1-1-2023

PROMIS Physical Function and Pain Interference scores correlate with the Lower Extremity Toronto Extremity Salvage Score

Julie Jin
Washington University School of Medicine in St. Louis
Zachery Hong
Washington University School of Medicine in St. Louis
Lee Rhea
Washington University School of Medicine in St. Louis
Douglas J. McDonald
Washington University School of Medicine in St. Louis
Regis J. O'Keefe
Washington University School of Medicine in St. Louis

See next page for additional authors

JB&JS OPEN ACCESS

PROMIS Physical Function and Pain Interference Scores Correlate with the Lower Extremity Toronto Extremity Salvage Score

Julie Jin, MD*, Zachery Hong, MD, MPHS*, Lee Rhea, PhD, Douglas J. McDonald, MD, Regis J. O'Keefe, MD, PhD, and Cara A. Cipriano, MD, MSc

Investigation performed at Washington University School of Medicine in St. Louis, St. Louis, Missouri

Background: The Toronto Extremity Salvage Score (TESS) and the National Institutes of Health Patient-Reported Outcomes Measurement Information System (PROMIS) are both utilized to measure patient-reported outcomes in adults with musculoskeletal oncologic conditions. However, the relationship between them has not been studied. We sought to describe a link between Lower Extremity (LE) TESS and PROMIS Physical Function (PF) scores, as well as between LE TESS and Pain Interference (PI) scores, to develop a method for converting scores between TESS and PROMIS and to examine whether TESS and PROMIS captured differences in pain and function between clinically relevant subgroups in our population.

Methods: Our study population consisted of 125 adult patients who underwent surgical treatment of a lower-extremity musculoskeletal tumor at a single sarcoma center between December 2015 and October 2018. The LE TESS questionnaire was administered to patients via paper and the PROMIS PF and PI were administered via iPad at a preoperative appointment. The relationship between LE TESS and PROMIS measures was analyzed with use of generalized linear modeling. Subgroup analyses were performed with a 2-tailed t test or 1-way analysis of variance.

Results: PROMIS PF had a very strong positive correlation with LE TESS (r = 0.83) and was related through the following equation: $PROMIS\ PF = 0.00294 \times (LE\ TESS)^2 + 22.6$. PROMIS PI had a strong negative correlation with LE TESS (r = –0.77) and was related through the following equation: $PROMIS\ PI = -0.00259 \times (LE\ TESS)^2 + 73.8$. PROMIS PF and PI performed similarly to LE TESS across multiple patient subgroups and captured the expected differences between subgroups.

Conclusions: LE TESS and PROMIS PF appeared to measure similar information in patients with an orthopaedic oncologic condition. Moreover, PROMIS PI scores were strongly correlated with functional disability as measured with the LE TESS. Understanding the relationship between TESS and PROMIS will allow the comparison and combination of data for both clinical and research purposes.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Historically, patient outcomes in medicine have been assessed by physicians. The field of orthopaedic oncology, for example, has traditionally relied on the Musculoskeletal Tumor Society (MSTS) score, which was introduced in 1987 and updated in 1993. However, the determination of disability made by a physician can differ from that made by the patient[1], and the importance of patient-reported outcomes (PROs) has been increasingly recognized across medical fields[2-7]. Accordingly, the Toronto Extremity Salvage Score (TESS) was developed as a patient-reported measure of functional disability in adult patients with surgically treated musculoskeletal tumors in the upper or lower limb. Currently, the TESS and MSTS (1993) questionnaires are the most commonly utilized measures of functional outcomes in adult patients with lower-extremity tumors[8].

The Patient-Reported Outcomes Measurement Information System (PROMIS) was developed by the National Institutes of Health to measure various patient-reported measures in any adult population. PROMIS can capture multiple aspects of well-being through >100 item banks that measure patient perceptions

*Julie Jin, MD, and Zachery Hong, MD, MPHS, contributed equally to this work.

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A534).

JBJS Open Access • 2023:e23.00011. openaccess.jbjs.org

of their health in 102 different domains, such as physical function, pain, social satisfaction, and emotional distress. In addition, research has shown that PROMIS decreases floor and ceiling effects as well as responder burden through its use of computer adaptive tests and item response theory[9-11]. A previous study comparing the time taken to complete PROMIS Physical Function (PF) versus Lower Extremity (LE) TESS surveys among patients with lower-extremity bone metastases demonstrated that 73% of participants completed the PROMIS PF in <1 minute, whereas the mean time to complete the LE TESS was >4 minutes[12]. Finally, PROMIS reduces administrative error because no manual calculation or data entry is required and scores are automatically entered into the electronic medical record once the surveys are completed, eliminating the possibility of forgetting to fill out the back side of a double-sided paper or misinterpretation of inaccurate marks. These advantages provided by PROMIS over other PRO measures have led to its increased use across medical fields, including orthopaedics[4,5,13,14] and oncology[2,3,6,15-17]. The PROMIS PF and Pain Interference (PI) domains have been validated in various orthopaedic[4,5,13,14] and oncologic populations[2,3,6,15-17]; however, they have not been as well studied in musculoskeletal oncology.

