Reporting and utilization of Patient-Reported Outcomes Measurement Information System® (PROMIS®) measures in orthopedic research and practice: a systematic review

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Abstract

Background: The Patient-Reported Outcomes Measurement Information System® (PROMIS®) is a dynamic system of psychometrically sound patient-reported outcome (PRO) measures. There has been a recent increase in the use of PROMIS measures, yet little has been written about the reporting of these measures in the field of orthopedics. The purpose of this study was to conduct a systematic review to determine the uptake of PROMIS measures across orthopedics and to identify the type of PROMIS measures and domains that are most commonly used in orthopedic research and practice.

Methods: We searched PubMed, Embase, and Scopus using keywords and database-specific subject headings to capture orthopedic studies reporting PROMIS measures through November 2018. Our inclusion criteria were use of PROMIS measures as an outcome or used to describe a population of patients in an orthopedic setting in patients ≥ 18 years of age. We excluded non-quantitative studies, reviews, and case reports.

Results: Our final search yielded 88 studies published from 2013 through 2018, with 57% (50 studies) published in 2018 alone. By body region, 28% (25 studies) reported PROMIS measures in the upper extremity (shoulder, elbow, hand), 36% (32 studies) reported PROMIS measures in the lower extremity (hip, knee, ankle, foot), 19% (17 studies) reported PROMIS measures in the spine, 10% (9 studies) reported PROMIS measures in trauma patients, and 6% (5 studies) reported PROMIS measures in general orthopedic patients. The majority of studies reported between one and three PROMIS domains (82%, 73 studies). The PROMIS Computerized Adaptive Test (CAT) approach was most commonly used (81%, 72 studies). The most frequently reported PROMIS domains were physical function (81%, 71 studies) and pain interference (61%, 54 studies).

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**Conclusion:** Our review found an increase in the reporting of PROMIS measures over the recent years. Utilization of PROMIS measures in orthopedic populations is clinically appropriate and can facilitate communication of outcomes across different provider types and with reduced respondent burden.

**Registration:** The protocol for this systematic review was designed in accordance with the PRISMA guidelines and is registered with the PROSPERO database (CRD42018088260).

**Keywords:** PROMIS, Patient-reported outcome measures, Orthopedics, Physical function, Pain

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**Introduction**
In order to determine if a patient has achieved a meaningful outcome, it is insufficient to evaluate treatment results solely on medical history, physical findings, laboratory tests, or imaging findings [1]. Patient-reported outcome (PRO) measures are a useful tool to quantify and communicate a patient's health status to healthcare providers that directly incorporates the patient's voice. Change in PROs can be one of the measures of “success” from a patient's perspective after an orthopedic procedure [2]. PROs are increasingly being used as part of the clinical encounter to guide treatment decisions and determine the effectiveness of interventions [3], but PROs have presented challenges with implementation and measure selection.

In orthopedic practice and research, there is great variability in the number of PRO measures available. As a result, there is confusion among orthopedic providers about which PRO measure is most appropriate given a patient population and how to appropriately interpret a patient’s score to enhance treatment recommendations. Subsequently, in orthopedics, there has been a recent increase in the adoption of a universally accepted set of PRO measures: the Patient-Reported Outcomes Measurement Information System® (PROMIS®). PROMIS has been compared against conventional general health and disease-specific PRO measures and has demonstrated the reliability and performance of PROMIS measures in orthopedic populations [2–10]. These reviews do not describe how the measures have been reported neither in the literature nor the general uptake of PROMIS measures across different provider types and with reduced respondent burden [4].

PROMIS measures were developed with support by the National Institutes of Health (NIH) as an effort to address the need for more valid, reliable, and generalizable measures of clinical outcomes that are important to patients [5]. PROMIS is a set of psychometrically sound measures to assess a patient's physical, mental, and social health across multiple conditions or diseases, including orthopedic conditions. PROMIS measures overcome the limitations of traditional PRO measures used in orthopedic research and practice by scoring all PROMIS domains using a common metric of a T-score that is normalized to the U.S. general population. PROMIS provides access to both fixed-length measures (e.g., 6-item measure of fatigue) and computerized adaptive testing (CAT) that tailors the measure for each individual to allow for efficient assessment when response burden is of concern [6].

