Performance of PROMIS Physical Function, Pain Interference, and Depression Computer Adaptive Tests Instruments in Patients Undergoing Meniscal Surgery

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Purpose: To compare the performance of the Patient-Reported Outcomes Measurement Information System (PROMIS) physical function (PF), pain interference (PIF), and depression computer adaptive tests (CAT) relative to legacy instruments in patients undergoing meniscal surgery. Methods: Patients scheduled to undergo meniscal surgery completed legacy knee function PROMs (International Knee Documentation Committee [IKDC]), Knee Injury and Osteoarthritis Outcome Score (KOOS) subscores), Marx Activity Rating Scale (MARS), Veterans-Rand 12 (VR12), Short Form 12 (SF12), and the Brief Resilience Scale (BRS) alongside PROMIS PF, PIF, and Depression preoperatively. Spearman rank correlations were calculated, and score distributions were examined for floor and ceiling effects. Results: 152 patients (46.6 ± 14.9 years, 67.1% male) completed PROMs for appropriate inclusion. PROMIS PF yielded high-moderate to high correlations with the IKDC and KOOS subscales (r = 0.61 to 0.73), demonstrating similar performance to the IKDC. PROMIS PIF demonstrated moderately high-moderate to high correlations with the IKDC, KOOS subscales, VR-12 Physical Component Score (PCS), and SF12 PCS (r = 0.62 to 0.71), performing comparably to KOOS Pain (r = 0.55 to 0.92). PROMIS Depression demonstrated moderate to high-moderate correlations with the mental health legacies (r = 0.46 to 0.66). Significant ceiling effects were observed for MARS (n = 29, 18.8%), and significant floor effects were exhibited by PROMIS Depression (n = 38, 25%) and MARS (n = 27, 17.6%). Conclusion: The PROMIS PF, PIF CAT, and Depression instruments exhibit comparable performance profiles relative to legacy knee PROMs. PROMIS PF and PIF demonstrated no floor and ceiling effects, whereas PROMIS Depression exhibited a significant relative floor effect. PROMIS PF and PIF may be appropriately used to establish functional baselines preoperatively. Level of Evidence: IV, diagnostic case series.

As health care experts and policy makers continue to examine value within the American health care system, patient-reported outcome (PRO) data are increasingly used in the orthopedic literature to assess clinical outcomes and gauge the effectiveness of surgical interventions.1–3 Numerous patient-reported outcome

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measures (PROMs) have been developed to evaluate various health domains, including function, mental health, pain, and health-related quality of life (HRQoL). Although the increase in PROMs has helped ensure thoroughness of assessment, important secondary limitations such as a lack of standardization have led to large variability in the PROMs selected to assess health states. Furthermore, each new instrument developed must be evaluated in each population of interest such that acceptable correlational strengths are confirmed.

The National Institutes of Health developed the Patient Reported Outcomes Management Information System (PROMIS) in an effort to unify instrument selection across research disciplines with a single, multidomain PROM. Integrating computer adaptive testing (CAT) and item response theory (IRT), PROMIS offers distinct advantages compared with traditional legacy instruments, including decreased question burden and time-to-completion, high instrument responsiveness, and the potential for early responsivity compared with traditional outcome instruments. As PROMIS measures continue to be introduced in new orthopedic disciplines, continued evaluation in specific patient populations before widespread adoption is essential.

Although the performance of the PROMIS PF CAT has previously been examined in meniscal surgery, the comparative performance of the PF CAT relative to gold standard function PROMs has yet to be established. Furthermore, the performance of PROMIS PIF and Depression has yet to be established in meniscal surgery.

In addition to correlations with legacy instruments, the presence of ceiling and floor effects can reduce instrument sensitivity, as variations in score above a ceiling or below a floor in any specific population of patients will remain undetected. This can have important implications in the utility of PROM instruments.

The purpose of this study is to compare the performance of PROMIS PF, PIF, and Depression relative to legacy instruments in patients undergoing meniscal surgery. We hypothesized that (1) PROMIS CAT scores based on physical function (PF) and pain interference (PI) would show strong correlations with the legacy functional and HRQoL PROMs comparable to the accepted standard, the International Knee Documentation Committee (IKDC) form and the Knee Injury and Osteoarthritis Outcome Score (KOOS) pain, respectively; (2) PROMIS Depression would correlate strongly with traditional mental health legacies such as the Brief Resilience Scale (BRS) and the Veterans-Rand 12 (VR12)/Short Form 12 (SF12) Mental Health Component Score (MCS); and (3) all PROMIS measures would exhibit fewer floor and ceiling effects than legacy scores.

### Methods

#### Study Design and Patient Selection

Power analysis performed assuming a 2-sided test, with a type I error rate of 5%, estimated that a sample size of 36 would provide 80% power to distinguish a correlation of 0.6 (good) from 0.2 (poor) when measuring the correlation between the PROMIS CAT and legacy instruments. PRO data were collected between January 2018 and January 2019 across 4 sports surgeons using a prospectively maintained institutional registry (Outcome Based Electronic Research Database; Universal Research Solutions, Columbia, MO). Inclusion criteria included full completion of preoperative PROMs and receipt of either an arthroscopic partial meniscectomy or arthroscopic meniscal repair. Patients without full PROM completion; those receiving significant concomitant procedures, including osteotomy, anterior cruciate ligament reconstruction, osteochondral allograft transplantation, or biological augmentation; patients with grade 2 MCL tears; and patients with grade 4 osteoarthritis on the Outerbridge Classification found on arthroscopy were excluded. Demographics and preoperative variables were collected inclusive of age and sex. Intraoperative variables collected by trained research assistants at the time of operation included the type and location of meniscal pathology as well as the presence of arthritis as seen on arthroscopy reported by the operating surgeon.

