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Preoperative Quadriceps Muscle Strength and Functional Ability Predict Performance-Based Outcomes 6 Months After Total Knee Arthroplasty: A Systematic Review

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Background. One-third of individuals report limitations in activities of daily living even 6 months after total knee arthroplasty (TKA). Moderate-quality evidence exists for several sociodemographic and clinical predictors of patient-reported outcome measures of perceived functionality. Objectively measured performance-based measures (PBMs) provide a less subjective approach to informing patient treatment after TKA; however, information about predictors of functionally relevant PBMs is scarce.

Purpose. This systematic review synthesized the available research on preoperative predictors of PBMs after primary TKA for osteoarthritis.

Data Sources. In June 2016 and January 2017, MEDLINE, EMBASE, and PsycINFO databases were searched.

Study Selection. Cohort studies exploring preoperative predictors of stair climbing, walking speed, and gait speed measured ≥ 6 months after primary TKA were included. Screening of abstracts and selection of full texts were undertaken by 2 independent reviewers.

Data Extraction. Information on study design, patient characteristics, analysis, and results was extracted using pilot-tested forms. Two independent reviewers assessed risk of bias using modified Quality in Prognostic Studies criteria.

Data Synthesis. Of the eligible 12 studies involving 6 prospective cohorts, 10 studies reported information on baseline predictors. Meta-analysis of predictors was not possible because of missing information on effect size or standard errors. Narrative synthesis of evidence of predictors was therefore performed.

Limitations. The quality of evidence was low because of the risk of bias and heterogeneity of included studies as well as nonreporting of measures of effect.

Conclusions. Low-quality evidence exists for an association of preoperative functional ability and quadriceps muscle strength with functionality at 6 months after TKA. Improved reporting of predictor analyses is needed to enable evidence generation for clinical management.



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Osteoarthritis of the knee is an age-related degenerative condition leading to considerable disability.^{1,2} Total knee arthroplasty (TKA) is a well-established procedure for treatment of end-stage osteoarthritis³ and has been shown to significantly improve pain, function, and quality of life.^{4,5} Systematic reviews of observational studies of patients undergoing TKA have shown improvements in walking speed,⁶ rates of return to work,⁷ or sports.⁸ Since the inception of TKA in 1970, both the surgical procedure and the prosthesis have evolved,⁹ leading to earlier recovery, greater range of motion, and longer prosthesis survival. Consequently, there has been an increase in the use of this procedure across developed and developing nations,^{10–12} with a shift toward younger (<60 years old) recipients.¹³

From a patient's perspective, gain in function and relief from pain are the most important outcomes after TKA.¹⁴ But evidence shows that 10% to 30% of patients have suboptimal relief from pain,¹⁵ and around 25% have limitations in activities of daily living.¹⁶ This is also corroborated by objective measures like limitation in stair climbing, which can persist 2 years after TKA.¹⁷ Such impairments and limitations contribute to dissatisfaction among patients.¹⁸ Longitudinal studies with repeated measurements of walking ability have shown that whereas acute recovery occurs during the first 3 months following the procedure, improvement continues beyond this period, peaking at 6 months and plateauing thereafter.^{19,20} Other studies^{21–24} have shown that maximum benefit in other measures of recovery follows a similar pattern. Therefore, follow-up until at least 6 months is required to gauge the extent of recovery and identify patients with suboptimal functional outcomes after TKA.

Functional recovery is measured using either subjective patient-reported outcome measures (PROMs)²⁵ or objective performance-based measures (PBMs).²⁶ Previous studies have shown that PROMs fail to capture actual objectively measured change.^{22,27,28} Use of PROMs alone has resulted in an overestimation of functional improvement, and a key reason for this discrepancy is confounding of perceived benefit by pain.²⁹ Hence, the current recommendation is to use both types of measurement tools to define extent of benefit after arthroplasty.^{30,31} However, PROMs are not a substitute for PBMs or vice versa. Other advantages of PBMs over PROMs are the ease of interpretation across varying contexts, interpretable units, and availability of minimally important change.³² Despite this, PROMs have dominated arthroplasty prognostic research, most likely because of their ease of use.

Several systematic reviews of cohort studies have identified predictors of suboptimal improvement in PROMs, such as post-TKA persistent pain,^{33,34} patient satisfaction,³⁵ and knee-specific quality of life.^{34,36,37} However, the predictors of objective functional outcomes

are comparatively less well understood. Predictors of objective outcomes might possibly differ from those of subjective outcomes because of poor agreement between them.^{22,27,28,38} Hence, knowledge of predictors of suboptimal objective functional outcomes alongside the existing knowledge of predictors of PROMs will better inform the surgeon and physical therapist, enabling them to identify individuals who could have persistent functional impairment and to communicate this information to patients before TKA. Further, any modifiable preoperative predictor could also form the basis for preoperative interventions aiming to improve post-TKA outcomes. A previous systematic review³⁹ collated evidence on predictors of stair-climbing (SC) ability in the post-TKA population and was inconclusive because of an insufficient number of studies. This previous review also included cross-sectional studies, which have limited value for identifying predictors, and the studies focused on only a single outcome (SC). Subsequently, several newer cohort studies of varying follow-up periods have been published; these have reported on predictors of other standardized single-activity PBMs such as walking speed (WS) and gait speed.

Therefore, we asked the following 2 research questions for this systematic review: What is the average change in PBMs from the preoperative state to ≥ 6 months after TKA? What are the preoperative predictors of objectively determined PBMs at 6 months after primary TKA for osteoarthritis?

Methods

Overall Approach

Search methods, eligibility criteria, methods for selection, and data extraction of eligible studies were prespecified in a protocol registered at PROSPERO 2016: CRD42016039872,⁴⁰ and we report this review as per requirement of the PRISMA statement.⁴¹

Data Sources and Searches

We searched MEDLINE (OVID interface, 1948 onwards), EMBASE (OVID interface, 1980 onwards), and PsycINFO) in June 2016 and updated the search in January 2017, using a combination of the search terms “Knee Arthroplasty,” “Osteoarthritis,” “Outcomes,” and “Predictors.” We restricted the search to human studies and to journal publications only. No study design or language restrictions were imposed in the search. The search strategy for MEDLINE is shown in the Appendix.

Study Inclusion Criteria

We included observational and experimental prospective cohorts, and retrospective cohort studies. Cross-sectional and case-control studies were not included.