In recent years, a proliferation of studies have reported the association of PROMIS measures with traditional measures and have demonstrated the reliability and performance of PROMIS measures in orthopedic populations. While there have been a few systematic reviews about the use of PROMIS measures in certain disciplines within orthopedics [7–10], these reviews do not describe how the measures have been reported neither in the literature nor the general uptake of PROMIS measures within orthopedic research and practice. Thus, we sought to evaluate the adoption of PROMIS measures in orthopedics by describing how the measures are used and reported on, including the PROMIS domains evaluated, the type of PROMIS instrument used, and other traditional measures that were reported along with PROMIS measures.

**Methods**

**Review design**
The protocol for this systematic review was designed in accordance with the PRISMA guidelines [11] and is registered with the PROSPERO database (CRD42018088260) [12]. We collaborated with a research librarian (LL) to develop an appropriate search strategy and management of the literature review.

**Data sources and search strategy**
We performed a literature search of PubMed, Embase, and Scopus from inception to November 4, 2018, using a combination of keywords and database-specific subject headings to capture studies done in an orthopedic setting and/or procedures that reported a PROMIS measure as an outcome (Additional file 1). We added search filters to exclude case studies or reports, editorials, letters to the editor, and studies not written in English.

**Inclusion and exclusion criteria**
Inclusion criteria included the use of PROMIS measures in studies conducted in orthopedic settings for clinical care purposes or studies that used PROMIS measures to assess an outcome from an orthopedic intervention. Our exclusion criteria were study population < 18 years of age.
age; non-orthopedic interventions, settings, or providers performing the intervention; and qualitative studies, commentaries, or systematic reviews. All included studies were peer-reviewed, reported at least one PROMIS measure, and used an experimental, quasi-experimental, or observational design. Two authors screened articles (MH and SZG) and a third author (ER) resolved any conflicts.

**Study selection and data extraction**

After databases were searched, titles and abstracts of studies were uploaded into Covidence, a systematic review management software [13]. The article selection process was done in two phases. In the first phase, two authors (MH and SZG) performed independent reviews of titles and abstracts in Covidence using the predefined inclusion and exclusion criteria. Articles were moved to full-text review if one or both authors found the article potentially relevant. In the second phase, the same two authors independently reviewed full-text articles for eligibility. Any conflicts were resolved by the third author.

**Data analysis**

Included studies were evaluated from November 2018 to June 2020. The primary purpose of this review was to describe the uptake of PROMIS measures in orthopedic research and practice through qualitative synthesis, and then rate the quality of included studies. Therefore, we did not perform a meta-analysis of data. For the qualitative synthesis, we described the studies by publication year, clinical population, study type, and sample size. We evaluated the reporting of PROMIS measures by recording the PRO domains reported in each study and the type of PROMIS measures used (i.e., domain-specific fixed short forms, multiple domain profile short forms, or CAT). Last, we described the frequency in which PROMIS measures were reported alongside traditional measures by the clinical population. Traditional measures are non-PROMIS established measures used in orthopedics.

**Quality assessment**

We used the Newcastle-Ottawa Scale (NOS) to assess the quality of included studies (Additional file 2). Because this review included a heterogeneous group of studies with a wide variety of methodologies, there is likely no single risk of bias tool to perfectly evaluate study quality across such a diverse group. The NOS was developed to assess the quality of nonrandomized studies, and evaluates studies within three domains: the selection of study groups, the comparability between these groups, and the determination of the outcome of interest. We used a version of the NOS specifically adapted for cross-sectional studies [14] and for case control and cohort studies [15]. The NOS scoring of seven or more stars is generally considered high quality, though no ranges have been officially reported in the literature [16].

**Results**

Our preliminary search yielded 1046 citations, and after duplicates were removed, 513 citations were reviewed by their titles and abstracts. Of those, 376 were moved forward to the full-text review stage, and 88 articles remained for inclusion in the systematic review [3, 17–103] (Fig. 1). After conflicts were resolved by the third author, we calculated an 81.6% agreement between the authors performing full-text review.

**Study characteristics**

Table 1 shows the characteristics of included studies by year, clinical population, study type, and sample size.

