Patient-reported outcome measures (PROMs) are being used increasingly in total knee arthroplasty (TKA). We conducted a systematic review aimed at identifying psychometrically sound PROMs by appraising their measurement properties. Studies concerning the development and/or evaluation of the measurement properties of PROMs used in a TKA population were systematically retrieved via PubMed, Web of Science, Embase, and Scopus. Ratings for methodological quality and measurement properties were conducted according to updated COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) methodology. Of the 155 articles on 34 instruments included, nine PROMs met the minimum requirements for psychometric validation and can be recommended to use as measures of TKA outcome: Oxford Knee Score (OKS); OKS–Activity and Participation Questionnaire (OKS-APQ); 12-item short form Knee Injury and Osteoarthritis Outcome (KOOS-12); KOOS Physical function Short form (KOOS-PS); Western Ontario and McMaster Universities Arthritis Index-Total Knee Replacement function short form (WOMAC-TKR); Lower Extremity Functional Scale (LEFS); Forgotten Joint Score (FJS); Patient’s Knee Implant Performance (PKIP); and University of California Los Angeles (UCLA) activity score. The pain and function subscales in WOMAC, as well as the pain, function, and quality of life subscales in KOOS, were validated psychometrically as standalone subscales instead of as whole instruments. However, none of the included PROMs have been validated for all measurement properties. Thus, further studies are still warranted to evaluate those PROMs. Use of the other 25 scales and subscales should be tempered until further studies validate their measurement properties.

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Article focus
- We summarized available patient-reported outcome measures (PROMs) used in a total knee arthroplasty (TKA) population, and identified those with high quality by evaluating their measurement properties.

Key messages
- Nine instruments and six subscales in two instruments met the minimal requirements for psychometric validation, and can be recommended to use as measures for TKA outcome.
- However, none of the included PROMs have been validated for all nine measurement properties.
- Further studies are warranted to assess the measurement properties of existing instruments, especially for content validity, cross-culture validity, and structure validity.
Strengths and limitations
- We undertook a comprehensive review under the latest CONsensus-based Standards for the selec-
tion of health Measurement Instruments (COSMIN) methodology.
- We also used meta-analysis to summarize results quantitatively.
- Our strict selection criteria meant that only a TKA population could be assessed.

Introduction
Total knee arthroplasty (TKA) has been performed for more than 40 years. It is regarded as efficacious treat-
ment for end-stage knee arthritis, capable of improving quality of life by reducing pain and ameliorating long-
term knee function.1 Thanks to optimization of surgical methods and prosthetic designs, the ten-year survival of
knee prostheses exceeds 90%.2 However, the proportion of dissatisfied TKA recipients remains > 10%.3,4

TKA is an elective procedure, so patient-reported outcome measures (PROMs) are crucial to assess how well this type of intervention serves the patients’ goals rather than strictly objective measures alone.5

PROMs have advantages over objective measure-
ments because they: 1) largely eliminate clinicians’ biases and measure health status accurately from the patients’ perspective;6 2) enable better detection of what patients account for, and help to address possibly modifiable factors;7 3) aid the possibility of follow-up of patients regardless of their direct attendance; and 4) facilitate decision-making for surgical procedures.8-10

In clinical practice and research, it is critical (but difficult) to opt for psychometrically sound rather than frequently used PROMs for certain purposes. In this context, systematic reviews were published in 2016 and 2017 evaluating the measurement properties of PROMs in knee arthroplasty population, using CONsensus-based Standards for the selection of health Measurement In-
struments (COSMIN) methodology.11-13 Since then, many studies assessing PROMs in TKA have been conducted. Moreover, the COSMIN methodology for systematic review of PROMs has been developed further. This meth-
ology has: 1) established specific and comprehensive guidelines for evaluating content validity;14 2) updated criteria for good measurement properties, risk of bias checklist,15 approach for grading the quality of evidence, and synthesizing the overall rating; and 3) formulated recommendation standards for selection of PROMs.16 For these reasons, we conducted a systematic review following the updated COSMIN methodology to establish a comprehensive quality assessment of PROMs for TKA.

Methods
Search strategy. We systematically searched for studies reporting the measurement properties of PROMs used in the TKA population in PubMed, Web of Science, Embase, and Scopus from commencement to 8 March 2020. To find eligible studies, we used keywords from three terms: 1) patient-reported outcome measure; 2) measurement properties (including validity, reliability, internal consistency, measurement error, responsiveness, and minimal clinically important difference (MCID)); and 3) total knee arthroplasty population. The full search strategy for PubMed is shown in detail in the Supplementary Material.

Inclusion and exclusion criteria. Articles were considered eligible if published as full texts in English and if they detailed the development or evaluated the measurement properties of PROMs used in TKA. Articles were excluded if they: 1) did not report one of the nine measurement properties or MCID; 2) did not focus on patients undergoing (or who had undergone) TKA; 3) were not published in the English language; or 4) were not full reports (e.g. only abstracts were available) because they were unlikely to contain sufficient information.

Study selection and data extraction. After removal of du-
plicate articles, two reviewers (SZ and XC) screened titles and abstracts independently, and identified eligible articles. Then, full manuscripts were extracted and screened for final inclusion. Discrepancies between the reviewers were resolved by discussion. The bibliographies of all selected full-text articles were screened to retrieve additional citations.

The data extraction was undertaken by two reviewers (SZ and XC) independently. First, the characteristics of included PROMs were extracted from development studies, questionnaires, and user manuals. Second, results from included studies for evaluating the methodological quality of studies and measurement properties, as well as descriptive data on feasibility and interpret-
ability, were recorded on a standardized form.

Assessment of the measurement properties of PROMs. The measurement properties of PROMs were evaluated under the updated COSMIN methodology,12-14 which required the following consecutive procedures: evaluation of the methodological quality and measurement properties of single studies; qualitative and quantitative summary of the results of each instrument; and grading the quality of evidence and selecting instruments.