Patients were undergoing primary unilateral or bilateral TKA for degenerative osteoarthritis. Studies including patients undergoing surgical procedures for knee and/or

Functionality Predictors After Knee Arthroplasty

hip replacement were excluded if data were not presented separately. We excluded studies focusing on patients undergoing unicompartment knee arthroplasty or arthroplasty for knee injuries or rheumatoid arthritis.

Predictors. Any patient-related predictor measured before undergoing TKA was included.

Outcomes. Four objectively measured functional outcomes—SC ability, WS, chair-rising test, and Timed “Up & Go” Test (TUG)—at a minimum follow-up period of 6 months were used. The prespecified definitions of the outcomes were as follows:

- WS—timed distance in meters (eg, 6-Minute Walk Test) or time taken to cover a fixed distance at self- or fast-paced walking
- SC ability—total time in seconds needed to ascend and descend stairs (9 steps and 12 steps, respectively, with a height of 16–20 cm) with or without the use of a handrail, or speed of ascending or descending stairs
- TUG—total time in seconds needed to get up from a chair, walk up to 3 m, turn around, walk back, and sit on the same chair
- Chair-rising test—number of times a patient came to a full standing position from a chair (with a height of ~43 cm [17 in]) in 30 seconds without taking support from an arm of the chair or a walking aid

Types of analysis. We included studies that reported univariable or multivariable regression analysis irrespective of the phase of prognosis research.⁴²

Selection of Studies

Two independent reviewers (N.D. and S.S.) performed nonmasked screening of title and abstract. Disagreements were resolved by discussion, and the opinion of a third reviewer (R. Maddison) was sought only if agreement was not reached between N.D. and S.S. Full texts of potentially eligible articles were further screened for eligibility. An online systematic review data management system (COVIDENCE; www.covidence.org) was used for the screening and selection process. We did inverse searching of the reference lists of eligible articles and systematic reviews in this topic to identify further eligible studies.

Data Extraction and Quality Assessment

Two reviewers (N.D. and S.S.) independently extracted data from eligible full texts on patient characteristics, study design, sample size at baseline and follow-up visits, outcomes (mean and standard deviation [SD]) along with their definitions, predictor information along with coefficients and 95% CI or standard error of estimate, and data related to quality assessment at the study level. When authors reported stepwise regression, change in R^2 ($R^2 =$

multivariate coefficient of determination) was extracted for each predictor. If predictor analysis was provided for multiple time points, then data were extracted for all time points ≥ 6 months.

The assessment of the risk of bias of individual studies was undertaken using the modified version of the Quality in Prognostic Studies criteria described by Hayden et al.⁴³ This approach uses information on selection of patients (convenience sample or consecutive/random patients); collection of predictor data (prospective or retrospective); selection criteria for predictors (statistical or clinical criteria or both); extent and method of handling missing data (above or below 5% of the sample size and whether a complete data set analysis was performed or whether robust imputation methods were used); overfitting (<10 participants per predictor for linear regression and <10 outcomes per predictor for logistic regression); testing for linearity of continuous predictors; and testing for model assumptions. Studies were categorized as high risk or low risk of bias on the basis of the criteria elaborated in eTable 1 (available at <https://academic.oup.com/ptj>). We planned to assess the quality of evidence of a predictor for a given outcome or related outcomes using principles of the Grading of Recommendations Assessment, Development, and Evaluation system of rating quality of evidence.⁴⁴ The consistency of direction of effect, directness, risk of bias of included studies, and imprecision around the effect estimate were assessed for each predictor that was included in at least 3 studies.

Data Synthesis and Analysis

For the first objective of this review, quantitative pooling of standardized mean differences (SMDs) between preoperative and postoperative PBMs was done with random-effects methods using Stata 14.2 (Stata Statistical Software: Release 14; StataCorp LP, College Station, Texas) whenever at least 2 studies with the same outcomes from unique cohorts reported preoperative and post-TKA sample size, mean, and SD or standard error (SE). If 2 studies from overlapping cohorts reported an outcome for the same time point, only the study with the largest sample size was included in this analysis.

Quantitative synthesis of effect of predictors was not possible because of inadequate reporting of statistical results (beta coefficients and SE or 95% CI), or variations in the way predictors were included in the prediction model across studies, or availability of <2 unique cohorts per predictor. Therefore, a narrative synthesis of the findings from the included studies structured around each predictor was undertaken in line with the guidance for narrative synthesis from the Centre for Reviews and Dissemination.⁴⁵ As an initial step to qualitative synthesis, we used: a tabulation method for collating information on study characteristics; descriptive data for outcomes measured at various time points, along with the measure of variance; and predictor-wise results across studies for

each of the outcomes, with information on type of analysis, adjusted or unadjusted, along with magnitude, direction of effect, and strength of association quantified by *P* value. The narrative synthesis is presented only for predictors that were evaluated in 3 or more unique cohorts. If 2 studies from the same cohort reported a predictor for an outcome, only the study with the largest sample size was included in this synthesis.

Results

Identification and Selection of Studies

Our search yielded 2412 articles (excluding duplicates), of which we reviewed 295 full texts in detail for eligibility. Twelve studies were included in this review, of which 4 were obtained from reverse search. Six^{22,23,46–49} of these 12 studies were from a single cohort of a randomized controlled trial (RCT).⁵⁰ Hence, only reports from unique cohorts contributed to the qualitative synthesis of predictors, and 2 of the longitudinal studies^{22,23} had performed only correlation analysis at each time point rather than a predictor analysis. The PRISMA flowchart (Fig. 1) shows the summary of the search and selection process and the reasons for the exclusion of full-text articles (see also eTab. 2, available at <https://academic.oup.com/ptj>).

Study Characteristics

We report the patient characteristics of each study in Table 1. Two unique cohorts^{50,51} reported SC ability (*n* = 279 patients; mean age = 68.2 years; mean percent women = 47.5; mean body mass index [BMI] = 29.3 kg/m²) and from these, 6 studies^{46–51} reported various predictors for this outcome. Five unique cohorts^{20,50–53} reported predictors for WS (*n* = 698 patients; mean age = 65.6 years; mean percent women = 53.7; mean BMI = 29.7 kg/m²) and 2 cohorts^{50,54} reported gait speed quantified by the TUG (*n* = 287 patients; mean age = 70.1 years; mean percent women = 68; mean BMI = 27.85 kg/m²); using these 2 cohorts, 5 studies^{46,47,49,50,54} reported predictors for gait speed. The maximum follow-up period after TKA was 24 months. No study reported predictors for chair-rising ability. None of the studies reported explicitly if their research was aimed at establishing etiological factors or was aimed at developing a prognostic model for poor functional outcomes after TKA.