None of the aforementioned outcome measures have been universally utilized in orthopaedic oncology, preventing the combination of data across institutions as well as the comparison of studies within the existing literature. These research limitations are especially unfortunate because sarcomas are both rare and diverse, which makes it challenging to collect a meaningful number of cases for study. In the absence of a common measure, understanding the relationship between existing measures would facilitate the accumulation of data and the development of evidence-based care. Therefore, our goals were to calculate the correlation of LE TESS with each PROMIS domain (PF or PI), to define a mathematical relationship between LE TESS and PROMIS PF and between LE TESS and PROMIS PI in order to enable comparison of those measures, and to determine whether LE TESS, PROMIS PF, and PROMIS PI capture differences in pain and function between various clinically relevant subgroups.

Materials and Methods

Approval for this study was obtained from the institutional review board at the Washington University School of Medicine in St. Louis, and informed consent was obtained from all patients. The study population consisted of 125 consecutive adult patients with a lower-extremity bone or soft-tissue tumor who received preoperative outpatient evaluation and surgical treatment between December 2015 and October 2018 at a single, university-based, tertiary care institution.

At their preoperative appointment, patients completed the LE TESS questionnaire via paper and the PROMIS PF (PROMIS Bank v1.2 and v2.0 - Physical Function) and PROMIS PI (PROMIS Item Bank v1.1 - Pain Interference) via tablet computer (mini iPad; Apple). The median number of LE TESS questions answered was 32 (interquartile range [IQR], 1 to 32), the median number of PROMIS PF questions answered was 4 (IQR, 4 to 12), and the median number of PROMIS PI questions answered was 4 (IQR, 4 to 12). LE TESS surveys were manually entered into a secure database and then scored via a Microsoft Excel algorithm. PROMIS surveys were collected over a secure wireless network, scored, and immediately stored in the electronic medical record. The median length of time between the preoperative appointment and surgery was 13 days (IQR, 6 to 22 days) (Table I).

The TESS ranges from 0 to 100 and is calculated by dividing the sum of patient responses to questions by the maximum possible score based on the number of questions answered. Higher scores indicate less disability, whereas lower scores indicate more disability. PROMIS scores are set on a normal distribution centered at 50 with a standard deviation of 10. For PROMIS PF, higher scores indicate more physical function, whereas lower scores indicate less physical function. For PROMIS PI, higher scores indicate more pain interference, whereas lower scores indicate less pain interference.

Statistical Analysis

The statistical analysis was performed with use of SAS version 9.4 (SAS Institute) and Microsoft Excel 2016. A general linear model analysis package was utilized to analyze the relationship between LE TESS and PROMIS PF as well as between LE TESS and PROMIS PI. Curve fitting was performed, and correlation coefficients were derived from the r^2 of the model. Correlation coefficients were interpreted as proposed by Evans (0.00 to 0.19, very weak; 0.20 to 0.39, weak; 0.40 to 0.59, moderate; 0.60 to 0.79, strong; 0.80 to 1.00, very strong)[18]. Bivariate analyses were conducted to detect differences in scores for PROMIS PF, PROMIS PI, and LE TESS between relevant demographic and clinical subgroups. The effects of patient age and the number of days between the preoperative appointment and surgery were analyzed with use of simple linear regression and the Pearson correlation coefficient. The effects of patient gender and tumor characteristics (i.e., soft tissue compared with bone, primary compared with

TABLE I Patient Age and Time from Preoperative Appointment to Surgery

		Correlation with LE TESS		Correlation with PROMIS PF		Correlation with PROMIS PI	
Patient Characteristics	Median (IQR)	Pearson Correlation Coefficient (r)	P Value	Pearson Correlation Coefficient (r)	P Value	Pearson Correlation Coefficient (r)	P Value
Patient age in years	53 (40-68)	–0.13	0.14	–0.20	0.03	–0.05	0.56
Days before surgery	13 (6-22)	0.10	0.26	0.23	0.01	–0.15	0.09

TABLE II Patient and Tumor-Related Characteristics Included in the Analysis*

Characteristics	No. (%)	Mean LE TESS (Range)	Mean PROMIS PF Score (Range)	Mean PROMIS PI Score (Range)
Gender†				
Female	62 (50%)	75.4 (6.7-100)	41.4 (39-84)	57.7 (20-70)
Male	63 (50%)	74.7 (0-100)	40.9 (39-78)	57.5 (19-73)
Difference in means		0.7	0.5	0.2
2-tailed t test		P = 0.87	P = 0.79	P = 0.91
Location†				
Pelvis	12 (10%)	67.0 (12.5-100)	36.4 (19-55)	62.1 (39-74)
Thigh	54 (43%)	70.9 (6.7-100)	40.9 (20-66)	55.9 (39-74)
Knee	24 (19%)	80.0 (10-100)	42.1 (20-60)	57.8 (39-78)
Calf	25 (20%)	80.0 (0-100)	42 (20-73)	57.6 (39-84)
Foot	10 (8%)	82.6 (67.5-98.3)	44.2 (36-70)	60.6 (47-74)
1-way ANOVA		P = 0.29	P = 0.55	P = 0.40
Soft tissue vs. bone†				
Soft tissue	88 (70%)	81.4 (0-100)	44.5 (19-73)	54.8 (39-74)
Bone	37 (30%)	60.1 (10-100)	33.2 (20-51)	64.2 (39-84)
Difference in means		21.3	11.3	–9.4
2-tailed t test		**P < 0.001**	**P < 0.001**	**P < 0.001**
Primary vs. metastatic†				
Primary	111 (89%)	80.0 (0-100)	43.1 (19-73)	56.3 (39-84)
Metastatic	14 (11%)	35.6 (10-67.3)	25.6 (20-32)	67.7 (39-78)
Difference in means		44.4	17.5	–11.4
2-tailed t test		**P < 0.001**	**P < 0.001**	**P < 0.001**
Benign vs. malignant†				
Benign	66 (53%)	82.3 (19.2-100)	44.7 (20-73.3)	56.0 (38.7-83.8)
Malignant	59 (47%)	67 (0-100)	37.2 (19.1-60.4)	59.0 (38.7-77.8)
Difference in means		15.3	7.5	–3.0
2-tailed t test		**P = 0.001**	**P < 0.001**	P = 0.12