Evaluation of the methodological quality of individual studies. The methodological quality of studies was assessed using the COSMIN risk of bias checklist, which consists of ten ‘tick boxes’ in accordance with development studies and nine measurement properties. Each tick box includes 3 to 35 items, which are rated as “very good”, “adequate”, “doubtful”, or “inadequate” against standards. Two reviewers (YW and MY) completed the corre-
sponding tick box per article independently. Besides, the overall rating of the methodological quality was based on the worst rating within each tick box.13

Evaluation of measurement properties for individual stud-
ies. We used the COSMIN methodology to assess con-
tent validity.12 COSMIN set the criteria for good content
validity from three aspects: 1) relevance (i.e. all items in a PROM should be relevant for the construct of interest within a specific population and context of use); 2) comprehensiveness (i.e. no key aspects of the construct should be missing); and 3) comprehensibility (i.e. the items should be understood by patients as intended). The rating for the content validity of each included PROM was conducted for a development study, content validity studies, and the instrument itself separately against the criteria. For the latter, the English version of included instruments was reviewed by English-fluent TKA-expert authors independently. Other measurement properties of the included instruments were evaluated according to the criteria described in Supplementary table i.4 The results of each study were rated qualitatively as “sufficient” (+), “insufficient” (–), or “indeterminate” (?). All results were evaluated by two reviewers (YW and MY) independently, and a third party (WQ) was consulted if consensus could not be reached.

**Qualitative syntheses of the results of each instrument.** The results for each measurement property from single studies per instrument were summarized qualitatively (i.e. + / – / ± / ?). An overall “sufficient” (+) or “insufficient” (–) rating was given if > 75% of results were concurrent. An “inconsistent” (±) rating was given if no rating exceeded 75% and no appropriate explanation for inconsistency could be given. An “indeterminate” (?) rating was given only if all single study results were indeterminate.

**Quantitative syntheses of the results of each instrument.** For PROMs with more than two available results on internal consistency, test–retest reliability or construct validity (i.e. Cronbach’s α, intraclass correlation coefficients (ICCs), and Pearson correlation coefficients) were also pooled statistically in a meta-analysis. Weighted means and 95% confidence intervals were calculated for Pearson correlation coefficients against 36-Item Short-Form Health Survey questionnaire (SF-36; the most commonly used and validated comparator for evaluating instrument development). Around half of PROMs were given an “indeterminate” rating for all three aspects of development procedures and lack of content validity studies, so content validity could be rated based only on the reviewers’ rating about the instruments themselves. Supplementary Table iv shows the methodological quality and rating for the remaining measurement properties for each included study.

**Formulating recommendations for selection of instruments.** As COSMIN suggested, each PROM was placed in a recommendation category (A to C) according to its overall ratings and quality of evidence. PROMs with sufficient content validity and at least low-quality evidence for sufficient internal consistency were placed in category A, which meant they could be recommended for use and results obtained with these PROMs could be trusted. PROMs with high-quality evidence for an insufficient measurement property were placed into category C and should not be recommended for use. PROMs were placed in category B if they were categorized neither in A nor in C, which required further research to demonstrate their measurement properties.14

**Results**

**Selection and characteristics of studies.** In total, 155 articles were ultimately selected from 5,145 references (Figure 1). As a result, 34 PROMs were evaluated and their characteristics are presented in Table I.17–50 Among them, the Oxford Knee Score (OKS; 39 articles),42 Western Ontario and McMaster Universities Arthritis Index (WOMAC; 33 articles),43 Knee Injury and Osteoarthritis Outcome Score (KOOS; 18 articles),23 New Knee Society Scoring System (14 articles),12 and Forgotten Joint Score (FJS; 12 articles)20 were the most commonly evaluated instruments, with over ten included articles.

**Methodological quality and rating for measurement properties.** The methodological quality and rating for content validity is displayed in Supplementary Table iii. All included studies were of “doubtful” or “inadequate” methodological quality except for Patient’s Knee Implant Performance (PKIP),15 which had an “adequate” rating for instrument development. Around half of PROMs were given an “indeterminate” rating for all three aspects of development procedures and lack of content validity studies, so content validity could be rated based only on the reviewers’ rating about the instruments themselves. Supplementary Table iv shows the methodological quality and rating for the remaining measurement properties for each included study.

**Overall rating and quality of evidence for included PROMs.** Table II presents the qualitatively summarized ratings for the measurement properties of the included instruments. None of the PROMs reported overall ratings for all nine measurement properties, due to no rating being given for cross-cultural validity. Ratings for measurement invariance and criterion validity were reported for three and four instruments, respectively. We also analyzed quantitatively eight instruments with > 2 available results in internal consistency, reliability, or construct validity (Table III). Most results coincided except for the test–retest reliability results of Interim and Constant Osteoarthritis Pain (ICOAP) and Function,21 and the sports and recreation activities subscale in the KOOS— with better rating under quantitative analyses.
**Recommendation for selection of PROMs.** Eight instruments with “sufficient” ratings for the three indispensable measurement properties were placed in category A, fulfilling COSMIN standard for use as TKA outcome measures: OKS, Lower Limb Functional Scale (LEFS), KOOS Physical function Short form (KOOS-PS), FJS, WOMAC-Total Knee Replacement function short form (WOMAC-TKR), Oxford Knee Score—Activity and Participation Questionnaire (OKS-APQ), PKIP, and 12-item short form KOOS (KOOS-12).

In addition, the pain and function subscales in WOMAC, as well as the pain, function, and quality of life subscales in KOOS, were recommended for use as stand-alone subscales instead of whole instrument due to the “insufficient” internal consistency of the other subscales.

University of California Los Angeles (UCLA) activity score and Lower-Extremity Activity Scale (LEAS)—one-item questionnaire with sufficient content validity—also met the standard. However, we placed LEAS in category B because of “insufficient” construct validity and responsiveness.

The remaining scales were all placed in category B and required further validation studies. No included PROM was in category C.

**Feasibility and interpretability.** Descriptive data on feasibility and interpretability are shown in Supplementary Table v. For the recommended PROMs stated above, OKS, function subscale in WOMAC, and the function, sports and recreational activities subscale in KOOS had studies reporting > 10% items missing. Studies of ceiling effects—generally defined as > 15% of the respondents achieving the highest possible score—revealed that such effects emerged 6 to 12 months postoperatively for WOMAC, KOOS, and their adapted versions, despite the considerable variation in results between studies.
### Table 1. The characteristics of included patient-reported outcome measures.