Assessment of Risk of Bias

Of the 12 studies from 6 cohorts, 7 were classified as high risk of bias for method of selection of participants. The overlapping cohorts^{22,23,46–49} did not clearly report how their sample was derived from the trial cohort.⁵⁰ Seven of 12 studies were classified as high risk for selection predictors as they used solely statistical criteria for retaining predictors in the model. Eight studies did not report to have assessed for testing the linearity assumption and test for model fit and, hence, were classified as high risk for both these items. For the items on measurement of

predictors (*n* = 12 studies) and overfit of models (*n* = 11 studies), the risk of bias was low. For the item of missing data, 5 studies were considered as low risk of bias. The summary of risk of bias of each study across 7 items is presented in Table 2.

Outcome at 6 Months and Beyond

Nine^{22,23,46–49,51,52,54} of the 12 studies reported at least 1 of the functional outcomes measured at baseline and at various time points after TKA. However, several of the eligible studies (eTab. 3, available at <https://academic.oup.com/ptj>) did not report a measure of variance and hence could not be included in estimating the pooled SMD. Our attempts to contact authors to provide the information on SD or SE did not yield the missing information. Pooling was not possible for change in SC ability after TKA because of lack of more than 1 unique cohort reporting SCT using similar procedures. For WS, the pooled SMD was 0.66 (95% CI = 0.29–1.03) from 3 studies^{47,51,52} (*I*² = 74.1%; *P* for heterogeneity = .021) (eFig. 1, available at <https://academic.oup.com/ptj>). The pooled SMD from 3 studies^{47,52,54} for the TUG at 6 months was –0.73 (95% CI = –1.05 to –0.44) (*I*² = 68.2%; *P* = .043) (eFig. 2, available at <https://academic.oup.com/ptj>).

Predictors of Stair-Climbing Ability

Six studies^{46–51} of 2 cohorts^{50,51} reported predictors for SC ability (ie, the sociodemographic characteristics age and sex), clinical characteristics (ie, BMI, comorbidity, preoperative functional ability, and impairment measures), knee or bodily pain, range of motion (ROM: flexion and extension), and quadriceps muscle strength (ipsilateral and contralateral). Of these, age, BMI, active flexion of knee, contralateral and ipsilateral quadriceps strength, and preoperative SC function predicted post-TKA SC ability in at least 1 study. None of the predictors were reported for more than 2 unique cohorts, and even in those, effect estimates and 95% CIs were not reported in most studies (Tab. 3).

Increasing age showed a statistically significant detrimental effect on SC ability in 1 study⁴⁹ and no effect in another.⁵¹ Higher BMI was associated with poorer SC ability in 2 studies.^{49,51} Preoperative knee flexion was a significant predictor in 1 study,⁵⁰ and the direction of effect was not reported. Preoperative pain (knee or bodily pain) was not associated with post-TKA SC in 2 cohorts.^{49–51}

Predictors of Walking Speed

Ten predictors were reported across 6 studies from 5 cohorts (Tab. 4).^{20,50–53} Female sex, presence of comorbidity, higher ipsilateral quadriceps strength, preoperative WS, and shorter preoperative TUG time were statistically significantly associated with faster post-TKA WS in at least 1 study. Preoperative pain was reported in 3 cohorts^{50,51,53} and it was not associated with WS. Higher

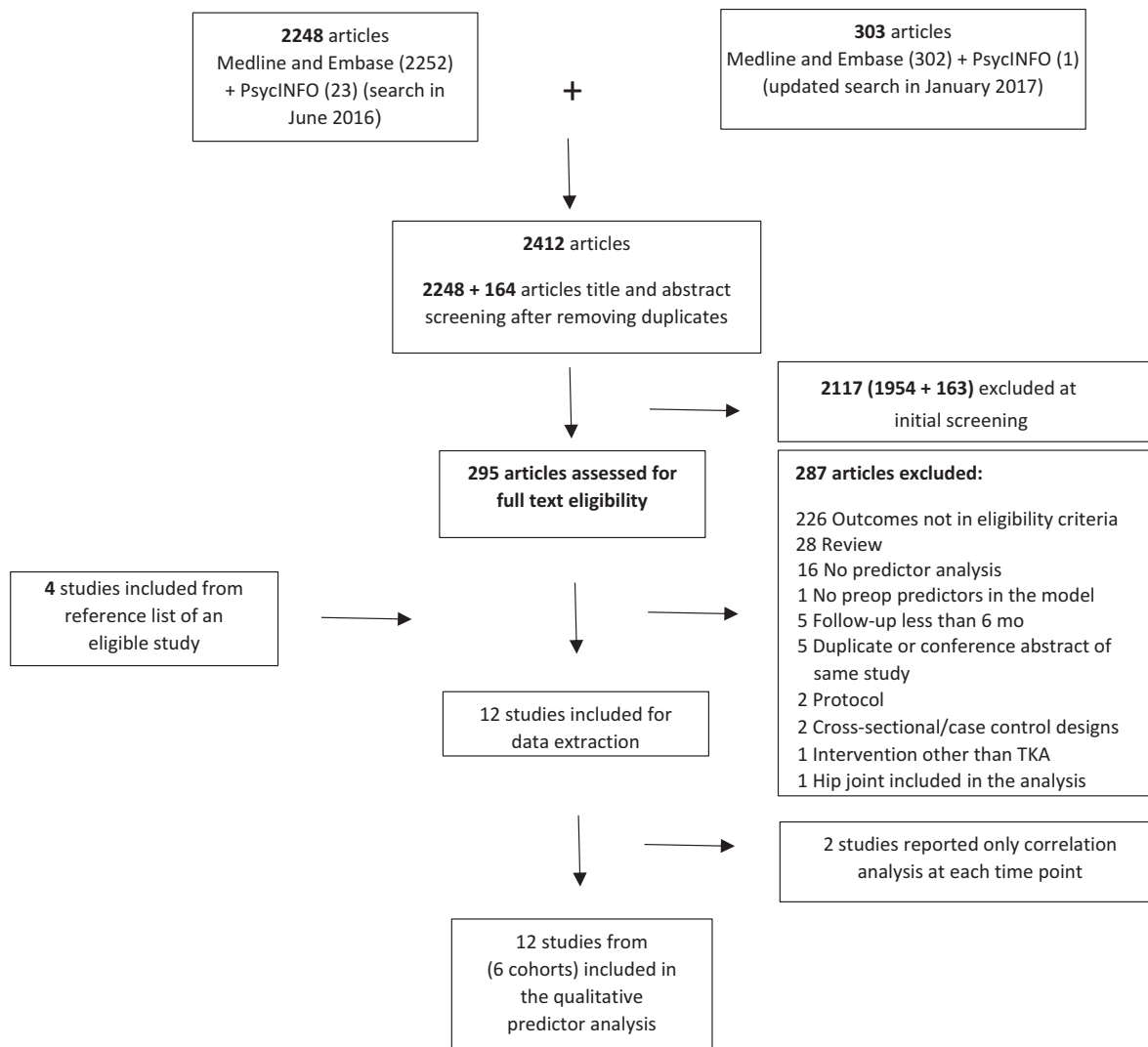


Figure 1.
PRISMA flowchart. TKA = total knee arthroplasty.