*For each factor, the frequency in the study population; the mean LE TESS, PROMIS PF, and PROMIS PI scores; and the association between the characteristic and outcome measure scores are shown. Significant p values are shown in bold. †Values are given as the number and percentage of patients. ‡Values are given as the number and percentage of tumors.

metastatic, benign compared with malignant) were analyzed with use of 2-tailed Welch t testing. A subgroup analysis of tumor location was performed with use of 1-way analysis of variance (ANOVA). The level of significance was set at $\alpha = 0.05$.

Source of Funding
No external funding was received for this study.

Results

The median age of the 125 included patients was 53 years (IQR, 40 to 68 years), and there were similar proportions of men and women (Tables I and II). Of the tumors, 30% (37 of 125) were bone tumors, whereas 70% (88 of 125) were soft-tissue tumors. The majority of tumors (53% [66 of 125]) were benign, and the most common anatomic location of tumor occurrence was the thigh (43% [54 of 125 tumors]) (Table II). Based on the final histopathologic diagnosis, the most common subtypes of bone tumor were metastatic carcinoma, chondrosarcoma, and osteosarcoma, whereas the most common subtypes of soft-tissue tumor were lipoma, undifferentiated pleomorphic sarcoma, synovial sarcoma, and simple cyst (Tables III and IV).

PROMIS PF had a very strong positive correlation with LE TESS (r = 0.83), demonstrating that better physical function (measured with PROMIS PF) was correlated with less disability (measured with LE TESS) (Fig. 1). PROMIS PI had a strong negative correlation with LE TESS (r = –0.77),showing that more pain (measured with PROMIS PI) was correlated with greater disability (measured with LE TESS) (Fig. 2).

The relationship between LE TESS and PROMIS PF and that between LE TESS and PROMIS PI were mathematically defined with the following equations, respectively:

$$PROMIS\ Physical\ Function = 0.00294*(LE\ TESS)^2 + 22.6$$
$$PROMIS\ Pain\ Interference = -0.00259*(LE\ TESS)^2 + 73.8$$

TABLE III Histopathologic Diagnoses of Bone Tumors (N = 37)

Bone Tumor Subtype	No. of Tumors (%)
Metastatic carcinoma	14 (37.8)
Chondrosarcoma	8 (21.6)
Osteosarcoma	3 (8.1)
Enchondroma	2 (5.4)
Giant cell tumor	2 (5.4)
Osteochondroma	2 (5.4)
Aneurysmal bone cyst	2 (5.4)
Solitary bone cyst	2 (5.4)
Ewing sarcoma	1 (2.7)
Multiple myeloma	1 (2.7)

Patients with a bone tumor had lower scores for LE TESS (mean difference, 21; $p < 0.001$), lower PROMIS PF scores (mean difference, 11; $p < 0.001$), and higher PROMIS PI scores (mean difference, 9; $p < 0.001$) than those with a soft-tissue tumor (Table II). Patients with a metastatic tumor had lower scores for LE TESS (mean difference, 44; $p < 0.001$), lower PROMIS PF scores (mean difference, 18; $p < 0.001$), and higher PROMIS PI scores (mean difference, 11; $p < 0.001$) than those with a primary tumor (Table II). Patients with a malignant tumor had lower scores for LE TESS (mean difference, 15; $p = 0.001$) and lower PROMIS PF scores (mean difference, 8; $p < 0.001$) than those with a benign tumor; however, the difference in PROMIS PI scores between these 2 subgroups was not significant (mean difference, 3; $p = 0.12$) (Table II).

No strong correlations were found between TESS or PROMIS scores and patient gender, age, or associations between them and tumor location (Tables I and II).

Discussion

PROs have been increasingly utilized to better understand patient wellness and to better guide clinical management. Compared with previous PRO measures, PROMIS has advantages such as public availability for ease of access, utilization of computer adaptive tests and short forms to increase accuracy and to reduce responder burden, and standardization to allow for easier comparison and interpretation. The present study was built on previous work, which demonstrated that PROMIS PF and PI had very strong positive and strong negative correlations, respectively, with LE TESS in patients with musculoskeletal tumors[9]. We further explored these relationships by generating unique models to convert scores between LE TESS and PROMIS PF or PI and by performing subgroup analyses to detect differences in scores between patients with various demographic and tumor characteristics.