**Year**

Studies included in this review were published from 2013 through 2018. The number of publications reporting PROMIS measures notably increased across time: 2013 (1%, 1 study), 2014 (7%, 6 studies), 2015 (6%, 5 studies), 2016 (13%, 11 studies), 2017 (17%, 15 studies). The majority of studies were published in 2018 (57%, 50 studies).

**Clinical population**

PROMIS measures were reported in orthopedic studies across multiple clinical populations. For reporting, we grouped the studies by body region rather than specific diagnosis. The majority of studies (36%, 32 studies) reported PROMIS measures in lower extremity disorders (hip, knee, ankle, foot), followed by upper extremity disorders (shoulder, elbow, hand) (28%, 25 studies), spine disorders (19%, 17 studies), orthopedic trauma (10%, 9 studies). Few studies (6%, 5 studies) reported PROMIS measures in general orthopedic patients.

**Study type and sample size**

The studies in this review varied in the study design used to assess outcomes. The largest percentage of studies were cohort studies (59%, 52 studies). Most of these were prospective observational designs (38%, 33 studies), and 22% (19 studies) were retrospective observational designs. Many studies (41%, 36 studies) used a cross-sectional study design to analyze the psychometric properties of PROMIS or to validate in a patient population. No randomized controlled trials were reported using PROMIS measures as an outcome measure. Sample sizes in the studies ranged from 11 patients to 14,679 patients, with 133 patients as the median number reported. Five studies included patients from registries including the American Orthopedic Foot and Ankle Society’s National Orthopedic Foot and Ankle Research Outcomes Network and the Maryland Orthopedic Registry.
Reporting of PROMIS measures

The most frequently reported PROMIS domains in the studies included in this review were physical function (81%, 71 studies), pain interference (61%, 54 studies), depression (31%, 28 studies), physical function-upper extremity (18%, 16 studies), physical function-lower extremity (3%, 3 studies), and anxiety (15%, 13 studies) (Table 2). Most studies (75%, 66 studies) reported more than one PROMIS domain. Approximately a third of studies (32%, studies) reported two PROMIS domains, 25% (22 studies) reported three PROMIS domains, 9% (8 studies) reported four PROMIS domains, and the remainder (9%, 8 studies) reported between 5 and 9 PROMIS domains. Only a quarter (25%, 22 studies) reported one PROMIS domain. Of the type of PROMIS instrument used (i.e., CAT, short form, or profile), the vast majority of studies (81%, 71 studies) reported using the PROMIS CAT approach. A small percentage of studies reported only fixed-length instruments (15%, 13 studies) and (4%, 4 studies) reported a combination of CAT and fixed-length questionnaires.

PROMIS and traditional PROs

Fourteen studies in this review reported PROMIS as the sole outcome measure. Of those 14 studies, 9 were published in 2018 alone. Widely reported traditional measures were reported alongside PROMIS measures in all studies. Traditional measures included measuring the constructs of pain, disability, psychosocial comorbidity, and quality of life. Table 3 describes the reporting of traditional measures alongside PROMIS measures by body region.

Quality of studies and risk of bias

A majority of studies assessed had a low risk of bias. All cohort and cross-sectional studies scored seven or above in their respective versions of the NOS quality assessment tool, and, with one exception, all case-control studies scored eight or above. Table 4 describes the risk of bias summary for individual studies included in this review, and Additional file 2 contains detailed results of the quality assessment.

Discussion

In this review, we evaluated the uptake of PROMIS measures in orthopedic research and practice by describing
Table 1  Study characteristics