| Instrument                                                        | Reference to the first article | Year initially published | Construct                                                                 | Recall period          | Number of items | Number of domains | Response options         | Scoring | Range of score | Interpretation of the score | Numbers of articles included |
|-------------------------------------------------------------------|--------------------------------|--------------------------|---------------------------------------------------------------------------|------------------------|-----------------|--------------------|--------------------------|---------|----------------|-------------------------------|-------------------------------|
| American Academy of Orthopaedic Surgeons (AAOS) Hip & Knee Core Scale | Johanson et al. (1)           | 2004                     | Impact on quality of life in hip & knee problem                           | Past week              | 7               | 3                  | 5-, 6-, 7-point ordinal response | Sum up and convert to a metric of 0 to 100 | 0 to 100 | 100 for the best possible score | 3                            |
| Anterior Knee Pain Scale (AKPS)                                  | Kujala et al. (2)             | 1993                     | Anterior knee pain symptoms                                               | Not mention            | 13              | 1                  | 3 to 4-, 5-point ordinal response | Sum up | 0 to 100 | 0 for the worst possible score | 2                            |
| Activity Scale for Arthritis Patients (ASAP)                     | Domczalik et al. (3)          | 2010                     | High level functioning and participating for arthroplasty recipients       | Today                  | 10              | 1                  | 4-point Likert response         | Sum up | 10 to 40 | 10 for the worst possible score | 2                            |
| Core Outcome Measures Index Knee (COMiKnee)                      | Impellizzeri et al. (4)       | 2016                     | Lack of clear description                                                 | Item dependent         | 6               | 5                  | 5-point Likert response         | Take the average of score (mean) for each domain | 0 to 10 | 0 for the best possible score                             | 1                            |
| Forgotten Joint Score (FJS)                                      | Behrendt et al. (5)           | 2012                     | Ability to forget the artificial joint                                     | Not mention            | 12              | 1                  | 3-point Likert response         | Sum up and convert to a metric of 0 to 100 | 0 to 100 | 0 for the worst possible score | 13                           |
| High Activity Arthroplasty Score (HAAS)                          | Talbot et al. (6)             | 2010                     | Valuation in functional ability after arthroplasty                        | Not mention            | 4               | 1                  | 4-, 5-, 6-, 7-point ordinal response | Sum up | 0 to 18 | 0 for the worst possible score | 3                            |
| High-Flaxion Knee Score (HFKs)                                   | Na et al. (7)                 | 2012                     | Knee status in the high-function range                                     | Not mention            | 9               | 2                  | 3-point Likert response         | Sum up and convert to a metric of 0 to 100 | 9 to 45 | 9 for the worst possible score | 1                            |
| Intermittent and Constant Osteoarthritis Pain (ICOPAP)           | Hawker et al. (8,9)           | 2007                     | Constant and intermittent pain experienced by hip & knee OA patients      | Past week              | 11              | 2                  | 5-point Likert response         | Sum up and convert to a metric of 0 to 100 for each subscale and total score | 0 to 100 | 0 for the best possible score | 9                            |
| Knee Injury and Osteoarthritis Outcome Score (KOOS)              | Roos et al. (10)              | 1998                     | Symptoms and function disability in knee injury and osteoarthritis patients | Past week              | 42              | 5                  | 5-point Likert response         | Sum up and convert to a metric of 0 to 100 for each subscale | 0 to 100 | 0 for the worst possible score | 18                           |
| Knee Injury and Osteoarthritis Outcome Score Joint Arthroplasty (KCOOL J) | Lyhman et al. (11)          | 2016                     | Knee health status before and after knee arthroplasty                      | Past week              | 7               | 1                  | 5-point Likert response         | Sum up and convert to a metric of 0 to 100 for each subscale | 0 to 100 | 0 for the worst possible score | 4                            |
| Knee Injury and Osteoarthritis Outcome/Physical function Short form (KCOOS-PS) | Perruccio et al. (12)        | 2008                     | Physical function states that represent the progression of psychological disability from early to late knee OA | Past week              | 7               | 1                  | 5-point Likert response         | Sum up and convert to a metric of 0 to 100 for each subscale | 0 to 100 | 0 for the best possible score | 8                            |
| 12-item short forms Knee Injury and Osteoarthritis Outcome (KIDOS-12) | Gandek et al. (13)           | 2018                     | Difficulties experienced by knee OA patients by measuring knee specific pain, function and quality of life | Past week              | 12              | 3                  | 5-point Likert response         | Sum up and convert to a metric of 0 to 100 for each subscale | 0 to 100 | 0 for the worst possible score | 2                            |
| Activities of Daily Living Scale of the Knee Outcome Survey (KOS-ADL S) | Irrgang et al. (14)          | 1998                     | Symptoms and functional limitations during activities of daily living      | Past 1 to 2 days       | 14              | 2                  | 6-point Likert response         | Sum up and convert to a metric of 0% to 100% | 0% to 100 | 0 for the worst possible score | 4                            |
| Knee Pain Questionnaire (KPQ)                                    | BÃœckstyns et al. (15)       | 1987                     | Knee pain                                                                 | Not mention            | 10              | 1                  | Dichotomous response           | The sum of positive and unanswered questions | 0 to 10 | 0 for the best possible score | 2                            |