preoperative WS was significantly associated with better post-TKA WS in 3 cohorts.^{20,47,52}

Predictors of Timed “Up & Go” Test

Seven preoperative predictors (age, BMI, preoperative TUG, flexion and extension ROM, pain, and muscle strength), 4 early postoperative predictors (pain, flexion ROM, and ipsilateral and contralateral muscle strength), and 2 postoperative predictors (physical activity and change in sit-to-stand time) were explored in 5 studies^{23,47,49,50,54} from 2 cohorts^{50,54} (eTab. 4, available at <https://academic.oup.com/ptj>). The preoperative predictors (ie, increasing age, shorter preoperative TUG time, higher ipsilateral quadriceps muscle strength, and flexion ROM) were statistically associated with improved postoperative gait speed in at least 1 study. Shorter

preoperative TUG time was significantly associated with better function in 2 cohorts.^{49,54}

Consistency in Association of Predictors Across Outcomes and Quality of Evidence

Across outcomes, preoperative functional status and ipsilateral quadriceps strength showed a positive association with postoperative function (low-level evidence because of risk of bias of included studies and no measure of precision). Greater preoperative pain failed to show statistical significance in all studies across outcomes. However, owing to serious risk of bias, heterogeneity in inclusion of predictors in the model, and lack of information on imprecision, the level of evidence was low. The level of evidence for age and active flexion ROM was very low because of inconsistency in results,

Table 1.
Characteristics of Included Studies (n = 12)^a

Study	Characteristics of Patients Undergoing TKA	Performance-Based Outcome(s)	Predictors Reported	Type of Analysis
Lamb and Frost, 2003 (United Kingdom) ⁵¹	n = 79 Mean age = 71.2 (SD = 6.8) 49% women Mean BMI = 29.1 (SD = 3.81)	Fast-paced 5-m walking speed, 5-step ascent time	Age in years, sex, pain (OKS knee pain, 1–5), comorbidities, flexion ROM, BMI, total quadriceps power (Nottingham Leg Extensor Power Rig)	Multivariate repeated ANOVA
Mizner et al, 2005 (United States) ^{46, b}	n = 40 Mean age = 63 (SD = 8) 37% women Mean BMI = 29.4 (SD = 4.2)	TUG, SCT	Age in years, flexion ROM, bodily pain (SF-36 bodily pain, 0–100; 100 = no pain), quadriceps strength (electromechanical dynamometer)	Multivariable stepwise linear regression
Mizner et al, 2005 (United States) ^{23, b}	n = 40 Mean age = 64 (SD = 9) 45% women Mean BMI = 31.4 (SD = 3.7)	TUG, SCT	No baseline predictors reported	Only cross-sectional correlation analysis reported
Mizner et al, 2011 (United States) ^{22, b}	n = 100 Mean age = 65 (SD = 9) 48% women Mean BMI = 30.8 (SD = 4.5)	TUG, 6MW, SCT	No baseline predictors reported	Only cross-sectional correlation analysis reported
Kennedy et al, 2008 (Canada) ²⁰	44 women Median age = 60 (IQR = 64–71) Median BMI = 29 (IQR = 32–34)	6MW	Preop walk speed stratified by sex	Nonlinear mixed-effects modeling with stepwise regression
	40 men Median age = 61 (IQR = 67–74) Median BMI = 27 (IQR = 29–32)			
Petterson et al, 2009 (United States) ^{50, b}	n = 200 Mean age = 65.2 (SD = 8.5) 46% women Mean BMI = 29.8 (SD = 4.9)	TUG, SCT, 6MW	Quadriceps strength (electromechanical dynamometer), extension ROM, pain (KOS pain score, 0–6)	Multivariable hierarchical linear regression
Zeni and Snyder-Mackler, 2010 (United States) ^{48, b}	n = 105 Mean age = 65.8 (SD = 8.9) 45% women Mean BMI = 30.9 (SD = 5.2)	Use of handrail during stair ascent or descent	Age in years, preop handrail use, quadriceps index (electromechanical dynamometer)	Multivariable forward stepwise logistic regression
Zeni and Snyder-Mackler, 2010 (United States) ^{49, b}	n = 155 Mean age = 64.9 (SD = 8.7) 43% women Mean BMI = 30.2 (SD = 4.9)	TUG, SCT	Age in years, BMI, early postop SCT, TUG, ROM, pain (KOS pain score, 0–6), ipsilateral and contralateral quadriceps strength (electromechanical dynamometer)	Multivariable hierarchical linear regression
Stevens-Lapsley et al, 2010 (United States) ^{47, b}	n = 140 Mean age = 65.3 (SD = 9.2) 53.5% women Mean BMI = 30.8 (SD = 5.2)	TUG, SCT, 6MW	Preop function (TUG, SCT, 6MW), BMI	Multivariable hierarchical linear regression
Maxwell et al, 2013 (United States) ⁵³	n = 271 Mean age = 67 (SD = 7.5) 72.1% women Mean BMI = NR	Slow walking speed: (<1 m/s) in 20-m self-paced walk test	Contralateral limb pain quantified by WOMAC pain and categorized as 0, 1–4, 5–9, and 10–20	Multivariable logistic regression

Functionality Predictors After Knee Arthroplasty

Table 1.
Continued

Study	Characteristics of Patients Undergoing TKA	Performance-Based Outcome(s)	Predictors Reported	Type of Analysis
Bade et al, 2014 (United States) ⁵²	n = 64 Mean age = 64.6 (SD = 8.5) 50.5% women Mean BMI = 30.6 (SD = 4.8)	6MW	Age in years, sex, preop TUG, preop ROM, acute TUG	Multivariable hierarchical linear regression
Taniguchi et al, 2016 (Japan) ⁵⁴	n = 87 Mean age = 72.1 (SD = 7) 90% women Mean BMI = 25.9 (SD = 4.1)	TUG	Physical activity at 6 mo after surgery, change in sit-to-stand time from baseline, preop TUG	Stepwise multivariable linear regression analysis