Correlation and Mathematical Relationship Between LE TESS and PROMIS PF or PI

PROMIS PF and PI had a very strong positive ($r = 0.83$) and strong negative ($r = -0.77$) correlation, respectively, with LE TESS. Our findings replicate the strength and directionality of the correlation between LE TESS and each of these 2 PROMIS domains shown in prior literature[9]. To further define the relationship between these systems, we calculated a mathematical relationship between PROMIS PF and LE TESS and between PROMIS PI and LE TESS that investigators can use to convert scores between measures.

Our proposed equations have several potential applications. In the clinical setting, providers would be able to understand the outcomes reported by their patients in the context of both PROMIS and TESS literature, even when only 1 of the measures was administered. In the research setting, the development of conversion models such as these would optimize the value of new and existing literature by making studies that use TESS and those that use PROMIS mutually intelligible. In addition, bridging these outcome measures is a crucial step toward producing high-powered research in the field of orthopaedic oncology. Sarcoma is a rare and heterogeneous group of diseases, which increases the challenge of collecting sufficient data to develop evidence-based recommendations. The MSTS recognized this issue and has since aimed to increase collaborative and multi-institutional research projects through the establishment of the Musculoskeletal Oncology Research Initiative (MORI) and through the funding of multicenter trials such as Prophylactic Antibiotic Regimens in Tumor Surgery (PARITY) and Surveillance After Extremity Tumor Surgery (SAFETY).

TABLE IV Histopathologic Diagnoses of Soft-Tissue Tumors (N = 88)

Soft-Tissue Tumor Subtype	No. of Tumors (%)
Lipoma	17 (19.3)
Undifferentiated pleomorphic sarcoma	11 (12.5)
Synovial sarcoma	6 (6.8)
Simple cyst	6 (6.8)
Myxoma	5 (5.7)
Myxofibrosarcoma	5 (5.7)
Neurilemmoma	5 (5.7)
Pigmented villonodular synovitis	5 (5.7)
Liposarcoma	4 (4.5)
Sarcoma, unspecified	4 (4.5)
Ganglion cyst	4 (4.5)
Chondromyxoid fibroma	3 (3.4)
Hemangioma	3 (3.4)
Giant cell tumor of the tendon sheath	2 (2.3)
Popliteal cyst	2 (2.3)
Synovial chondromatosis	2 (2.3)
Angiosarcoma	1 (1.1)
Fibrosarcoma	1 (1.1)
Hemangiopericytoma	1 (1.1)
Sweat gland carcinoma	1 (1.1)

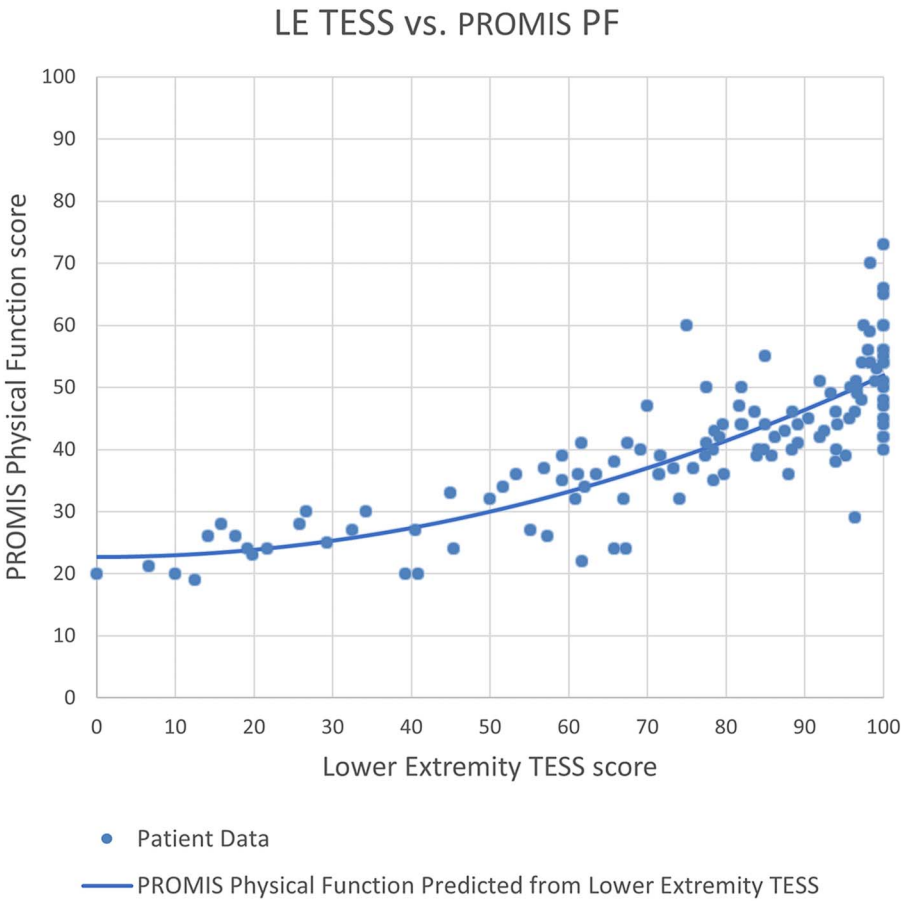

Fig. 1

Scatterplot showing scores for LE TESS compared with PROMIS PF. The 2 measures had a very strong positive correlation (r = 0.83). A relationship between these 2 metrics was represented with the following equation: $PROMIS\ PF = 0.00294 \times (LE\ TESS)^2 + 22.6$.