#### Patient-Reported Outcome Measures

The legacy PROMs of interest in this study include the BRS, Marx Activity Ratings Scale (MARS), VR12, SF12, Knee Injury and Osteoarthritis Outcome Score (KOOS) subscales include Joint Replacement (JR), Physical Function (PS), Symptoms (Sx), Pain, Activities of Daily Living (ADL), Sport, and Quality of Life (QoL) and the IKDC score. The PROMIS instruments of interest include the PROMIS Physical Function (PF CAT), Pain Interference (PIF CAT), and Depression CAT. KOOS PS, as well as the PIF and Depression CATs, are scored in an inverted scale with higher scores correlating to worse clinical status. Questionnaires were administered in the following order: KOOS components, MARS, VR/SF-12, PF CAT, PIF CAT, Depression CAT, and IKDC.

#### Statistical Analysis

PROM scores were evaluated with a Shapiro-Wilk test for normality. Spearman rank correlations were calculated between the PROMIS CATs and the legacy PROMs, with \( r \) values of 0 to 0.3 indicating weak correlation; 0.31 to 0.39, moderate-weak correlation; 0.4 to 0.6, moderate correlation; 0.61 to 0.69, high-moderate correlation; and \( \geq 0.70 \), high correlation. Floor and ceiling effects were
evaluated. Absolute floor and ceiling effects were considered significant if ≥15% of patients scored the absolute minimum or maximum possible scores on each measure, respectively. Relative effects were considered significant if ≥15% of patients scored the highest and lowest available score within the score distribution. Subgroup analyses were performed to identify demographic variables contributing to significant ceiling and floor effects. Continuous variables were compared with Welch’s t test, and categorical variables were compared using Mann-Whitney U test. All statistical analysis was performed using RStudio software version 1.0.143 (R Foundation for Statistical Computing, Vienna, Austria).

Results
There were 237 patients available for eligibility screening. Of these, patients without full PROM completion (n = 68, 29%), those receiving significant concomitant procedures (eg, osteotomy, biological augmentation, anterior cruciate ligament reconstruction) (n = 12, 5%), and those with grade 4 arthritis on arthroscopy (5, 2%) were excluded. A total of 152 patients (102, 67.1% male) with a mean (± standard deviation) age of 46.6 ± 14.9 years met inclusion criteria. The mean follow-up was 12 weeks (range 2 to 30). A total of 134 patients underwent partial meniscectomy (89.2%), and 18 underwent meniscal repair (11.8%). Of the partial meniscectomy patients, 98 (64.5%) patients underwent partial medial meniscectomy, 33 patients underwent partial lateral meniscectomy (21.7%), and 21 patients underwent bilateral partial meniscectomy (13.8%) (Table 1).

Respondents answered an average of 4.19, 4.23, and 4.23 questions on completing the PF, PIF, and Depression CATs, respectively. By comparison, 12 questions were required to complete the VR/SF-12, 42 items to complete the KOOS, and 19 items for the IKDC questionnaire. Average time to completion was ≤1.5 minutes for the PF, PIF, and Depression CAT, whereas average completion time for the IKDC, KOOS, and MARS were all ≥3.5 minutes. The BRS required 1.5 minutes to complete, comparable to the PROMIS CAT. Mean preoperative scores were 41.3 ± 6.78 for the PF CAT, 59.8 ± 6.74 for the PIF CAT, and 45.3 ± 8.45 for the Depression CAT (Table 2). Preoperative scores on legacy instruments are also provided in Table 2.

The PF CAT exhibited high correlations with the KOOS Sport and Recreational, KOOS PS, and IKDC (r = 0.70 to 0.73). Significant high-moderate correlations were demonstrated relative to KOOS Pain, KOOS JR, VR-12 PCS, SF12 PCS, and KOOS QoL (0.61 to 0.68). Overall, the PF CAT demonstrated 5 high-moderate to high correlations, comparable to the IKDC measure (Tables 3 and 4).

The PIF CAT demonstrated significant high correlations with IKDC and KOOS ADL (r = −0.71) and significant high-moderate correlations with KOOS PS, KOOS Pain, KOOS JR, VR-12 PCS, and SF12 PCS (r = 0.62 to 0.69). Overall, the PIF CAT demonstrated 7 high-moderate to high correlations with legacies.