^aANOVA = analysis of variance; BMI = body mass index; IQR = interquartile range; KOS = Knee Outcomes Survey; NR = not reported; OKS = Oxford Knee Score; postop = after surgery; preop = before surgery; ROM = range of motion (active knee flexion and extension ROM measured in the supine position with a long-axis goniometer); SCT = stair-climbing test (time taken for ascent or descent of 12 steps); SF-36 = Medical Outcomes Study 36-Item Health Survey Questionnaire; TKA = total knee arthroplasty; TUG = Timed "Up & Go" Test (time to rise from a seated position in an armchair [seat height = 46 cm], walk for 3 min, turn around, and return to a seated position); WOMAC = Western Ontario and McMaster Universities Arthritis Index; 6MW = 6-Minute Walk Test (distance covered in meters in 6 min of self-paced walking).

^bThese studies had overlap of cohorts, and samples were derived from Petterson et al.⁵⁰

Table 2.
Assessment of Risk of Bias (n = 12)^a

Study	Year	Patient Sampling	Measurement of Predictors	Selection of Predictors	Missing Data	Linearity Assumption	Overfit	Model Assumptions
Lamb and Frost ⁵¹	2003	Low	Low	High	High	Low	High	Low
Mizner et al ²³	2005	High	Low	High	Low	High	Low	High
Mizner et al ⁴⁶	2005	High	Low	Low	Low	Low	Low	Low
Mizner et al ²²	2011	High	Low	Low	High	Low	Low	Low
Kennedy et al ²⁰	2008	Low	Low	Low	Low	High	Low	High
Petterson et al ⁵⁰	2009	Low	Low	Low	High	High	Low	High
Zeni and Snyder-Mackler ⁴⁸	2010	High	Low	High	High	High	Low	High
Zeni and Snyder-Mackler ⁴⁹	2010	High	Low	High	High	High	Low	High
Stevens-Lapsley et al ⁴⁷	2010	High	Low	High	High	High	Low	High
Maxwell et al ⁵³	2013	Low	Low	Low	Low	Low	Low	High
Bade et al ⁵²	2014	High	Low	High	Low	High	Low	High
Taniguchi et al ⁵⁴	2016	Low	Low	High	High	High	Low	Low

^aHigh = high risk of bias; Low = low risk of bias.

serious risk of bias of included studies, and lack of information on imprecision.

Discussion

Summary of Main Results

This systematic review included 5 prospective cohorts with a total of 701 patients undergoing primary TKA. There was a moderate-to-large improvement in functionality after 6 months compared with the preoperative state for WS and gait speed. Ten studies from 5 cohorts reported preoperative predictors of objectively measured functional outcomes ≥ 6 months after TKA. Quantitative synthesis of

predictors was not possible because of inadequate reporting of the included studies. Evidence from qualitative syntheses shows that patients with poor preoperative functional ability and poor preoperative ipsilateral quadriceps muscle strength were likely to have suboptimal, objectively measured, functional recovery at 6 months after TKA. Preoperative knee or bodily pain was not associated with poor objective functional outcomes. Association of age, sex, BMI, ROM, and comorbidity with PBM was inconclusive. In general, the overall quality of evidence was low to very low, mainly because of the poor methodological quality of the included studies.

Table 3.
Predictors of Stair-Climbing Ability^a

Predictors	No. of Studies	No. of Cohorts	Study	Sample Size	Magnitude of Effect	P	Covariates Adjusted ^a							
							Age	Sex	Comorbidity	BMI	Pain	Preop/Postop SCT	ROM	Muscle Strength
Age in years (per unit increase)	4	2	Lamb and Frost, 2003 ⁵¹	79	NR	.388		•	•	•	•		•	• (TP)
			Mizner et al, 2005 ^{23, b}	40	Change in R ² , 0.019	.393								
			Zeni and Snyder-Mackler, 2010 ^{48, b}	105	OR = 1.089 (for use of handrail at 2 y)	.001						• (Pre)		•
			Zeni and Snyder-Mackler, 2010 ^{49, b}	155	Change in R ² , 0.051 at year 1	.01						• (Post)		
					Change in R ² , 0.036 at year 2	.006						• (Post)		
Sex	1	1	Lamb and Frost, 2003 ⁵¹	79	NR; unclear base category	.483	•		•	•	•		•	• (TP)
Comorbidity	1	1	Lamb and Frost, 2003 ⁵¹		NR	.462	•	•		•	•		•	• (TP)
BMI in kg/m ² (per unit increase)	3	2	Lamb and Frost, 2003 ⁵¹		NR	.017	•	•	•		•		•	• (TP)
			Zeni and Snyder-Mackler, 2010 ^{49, b}		Change in R ² , 0.14 at year 1	.044	•					• (Pre)		
					Change in R ² , 0.14 at year 2	.078	•					• (Pre)		
			Stevens-Lapsley et al, 2010 ^{47, b}		Change in R ² , 0.0001	.698						• (Pre)		
Preop knee/bodily pain (per unit increase)	3	2	Lamb and Frost, 2003 ⁵¹		NR (OKS knee pain, 1–5)	.393	•	•	•	•			•	• (TP)
			Mizner et al, 2005 ⁴⁶		Change in R ² , 0.004 (SF-36 bodily pain, 0–100; 100 = no pain)	.7	•						•	
			Petterson et al, 2009 ⁵⁰		Change in R ² , 0.014 (KOS pain score, 0–6)	.1							•	•
Early postop pain	1	1	Zeni and Snyder-Mackler, 2010 ⁴⁹		Change in R ² , 0.004 at year 1	.251	•			•		• (Pre)		
					Change in R ² , 0.004 at year 2 (KOS pain score, 0–6)	.337	•			•		• (Pre)		
Preop knee active ROM (per unit increase)	3	2	Lamb and Frost, 2003 ⁵¹		NR (flexion)	.472	•	•	•	•	•			• (TP)
			Mizner et al, 2005 ⁴⁶		Change in R ² , 0.044 (flexion)	.193	•							
			Petterson et al, 2009 ⁵⁰		Change in R ² , 0.018 (flexion)	.007								•
			Petterson et al, 2009 ⁵⁰		Change in R ² , 0.001 (extension)	.653					•		• (F)	•