The need for multi-institutional research collaboration has also been emphasized in the context of PROs, yet inconsistency in the measures that are utilized across institutions remains a limitation[19]. PROs of function among patients with lower-extremity soft-tissue sarcomas were investigated in a systematic review by Kask et al., who demonstrated that TESS was utilized in 43% of the studies and that the MSTS score was utilized in 32%[8]. A total of 8 other previously reported measures were utilized in the remaining 25% of studies[8]. The use of such a wide variety of PRO measures in musculoskeletal oncology has made comparing and interpreting data between systems difficult. Ultimately, combining TESS and PROMIS data could generate the statistical power necessary to perform more definitive clinical studies and meta-analyses.

Both TESS and PROMIS are highly relevant in the field of orthopaedic oncology. TESS is currently the most widespread PRO measure in patients with musculoskeletal tumors of the extremities, and it has been validated in multiple countries as well as in both adult and pediatric patients[20-25]. Switching to a new system such as PROMIS would, on some level, disrupt the continuity of patient care and research databases; additionally, the implementation of PROMIS collection specifically may be hindered by logistical and financial barriers related to its electronic method of administration. The strengths of PROMIS include improved efficiency, reduced floor and ceiling effects, application across subspecialties, and ease of data collection and analysis. It also offers more specific information by providing individual scores for each domain, whereas TESS provides a single score encompassing all aspects of disability associated with musculoskeletal tumors. The use of both TESS and PROMIS systems in orthopaedic oncology will likely continue into the foreseeable future, making the need for a conversion model between them even more critical.

Patient and Tumor Characteristics in LE TESS and PROMIS PF and PI

We observed several associations between PRO scores and relevant clinicopathological variables. The effect of such characteristics on scores for the TESS has been investigated in several studies; however, the effect on PROMIS is incompletely understood in the context of musculoskeletal oncology. Wright et al. reported that social deprivation had no impact on PROMIS PF, PI, Depression, or Anxiety scores among patients with orthopaedic oncologic conditions[26]. In the present study,

JBJS Open Access • 2023:e23.00011.

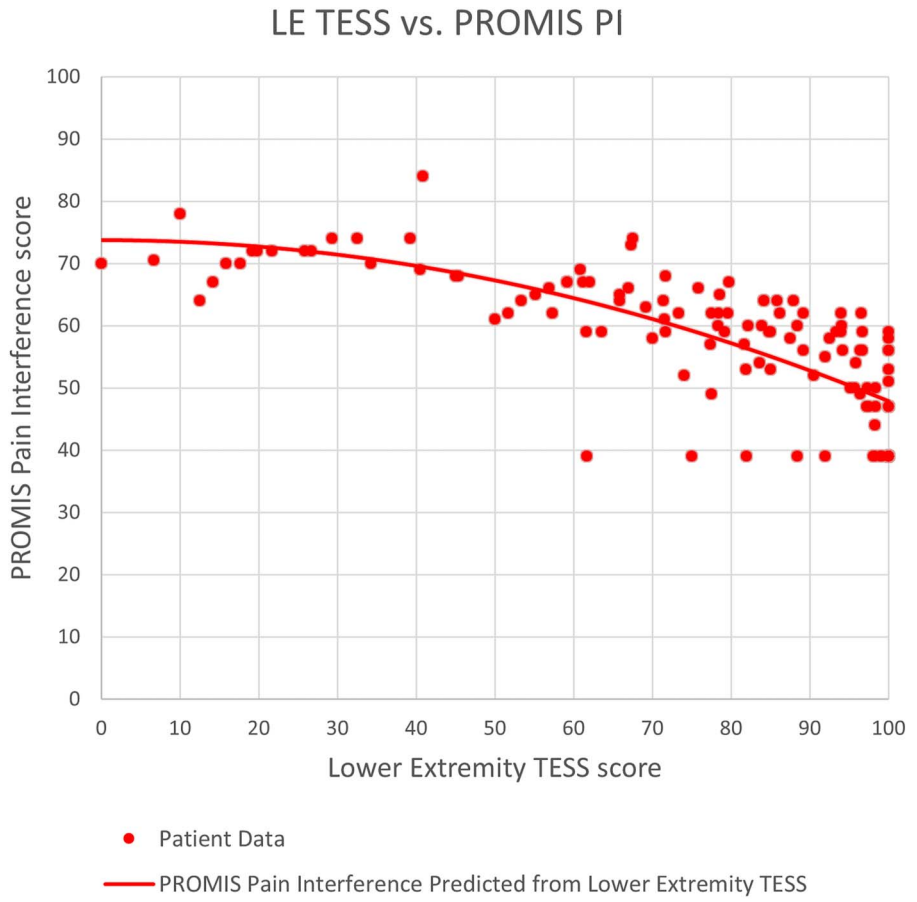

Fig. 2

Scatterplot showing scores for LE TESS compared with PROMIS PI. The 2 measures had a strong negative correlation ($r = -0.77$). A relationship between these 2 metrics was represented with the following equation: $PROMIS\ PI = -0.00259 \times (LE\ TESS)^2 + 73.8$.

we have added to the current understanding of the PROMIS by investigating the effects of additional patient characteristics (i.e., gender and age) and tumor characteristics (i.e., tissue type, location, primary compared with metastatic, and benign compared with malignant) on PROMIS PF and PI scores in patients with a musculoskeletal oncology condition.