| Year | Author | Orthopedic population | Study design                                      | N  |
|------|--------|-----------------------|---------------------------------------------------|----|
| 2013 | Hung et al. [17] | Lower extremity patients | Cross-sectional study                           | 288 |
| 2014 | Hung et al. [18] | Lower extremity patients | Cohort study (prospective observational study)    | 311 |
| 2014 | Hung et al. [19] | Lower extremity patients | Cross-sectional study                           | 126 |
| 2014 | Hung et al. [3] | Trauma patients        | Cross-sectional study                           | 153 |
| 2014 | Hunt et al. [20] | Lower extremity patients | Cohort study (prospective observational study)    | 140 |
| 2014 | Papuga et al. [21] | Lower extremity patients | Cohort study (prospective observational study)    | 106 |
| 2014 | Tyser et al. [22] | Upper extremity patients | Cross-sectional study                           | 134 |
| 2015 | Beckmann et al. [24] | Upper extremity patients | Cross-sectional study                           | 187 |
| 2015 | Mellema et al. [23] | Upper extremity patients | Cohort study (prospective observational study)    | 136 |
| 2015 | Morgan et al. [25] | Trauma patients        | Cross-sectional study                           | 47  |
| 2015 | Overbeek et al. [103] | Upper extremity patients | Cross-sectional study                           | 93  |
| 2015 | Stuart et al. [26] | Trauma patients        | Cross-sectional study                           | 55  |
| 2016 | Beckmann et al. [29] | Upper extremity patients | Cross-sectional study                           | 379 |
| 2016 | Dasa et al. [33] | Lower extremity patients | Retrospective cohort                            | 100 |
| 2016 | Fuchs et al. [27] | Lower extremity patients | Retrospective cohort                            | 93  |
| 2016 | Hermanussen et al. [37] | Upper extremity patients | Cross-sectional study                           | 111 |
| 2016 | Ho et al. [28] | Lower extremity patients | Cohort study (prospective observational study)    | 61  |
| 2016 | Note et al. [30] | Upper extremity patients | Cross-sectional study                           | 193 |
| 2016 | Oak et al. [34] | Lower extremity patients | Cohort study (prospective observational study)    | 45  |
| 2016 | Papuga et al. [35] | Spine patients         | Cross-sectional study                           | 319 |
| 2016 | Parrish et al. [31] | Upper extremity patients | Cross-sectional study                           | 112 |
| 2016 | Peters et al. [32] | Upper extremity patients | Cross-sectional study                           | 115 |
| 2016 | van Leeuwen et al. [36] | Trauma patients | Cross-sectional study                           | 124 |
| 2017 | Anthony et al. [46] | Upper extremity patients | Cross-sectional study                           | 70  |
| 2017 | Anthony et al. [45] | Upper extremity patients | Cross-sectional study                           | 82  |
| 2017 | Beleckas et al. [41] | Upper extremity patients | Cohort study (prospective observational study)    | 5202|
| 2017 | Dowdle et al. [47] | Upper extremity patients | Cross-sectional study                           | 53  |
| 2017 | Hancock et al. [43] | Lower extremity patients | Cross-sectional study                           | 107 |
| 2017 | Henn et al. [53] | Upper extremity patients | Cohort study (prospective observational study)    | 300 |
| 2017 | Kaat et al. [52] | Trauma patients        | Cohort study (prospective observational study)    | 132 |
| 2017 | Kazmers et al. [54] | Upper extremity patients | Cross-sectional study                           | 1299|
| 2017 | Kleimeyer et al. [50] | Spine patients        | Cohort study (prospective observational study)    | 88  |
| 2017 | Koltsov et al. [38] | Lower extremity patients | Cohort study (prospective observational study)    | 191 |
| 2017 | Nixon et al. [39] | Lower extremity patients | Cross-sectional study                           | 85  |
| 2017 | Oh et al. [40] | Upper extremity patients | Cross-sectional study                           | 125 |
| 2017 | Purvis et al. [49] | Spine patients         | Cohort study (prospective observational study)    | 148 |
| 2017 | Sheean et al. [42] | Lower extremity patients | Cross-sectional study                           | 42  |
| 2017 | St John et al. [55] | Upper extremity patients | Cross-sectional study                           | 722 |
| 2018 | Alvarez-Nebreda et al. [102] | Trauma patients | Cohort study (prospective observational study)    | 273 |
| 2018 | Anderson et al. [100] | Lower extremity patients | Cohort study (prospective observational study)    | 61  |
| 2018 | Anderson et al. [101] | Lower extremity patients | Retrospective cohort                            | 88  |
| 2018 | Austin et al. [99] | Lower extremity patients | Retrospective cohort                            | 2308|
| 2018 | Beleckas et al. [97] | General orthopedics    | Cross-sectional study                           | 14679|
| 2018 | Beleckas et al. [98] | General orthopedics    | Retrospective cohort                            | 3339|
| Year | Author | Orthopedic population | Study design | N   |
|------|--------|-----------------------|--------------|-----|
| 2018 | Beleckas et al. [58] | Upper extremity patients | Cross-sectional study | 3315 |
| 2018 | Bernholt et al. [96] | Lower extremity patients | Retrospective cohort | 75  |
| 2018 | Bernstein et al. [95] | Lower extremity patients | Cohort study (prospective observational study) | 500 |