Table 1. Patient Demographics and Tear Characteristics, Meniscal Surgery Group (n = 152)

| Variable                        | Value         |
|---------------------------------|---------------|
| Demographic variables           |               |
| Age (y)                         | 46.6 ± 14.9   |
| Male sex                        | 102 (67.1)    |
| Right side                      | 78 (51.3)     |
| Intraoperative and tear         |               |
| characteristics                 |               |
| Type of surgery                 |               |
| Meniscectomy                    | 134 (89.2)    |
| Meniscal repair                 | 18 (11.8)     |
| Tear location                   |               |
| Both                            | 21 (13.8)     |
| Medial                          | 98 (64.5)     |
| Lateral                         | 33 (21.7)     |
| Tear type                       |               |
| Horizontal cleavage             | 13 (8.55)     |
| Oblique                         | 4 (2.63)      |
| Peripheral                      | 7 (4.61)      |
| Degenerative                    | 34 (22.4)     |
| Flap Tear                       | 9 (5.92)      |
| Radial                          | 25 (16.45)    |
| Complex                         | 29 (19.1)     |
| Root Tear                       | 15 (9.87)     |
| Bucket Handle                   | 4 (2.63)      |
| Vertical                        | 12 (7.89)     |

Data are mean ± standard deviation or n (%).

Table 2. Preoperative Scores and Time to Complete Each PROM Instrument

| Instrument            | Baseline Score | Time to Complete (min) |
|-----------------------|----------------|------------------------|
| BRS                   | 3.98 ± 0.63    | 1.5 ± 2.8              |
| MARS                  | 8.32 ± 6.02    | 4.9 ± 1.4              |
| VR-12 MCS             | 57.2 ± 8.37    | 3.5 ± 7.1              |
| VR-12 PCS             | 39.8 ± 9.52    |                        |
| SF12 MCS              | 54.4 ± 9.07    |                        |
| SF12 PCS              | 37.8 ± 9.36    |                        |
| IKDC                  | 42.8 ± 16.2    | 4.5 ± 3.2              |
| KOOS Symptoms         | 57.9 ± 20.1    | 6.7 ± 5.7              |
| KOOS Pain             | 55.3 ± 20.4    |                        |
| KOOS ADL              | 63.1 ± 21.5    |                        |
| KOOS Sports           | 33.2 ± 24.1    |                        |
| KOOS QoL              | 29.7 ± 20.6    |                        |
| KOOS JR               | 55.9 ± 17.1    |                        |
| KOOS PS               | 41.8 ± 16.1    |                        |
| PF CAT                | 41.3 ± 6.78    | 1.5 ± 0.78             |
| PIF CAT               | 59.8 ± 6.74    | 1.5 ± 0.95             |
| Depression CAT        | 45.3 ± 8.45    | 1.2 ± 1.34             |

Data are mean ± standard deviation. Abbreviations: ADL, activities of daily living; BRS, Brief Resilience Score; CAT, computer adaptive testing; IKDC, International Knee Documentation Committee; JR, joint reconstruction; KOOS, Knee Injury and Osteoarthritis Outcome Score; MARS, Marx Activity Ratings Scale; MCS, Mental Component Score; PCS, Physical Component Score; PF, physical function; PIF, pain interference; PS, physical symptoms; QoL, quality of life; SF12, Short-Form 12; VR12, Veteran Rand.
The Depression CAT also demonstrated high-moderate to high correlations with mental health legacies. Second, significant ceiling and floor effects were observed on the MARS, and a significant floor effect was observed on the depression CAT. Finally, subgroup analysis found age to be significantly associated with those who achieved the ceiling/floor effect on the MARS. Preoperatively, high-moderate to high correlation was observed between the PF CAT and HRQoL and dedicated lower extremity function instruments, in agreement with extensive evidence from previous studies correlating the PF CAT with legacy instruments in other lower extremity pathology or sports injuries. Among legacy instruments, the KOOS sports and recreational activities component has consistently demonstrated remarkable agreement with the PF CAT, and we found it to have the strongest correlation in our group. Studies in shoulder instability and meniscal surgery made similar observations. However, these studies have not directly examined the correlation strengths of the PF CAT with the legacy gold standard. Side-by-side comparisons in this study demonstrated equal numbers of high to high moderate correlations with legacies between the PROMIS CATs and the IKDC, the VAS pain, and the VR/SF12 MCS in patients undergoing meniscal surgery, which further supports its implementation as a more efficient and equivalently sensitive approach.

### Discussion

The principle findings of this study were as follows. First, patients undergoing meniscal surgery reported PROMIS PF CAT and PIF CAT scores that demonstrated high-moderate to high correlations with functional and HRQoL legacies, respectively. The depression CAT also demonstrated high-moderate to high correlations with mental health legacies.

#### Table 3. Spearman Correlation Coefficients Between the PF CAT, the PIF CAT, the Depression CAT, and Physical Function, HRQoL, and Mental Health Legacies