We found that scores for LE TESS and PROMIS PF and PI were not impacted by gender or tumor location within the lower extremity. The effect of gender on the LE TESS has been variably reported in the literature, with 1 study demonstrating that female gender is associated with worse postoperative scores[7] but other studies demonstrating that gender differences do not exist[27-29]. However, the effect of tumor location within the lower extremity has not been previously reported. In the present study, PROMIS PF and PROMIS PI did capture other differences, such as those related to age and tumor type, that would be expected on the basis of existing literature. Older age and bone tumors (compared with soft-tissue tumors) have been associated with lower scores for the TESS[7,28]. In our population, we observed the same relationships for PROMIS PF, but the association between older age and greater disability did not reach significance for LE TESS, suggesting that PROMIS PF may be more sensitive for this measurement. PROMIS PI scores were higher in patients with a bone tumor, which was expected given the multiple factors that contribute to tumor-induced bone pain[30]. Consistent with a study by Dalton et al., we found that scores for PROMIS PF and LE TESS were worse in patients with a malignant tumor, whereas PROMIS PI scores did not differ between patients with a benign tumor and those with a malignant tumor[31]. Finally, patients with metastatic cancer reported lower physical function on both LE TESS and PROMIS PF, as well as higher levels of pain on PROMIS PI, than patients with nonmetastatic cancer. These findings confirm that PROMIS is able to capture differences between clinically relevant subgroups.

Limitations

Our study had several limitations. Our data only included preoperative scores obtained at a clinical visit with a variable length of time until surgery. Our purpose was to compare matched scores for LE TESS and PROMIS that were collected simultaneously, making consistent timing between patients less relevant; however, it is possible that our findings would have been different if we had included postoperative scores. Previous

studies have identified similar demographic and oncologic factors that influence postoperative scores for TESS and PROMIS PF in patients with lower-extremity musculoskeletal tumors. Female gender, older age, higher body mass index, history of smoking, and having a bone (compared with soft-tissue) lesion were associated with worse postoperative scores in LE TESS in patients who underwent limb-salvage surgery for bone and soft-tissue sarcoma[7]. Similarly, worse early postoperative PROMIS PF scores were seen in patients with older age and female gender, and in those with malignant tumors[31]. Although these parallels suggest that scores for LE TESS and PROMIS after surgery are correlated, high-powered studies with longitudinal data are needed to determine whether the conversion equations that we have proposed remain accurate in the postoperative setting.

Lastly, to our knowledge, there is no established threshold for clinically relevant change in the PROMIS scores of patients with an orthopaedic oncologic condition. The minimal clinically important difference (MCID), or the smallest difference in scores that has implications for patient care[32], has previously been calculated for LE TESS[33] as well as for PROMIS in other medical fields[13,17,34]. Calculating the PROMIS MCID in our patient population was beyond the scope of our study, but further investigation could allow greater understanding of the relative sensitivities of the 2 different PROMIS measures.

Conclusions

PROMIS PF and PI scores were strongly correlated with scores for LE TESS, suggesting that they measure similar information in patients with an orthopaedic oncologic condition. Score conversion between LE TESS and PROMIS PF can be estimated with the equation

$$\textit{PROMIS Physical Function} = 0.00294 * (\textit{LE TESS})^2 + 22.6 \ (r = 0.83)$$

whereas conversion between LE TESS and PROMIS PI can be estimated with the equation

$$\textit{PROMIS Pain Interference} = -0.00259 * (\textit{LE TESS})^2 + 73.8 \ (r = -0.77)$$

Moreover, the 3 measures consistently captured clinically relevant differences between subgroups, such as differences in patient pain and physical function depending on whether the tumor involved bone compared with soft tissue, primary compared with metastatic, and benign compared with malignant. Understanding the relationship between TESS and PROMIS will allow comparison and combination of data for both clinical and research purposes. Future investigations should be designed to confirm whether these relationships persist in the postoperative setting as well as in the upper extremity. ■

Julie Jin, MD[1]
Zachery Hong, MD, MPHS[1]
Lee Rhea, PhD[2]
Douglas J. McDonald, MD[1]
Regis J. O'Keefe, MD, PhD[1]
Cara A. Cipriano, MD, MSc[3]

[1]Division of Musculoskeletal Oncology, Department of Orthopaedic Surgery, Washington University School of Medicine in St. Louis, St. Louis, Missouri

[2]Division of Biostatistics, Washington University School of Medicine in St. Louis, St. Louis, Missouri

[3]Division of Orthopaedic Oncology, Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, Pennsylvania

Email for corresponding author: Cara.Cipriano@pennmedicine.upenn.edu

References

1. Janssen SJ, van Rein EAJ, Paulino Pereira NR, Raskin KA, Ferrone ML, Hornicek FJ, Lozano-Calderon SA, Schwab JH. The Discrepancy between Patient and Clinician Reported Function in Extremity Bone Metastases. Sarcoma. 2016; 2016:1014248.