| Knee Surgery Perception Questionnaire (KSPQ)                     | Levinger et al. (16)          | 2014                     | Discrepancy between patients’ expectations and actual functional abilities preceding to knee arthroplasty surgery | Current                | Part A:20       | 5                  | 6-point Likert response         | Part A&B: Sum up, Discrepancy score | Subtotal (the score of Part A+B) and Part B | Part A&B: 0 to 120 Discrepancy score: -120 to 120 | Part A&B: 0 for the worst possible score Discrepancy score: the lowest score for low expectation from surgery | 1                            |
| 2011 Knee Society Scoring System (KSS 2011)                      | Noble et al. (17)             | 2011                     | Health status of the knee by evaluating pain, functional limitations, satisfaction, and fulfillment of expectations | Not mention            | 34              | 7-2 subjective domains | 5, 6-, 7-point ordinal response | Sum up and convert to a metric of 0% to 100% | 0% to 100 | 0 for the worst possible score | 15                           |
| Adjusted 2011 Knee Society Scoring System (KSS-A)                | Dincer et al. (18)            | 2016                     | The same as KSS 2011                                                       | Not mention            | 25              | 5 (objective, 20 subjective) | 5 (objective, 4 subjective) | 3, 5-, 6-, 7-point ordinal response and NRS | Sum up and convert to a metric of 0% to 100% for each subscale and total score | 0% to 100 | 0 for the worst possible score | 1                            |
| Knee Society Scoring System short form (KSS short form)          | Scuderi et al. (19)           | 2015                     | The same as NKSS                                                          | Not mention            | 10              | 3                  | 3-, 5-, 6-, 7-point ordinal response and NRS | Sum up and convert to a metric of 0% to 100% for each subscale | Lack of clear description | Lack of clear description | 1                            |
| Instrument | Reference to the first article | Year initially published | Recall period | Number of items | Number of domains | Response options | Scoring | Range of score | Interpretation of the score | Numbers of articles included |
|------------|--------------------------------|--------------------------|---------------|----------------|------------------|-----------------|---------|---------------|----------------------------|------------------------------|
| Lower-Extremity Activity Scale (LeaS) | Saleh et al 35 | 2005 | Lower limb activity | Not mention | 18 | 1 | 1 point per checked item | 1 to 18 | 1 for the worst possible score | 2 |
| Lower Limb Functional Scale (LeFS) | Binkley et al 36 | 1999 | Lower limb function | Today | 20 | 1 | 3-point Likert response | Sum up | 0 to 80 | 0 for the worst possible score | 3 |
| Lequesne Algofunctional Index for the Knee (Lequesne) | Lequesne et al 37 | 1987 | Severity of knee OA | Not mention | 11 | 3 | 2-, 3-, 5-, 7-point ordinal response | Sum up and convert to six level of severity for knee OA. | 0 to 24 | 0 for the best possible score | 3 |
| Lysholm Knee Scoring Scale (Lysholm) | Lysholm et al 38 | 1982 | Lack of clear description | Not mention | 8 | 1 | 3-, 4-, 5-, 6-point ordinal response | Sum up | 0 to 100 | 0 for the worst possible score | 2 |
| Modified Forgotten Joint Score (MFJS) | Robinson et al 39 | 2018 | Ability to forget the artificial joint | Not mention | 10 | 1 | 5-point Likert response | Sum up and convert to a metric of 0% to 100% | 0% to 100% | 0 for the worst possible score | 1 |
| Computer-Adaptive Test for Hip and Knee OA (OA-CAT) | McDonough et al 40 | 2009 | Function, Pain and Disability associated with hip/ knee OA | Past month | 15 | 3 | 5-point ordinal response | Logit scores transformed to T-scores (Mean: 50, SD 10) | 0 to 100 | 0 for the worst possible score | 3 |
| Osteoarthritis of Knee and Hip Quality of Life Scale (OAKHQOL) | Rat et al 41 | 2006 | Quality of life affected by hip/ knee OA | Past 4 weeks | 43 | 5 | 11-point Likert response | Logit scores transformed to T-scores (Mean: 50, SD 10) | 0 to 100 | 0 for the worst possible score | 4 |
| Oxford Knee Score (OKS) | Dawson et al 42 | 1998 | Knee arthroplasty outcomes by measuring problems for knee arthroplasty recipients | Past 4 weeks | 12 | 1 | 5-point Likert response | Sum up | 0 to 48 | 0 for the worst possible score | 39 |
| Oxford Knee Score—Activity and Participation Questionnaire (OKS-APQ) | Dawson et al 43 | 2014 | Knee arthroplasty outcome by measuring physical activities and social participation | Past 4 weeks | 8 | 1 | 5-point Likert response | Sum up and convert to a metric of 0 to 100 | 0 to 100 | 0 for the worst possible score | 1 |
| Patient-Administered Questionnaires Knee (PAQ-knee) | Mancuso et al 44 | 2012 | Knee condition by measuring pain, function, psychological wellbeing, and satisfaction | Item dependent | 29 | 1 | 4-, 5-point ordinal response and VAS | Sum up 18 of the 29 questions | 0 to 100 | 0 for the best possible score | 1 |
| Patient’s Knee Implant Performance (PKP) | Lewis et al 45 | 2014 | Patients’ functional performance of their arthroplasty knee | Past week | 24 | 4 | 5-, 6-, 11-point ordinal response | Sum up and convert to a metric of 0 to 100 | 0 to 100 | 0 for the best possible score | 2 |
| Tegner Activity Scale | Tegner et al 46 | 1985 | Activity level | Current | 10 | 1 | 1 point per checked item | 0 to 10 | 0 for the worst possible score | 3 |
| University of California Los Angeles (UCLA) activity score | Amstutz et al 47 | 1984 | Activity level | Current | 10 | 1 | 1 point per checked item | 1 to 10 | 1 for the worst possible score | 7 |
| Western Ontario and McMaster Universities Arthritis Index (WOMAC) | Bellamy et al 48 | 1988 | Discomfort and disability in hip/knee OA patients | Past 48 hours | 24 | 3 | 5-point Likert response, VAS, or NRS | Sum up for each subscale | Dependent on response opinions | 0 for the best possible score | 34 |
| Western Ontario and McMaster Universities Arthritis Index—Total Knee Replacement function short form (WOMAC-TKR) | Libes et al 49 | 2013 | Knee specific function | Past 48 hours | 7 | 1 | VAS | Sum up and convert to a metric of 0 to 100 | 0 to 100 | 0 for the best possible score | 1 |
| Work, Osteoarthritis or joint-Replacement Questionnaire (WORKQ) | Kuech et al 50 | 2014 | Impact on work ability of knee problems | Past week | 13 | 1 | 5-point Likert response | Sum up and convert to a metric of 0 to 100 | 0 to 100 | 0 for the worst possible score | 2 |