| Instrument          | PF CAT Correlation | Strength | PIF CAT Correlation | Strength | Depression CAT Correlation | Strength |
|---------------------|--------------------|----------|---------------------|----------|---------------------------|----------|
|                     |                    |          |                     |          |                           |          |
| MARS                | 0.21               | Weak     | −0.09               | Weak     | 0.006                     | Weak     |
| KOOS Sport          | 0.70               | High     | −0.57               | Moderate | −0.19                     | Weak     |
| KOOS PS             | −0.70              | High     | 0.64                | High-moderate | −0.21                  | Weak     |
| KOOS Symptoms       | 0.51               | Moderate | −0.52               | Moderate | −0.27                     | Weak     |
| KOOS Pain           | 0.64               | High-moderate | −0.69           | High-moderate | −0.21                  | Weak     |
| KOOS JR             | 0.67               | High     | −0.68               | High-moderate | −0.20                  | Weak     |
| IKDC                | 0.73               | High     | −0.71               | High     | −0.14                     | Weak     |
| VR-12 PCS           | 0.68               | High-moderate | −0.66           | High-moderate | −0.13                  | Weak     |
| SF12 PCS            | 0.65               | High-moderate | −0.62           | High-moderate | −0.06                  | Weak     |
| KOOS ADL            | 0.73               | High     | −0.71               | High     | −0.19                     | Weak     |
| KOOS QoL            | 0.61               | High-moderate | −0.54           | High-moderate | −0.27                  | Weak     |
| BR5                  | 0.03               | Weak     | −0.11               | Weak     | −0.46                     | Moderate-weak |
| VR-12 MCS           | 0.34               | Moderate-weak | −0.36           | Moderate-weak | −0.66                  | High-moderate |
| SF12 MCS            | 0.18               | Weak     | −0.21               | Weak     | −0.59                     | Moderate |
| PF CAT              | −0.69              | High-moderate | −0.17           | Weak     |                           |          |
| Depression CAT      | −0.17              | Weak     | 0.18                | Weak     |                           |          |

*Significant correlation, p < .05.

Abbreviations: ADL, activities of daily living; BRS, Brief Resilience Score; CAT, computer adaptive testing; HRQoL, health-related quality of life; IKDC, International Knee Documentation Committee; JR, joint reconstruction; KOOS, Knee Injury and Osteoarthritis Outcome Score; MARS, Marx Activity Ratings Scale; MCS, Mental Component Score; PCS, Physical Component Score; PF, physical function; PIF, pain interference; PS, physical symptoms; SF12, Short-Form 12; VR12, Veteran’s Rand.

Comparable to the KOOS Pain, which demonstrated 8 (Table 5). The Depression CAT demonstrated significant high-moderate correlation only with the VR-12 MCS (r = 0.66) (Table 6).

Analysis of floor and ceiling effects yielded significant absolute ceiling (n = 29, 18.8%) and floor (n = 27, 17.6%) effects on the MARS, and a significant relative floor effect (n = 38, 25%) on the Depression CAT at a score of 34.2 (Table 7). Subgroup analysis found that patients who reported the absolute minimum score on the MARS were found to be older than those who did not report minimal scores (55.8 ± 10.3 versus 44.9 ± 15.3, p = .001). Similarly, patients who reported the absolute maximum score on the MARS were younger than those who did not (39.3 ± 17 versus 49.0 ± 14.1, p = .045). Subgroup analysis found no significant differences between patients exhibiting a relative minimum score on the Depression CAT and those who reported nonminimal scores with respect to age, sex, or length of follow-up.
Table 4. Comparison of Spearman Correlation Coefficients With Function Legacies Between the PROMIS PF CAT and the AAOS Recommended IKDC Score

| Instrument   | PROMIS PF CAT | AAOS IKDC |
|--------------|---------------|-----------|
|              | Strength      | Strength  |
| MARS         | 0.21          | 0.26      |
| KOOS Sport   | 0.70          | 0.74      |
| KOOS PS      | -0.70         | -0.80     |
| KOOS Symptoms| 0.51          | 0.69      |
| KOOS Pain    | 0.64          | 0.82      |
| KOOS JR      | 0.67          | 0.82      |
| IKDC         | 0.73          | High-moderate |

Abbreviations: IKDC, International Knee Documentation Committee; JR, joint reconstruction; KOOS, Knee Injury and Osteoarthritis Outcome Score; MARS, Marx Activity Ratings Scale; PS, physical symptoms; r, Spearman correlation coefficient.

*Significant correlation, p < .05.

alternative. Nonetheless the effect of specific numerical differences in the strengths of correlations on clinical application is a worthy topic of future investigation.

High-moderate to high correlations were similarly observed between the PIF CAT and functional as well as HRQoL legacies. The PIF CAT has been implemented to measure and capture the impact of pain in a number of orthopedic surgery populations including knee arthroscopy, knee arthroplasty, foot and ankle surgery, and orthopedic oncology. Additionally, multiple studies in the literature have emerged to support the use of the PIF CAT as an important augmentation to capturing physical function in patients with pain.

Kendall et al. correlated the PIF CAT with the PF CAT in a population of patients presenting with spinal pain and concluded that the PIF CAT is a useful augmentation to physical function measures. A recent study by Kenney et al. evaluated the PF CAT and the PIF CAT in a group of patients undergoing knee arthroscopy and observed high-moderate to high correlations (0.61 to 0.79) between both the PF CAT and the PIF CAT and the IKDC. However, the study population was limited to 76 patients undergoing heterogeneous knee procedures, and the present study is the first examination of the PIF CAT specifically in a group of meniscal surgery patients.

Compared with the KOOS pain component score, the PIF CAT exhibited a comparable number of high-moderate to high correlations (8 for the KOOS pain versus 7 for the PIF CAT). These findings present the PIF CAT as a viable multidomain alternative to legacy pain measurements in capturing the physical, psychosocial, and mental effects of pain on patient well-being. Of the PROMIS domains evaluated in this study, the depression CAT remains relatively unexplored in sports medicine orthopedics. Driban et al. evaluated the construct validity and floor/ceiling effects of the Depression CAT, among other PROMIS domains, in a group of patients undergoing conservative interventions for knee osteoarthritis. Kollmorgen et al. evaluated the Depression CAT with legacy instruments in patients undergoing hip arthroscopy but were able to correlate it only with functional legacies; the authors also noted a relative floor effect (25%). In the study population, the Depression CAT demonstrated moderate to high-moderate correlations with the legacy mental health measures (VR-12 and SF12 MCS), and notably, an identical floor effect (25%).