Functionality Predictors After Knee Arthroplasty

Table 3.
Continued

Predictors	No. of Studies	No. of Cohorts	Study	Sample Size	Magnitude of Effect	P	Covariates Adjusted ^a							
							Age	Sex	Comorbidity	BMI	Pain	Preop/Postop SCT	ROM	Muscle Strength
Early postop active flexion ROM	1	1	Zeni and Snyder-Mackler, 2010 ⁴⁹		Change in R^2 , 0.021 at year 1	.012	•			•	•	• (Pre)		
					Change in R^2 , 0.012 at year 2	.113	•			•	•	• (Pre)		
Preop quadriceps muscle strength (per unit increase)	4	1	Lamb and Frost, 2003 ⁵¹		NR (total power of both quadriceps in watts)	.003	•	•	•	•	•		•	
			Mizner et al, 2005 ⁴⁶		Change in R^2 , 0.471, ipsilateral quadriceps	<.001	•				•		•	
			Pettersen et al, 2009 ⁵⁰		Change in R^2 , 0.225, ipsilateral quadriceps	<.001								
			Zeni and Snyder-Mackler, 2010 ⁴⁸		Higher quadriceps index (ratio of power in limb that had surgery to power in limb that did not have surgery); less likelihood of handrail use	.024	•							•
			Zeni and Snyder-Mackler, 2010 ⁴⁸		Higher ipsilateral normalized quadriceps strength; less likelihood of handrail use	.022	•					•		• (QI)
Early postop quadriceps muscle strength	1	1	Zeni and Snyder-Mackler, 2010 ⁴⁸		Change in R^2 , 0.0 at year 1	.99	•			•	•	•	•	•
					Change in R^2 , 0.03 at year 2	.422	•			•	•	•	•	•
					Unit increase in ipsilateral quadriceps strength									
			Zeni and Snyder-Mackler, 2010 ⁴⁹		Change in R^2 , 0.054 at year 1	.001	•			•	•	•	•	•
					Change in R^2 , 0.064 at year 2	.001	•			•	•	•	•	•
					Unit increase in contralateral quadriceps strength									
Preop stair-climbing ability	2	1	Zeni and Snyder-Mackler, 2010 ⁴⁸		Preop use of handrail associated with handrail use after surgery	.002	•					•		• (QI)
			Stevens-Lapsley et al, 2010 ^{47, b}		Change in R^2 , 0.312	<.001				•				

Table 3.
Continued

Predictors	No. of Studies	No. of Cohorts	Study	Sample Size	Magnitude of Effect	P	Covariates Adjusted ^a							
							Age	Sex	Comorbidity	BMI	Pain	Preop/Postop SCT	ROM	Muscle Strength
Early postop stair-climbing ability	1	1	Zeni and Snyder-Mackler, 2010 ⁴⁹		Change in R^2 , 0.43 at year 1	.001								
					Change in R^2 , 0.42 at year 2	.001								

^aBullets indicate the factors adjusted for. BMI = body mass index; F = flexion range of motion; KOS = Knee Outcomes Survey; NR = not reported; OKS = Oxford Knee Score; OR = odds ratio; post = acute postsurgery function; postop = after surgery; pre = baseline; preop = before surgery; QI = Quadriceps Index (ratio of quadriceps strength of ipsilateral limb to that of contralateral limb); ROM = range of motion; R^2 = proportion of variance explained; SCT = stair-climbing test; SF-36 = Medical Outcomes Study 36-Item Health Survey Questionnaire; TP = total power of both quadriceps.

^bThese studies had an overlap of cohorts, and samples were derived from Petterson et al.⁵⁰

Applicability of Evidence

Quadriceps muscle strength could be a promising modifiable preoperative predictor. On the basis of the proportion of variance (R^2) explained by this predictor on the outcomes, strength of evidence (P value), and consistency of association across studies and outcomes, we conclude that higher ipsilateral quadriceps muscle strength was independently associated with better SC ability after TKA. However, the clinical meaningfulness of these findings is limited as the included studies did not report the magnitude of effect and the uncertainty around estimates. There are several prehabilitation (ie, preoperative rehabilitation) strategies for improving muscle strength during the waitlist period. A qualitative systematic review of prehabilitation physical therapist interventions aimed at improving preoperative quadriceps strength indicated lack of efficacy of such intervention strategies in improving post-TKA patient-reported subjective outcomes.⁵⁵ However, trials (sample size ranging from 22 to 120) evaluating the effect of prehabilitation interventions on objectively measured functional outcomes at 3 months after TKA demonstrated significant benefits at 3 months in WS,^{56–58} stair ascend and descend,^{57,58} and TUG.⁵⁹ The results of our systematic review and the findings from these RCTs suggest that prehabilitation interventions targeted at improving preoperative quadriceps strength might potentially improve objective outcomes after TKA. However, adequately sized RCTs with longer follow-ups are needed to establish this link conclusively. Further, the independent role for functional outcomes of contralateral quadriceps strength and other muscles like hip abductors needs further evaluation in future studies.

Predictors of patient-reported functional outcomes, such as post-TKA pain, satisfaction, and perceived function, have been extensively researched. Previous studies have yielded moderate-quality evidence on the role of preoperative pain in predicting persistent postoperative pain,³³ and of poor mental state⁶⁰ in predicting

postoperative perceived functional recovery. In contrast, our review indicated that preoperative pain did not predict objective functional recovery. This discrepancy could relate to the poor agreement between perceived and objective outcomes.^{22,27,28} It is plausible that other preoperative subjective measures (such as mental state and pain catastrophizing) could similarly not correlate with objective functional recovery. Therefore, risk profiling of patients on the basis of preoperative pain and mental state might not be useful when measuring recovery objectively.

The pooled analysis of change scores after TKA from baseline showed a moderate-to-large effect at midterm for walking (SMD = 0.66; 95% CI = 0.29–1.03) and gait speed (–0.73; 95% CI = –1.05 to –0.44) expressed in terms of SMD (interpretation: small SMD = 0.2; medium SMD = 0.5; large SMD = 0.8). A previous systematic review⁶ reported short-, mid-, and long-term improvement in WS from 16 pre-TKA and post-TKA comparisons that included WS measured by various measurement methods. The 95% CI of the SMD between 6 and 12 mo reported in this study⁶ was 0.68–1. This same review⁶ showed a large heterogeneity in WS between 0.5 and 5 mo⁶ because of varying recovery rates. Hence, studies aiming to evaluate predictors of functional measures should have a follow-up period of ≥ 6 mo when functional recovery reaches its peak.