NRS, numerical rating scales; OA, osteoarthritis; VAS, visual analogue scale.
### Table II. Overall qualitative rating and quality of evidence for measurement properties of each instrument.

| Instrument             | Subscales                                      | Content validity | Structural validity | Internal consistency | Cross-cultural validity | Measurement invariance |
|------------------------|------------------------------------------------|------------------|---------------------|----------------------|-------------------------|-------------------------|
|                        | Overall rating | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence |
| AAOS Hip and Knee      | ±               | Very low           |                 |                      | ?            | Low                  |             |                      |             |                     |
| AKPS                   | +               | Very low           |                 |                      | ?            | Low                  |             |                      |             |                     |
| ASAP                   | ±               | Very low           |                 |                      | ?            | Low                  |             |                      |             |                     |
| COMI-knee               | +               | Very low           |                 |                      |             |                      |             |                      |             |                     |
| FJS                    | +               | Moderate           | +               | High                 | +           | High                 |             |                      |             |                     |
| HAAS                   | +               | Moderate           |                 |                      | ?            | Moderate              |             |                      |             |                     |
| HFKS                   | +               | Very low           |                 |                      |             |                      |             |                      |             |                     |
| ICOAP                  | Constant pain  | +                 | Very low | ?                      | Moderate             |                      |             |                      |             |                     |
|                        | Intermittent pain | +            | Very low | ?                      | Moderate             |                      |             |                      |             |                     |
| KOOS                   | Pain            | +                 | Moderate | +                       | High             | +                     | High                 |             |                      |             |                     |
|                        | Function, daily living | +         | Very low | +                       | Moderate             |                      |             |                      |             |                     |
|                        | Function, sports and recreational activities | +          | Moderate | +                       | High             | +                     | High                 |             |                      |             |                     |
|                        | Quality of life | +                 | Moderate | +                       | High             | +                     | High                 |             |                      |             |                     |
|                        | Symptoms        | +                 | Moderate | +                       | High             | +                     | High                 |             |                      |             |                     |
| KOOS, JR               | +               | Very low           |                 |                      | ?            | Moderate              |             |                      |             |                     |
| KOOS-PS                | +               | Low               | +               | Moderate             | +           | High                 |             |                      |             |                     |
| KOOS-12                | +               | Very low           | +               | Moderate             | +           | High                 |             |                      |             |                     |
| KOS-ADLS               | +               | Very low           | +               | Moderate             | ?           | Low                  |             |                      |             |                     |
| KPQ                    | +               | Very low           | +               | Moderate             | ?           | Moderate              |             |                      |             |                     |
| KSPQ                   | +               | Very low           | +               | Moderate             | ?           | Moderate              |             |                      |             |                     |
| KSS (2011)             | +               | Very low           | ?               | Moderate             | ?           | Moderate              |             |                      |             |                     |
| KSS-A                  | +               | Very low           | +               | Low                  | ?           | Low                  |             |                      |             |                     |
| KSS short form         | +               | Very low           | ?               | Moderate             | ?           | Moderate              |             |                      |             |                     |
| LEAS                   | +               | Very low           | +               | Low                  | +           | Moderate              |             |                      |             |                     |
| LEFS                   | +               | Very low           | +               | Low                  | ?           | Very low              |             |                      |             |                     |
| Lequesne               | +               | Very low           | +               | Low                  | ?           | Very low              |             |                      |             |                     |
| Lysholm                | ?               | Very low           | +               | Moderate             | ?           | Low                  |             |                      |             |                     |
| MFJS                   | +               | Very low           | +               | Moderate             | ?           | Low                  |             |                      |             |                     |
| OA-CAT                 | ?               | +                 | Moderate | +                       | Moderate             |                      |             |                      |             |                     |
| OAKH QOL               | +               | Moderate           |                 |                      |             |                      |             |                      |             |                     |
| OKS                    | +               | Moderate           | +               | High                 | +           | High                 |             |                      |             |                     |
| OKS-APQ                | +               | Very low           | +               | Low                  | +           | Moderate              |             |                      |             |                     |
| PAQ-knee               | +               | Very low           | +               | Moderate             | ?           | Low                  |             |                      |             |                     |
| PKP                    | +               | Moderate           | +               | High                 | +           | High                 |             |                      |             |                     |
| Tegner                 | ±               | Very low           |                 |                      |             |                      |             |                      |             |                     |

Continued
| Instrument Subscales | Content validity | Structural validity | Internal consistency | Cross-cultural validity | Measurement invariance |
|----------------------|------------------|---------------------|---------------------|------------------------|------------------------|
| Overall rating       | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence |
| UCLA                 | +                | Very low             | +                   | Low                 | +                     | High          |
| WOMAC                | +                | Very low             | +                   | Low                 | ?                     | Moderate      |
| WOMAC-TKR            | +                | Very low             | +                   | Low                 | +                     | Moderate      |
| WORQ                 | +                | Moderate             | ?                   | Low                 | ?                     | Low           |
| Overall rating       | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence |
| Instrument Subscales | Reliability      | Measurement error    | Criterion validity  | Construct validity  | Responsiveness         | Overall rating | Quality of evidence | Overall rating | Quality of evidence |
| Overall rating       | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence | Overall rating | Quality of evidence |
| AAOS Hip and Knee    | +                | Very low             | +                   | Moderate            | +                     | Moderate      |
| AKPS                 | +                | Very low             | +                   | Moderate            | +                     | Low           |
| ASAP                 | +                | Moderate             | ?                   | Low                 | +                     | Moderate      |
| COMI-knee            | +                | Very low             | ?                   | Very low            | +                     | Moderate      |
| FJS                  | +                | High                 | –                   | Low                 | +                     | High          |
| HAAS                 | +                | Low                  | ?                   | Low                 | +                     | Moderate      |
| HKFS                 | +                | Moderate             | -                   | Very low            | +                     | Very low      |
| ICOAP                | ±                | Moderate             | –                   | Very low            | +                     | High          |
| Intermittent pain    | –                | Moderate             | –                   | Very low            | +                     | Low           |
| KOOS                 | +                | Moderate             | +                   | Low                 | ±                     | High          |
| Function, daily living | +          | Moderate             | +                   | Very low            | +                     | Moderate      |
| Function, sports and recreational activities | ± | Moderate | – | Moderate | + | High |
| Quality of life Symptoms | + | Moderate | – | Very low | + | High |
| KOOS, JR             | +                | Moderate             | –                   | Very low            | +                     | Moderate      |
| KOOS-PS              | ±                | Moderate             | +                   | Very low            | +                     | High          |
| KOOS-12              | +                | Moderate             | +                   | Very low            | +                     | Moderate      |
| KOS-ADLS             | +                | Low                  | ?                   | Low                 | +                     | High          |
| KPQ                  | –                | Very low             | +                   | Moderate            | +                     | Very low      |
| KSPQ                 | +                | Moderate             | +                   | Very low            | +                     | Moderate      |
| KSS (2011)           | +                | High                 | +                   | Moderate            | +                     | Low           |
| KSS-A                | +                | Moderate             | +                   | Moderate            | +                     | Very low      |
| KSS short form       | +                | Moderate             | +                   | Very low            | +                     | Moderate      |
| LEAS                 | +                | Very low             | +                   | Moderate            | +                     | Moderate      |
| LEFS                 | +                | Very low             | +                   | Moderate            | +                     | Very low      |