| 2018 | Bhatt et al. [94] | Spine patients | Cohort study (prospective observational study) | 78  |
| 2018 | Boody et al. [56] | Spine patients | Cohort study (prospective observational study) | 59  |
| 2018 | Cavallero et al. [93] | Trauma patients | Retrospective cohort | 56  |
| 2018 | Chen et al. [92] | Lower extremity patients | Retrospective cohort | 233 |
| 2018 | Crijns et al. [91] | Upper extremity patients | Retrospective cohort | 4511|
| 2018 | Fishauer et al. [59] | Upper extremity patients | Cross-sectional study | 105 |
| 2018 | Fram et al. [90] | Upper extremity patients | Retrospective cohort | 11  |
| 2018 | Gaudsen et al. [89] | Lower extremity patients | Cohort study (prospective Observational study) | 132 |
| 2018 | Gaudsen et al. [88] | Trauma patients | Cohort study (prospective observational study) | 174 |
| 2018 | Hancock et al. [87] | Lower extremity patients | Cross-sectional study | 100 |
| 2018 | Haskell et al. [61] | General orthopedics | Cross-sectional study | 4524|
| 2018 | Haws et al. [86] | Spine patients | Retrospective cohort | 74  |
| 2018 | Hung et al. [85] | Lower extremity patients | Cohort study (prospective Observational study) | 785 |
| 2018 | Hung et al. [44] | Lower extremity patients | Cohort study (prospective observational study) | 983 |
| 2018 | Hung et al. [83] | Lower extremity patients | Cohort study (prospective observational study) | 2226|
| 2018 | Hung et al. [84] | Lower extremity patients | Cohort study (prospective observational study) | 3069|
| 2018 | Hung et al. [81] | Spine patients | Cohort study (prospective observational study) | 763 |
| 2018 | Hung et al. [82] | Spine patients | Cohort study (prospective observational study) | 1945|
| 2018 | Hung et al. [60] | Upper extremity patients | Cross-sectional study | 1759|
| 2018 | Kadri et al. 3 [80] | General orthopedics | Cross-sectional study | 841 |
| 2018 | Kagan et al. [79] | Lower extremity patients | Cohort study (prospective observational study) | 91  |
| 2018 | Karns et al. [78] | Lower extremity patients | Retrospective cohort | 434 |
| 2018 | Khechen et al. [77] | Spine patients | Retrospective cohort | 41  |
| 2018 | Kleimeyer et al. [76] | Spine patients | Retrospective cohort | 75  |
| 2018 | Kohring et al. [75] | Lower extremity patients | Retrospective cohort | 271 |
| 2018 | Kohring et al. [74] | Lower extremity patients | Retrospective cohort | 540 |
| 2018 | Kootstra et al. [73] | Upper extremity patients | Cross-sectional study | 126 |
| 2018 | Medina et al. [72] | General orthopedics | Cross-sectional study | 937 |
| 2018 | Meredith et al. [71] | Lower extremity patients | Cross-sectional study | 383 |
| 2018 | Merrill et al. [51] | Spine patients | Cohort study (prospective observational study) | 111 |
| 2018 | Nixon et al. [70] | Lower extremity patients | Retrospective cohort | 159 |
| 2018 | Owen et al. [48] | Spine patients | Cohort study (prospective observational study) | 60  |
| 2018 | Patel et al. [69] | Spine patients | Cohort study (prospective observational study) | 98  |
| 2018 | Patterson et al. [68] | Upper extremity patients | Cross-sectional study | 164 |
| 2018 | Patton et al. [67] | Lower extremity patients | Retrospective cohort | 680 |
| 2018 | Purvis et al. [66] | Spine patients | Cohort study (prospective observational study) | 231 |
| 2018 | Raad et al. [65] | Spine patients | Cohort study (prospective observational study) | 76  |
| 2018 | Rubery et al. [64] | Spine patients | Retrospective cohort | 78  |
| 2018 | Schwartz et al. [63] | Spine patients | Cohort study (prospective observational study) | 167 |
| 2018 | Stoop et al. [57] | Upper extremity patients | Cross-sectional study | 122 |
| 2018 | Vincent et al. [62] | Trauma patients | Cohort study (prospective Observational study) | 101 |
how PROMIS measures were reported in published studies. The number of studies reporting the use of PROMIS measures increased exponentially from 2013 through 2017, with a spike in studies reporting PROMIS measures in 2018 alone (57% of total studies). This large increase in studies potentially indicates that PROMIS measures are being more widely adopted within orthopedic research and practice as an outcome measure. This increase may be due to the evolution of PROMIS measures from the short form, fixed instrument to the CAT instrument. Additionally, progress has been made with the availability and integration of PROMIS measures into Electronic Health Record (EHR) systems, allowing easier use of PROMIS CAT in the clinical setting [104, 105]. However, in relation to the increase in reporting of PROMIS measures in the literature, the vast majority of studies in our review reported the use of traditional measures alongside PROMIS measures [106]. This finding supports that, while PROMIS measures are gaining traction within orthopedics, researchers and clinicians may not be ready to abandon traditional measures in favor of PROMIS measures, despite evidence that the PROMIS domains of physical function and pain interference outperform traditional measures [107]. The reasons for this hesitancy may be related to familiarity with traditional measures, participation in registries that do not have PROMIS measures as part of the core set of measures, or a perceived lack of applicability in their patient populations. However, it may be noted that any new PRO measure should be considered experimental; thus, established measures are included both for validation purposes and to gain more understanding of how they relate to each other.