2. Basch E, Abernethy AP, Mullins CD, Reeve BB, Smith ML, Coons SJ, Sloan J, Wenzel K, Chauhan C, Eppard W, Frank ES, Lipscomb J, Raymond SA, Spencer M, Tunis S. Recommendations for incorporating patient-reported outcomes into clinical comparative effectiveness research in adult oncology. J Clin Oncol. 2012 Dec 1; 30(34):4249-55.

3. Cella D, Choi S, Garcia S, Cook KF, Rosenbloom S, Lai JS, Tatum DS, Gershon R. Setting standards for severity of common symptoms in oncology using the PROMIS item banks and expert judgment. Qual Life Res. 2014 Dec;23(10):2651-61.

4. Chen RE, Papuga MO, Nicandri GT, Miller RJ, Voloshin I. Preoperative Patient-Reported Outcomes Measurement Information System (PROMIS) scores predict postoperative outcome in total shoulder arthroplasty patients. J Shoulder Elbow Surg. 2019 Mar;28(3):547-54.

5. Chen RE, Papuga MO, Voloshin I, Nicandri GT, Goldblatt JP, Bronstein RD, Rouse LM, Maloney MD. Preoperative PROMIS Scores Predict Postoperative Outcomes After Primary ACL Reconstruction. Orthop J Sports Med. 2018 May 8;6(5): 2325967118771286.

6. Gressel GM, Dioun SM, Richley M, Lounsbury DW, Rapkin BD, Isani S, Nevadunsky NS, Kuo DYS, Novetsky AP. Utilizing the Patient Reported Outcomes Measurement Information System (PROMIS®) to increase referral to ancillary support services for severely symptomatic patients with gynecologic cancer. Gynecol Oncol. 2019 Mar;152(3):509-13.

7. Heaver C, Isaacson A, Gregory JJ, Cribb G, Cool P. Patient factors affecting the Toronto Extremity Salvage Score following limb salvage surgery for bone and soft tissue tumors. J Surg Oncol. 2016 Jun;113(7):804-10.

8. Kask G, Barner-Rasmussen I, Repo JP, Kjäldman M, Kilk K, Blomqvist C, Tukiainen EJ. Functional Outcome Measurement in Patients with Lower-Extremity Soft Tissue Sarcoma: A Systematic Literature Review. Ann Surg Oncol. 2019 Dec; 26(13):4707-22.

9. Ploetze KL, Dalton JF, Calfee RP, McDonald DJ, O'Keefe RJ, Cipriano CA. Patient-Reported Outcomes Measurement Information System physical function correlates with Toronto Extremity Salvage Score in an orthopaedic oncology population. J Orthop Translat. 2019 Mar 8;19:143-50.

10. Döring AC, Nota SPFT, Hageman MGJS, Ring DC. Measurement of upper extremity disability using the Patient-Reported Outcomes Measurement Information System. J Hand Surg Am. 2014 Jun;39(6):1160-5.

11. Kortlever JTP, Janssen SJ, van Berckel MMG, Ring D, Vranceanu AM. What Is the Most Useful Questionnaire for Measurement of Coping Strategies in Response to Nociception? Clin Orthop Relat Res. 2015 Nov;473(11):3511-8.

12. Janssen SJ, Paulino Pereira NR, Raskin KA, Ferrone ML, Hornicek FJ, van Dijk CN, Lozano-Calderón SA, Schwab JH. A comparison of questionnaires for assessing physical function in patients with lower extremity bone metastases. J Surg Oncol. 2016 Nov;114(6):691-6.

13. Hung M, Saltzman CL, Kendall R, Bounsanga J, Voss MW, Lawrence B, Spiker R, Brodke D. What Are the MCIDs for PROMIS, NDI, and ODI Instruments Among Patients With Spinal Conditions? Clin Orthop Relat Res. 2018 Oct; 476(10):2027-36.

14. Brodke DJ, Saltzman CL, Brodke DS. PROMIS for Orthopaedic Outcomes Measurement. J Am Acad Orthop Surg. 2016 Nov;24(11):744-9.

15. Garcia SF, Cella D, Clauser SB, Flynn KE, Lad T, Lai JS, Reeve BB, Smith AW, Stone AA, Weinfurt K. Standardizing patient-reported outcomes assessment in cancer clinical trials: a Patient-Reported Outcomes Measurement Information System initiative. J Clin Oncol. 2007 Nov 10;25(32):5106-12.

16. Rothrock NE, Cook KF, O'Connor M, Cella D, Smith AW, Yount SE. Establishing clinically-relevant terms and severity thresholds for Patient-Reported Outcomes Measurement Information System® (PROMIS®) measures of physical function, cognitive function, and sleep disturbance in people with cancer using standard setting. Qual Life Res. 2019 Dec;28(12):3355-62.