Continued
### Table II. Continued

| Instrument | Subscales | Content validity | Structural validity | Internal consistency | Cross-cultural validity | Measurement invariance |
|------------|-----------|------------------|---------------------|----------------------|-------------------------|------------------------|
|            |           | Overall rating    | Quality of          | Overall rating       | Quality of evidence     | Overall rating         | Quality of evidence    |
|            |           | Quality of        | evidence            | Quality of evidence  |                         |                        |                      |
| Lequesne   |           | --                | Low                 | ?                    | Very low                | +                      | Very low              |
| Lysholm    |           | +                 | Very low            | ?                    | Very low                | +                      | Moderate              |
| MFJS       |           | +                 | Very low            | --                   | Low                     | +                      | Moderate              |
| OA-CAT     |           | --                | Low                 | ?                    | Very low                | +                      | Moderate              |
| OAKHQOL    |           |                  |                     | --                   | Low                     | +                      | Low                  |
| OKS        |           | +                 | High                | +                    | Moderate                | +                      | High                 |
| OKS-APQ    |           | +                 | Very low            | --                   | Low                     | +                      | Very low              |
| PAQ-knee   |           | +                 | Low                 | --                   | Low                     | +                      | Low                  |
| PKIP       |           | +                 | Very low            | ?                    | Low                     | +                      | Moderate              |
| Tegner     |           | +                 | Very low            | ?                    | Very low                | +                      | Moderate              |
| UCLA       |           | +                 | Low                 | ?                    | Low                     | +                      | Moderate              |
| WOMAC      | Pain, and | +                 | High                | +                    | Low                     | +                      | Low                  |
|            | Function  |                   |                     |                      |                         |                        |                      |
| WOMAC-TKR  | Stiffness | +                 | High                | --                   | Low                     | +                      | Moderate              |
| WORQ       |           | +                 | Moderate            | +                    | Very low                | +                      | Very low              |

*+, sufficient; –, insufficient; ±, inconsistent; ?, indeterminate; AAOS Hip and Knee, AAOS Hip and Knee Core Scale; AKPS, Anterior Knee Pain Scale; ASAP, Activity Scale for Arthroplasty Patients; COMI-knee, Core Outcome Measures Index knee; FJS, Forgotten Joint Score; HAAS, High-Activity Arthroplasty Score; HFKS, High-Flexion Knee Score; ICDAP, Intermittent and Constant Osteoarthritis Pain; KOOS, Knee Injury and Osteoarthritis Outcome Score; KOOS-JR, Knee Injury and Osteoarthritis Outcome Score Joint Arthroplasty; KOOS-PS, Knee Injury and Osteoarthritis Outcome Physical Function Short form; KOOS-12, 12-item short forms Knee Injury and Osteoarthritis Outcome; KOS-ADLS, Activities of Daily Living Scale of the Knee Outcome Survey; KPQ, Knee Pain Questionnaire; KSPQ, Knee Surgery Perception Questionnaire; KSS (2011), 2011 Knee Society Scoring System; KSS-A, Adjusted 2011 Knee Society Scoring System; KSS short form, Knee Society Scoring System short form; LEAS, Lower-Extremity Activity Scale; LEFS, Lower Limb Functional Scale; Lequesne, Lequesne Algofunctional Index for the Knee; Lysholm, Lysholm Knee Scoring Scale; MFJS, Modified Forgotten Joint Score; OA-CAT, Computer-Adaptive Test for Hip and Knee OA; OAKHQOL, Osteoarthritis of Knee and Hip Quality of Life Scale; OKS, Oxford Knee Score; OKS-APQ, Oxford Knee Score—Activity and Participation Questionnaire; PAQ-knee, Patient Administered Questionnaires Knee; PKIP, Patient’s Knee Implant Performance; Tegner, Tegner Activity Scale; UCLA, University of California Los Angeles activity score; WOMAC, Western Ontario and McMaster Universities Arthritis Index; WOMAC-TKR, Western Ontario and McMaster Universities Arthritis Index—Total Knee Replacement function short form; WORQ, Work, Osteoarthritis or joint-Replacement Questionnaire.
Table III. Quantitative summarizing measurement properties for eligible instruments.

| Instruments | Subscales                             | Pooled Cronbach’s α Mean (Range) | Pooled ICC Mean (95% CI) | Pooled Pearson correlation coefficient Mean (95% CI) * |
|-------------|---------------------------------------|----------------------------------|--------------------------|-----------------------------------------------------|
|             |                                       |                                  | Bodily pain              | Physical function                                    | Role emotional          | Mental health          | PCS                     | MCS                     |
| FJS         | Constant pain                         | 0.94 (0.81, 0.97)                | 0.93 (0.92, 0.94)        |                                                      |                        |                        |                         |                         |
|             | Intermittent pain                     | 0.90 (0.76, 0.97)                | 0.93 (0.92, 0.94)        |                                                      |                        |                        |                         |                         |
| KOOS        | Pain                                  | 0.88 (0.81, 0.93)                | 0.83 (0.86, 0.90)        | 0.63 (0.63, 0.64) | 0.49 (0.49, 0.49) | 0.17 (0.16, 0.18) | 0.27 (0.27, 0.28)      |
|             | Function, daily living                | 0.94 (0.80, 0.96)                | 0.85 (0.82, 0.88)        | 0.62 (0.61, 0.62) | 0.60 (0.60, 0.60) | 0.29 (0.28, 0.30) | 0.32 (0.32, 0.32)      |
| KOOS-PS     | Quality of life                       | 0.82 (0.71, 0.92)                | 0.81 (0.78, 0.84)        | 0.53 (0.53, 0.54) | 0.48 (0.47, 0.48) | 0.19 (0.19, 0.20) | 0.28 (0.28, 0.28)      |
| KOOS-12     | Symptoms                              | 0.75 (0.56, 0.93)                | 0.85 (0.83, 0.88)        | 0.45 (0.45, 0.45) | 0.37 (0.37, 0.38) | 0.17 (0.17, 0.18) | 0.24 (0.24, 0.24)      |
| KSS (2011)  | Symptoms                              | 0.80 (0.31, 0.96)                | 0.89 (0.86, 0.91)        | 0.35 (0.32, 0.39) | 0.24 (0.21, 0.26) | 0.15 (0.13, 0.16) | 0.17 (0.15, 0.19)      | 0.36 (0.34, 0.38) | 0.19 (0.18, 0.20) |
|             | Patient satisfaction                  | 0.88 (0.79, 0.95)                | 0.88 (0.85, 0.90)        | 0.49 (0.47, 0.51) | 0.32 (0.30, 0.33) | 0.24 (0.22, 0.25) | 0.29 (0.27, 0.30)      | 0.33 (0.31, 0.36) | 0.30 (0.29, 0.30) |
|             | Patient expectations                  | 0.88 (0.73, 1.00)                | 0.85 (0.82, 0.87)        | 0.08 (0.06, 0.11) | 0.13 (0.11, 0.16) | 0.12 (0.12, 0.13) | 0.10 (0.08, 0.11)      | 0.05 (0.03, 0.08) | 0.10 (0.09, 0.11) |
|             | Walking and standing                  | 0.80 (0.68, 0.96)                | 0.84 (0.80, 0.87)        |                                                      |                        |                        |                         |                         |
|             | Standard activities                   | 0.88 (0.83, 0.94)                | 0.86 (0.82, 0.89)        |                                                      |                        |                        |                         |                         |
|             | Advanced activities                   | 0.84 (0.73, 0.93)                | 0.84 (0.80, 0.87)        |                                                      |                        |                        |                         |                         |
|             | Discretionary knee activities         | 0.79 (0.51, 0.94)                | 0.78 (0.72, 0.82)        |                                                      |                        |                        |                         |                         |
|             | Functional activities                 | 0.90 (0.80, 0.93)                | 0.92 (0.91, 0.94)        | 0.47 (0.46, 0.49) | 0.52 (0.50, 0.54) | 0.28 (0.26, 0.29) | 0.32 (0.30, 0.33)      | 0.57 (0.56, 0.59) | 0.24 (0.22, 0.25) |
| OKS         | Functional activities                 | 0.92 (0.66, 0.94)                | 0.93 (0.92, 0.94)        | 0.62 (0.61, 0.63) | 0.66 (0.66, 0.67) | 0.32 (0.31, 0.33) | 0.32 (0.31, 0.32)      | 0.65 (0.64, 0.66) | 0.46 (0.45, 0.48) |
| WOMAC       | Function                              | 0.94 (0.82, 0.98)                | 0.91 (0.89, 0.93)        | -0.56 (-0.56, -0.55) | -0.57 (-0.57, -0.57) | -0.30 (-0.31, -0.30) | -0.26 (-0.27, -0.26) |                         |                         |