Guattery et al. evaluated this floor effect in a sample of 77,211 orthopedic surgery patient visits and found that patients exhibiting the floor effect demonstrated significantly reduced seconds to completion compared with those who did not (4 ± 3 versus 7 ± 7), concluding that hasty completion by respondents may be responsible for this effect.

Consistent with the literature, the MARS demonstrated both significant ceiling (18.8%) and floor (17.6%) effects at baseline. Evidence of a significant ceiling effect limiting the use of MARS in the young and active population has also been shown. The present study found a significant difference in age of patients who achieved either the ceiling or the floor scores on the MARS, with older patients achieving the floor score and younger patients achieving the ceiling score. This observation suggests that the MARS may be of limited utility in differentiating baseline activity level for older patients as well.

Table 5. Performance Comparison Between PROMIS PIF CAT and the KOOS Pain Component

| Instrument     | PIF CAT | KOOS Pain |
|----------------|---------|-----------|
| Function legacies |         |           |
| MARS           | -0.09   | 0.17      |
| KOOS Sport     | -0.57   | 0.71      |
| KOOS PS        | 0.64    | -0.83     |
| KOOS Symptoms  | -0.52   | 0.79      |
| KOOS Pain      | -0.69   | High      |
| KOOS JR        | -0.68   | 0.95      |
| IKDC           | -0.71   | 0.82      |
| HRQoL legacies |          |           |
| VR-12 PCS      | -0.66   | High      |
| SF12 PCS       | -0.62   | 0.55      |
| KOOS ADL       | -0.71   | 0.86      |
| KOOS QoL       | -0.54   | 0.61      |
| Mental health legacies |       |           |
| BRS            | -0.11   | 0.10      |
| VR-12 MCS      | -0.36   | 0.41      |
| SF12 MCS       | -0.21   | 0.29      |

Abbreviations: ADL, activities of daily living; BRS, Brief Resilience Score; CAT, computer adaptive testing; HRQoL, health-related quality of life; IKDC, International Knee Documentation Committee; JR, joint reconstruction; KOOS, Knee Injury and Osteoarthritis Outcome Score; MARS, Marx Activity Ratings Scale; MCS, Mental Component Score; PCS, Physical Component Score; PF, physical function; PIF, pain interference; PS, physical symptoms; r, Spearman correlation coefficient; SF12, Short-Form 12; VR12, Veteran’s Rand.

*Significant correlation, p < .05.
The IRT nature of the PROMIS PF CAT suggests superiority over traditional instruments with respect to question burden, and an accumulating body of evidence provides support for this assertion by highlighting the reduced question load and increased responsiveness of the PF CAT in a variety of orthopedic patient populations. Hung et al. compared the PROMIS PF CAT with the short Musculoskeletal Function Assessment (SMFA) in the orthopedic trauma population and found that the PF CAT required a mean number of 4 responses and a mean time of 44 seconds to complete. A response requirement of ~4 questions with a mean time to completion ranging from 45 seconds to several minutes was similarly observed in multiple patient groups undergoing different orthopedic procedures. We observed an average of 4 responses over the course of 88 seconds to complete the PF CAT, consistent with the current literature. Compared with those observed for legacy measures from the present study as well as data from the literature for the KOOS (7 to 12 minutes), the IKDC (3 to 5 minutes), the SF12 (4 minutes), and the MARS (2 to 3 minutes), the PF CAT demonstrated clear superiority in both duration to completion and question burden. The BRS, while easily administered, does not correlate well with most PROMs because of its narrow domain focus.

These findings mark a substantial addition to the existing literature regarding the application of novel adaptive PROM instruments in the evaluation of preoperative patient health states. It demonstrates the PROMIS CATs to be of equal effectiveness to legacies, albeit with a more efficient usability profile, in those undergoing meniscal surgery. Future comparative evaluation of the multidomain PROMIS CATs against current legacies in other procedures can help identify viable alternatives that reduce question burden, optimize workflow, and improve patient satisfaction and value-based care.

### Limitations

Several limitations of our study should be considered in making an informed interpretation of our results. Our patient outcome collection system does not randomize

### Table 6. Performance Comparison Between PROMIS Depression CAT and Competing Mental Health Legacies

| Instrument    | Depression CAT | VR-12 MCS | SF12 MCS |
|---------------|----------------|-----------|----------|
|               | $r$            | Strength  | $r$      | Strength  | $r$      | Strength  |
| HRQoL         |                |           |          |           |          |          |
| VR-12 PCS     | $-0.13$        | Weak      | $0.39^*$ | Moderate-weak | $0.14$ | Weak   |
| SF12 PCS      | $-0.06$        | Weak      | $0.30^*$ | Moderate-weak | $0.02$ | Weak   |
| KOOS ADL      | $-0.19$        | Weak      | $0.37^*$ | Moderate-weak | $0.25^*$ | Weak   |
| KOOS QoL      | $-0.25^*$      | Weak      | $0.46$   | Moderate   | $0.25^*$ | Weak   |

