Med Care.* 2007;45(5 suppl 1):S3–S11.
2. Fries JF, Krishnan E, Rose M, et al. Improved responsiveness and reduced sample size requirements of PROMIS physical function scales with item response theory. *Arthritis Res Ther.* 2011;13:R147.
3. Beleckas CM, Padovano A, Guattery J, et al. Performance of Patient-Reported Outcomes Measurement Information System (PROMIS) upper extremity (UE) versus physical function (PF) computer adaptive tests (CATs) in upper extremity clinics. *J Hand Surg Am.* 2017;42:867–874.
4. Hung M, Saltzman CL, Greene T, et al. The responsiveness of the PROMIS instruments and the qDASH in an upper extremity population. *J Patient Rep Outcomes.* 2017;1:12.
5. Döring AC, Nota SP, Hageman MG, et al. Measurement of upper extremity disability using the Patient-Reported Outcomes Measurement Information System. *J Hand Surg Am.* 2014;39:1160–1165.
6. Morgan JH, Kallen MA, Okike K, et al. PROMIS physical function computer adaptive test compared with other upper extremity outcome measures in the evaluation of proximal humerus fractures in patients older than 60 years. *J Orthop Trauma.* 2015;29:257–263.
7. Kashikar-Zuck S, Carle A, Barnett K, et al. Longitudinal evaluation of patient-reported outcomes measurement information systems measures in pediatric chronic pain. *Pain.* 2016;157:339–347.
8. Franovic S, Gulledge CM, Kuhlmann NA, et al. Establishing "normal" patient-reported outcomes measurement information system physical function and pain interference scores: a true reference score according to adults free of joint pain and disability. *JB JS Open Access.* 2019;4:e0019.
9. Bernstein DN, Houck JR, Mahmood B, et al. Minimal clinically important differences for PROMIS physical function, upper extremity, and pain interference in carpal tunnel release using region- and condition-specific PROM tools. *J Hand Surg Am.* 2019;44:635–640.
10. Kazmers NH, Hung M, Rane AA, et al. Association of physical function, anxiety, and pain interference in nonshoulder upper extremity patients using the PROMIS platform. *J Hand Surg Am.* 2017;42:781–787.
11. Tyser AR, Beckmann J, Franklin JD, et al. Evaluation of the PROMIS physical function computer adaptive test in the upper extremity. *J Hand Surg Am.* 2014;39:2047–2051.e4.
12. Bernstein DN, Houck JR, Hammert WC. A Comparison of PROMIS UE versus PF: correlation to PROMIS PI and depression, ceiling and floor effects, and time to completion. *J Hand Surg Am.* 2019;44:901.e1–901.e7.
13. Kortlever JT, Janssen SJ, van Berckel MM, et al. What is the most useful questionnaire for measurement of coping strategies in response to nociception? *Clin Orthop Relat Res.* 2015;473:3511–3518.
14. Kazmers NH, Hung M, Bounsanga J, Voss MW, Howenstein A, Tyser AR. Minimal clinically important difference after carpal tunnel release using the PROMIS platform. *J Hand Surg Am.* 2019;44:947–953.e1.
15. Sandvall B, Okoroafor UC, Gerull W, et al. Minimal clinically important difference for PROMIS physical function in patients with distal radius fractures. *J Hand Surg Am.* 2019;44:454–459.e1.
16. Paradowski PT, Bergman S, Sundén-Lundius A, et al. Knee complaints vary with age and gender in the adult population. Population-based reference data for the Knee injury and Osteoarthritis Outcome Score (KOOS). *BMC Musculoskelet Disord.* 2006;7:38.
17. Aasheim T, Finsen V. The DASH and the QuickDASH instruments. Normative values in the general population in Norway. *J Hand Surg Eur Vol.* 2014;39:140–144.
18. Jevotovsky DS, Tishelman JC, Stekas N, et al. Age and gender confound PROMIS scores in spine patients with back and neck pain. *Global Spine J.* 2021;11:299–304.
19. Kendall R, Wagner B, Brodke D, et al. The relationship of PROMIS pain interference and physical function scales. *Pain Med.* 2018;19:1720–1724.
20. Dibenedetti DB, Nguyen D, Zografos L, et al. Prevalence, incidence, and treatments of Dupuytren's disease in the United States: results from a population-based study. *Hand (N Y).* 2011;6:149–158.

21. Lee IH, Kim YK, Kang DM, et al. Distribution of age, gender, and occupation among individuals with carpal tunnel syndrome based on the national health insurance data and national employment insurance data. *Ann Occup Environ Med.* 2019; 31:e31.
22. Atroshi I, Gummesson C, Johnsson R, et al. Prevalence of carpal tunnel syndrome in a general population. *JAMA.* 1999;282: 153–158.
23. Rosberg HE, Dahlin LB. An increasing number of hand injuries in an elderly population - a retrospective study over a 30-year period. *BMC Geriatr.* 2018;18:68.
24. Loos B, Puschkin V, Horch RE. 50 years experience with Dupuytren's contracture in the Erlangen University Hospital–a retrospective analysis of 2919 operated hands from 1956 to 2006. *BMC Musculoskelet Disord.* 2007;8:60.
25. Moriatis Wolf J, Turkiewicz A, Atroshi I, et al. Prevalence of doctor-diagnosed thumb carpometacarpal joint osteoarthritis: an analysis of Swedish health care. *Arthritis Care Res (Hoboken).* 2014;66:961–965.
26. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42:377–381.
27. Bernstein DN, Franovic S, Smith DG, et al. Pediatric PROMIS computer adaptive tests are highly correlated with adult PROMIS computer adaptive tests in pediatric sports medicine patients. *Am J Sports Med.* 2020;48:3620–3625.