Continued
### Table III. Continued

| Instruments | Subscales | Pain | Stiffness |
|-------------|-----------|------|----------|
|             | Pooled Cronbach's α Mean (95% CI) | Pooled Pearson correlation coefficient Mean (95% CI)* | Pooled Cronbach's α Mean (95% CI) | Pooled Pearson correlation coefficient Mean (95% CI)* |
| Bodily pain  | 0.88 (0.67, 0.91) | 0.86 (0.84, 0.90) | 0.84 (0.79, 0.91) | 0.80 (0.67, 0.91) |
| Physical function | 0.73 (0.60, 0.83) | 0.65 (0.54, 0.74) | 0.66 (0.62, 0.70) | 0.56 (0.40, 0.76) |
| Role emotional | 0.71 (0.61, 0.80) | 0.62 (0.49, 0.73) | 0.64 (0.60, 0.68) | 0.54 (0.35, 0.72) |
| Mental health | 0.70 (0.59, 0.79) | 0.61 (0.48, 0.72) | 0.63 (0.59, 0.67) | 0.53 (0.35, 0.71) |
| PCS | -0.49 (0.37, 0.59) | -0.40 (0.29, 0.50) | -0.39 (0.28, 0.49) | -0.33 (0.22, 0.44) |
| MCS | -0.26 (0.12, 0.38) | -0.22 (0.09, 0.36) | -0.21 (0.09, 0.34) | -0.19 (0.07, 0.32) |

*Pearson coefficients with 36-Item Short-Form Health Survey questionnaire.

**Table III.**

### Discussion

Our review systematically summarized 155 articles evaluating the measurement properties of 34 PROMs according to the latest COSMIN methodology. Nine PROMs (OKS, LEFS, KOOS-PS, FJS, WOMAC-TKR, OKS-APQ, PKIP, KOOS-12, and UCLA) met the COSMIN standard for recommendation of use for assessing TKA outcomes. WOMAC and KOOS were recommended for use as separate subscales, rather than a total score. The other 23 instruments, including the stiffness subscale in WOMAC, and the symptoms subscale in KOOS, had the potential for use but would need further validation studies.

The strengths of our review were its size and use of the latest COSMIN methodology. We identified 34 specific PROMs in the TKA population, which exceeded the 13 scales in the review by Harris et al (five knee scores and eight lower-limb scores). Thus, with new articles published in the last five years, it is no wonder that we identified more psychometrically validated PROMs than those in OKS and OKS-APQ as revealed by Harris et al. With regard to WOMAC, our results concurred with the supporting measurement properties identified by Harris et al for pain and function subscales, but without evidence for sufficient structure validity for the stiffness subscale. Thus, we recommended to use pain and function subscales solely.

We also identified 68 additional articles that were not included in the review by Gagnier et al. Of these, 31 documented development or assessed the psychometric properties of 11 additional PROMs (Core Outcome Measures Index Knee, High-Flexion Knee Score, KOOS, Joint Replacement, KOOS-12, 2011 KSS, KOOS-12, 2011 KSS, Adjusted 2011 KSS, KSS short form, LEFS, Modified FJS, Computer-Adaptive Test for Hip and Knee OA, and UCLA). Eight instruments were not selected for our review: the British Orthopaedic Association Score and Original KSS were not completely patient-reported; the Physical Activity Scale for the Elderly questionnaire, Self-Efficacy for Rehabilitation outcome scale, and Short Musculoskeletal Function Assessment Questionnaire did not aim to measure TKA outcomes; Arthritis ImpactMeasurement Scales, Japanese Knee Osteoarthritis Measure, and the Lower Limb Activity Profile were not evaluated for their psychometric properties in a specific TKA population. We concurred with the review by Harris et al as they considered Musculoskeletal Outcomes Data Evaluation and Management System and AAOS Hip and Knee Questionnaire as the same instrument, and combined their results. However, our findings are completely different from those in a systematic review by Gagnier et al in that they concluded Work, Osteoarthritis or joint-Replacement Questionnaire (WORQ) to be a promising instrument. This change could be explained by the addition of recently published literature in our study, especially on those evaluating structure validity (one of the determinants for recommendation).
as well as modifications in methodological instruments. The updated COSMIN methodology established a standard for instrument selection instead of counting positive ratings for properties.

**Measurement properties related to recommendation formulation.** Content validity and internal consistency were related to the quality of items and internal structure of instruments. Thus, sufficient ratings of these properties constituted the basic requirement for instrument selection.14

**Content validity.** The rating for content validity of a PROM was given based on the information on development study, content validity studies, and the instrument itself. As for PROMs development, 11/34 included development studies that provided a clear description of representative patient involvement in elicitation of items, which was in concordance with a previous study which revealed that more than one-quarter of the development procedures lacked patient involvement.76 Approximately one-half of 11 PROMs were developed based on a TKA population, which would degrade the quality of evidence for the other half of instruments because of indirectness. PROMs were developed to reflect disease effects on patients from their perspective. Items failed to achieve this purpose if they were generated by physicians or focus groups without a targeted population. Thus, PROMs should be “indeterminate” because we could not formulate a hypothesis without knowing the true change.