### Table 7. Absolute Ceiling and Floor Effects

| Instrument    | Ceiling | Floor |
|---------------|---------|-------|
|               | $n$ | % | $n$ | % |
| Function      |       |    |     |    |
| PF CAT        | $1^*$ | $1.2$ | $1^*$ | $1.2$ |
| MARS          | $29^*$ | $18.8$ | $27$ | $17.6$ |
| KOOS Sports   | $1$ | $1.2$ | $9$ | $5.9$ |
| KOOS JR Score | $2$ | $2.4$ | $1$ | $1.2$ |
| KOOS PS Score | $1$ | $1.2$ | $3$ | $3.6$ |
| KOOS Symptoms Score | $1$ | $1.2$ | $1$ | $1.2$ |
| KOOS Pain Score | $2$ | $2.4$ | $1$ | $1.2$ |
| IKDC          | $1^*$ | $1.2$ | $1$ | $1.2$ |
| HRQoL         |       |    |     |    |
| VR-12 PCS     | $1^*$ | $1.2$ | $1^*$ | $1.2$ |
| SF12 PCS      | $1^*$ | $1.2$ | $1$ | $1.2$ |
| KOOS QoL      | $2$ | $2.4$ | $9$ | $5.0$ |
| KOOS ADL      | $6$ | $3.15$ | $1$ | $0.4$ |
| PIF CAT       | $1^*$ | $1.2$ | $3^*$ | $3.6$ |

### Mental Health

| VR-12 MCS     |       |    |     |    |
|               | $1^*$ | $1.2$ | $1^*$ | $1.2$ |
| SF12 MCS      | $1^*$ | $1.2$ | $1$ | $1.2$ |
| BRS           | $17$ | $11.2$ | $1^*$ | $1.2$ |
| Depression CAT | $1^*$ | $1.2$ | $3^*$ | $25^*$ |

Minimum and maximum values: PROMIS PF CAT, 20 to 80; KOOS components, VR/SF-12 PCS/MCS, defined as ± 3 SD; MARS, 0 to 16; IKDC, 0 to 100. Abbreviations: ADL, activities of daily living; BRS, Brief Resilience Score; CAT, computer adaptive testing; HRQoL, health-related quality of life; IKDC, International Knee Documentation Committee; JR, joint reconstruction; KOOS, Knee Injury and Osteoarthritis Outcome Score; MARS, Marx Activity Ratings Scale; MCS, Mental Component Score; PCS, Physical Component Score; PF, physical function; PIF, pain interference; QoL, quality of life; $r$, Spearman correlation coefficient; SF12, Short-Form 12; VR12, Veteran's Rand.

*Significant effects.

$^*$Relative floor effects, in cases where absolute minimum/maximum scores were not achieved.
questionnaire order, which may introduce question fatigue, as each patient completed the instruments in the same order. To be as inclusive as possible in selection of patients with meniscal tears, we included patients from multiple surgeons, as well as a small percentage of patients who underwent meniscal repair, which may introduce heterogeneity into postoperative outcomes. However, only preoperative PROMs were evaluated, and regardless of treatment, patients in previous investigations into meniscal surgeries have included both meniscectomy and repair. These findings come from a high-volume academic orthopedic institution and thus interpretation and application to smaller, community-based hospitals must be done with consideration of the population differences that exist. Additionally, while the IRT nature of the PROMIS CAT suggests adaptability across health and functional domains, the reality is that the PROMIS CATs remain limited by domain differences, and cross-coverage of pathologies is not advised. Furthermore, the domain-specific PROMIS CATs evaluated in this study may not adequately describe the patient’s health state as other more time-consuming legacies, such as the full roster of KOOS component scores, and physicians may risk sacrificing granularity for expedience.

Conclusions

The PROMIS PF, PIF CAT, and Depression instruments exhibit comparable performance profiles relative to legacy knee PROMs. PROMIS PF and PIF demonstrated no floor and ceiling effects, whereas PROMIS Depression exhibited a significant relative floor effect. PROMIS PF and PIF may be appropriately used to establish functional baselines preoperatively.