17. Yost KJ, Eton DT, Garcia SF, Cella D. Minimally important differences were estimated for six Patient-Reported Outcomes Measurement Information System-Cancer scales in advanced-stage cancer patients. J Clin Epidemiol. 2011 May;64(5):507-16.

18. Evans JD. Straightforward Statistics for the Behavioral Sciences. Pacific Grove: Brookes/Cole; 1995.

19. O'Connor DP. CORR Insights®: A Crosswalk Between UCLA and Lower Extremity Activity Scales. Clin Orthop Relat Res. 2017 Feb;475(2):549-51.

20. Piscione J, Barden W, Barry J, Malkin A, Roy T, Sueyoshi T, Mazil K, Salomon S, Dandachli F, Griffin A, Saint-Yves H, Giuliano P, Gupta A, Ferguson P, Scheinemann K, Ghert M, Turcotte RE, Lafay-Cousin L, Werier J, Strahlendorf C, Isler M, Mottard S, Afzal S, Anderson ME, Hopyan S. The Pediatric Toronto Extremity Salvage Score (pTESS): Validation of a Self-reported Functional Outcomes Tool for Children with Extremity Tumors. Clin Orthop Relat Res. 2019 Sep;477(9):2127-41.

21. Xu L, Sun M, Sun W, Qin X, Zhu Z, Wang S. Cross-cultural adaptation and validation of the Chinese version of Toronto Extremity Salvage Score for patients with extremity sarcoma. Springerplus. 2016 Jul 19;5(1):1118-23.

22. Willeumier JJ, van der Wal CWPG, van der Wal RJP, Dijkstra PDS, Vliet Vlieland TPM, van de Sande MAJ. Cross-Cultural Adaptation, Translation, and Validation of the Toronto Extremity Salvage Score for Extremity Bone and Soft Tissue Tumor Patients in Netherlands. Sarcoma. 2017;2017:6197525.

23. Kim HS, Yun J, Kang S, Han I. Cross-cultural adaptation and validation of the Korean Toronto Extremity Salvage Score for extremity sarcoma. J Surg Oncol. 2015 Jul;112(1):93-7.

24. Rossi L, Boffano M, Comandone A, Ferro A, Grignani G, Linari A, Pellegrino P, Piana R, Ratto N, Davis AM. Validation process of Toronto Exremity Salvage Score in Italian: A quality of life measure for patients with extremity bone and soft tissue tumors. J Surg Oncol. 2020 Mar;121(4):630-7.

25. Davis AM, Wright JG, Williams JI, Bombardier C, Griffin A, Bell RS. Development of a measure of physical function for patients with bone and soft tissue sarcoma. Qual Life Res. 1996 Oct;5(5):508-16.

26. Wright MA, Adelani M, Dy C, O'Keefe R, Calfee RP. What is the Impact of Social Deprivation on Physical and Mental Health in Orthopaedic Patients? Clin Orthop Relat Res. 2019 Aug;477(8):1825-35.

27. Davis AM, Sennik S, Griffin AM, Wunder JS, O'Sullivan B, Catton CN, Bell RS. Predictors of functional outcomes following limb salvage surgery for lower-extremity soft tissue sarcoma. J Surg Oncol. 2000 Apr;73(4):206-11.

28. Clayer M, Doyle S, Sangha N, Grimer R. The Toronto Extremity Salvage Score in unoperated controls: an age, gender, and country comparison. Sarcoma. 2012; 2012:717213.

29. Gazendam AM, Schneider P, Heels-Ansdell D, Bhandari M, Busse JW, Ghert M. Predictors of Functional Recovery among Musculoskeletal Oncology Patients Undergoing Lower Extremity Endoprosthetic Reconstruction. Curr Oncol. 2022 Oct 13;29(10):7598-606.

30. Jimenez-Andrade JM, Mantyh WG, Bloom AP, Ferng AS, Geffre CP, Mantyh PW. Bone cancer pain. Ann N Y Acad Sci. 2010 Jun;1198(1):173-81.

31. Dalton JF, Furdock R, Cluts L, Jilakara B, Mcdonald D, Calfee R, Cipriano C. Preoperative and Postoperative Patient-Reported Outcome Measurement Information System Scores in Patients Treated for Benign Versus Malignant Soft Tissue Tumors. Cureus. 2022 May 31;14(5):e25534.

32. Wyrwich KW, Bullinger M, Aaronson N, Hays RD, Patrick DL, Symonds T; Clinical Significance Consensus Meeting Group. Estimating clinically significant differences in quality of life outcomes. Qual Life Res. 2005 Mar;14(2): 285-95.

33. Ogura K, Uehara K, Akiyama T, Shinoda Y, Iwata S, Tsukushi S, Kobayashi E, Hirose T, Yonemoto T, Endo M, Tanzawa Y, Nakatani F, Kawano H, Tanaka S, Kawai A. Minimal clinically important differences in Toronto Extremity Salvage Score for patients with lower extremity sarcoma. J Orthop Sci. 2020 Mar;25(2): 315-8.

34. Hung M, Baumhauer JF, Licari FW, Voss MW, Bounsanga J, Saltzman CL. PROMIS and FAAM Minimal Clinically Important Differences in Foot and Ankle Orthopedics. Foot Ankle Int. 2019 Jan;40(1):65-73.