Our review also found that the use of PROMIS measures across clinical populations varied, with 37% of studies examining lower extremity conditions, followed by upper extremity (28%) and spine conditions (19%). This finding is consistent with the supporting literature where the use of PROMIS measures in lower, upper, and spine is increasing as a primary measure across clinical populations [1, 4, 108]. Last, most studies in our review reported the use of CAT-based assessments as the PROMIS assessment type. This finding is not surprising, as the primary benefits of the PROMIS CAT measures are the decrease in patient burden and the precision of the estimate. The majority of studies reported between one and three PROMIS domains. Unsurprisingly, the most commonly reported PROMIS domains were physical function and pain interference, which are validated and compared to many traditional measures. Of the psychological domains, depression was reported more frequently than anxiety. While the field of orthopedics is focused on improved functioning and reduced pain, we would encourage a more holistic view of the patient by incorporating more psychological constructs that may affect patient prognosis. This review provides evidence that the prevalence and support for use of PROMIS measures is growing in orthopedics and that PROMIS is being recognized as a PRO measure of choice for clinical trials [109].

Limitations
Our systematic review has some limitations. First, we aimed to describe the prevalence and use of PROMIS measures within orthopedic practice and research rather than to compare outcomes or exposures in the studies. Our review had broad inclusion criteria, and thus there was high variability, with study designs often considered less rigorous. The majority of studies were retrospective and prospective cohort studies. No studies in our review were randomized clinical trials; however, this is likely because of the relative unavailability of PROMIS measures until recently. It will take some time before clinical trials that use PROMIS measures as endpoints are published.

Second, we reported on the PROMIS domains but did not perform meta-analyses to examine the effects of treatment or compare the performance of PROMIS measures with other reported measures. Last, many studies