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References

1. Bushnell BD. Bundled payments in orthopedic surgery. Orthopedics 2015;38:128-135.
2. Hurwitz SR, Slawson D, Shaughnessy A. Orthopaedic information mastery: applying evidence-based information tools to improve patient outcomes while saving orthopaedists’ time. J Bone Joint Surg Am 2000;82:888-894.
3. Nwachukwu BU, Hamid KS, Bozic KJ. Measuring value in orthopaedic surgery. JBJS Rev 2013;1.
4. McHorney CA, Ware JE Jr, Raczek AE. The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and clinical tests of validity in measuring physical and mental health constructs. Med Care 1993;31:247-263.
5. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992;30:473-483.
6. Roos EM, Lohmander LS. The Knee Injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. Health Quality Life Outcomes 2003;1:64.
7. Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF. Development and evaluation of an activity rating scale for disorders of the knee. Am J Sports Med 2001;29:213-218.
8. Smith BW, Dalen J, Wiggins K, Tooley E, Christopher P, Bernard J. The brief resilience scale: assessing the ability to bounce back. Int J Behav Med 2008;15:194-200.
9. Makhni EC, Meadows M, Hamamoto JT, Higgins JD, Romeo AA, Verma NN. Patient Reported Outcomes Measurement Information System (PROMIS) in the upper extremity: the future of outcomes reporting? J Shoulder Elbow Surg 2017;26:352-357.
10. Makhni EC, Steinhaus ME, Morrow ZS, et al. Outcomes assessment in rotator cuff pathology: what are we measuring? J Shoulder Elbow Surg 2015;24:2008-2015.
11. Makhni EC, Meyer MA, Saltzman BM, Cole BJ. Comprehensiveness of outcome reporting in studies of articular cartilage defects of the knee. Arthroscopy 2016;32:2133-2139.
12. Anthony CA, Glass NA, Hancock K, Bollier M, Wolf BR, Hettrich CM. Performance of PROMIS instruments in patients with shoulder instability. Am J Sports Med 2017;45:449-453.
13. Sahinoglu E, Ergin G, Unver B. Psychometric properties of patient-reported outcome questionnaires for patients with musculoskeletal disorders of the shoulder. Knee Surg Sports Traumatol Arthrosc 2019;27:3188-3202.
14. Ponkilainen VT, Tukiainen EJ, Uimonen MM, Hakkinen AH, Repo JP. Assessment of the structural validity of three foot and ankle specific patient-reported outcome measures. Foot Ankle Surg 2019;26:169-174.
15. Gandek B, Roos EM, Franklin PD, Ware JE Jr. A 12-item short form of the Knee injury and Osteoarthritis Outcome Score (KOOS-12): tests of reliability, validity and responsiveness. Osteoarthritis Cartilage 2019;27:762-770.
16. Kahan JB, Kassam HF, Nicholson AD, Saad MA, Kovacevic D. Performance of PROMIS Global-10 to legacy instruments in patients with lateral epicondylitis. Arthroscopy 2019;35:770-774.
17. Cella D, Yount S, Rothrock N, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS): progress of an NIH Roadmap cooperative group during its first two years. Med Care 2007;45:S3-S11.
18. Garcia SF, Cella D, Clauer SB, et al. Standardizing patient-reported outcomes assessment in cancer clinical trials: a patient-reported outcomes measurement information system initiative. J Clin Oncol 2007;25:5106-5112.
19. Khanna D, Maranian P, Rothrock N, et al. Feasibility and construct validity of PROMIS and “legacy” instruments in an academic scleroderma clinic. Value Health 2012;15:128-134.
20. Senders A, Hanes D, Bourdette D, Whitham R, Shinto L. Reducing survey burden: feasibility and validity of PROMIS measures in multiple sclerosis. Mult Scler 2014;20:1102-1111.
21. 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.
22. Lee AC, Driban JB, Price LL, Harvey WF, Rodday AM, Wang C. Responsiveness and minimally important differences for 4 patient-reported outcomes measurement information system short forms: physical function, pain interference, depression, and anxiety in knee osteoarthritis. *J Pain* 2017;18:1096-1110.

23. Brodke DJ, Saltzman CL, Brodke DS. PROMIS for orthopaedic outcomes measurement. *J Am Acad Orthop Surg* 2016;24:744-749.

24. Dowdle SB, Glass N, Anthony CA, Hettrich CM. Use of PROMIS for patients undergoing primary total shoulder arthroplasty. *Orthop J Sports Med* 2017;5:2325967117726044.

25. Kadri O, Jildeh TR, Meldau JE, et al. How long does it take for patients to complete PROMIS scores? An assessment of PROMIS CAT questionnaires administered at an ambulatory sports medicine clinic. *Orthop J Sports Med* 2018;6:2325967118791180.

26. Bernholt D, Wright RW, Matava MJ, Brophy RH, Bogunovic L, Smith MV. Patient reported outcomes measurement information system scores are responsive to early changes in patient outcomes following arthroscopic partial meniscectomy. *Arthroscopy* 2018;34:1113-1117.

27. Lizzio VA, Blanchett J, Borowsky P, et al. Feasibility of PROMIS CAT administration in the ambulatory sports medicine clinic with respect to cost and patient compliance: a single-surgeon experience. *Orthop J Sports Med* 2019;7:2325967118821875.

28. 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* 2019;44:901.e1-901.e7.

29. Nicholson AD, Kassam HF, Pan SD, Berman JE, Blaine TA, Kovacevic D. Performance of PROMIS Global-10 compared with legacy instruments for rotator cuff disease. *Am J Sports Med* 2019;47:181-188.

30. Saad MA, Kassam HF, Suriani RJ Jr, Pan SD, Blaine TA, Kovacevic D. Performance of PROMIS Global-10 compared with legacy instruments in patients with shoulder arthritis. *J Shoulder Elbow Surg* 2018;27:2249-2256.

31. Hancock KJ, Glass N, Anthony CA, et al. Performance of PROMIS for healthy patients undergoing meniscal surgery. *J Bone Joint Surg Am* 2019;99:954-958.

32. Perruccio AV, Stefan Lohmander L, Canizares M, et al. The development of a short measure of physical function for knee OA KOS-Physical Function Shortform (KOS-PS): an OARSI/OMERACT initiative. *Osteoarthritis Cartilage* 2008;16:542-550.