All studies included in this review were conducted in developed countries (United States, Canada, and Japan), indicating a lack of representativeness for developing nations where TKA is increasingly being performed.^{61,62} There are limited published data on outcomes after arthroplasty from developing countries. This is important because patients undergoing TKA in developing countries can differ in their preoperative activity levels, access to rehabilitation after surgery, and awareness about the recovery process. This is supported by evidence to suggest racial and ethnic disparities in arthroplasty outcomes within developed countries.⁶³ There is a need to establish

Table 4.
Predictors of Walking Speed^a

Predictors	No. of Studies	No. of Cohorts	Study	Magnitude	P	Covariates Adjusted ^b								Preop/ Postop WS	Flexion/ Extension	Muscle Strength
						Age	Sex	Race	Education	Mental State	Comorbidity	BMI	Pain			
Age in years (per unit increase)	2	2	Bade et al, 2014 ⁵²	MD, -1.3 m; SE, 0.98	.21		•							• (Pre)		
			Lamb and Frost, 2003 ⁵¹	NR	.847		•				•	•	•	• (Post)	•	• (TP)
Sex	2	2	Lamb and Frost, 2003 ⁵¹	NR; unclear base category	.266	•					•	•	•	• (Pre)	•	• (TP)
			Bade et al, 2014 ⁵²	For men vs women: MD, 34.2 m; SE, 16.2	.04	•								• (Post)		
BMI (kg/m ²) unit increase	2	2	Lamb and Frost, 2003 ⁵¹	NR	.06	•	•				•		•		•	• (TP)
			Stevens-Lapsley et al, 2010 ^{47, c}	Change in R ² , 0.006, compared with null model	.247									• (Pre)		
Comorbidity (yes vs no)	1	1	Lamb and Frost, 2003 ⁵¹	NR	.02	•	•						•		•	• (TP)
Knee pain (unit increase in pain score)	3	2	Lamb and Frost, 2003 ⁵¹	NR (OKS pain score, 1–5)	.125	•	•				•	•			•	• (TP)
			Petterson et al, 2009 ^{50, c}	Change in R ² , 0.005 (KOS pain, 0–6)	.387										• (E)	
			Maxwell et al, 2013 ⁵³	WOMAC pain in contralateral limb (RR [95% CI]): 1–4 vs 0 (1.3 [0.5–2.9]); 5–9 vs 0 (1.3 [0.6–3.0]); 10+ vs 0 (1.9 [0.6–5.9])	>.05	•	•	•	•	•						
Quadriceps muscle strength	2	2	Lamb and Frost, 2003 ⁵¹	NR (total power in watts)	<.001	•	•				•	•	•		•	•

Table 4.
Continued

Predictors	No. of Studies	No. of Cohorts	Study	Magnitude	P	Covariates Adjusted ^b										Pain	Preop/ Postop WS	Flexion/ Extension	Muscle Strength
						Age	Sex	Race	Education	Mental State	Comorbidity	BMI							
			Petterson et al, 2009 ⁵⁰	Change in R ² , 0.352 (ipsilateral)	<.001														
Active knee flexion	2	2	Lamb and Frost, 2003 ⁵¹	NR	.497	•	•				•	•				• (TP)			
			Petterson et al, 2009 ^{50, c}	Change in R ² , 0.003	.532											• (E)			
Active knee extension	1	1	Petterson et al, 2009 ^{50, c}	Change in R ² , 0.013	.16												•		
Preop function	3	3	Bade et al, 2014 ⁵²	For every 1% increase in preop TUG time, walk distance decreased by 2 m	<.001	•	•									• (Pre)			
			Kennedy et al, 2008 ²⁰	MD in m: 0.6 (SE = 0.1) for women; 0.5 (SE = 0.1) for men	<.05 for women; <.05 for men														
			Stevens-Lapsley et al, 2010 ^{47, c}	Change in R ² , 0.545	<.001							•							
Early postop function	1	1	Bade et al, 2014 ⁵²	For every 1% increase in acute TUG time, walk distance increased by 0.067 m	.65	•	•									• (Post)			

^aBMI = body mass index; E = extension range of motion; KOS = Knee Outcomes Survey; MD = mean difference; NR = not reported; OKS = Oxford Knee Score; post = acute postsurgery function; postop = after surgery; pre = baseline; preop = before surgery; R^2 = proportion of variance explained; ROM = range of motion; RR = relative risk; TP = total power of both quadriceps; TUG = Timed "Up & Go" Test; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index; WS = walking speed.

^bBullets indicate the factors adjusted for.

^cThese studies had an overlap of cohorts, and samples were derived from Petterson et al.⁵⁰

registries and cohorts in developing countries to bridge this knowledge gap.

Strengths and Limitations of This Review

The key strength of our systematic review is its methodological rigor, because we followed the currently recommended guideline⁴⁵ that improves the objectivity of narrative synthesis. We rated the quality of evidence not only on the basis of the risk of bias of included studies but also on other elements—such as the consistency of results across studies, indirectness, and imprecision—as advocated by the Grading of Recommendations Assessment, Development, and Evaluation system of rating quality of evidence.⁴⁴

The main limitation of this systematic review was the inability to perform a meta-analysis to quantify the predictors' effects. The key reason was that fewer cohorts were available for the synthesis. Six of the eligible studies^{22,23,46–49} had derived their sample for predictor analyses from 1 randomized trial,⁵⁰ and there seemed to be considerable overlap in the study population. Hence, only the study with the largest sample size could be used per predictor per outcome. Missing information on the magnitude of the effect and CIs was a greater concern than heterogeneity due to heterogeneity in outcome measurements. Multiple attempts to contact the original researchers did not yield the required information. The findings of this review are based solely on *P* values, which alone provide very limited information to clinicians as opposed to the effect estimate along with the CIs.⁶⁴ Further, the measurement of predictors like muscle strength, ROM, and outcomes (SC, WS, and TUG) were similar across studies, but the predictors were variably included in the statistical models across studies (eg, as continuous or categorical variables). Preoperative pain intensity was measured using various tools, such as the Medical Outcomes Study 36-Item Health Survey Questionnaire, Western Ontario and McMaster Universities Arthritis Index, Knee Outcomes Survey, and Oxford Knee Score. Hence, it is unclear whether this heterogeneity in measurement tools would have had any impact on the association of preoperative pain intensity with functional outcomes.