**Feasibility and interpretability.** In recent decades, conventional PROMs (e.g. WOMAC, KOOS, OKS) have been blamed for their postoperative ceiling effects (15% of the respondents achieving the highest possible score). We found that ceiling effects started to occur in WOMAC, KOOS, and their adapted versions six to 12 months after TKA (especially for pain subscales). Obvious ceiling effects were not revealed for OKS or other PROMs under this definition.

The ceiling effect is crucial because it prevents detection of further improvements in patients who have reached the highest score, which influences the discriminative power of the instrument. Improvements in surgical methods and changes in TKA recipients (e.g. increase in the number of younger patients with higher functional demands and expectations)90 require expansion of the threshold for the best possible state defined 20 to 30 years previously.

**Reliability and measurement error.** Reliability and measurement error were assessed based on test–retest designs, but reliability (i.e. ICC) was more commonly calculated than measurement error. With respect to the methodological quality of test–retest designs, nearly three-quarters of studies had a “dubtful” or “inadequate” rating due to inappropriate time intervals and/or unclear test conditions. Time intervals between the two tests should be neither too short nor too long to avoid a recall bias and changes in the patient’s state, respectively. A time interval of two weeks is, in general, considered appropriate, albeit this is not standardized.89

**Hypothesis for construct validity and responsiveness.** The latest COSMIN methodology deletes all standards for formulating hypotheses, and is recommended to set or adopt hypotheses by the review teams themselves.14 This strategy led to more evidence on hypotheses for construct validity (30/34 of included instruments) and responsiveness (26/34 of included instruments). More than 80% of included studies measured responsiveness by calculating the effect size rather than a correlation coefficient. The effect size measures the magnitude of change, but gives little information about the ability of the instrument to detect changes over time (i.e. responsiveness).89 We rated these results as “indeterminate” because we could not formulate a hypothesis without knowing the true change.

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The ceiling effect is crucial because it prevents detection of further improvements in patients who have reached the highest score, which influences the discriminative power of the instrument. Improvements in surgical methods and changes in TKA recipients (e.g. increase in the number of younger patients with higher functional demands and expectations)90 require expansion of the threshold for the best possible state defined 20 to 30 years previously.

As PROMs, scores for ceiling effects are thought to reflect patients’ perception of their health status rather than the ability to discriminate changes.91 The goal of TKA is to achieve freedom from pain and functional satisfaction. In addition, many patients do not experience pain postoperatively, which leads to a skewed distribution of postoperative scores.

Thus, ceiling effects have a limited impact on the use of all recommended PROMs in TKA recipients overall. However, for long-term follow-up studies (or younger patients with high activity demands), instruments with...
a specific construct (e.g. “forgotten artificial joints”) or developed for a specific population (e.g. OKS-APQ) can be implemented.

**Current trends.** Recently, researchers have shown an increased interest in PROMs as an outcome measure for TKA. In our systematic review, though the first included PROM was introduced in 1982, half of the PROMs and more than 60% of studies included were developed within the last decade. A systematic review also showed an increase in use of PROMs in TKA studies.

However, the most frequently evaluated and used PROMs remain OKS, WOMAC, and KOOS, which were developed more than 20 years ago. However, except for OKS, other instruments were not of sufficient quality. Also, sufficient internal consistency for subscales in KOOS and WOMAC was not demonstrated until publication of a study in 2019, which highlighted the need for recommending PROMs of sufficient measurement properties to use in clinical practice and research.

In our review, no instrument was evaluated for all nine measurement properties. Also, no study of high methodological quality assessed content validity or cross-cultural validity. To this extent, the recommended PROMs only met the minimal requirements for psychometric validity and still require further validation studies. Further studies are still warranted to evaluate existing PROMs, especially for a study evaluating content validity of included PROMs by interviewing patients and experts because content validity studies are the only variable determinants for this measurement property.

Additionally, we used qualitative and quantitative methods to synthesize ratings for measurement properties, and quantitative methods produced better ratings. Often, a quantitatively pooled method has a better ability to detect subtle changes than a qualitatively summarized method. Thus, we suggest using both qualitative and quantitative methods when conducting COSMIN review in the future.

Our systematic review had three main limitations. First, although we undertook exhaustive research unlikely missing any major trials, omissions might have occurred. Thus, we searched all the references of included studies manually, and included all the relevant articles. Second, we only included studies evaluating measurement properties in a TKA population. Thus, the results tested on populations combining TKA, total hip arthroplasty, or other patients were eliminated, which contributed to some PROMs and studies in previous systematic reviews not being included in our study. We believe that this strict inclusion criterion could increase the accuracy of our results in TKA patients. Finally, the recommendation formulated by our review does not necessarily mean the other 23 instruments are of “poor” quality. To some extent, they require further robust studies to evaluate their measurement properties.

In conclusion, nine PROMs and six subscales in two PROMs met the minimum requirements for psychometric validation and can be recommended for use as measures of TKA outcome. These are OKS, LEFS, KOOS-PS, FJS, WOMAC-TKR, OKS-APQ, PKIP, KOOS-12, UCLA, the pain and function subscales in WOMAC, and the pain, function, and quality-of-life subscales in KOOS. However, none of the included PROMs have been validated for all measurement properties. Thus, further studies are still warranted to evaluate those PROMs. Use of the other 25 scales and subscales should be tempered until further studies validate their measurement properties.

**Supplementary material**

Includes PubMed search strategy, tables showing Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) criteria and approach, and tables documenting methodological quality, qualitative rating, and descriptive data for each instrument per article. References of all included studies are also provided.

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Author information:
- Y. Wang, MD, Surgeon
- S. Zhu, MD, Surgeon
- X. Chen, MD, Surgeon
- W. Qian, MD, Chief surgeon
- Department of Orthopedic Surgery, Peking Union Medical College Hospital, Peking Union Medical College, Chinese Academy of Medical Science, Beijing, China.
- M. Yin, BSc, Researcher, Institute of Basic Medical Sciences Chinese Academy of Medical Sciences, School of Basic Medicine Peking Union Medical College, Beijing, China.
- H. Zhou, MD, Surgeon, Plastic Surgery Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China.

Author contributions:
- Y. Wang: Designed the study, Performed the systematic evaluation, Drafted the article.
- M. Yin: Performed the systematic evaluation and statistical analysis.
- S. Zhu: Acquired and extracted the data.
- X. Chen: Acquired and extracted the data.
- H. Zhou: Drafted the manuscript.
- W. Qian: Advised and revised the study design, Edited the manuscript.

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