| Domain                                | Studies reporting domain | % CAT instrument format |
|---------------------------------------|--------------------------|------------------------|
| Physical function                     | 81% (71)                 | 93%                    |
| Pain interference                     | 61% (54)                 | 85%                    |
| Pain behavior                         | 4% (4)                   | 100%                   |
| Emotional distress - depression       | 32% (28)                 | 85%                    |
| Physical function - upper extremity   | 18% (16)                 | 69%                    |
| Physical function - lower extremity   | 3% (3)                   | 100%                   |
| Physical function - mobility          | 1% (1)                   | 100%                   |
| Emotional support                     | 1% (1)                   | 100%                   |
| Psychological illness                 | 2% (2)                   | 100%                   |
| Instrumental support                  | 1% (1)                   | 100%                   |
| Sleep disturbance                     | 4% (4)                   | 50%                    |
| Emotional distress - anger            | 1% (1)                   | 100%                   |
| Emotional distress - anxiety          | 13% (12)                 | 83%                    |
| Fatigue                               | 8% (7)                   | 71%                    |
| Ability to participate in social roles and activities | 1% (1) | 100% |
| Satisfaction with participation in social roles | 10% (9) | 78% |
| Global health                         | 7% (6)                   | 0%                     |
| Pain intensity                        | 4% (4)                   | 0%                     |
| Emotional distress                    | 1% (1)                   | 0%                     |
| PROMIS domains/constructs                          | Traditional PRO measures                                                                 |
|--------------------------------------------------|------------------------------------------------------------------------------------------|
| **General orthopedics**                          |                                                                                          |
| Physical function                                | International Knee Documentation Committee                                               |
| Pain interference                                | American Shoulder and Elbow Surgeons Shoulder Score                                      |
| Emotional distress—depression                    | Musculoskeletal Outcomes Data Evaluation and Management System                           |
| Emotional distress—anxiety                       | Tegner Activity Scale                                                                     |
| Fatigue                                          | Marx Activity Rating Scales                                                               |
| Satisfaction with participation in social roles  | Brief Michigan Hand Questionnaire                                                         |
| Physical function—upper extremity                | International Physical Activity Questionnaire                                             |
| Pain intensity                                   | Numeric Pain Scale—Global                                                                |
| Global health                                    | Numeric Pain Scale—Local                                                                 |
| Physical functional—lower extremity              |                                                                                          |
| **Lower extremity**                              |                                                                                          |
| Physical function                                | Knee Injury and Osteoarthritis Outcome Score                                              |
| Pain interference                                | Western Ontario and McMaster Universities Arthritis Index                                 |
| Emotional distress—depression                    | Hip Disability and Osteoarthritis Outcome Score                                           |
| Emotional distress—anxiety                       | Knee Injury and Osteoarthritis Outcome Score for Joint Replacement                       |
| Emotional distress—anger                         | Hip Disability and Osteoarthritis Outcome Score for Joint Replacement                    |
| Pain intensity                                   | GAITRite Walk Testing                                                                    |
| Fatigue                                          | International Knee Documentation Committee                                               |
| Satisfaction with participation in social roles  | Oxford Knee Score                                                                        |
| Sleep disturbance                                | Short Form 12                                                                             |
| Pain behavior                                    | Numeric Pain Scale—Global                                                                |
| Ability to participate in social roles and activities | Numeric Pain Scale—Local                                                               |
| Global health                                    | Musculoskeletal Outcomes Data Evaluation and Management System                           |
| Physical function—mobility                       | Tegner Activity Scale                                                                     |
| Physical function—upper extremity                | Marx Activity Rating Scales                                                               |
| Physical functional—lower extremity              | Short Form 36                                                                             |
| Physical functional—lower extremity              | EuroQol EQ-SD                                                                            |
|                                                   | Douleur Neuropathique 4 (DN4-I)                                                           |
|                                                   | Visual Analog Scale                                                                      |
|                                                   | International Physical Activity Questionnaire                                             |
|                                                   | Press Ganey Outpatient Medical Practice Survey                                           |
|                                                   | Veterans RAND 12 (VR-12)                                                                  |
|                                                   | Modified Harris Hip Score                                                                |
|                                                   | Posture Assessment Scale for Stroke                                                       |
|                                                   | Olerud-Molander Ankle Score                                                              |
|                                                   | Foot and Ankle Ability Measure                                                           |
|                                                   | Foot Function Index                                                                      |
|                                                   | Foot and Ankle Outcome Score                                                             |
|                                                   | Short Form 36                                                                             |
|                                                   | International Hip Outcome Tool (iHOT-33)                                                  |
|                                                   | Single Assessment Numeric Evaluation                                                     |
|                                                   | American Society of Anesthesiologists classification                                     |
included in the review examined the reliability and validity of PROMIS measures in orthopedic populations, so the studies that reported PROMIS measures as the primary outcomes were less frequent, potentially leading to the impression that there is a higher prevalence of reporting PROMIS measures in the literature.