Finally, selectively reporting predictors that were only statistically significant could have biased the overall evidence. This review highlights the need for consistency and adherence in following reporting guidelines for cohort studies and RCTs. Clear identification of reports as primary or secondary analyses of the original cohort and of any overlaps in samples from previous published studies is crucial for unbiased evidence synthesis.

Implications for Clinical Practice

Patients with poor preoperative functionality and poor preoperative ipsilateral quadriceps strength might have suboptimal improvement in function. Severity of

preoperative pain might not indicate poorer post-TKA functional ability. Further, predictors of objective functional outcomes need to be considered alongside patient-reported outcomes for better clinical decision-making and patient management.

Implications for Future Research

Despite the large body of research in the field of arthroplasty, generated primarily from developed nations, there is lack of high-quality evidence regarding predictors of long-term functional outcomes after TKA. This is primarily due to deficiencies in study methodology, incomplete reporting, and use of varied measurement tools leading to inability to pool evidence quantitatively. This review has identified specific gaps that need to be addressed in future studies. We provide some suggestions, outlined in Figure 2, to be considered at design stage and to improve the quality of reporting of predictor analyses⁴² to enable evidence synthesis and the effective use of research findings in daily practice. Establishing the role of other known predictors of PROMs, like preoperative pain and mental state, in objective functional recovery is required for risk profiling of patients who are likely to have poorer outcomes. Adequately powered RCTs are needed to evaluate the efficacy of prehabilitation interventions that strengthen lower limb muscles on objective functional outcomes. The independent role of contralateral quadriceps and other muscle groups, such as hamstrings and hip abductors, in functional outcomes before and after TKA will guide future physical therapy rehabilitation regimens. Data are required from developing nations for better applicability of such research in patient management.

Systematic Review Registration

This study was registered in PROSPERO (ref. no. PROSPERO2016: CRD42016039872).

Author Contributions and Acknowledgments

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Ethics Approval

This work was a systematic review of published studies; therefore, ethics approval was not required.

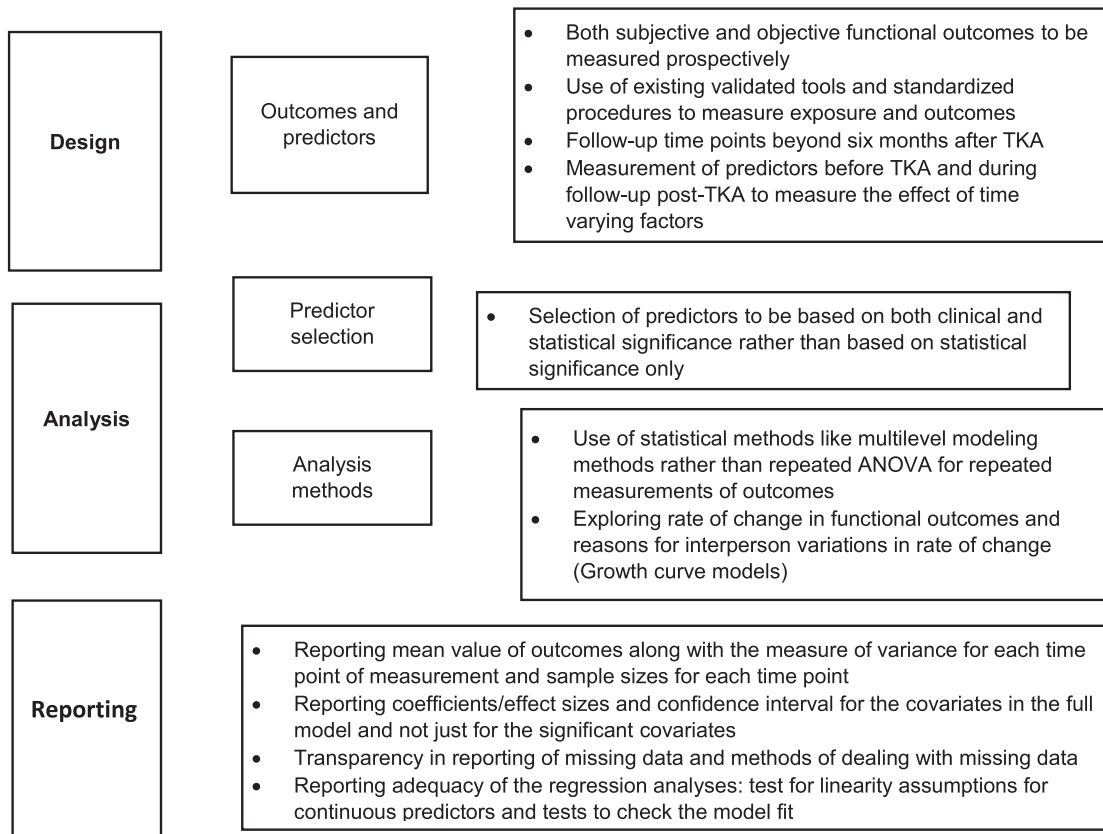


Figure 2.

Suggestions for improving the design, analysis, and reporting of prospective studies that generate data for the prediction of functional outcomes after total knee arthroplasty (TKA). ANOVA = analysis of variance.

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Appendix

Search Strategy

- a. Dates of searches: June 1, 2016, and January 24, 2017
 - b. Databases: MEDLINE, EMBASE, and PsycINFO
 - c. Search via: EBSCO host
 - d. Period of search: the initial search was from the conception of each database; the second searches were from May 2016 to February 2017 for PsycINFO, and from January 2016 to January 2017 for EMBASE.
 - e. Search results: June for EMBASE (2252) and PsycINFO (23); January for EMBASE (302) and PsycINFO (1)
 - f. Limits: English and Human
1. "Knee Arthropla*"
 2. TKA
 3. TKR
 4. "Knee Prosthesis"
 5. 1 or 2 or 3 or 4
 6. outcome*
 7. stair*
 8. climb*
 9. walk*
 10. "chair ris*"
 11. "Up & Go"
 12. TUG
 13. SCT
 14. CRT
 15. activity
 16. muscle*
 17. exercis*
 18. 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
 19. risk*
 20. predict*
 21. predispo*
 22. prognos*
 23. caus*
 24. determinant*
 25. 19 or 20 or 21 or 22 or 23 or 24
 26. osteoarthr*
 27. arthrit*
 28. 26 or 27
 29. 5 and 18 and 25 and 28