33. Terwee CB, Bot SD, de Boer MR, et al. Quality criteria were proposed for measurement properties of health status questionnaires. *J Clin Epidemiol* 2007;60:34-42.

34. Driban JB, Morgan N, Price LL, Cook KF, Wang C. Patient-Reported Outcomes Measurement Information System (PROMIS) instruments among individuals with symptomatic knee osteoarthritis: a cross-sectional study of floor/ceiling effects and construct validity. *BMC Musculoskelet Disord* 2015;16:253.

35. Hancock KJ, Glass N, Anthony CA, et al. PROMIS: a valid and efficient outcomes instrument for patients with ACL tears. *Knee Surg Sports Traumatol Arthrosc* 2019;27:100-104.

36. Padilla JA, Rudy HL, Gabor JA, et al. Relationship between the patient-reported outcome measurement information system and traditional patient-reported outcomes for osteoarthritis. *J Arthroplasty* 2019;34:265-272.

37. Papuga MO, Beck CA, Kates SL, Schwarz EM, Maloney MD. Validation of GAITRite and PROMIS as high-throughput physical function outcome measures following ACL reconstruction. *J Orthop Res* 2014;32:793-801.

38. Scott EJ, Westermann R, Glass NA, Hettrich C, Wolf BR, Bollier MJ. Performance of the PROMIS in patients after anterior cruciate ligament reconstruction. *Orthop J Sports Med* 2018;6:2325967118774509.

39. van der Vliet QM, Paulino Pereira NR, Janssen SJ, et al. What factors are associated with quality of life, pain interference, anxiety, and depression in patients with metastatic bone disease? *Clin Orthop Rel Res* 2017;475:498-507.

40. Kagan R, Anderson MB, Christensen JC, Peters CL, Gilliland JM, Pelt CE. The recovery curve for the patient-reported outcomes measurement information system-patient-reported physical function and pain interference computerized adaptive tests after primary total knee arthroplasty. *J Arthroplasty* 2018;33:2471-2474.

41. Kenney RJ, Houck J, Giordano BD, Baumhauer JF, Herbert M, Maloney MD. Do Patient Reported Outcome Measurement Information System (PROMIS) scales demonstrate responsiveness as well as disease-specific scales in patients undergoing knee arthroscopy? *Am J Sports Med* 2019;47:2325967118781023.

42. Nixon DC, McCormick JJ, Johnson JE, Klein SE. PROMIS Pain Interference and Physical Function scores correlate with the foot and ankle ability measure (FAAM) in patients with hallux valgus. *Clin Orthop Rel Res* 2017;475:2775-2780.

43. Kendall R, Wagner B, Brodke D, et al. The relationship of PROMIS Pain Interference and Physical Function scales. *Pain Med* 2018;19:1720-1724.

44. Kollmorgen RC, Hutrya CA, Green C, Lewis B, Olson SA, Mather RC 3rd. Relationship between PROMIS computer adaptive tests and legacy hip measures among patients presenting to a tertiary care hip preservation center. *Am J Sports Med* 2019;47:876-884.

45. Guatterie JM, Dardas AZ, Kelly M, Chamberlain A, McAndrew C, Calfee RP. Floor effect of PROMIS depression CAT associated with hasty completion in orthopaedic surgery patients. *Clin Orthop Rel Res* 2018;476:696-703.

46. Shirazi CP, Israel HA, Kaar SG. Is the Marx Activity Scale reliable in patients younger than 18 years? *Sports Health* 2016;8:145-148.

47. Hung M, Stuart AR, Higgins TF, Saltzman CL, Kubiak EN. Computerized adaptive testing using the PROMIS Physical Function item bank reduces test burden with less ceiling effects compared with the Short Musculoskeletal Function assessment in orthopaedic surgery patients. *Clin Orthop Rel Res* 2018;476:696-703.

48. Anthony CA, Glass N, Hancock K, Bollier M, Hettrich CM, Wolf BR. Preoperative performance of the patient-reported outcomes measurement information system in patients with rotator cuff pathology. *Arthroscopy* 2017;33:1770-1774.e1771.
49. Collins NJ, Prinsen CAC, Christensen R, Bartels EM, Terwee CB, Roos EM. Knee Injury and Osteoarthritis Outcome Score (KOOS): systematic review and meta-analysis of measurement properties. Osteoarthritis Cartilage 2016;24:1317-1329.

50. Maniar RN, Maniar PR, Chanda D, Gajbhare D, Chouhan T. What is the responsiveness and respondent burden of the New Knee Society Score? Clin Orthop Rel Res 2017;475:2218-2227.

51. Stegmeier N, Oak SR, O’Rourke C, et al. No clinically significant difference between adult and pediatric IKDC subjective knee evaluation scores in adults. Sports Health 2017;9:450-455.

52. Robins RJ, Anderson MB, Zhang Y, Presson AP, Burks RT, Greis PE. Convergent validity of the patient-reported outcomes measurement information system’s physical function computerized adaptive test for the knee and shoulder injury sports medicine patient population. Arthroscopy 2017;33:608-616.

53. Naal FD, Impellizzeri FM, Leunig M. Which is the best activity rating scale for patients undergoing total joint arthroplasty? Clin Orthop Rel Res 2009;467:958-965.