Conclusions
PROMIS measures have been increasingly reported in orthopedic research and practice and present a new era of PRO measurement for clinical practice and scientific dissemination. Our findings are relevant for orthopedic researchers and clinicians who are using, or considering using, PROMIS measures. Our findings can provide guidance for stakeholders about the selection and administration of PRO measures, supporting value-based decisions both in clinics and prostheses procurement [110]. The domains of physical function and pain interference are the most commonly reported PROMIS domains, and these measure similar constructs to the traditional, body region-specific measures. Considerations about which PROMIS measures to administer in clinical populations should be made by determining what constructs are most important and whether PROMIS measures are sufficient alone or if traditional measures are needed to supplement the PROMIS measures.

Table 3 PROMIS domains and traditional PROs by body region (Continued)

| PROMIS domains/constructs | Traditional PRO measures |
|---------------------------|--------------------------|
| Spine                     |                          |
| Physical function         | Oswestry Disability Index|
| Pain interference         | Neck Disability Index    |
| Emotional distress—depression | Modified Japanese Orthopedic Association Scale |
| Emotional distress—anxiety| Short Form 12            |
| Pain behavior             | Global Rating of Change  |
| Satisfaction with participation in social roles | Visual Analog Scale |
| Fatigue                   | EuroQol EQ-5D            |
| Sleep disturbance         | Scoliosis Research Society (SRS-22r) |
| Pain intensity            | Generalized Anxiety Disorder (GAD-7) |
| Emotional distress        | Patient Health Questionnaire for Depression Scale (PHQ-8) |
|                          | Short Form 36 (Rand-36 / SF-36) |
|                          | Zurich Claudication Questionnaire |
|                          | Brief Pain Inventory     |
|                          | North America Spine Society Patient Satisfaction Index |
|                          | Coccygodynia Disability Index (CDI) |
| Trauma                   |                          |
| Physical function         | Visual Analog Scale (VAS) |
| Pain intensity            | Disabilities of the Arm, Shoulder, and Hand (DASH) |
| Physical function—upper extremity | Quick Disability of the Arm, Shoulder, and Hand (QuickDASH) |
| Satisfaction with participation in social roles | Constant Shoulder Score |
| Psychological illness     | Short Musculoskeletal Functional Assessment (SMFA) |
|                          | Timed Up and Go          |
|                          | Short Form 36 (Rand-36/SF-36) |
|                          | Injustice Experience Questionnaire |
|                          | Patient Health Questionnaire for Depression short form (PHQ-2) |
|                          | Pain Self-Efficacy Questionnaire short form (PSEQ-2) |
|                          | Pain Catastrophizing     |
|                          | FRAIL Questionnaire      |
|                          | UCLA Shoulder Score      |

Table 4 Risk of bias summary table

|                          | # Studies | % Studies |
|--------------------------|-----------|-----------|
| Low (7 or above)         | 87        | 98.8%     |
| Moderate to high (6 or below) | 1        | 1.2%      |
Given the evidence for the validity and reliability of PROMIS in orthopedics, we expect a decrease in the use of other established PRO measures in order to reduce respondent burden.

The implications for future research and practice in orthopedics support that PROMIS measures are versatile, reliable, and valid for orthopedic research and practice. Further, PROMIS measures provide distinct advantages over traditional measures, particularly, when the study population is heterogeneous. Multiple recent studies indicate that widespread variability exists in the particular PROs used in studies of the same diagnosis, thereby significantly limiting the translatability of many of these high-impact studies [6, 8, 111, 112]. Future research on the use of PROMIS measures in orthopedics should focus on the use of PROMIS measures as the primary outcome measure, particularly in studies that examine heterogeneous patient populations. Last, PROMIS measures hold immense potential for improving patient and provider communication, particularly across specialties.

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Additional file 1: Search Strategies.
Additional file 2: Quality Assessment.

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Authors’ contributions
All authors meet the criteria for authorship based on the International Committee of Medical Journal Editors. MH was responsible for the design of the study, reviewing articles, and preparing the manuscript; SG for reviewing articles and preparing the manuscript; ER for the design of the study, reviewing articles, and preparing the manuscript; BR for participating in the writing of the manuscript; and LC for reviewing articles and preparing the manuscript. All authors have reviewed the manuscript prior to publication. The author(s) read and approved the final manuscript.

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A limited data set with fields reported in this paper is available upon request via email to the corresponding author, with no limitations on the reuse of the data.

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This study was exempt from the Institutional Review Board at Duke University.

Consent for publication
All authors consent to the publication of the data in this manuscript.

Competing interests
None to report.

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