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Factors associated with gait speed recovery after total knee arthroplasty:  
A longitudinal study

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**Abbreviated title**: Factors associated with post-TKA gait speed

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ABSTRACT

Objectives: Gait speed limitations can remain significant issues after a total knee arthroplasty (TKA) but their associated factors are not well understood. This study aimed to identify the factors associated with acute gait speed recovery post TKA.

Methods: We performed a prospective longitudinal study of 1765 patients who underwent primary TKA between July 2013 and July 2015. At 4, 8, 12, and 16 weeks post surgery, fast gait speed was measured. The factors associated with gait speed over time since TKA were identified using multivariable generalized least-squares modeling.

Results: Lower postoperative quadriceps strength and knee flexion range-of-motion were closely associated with lower gait speed over time (0.084m/s, 0.064m/s, and 0.055m/s change in gait speed per interquartile range change in ipsilateral quadriceps strength, contralateral quadriceps strength, and knee flexion range-of-motion, respectively). Additional strong predictors of lower gait speed included older age (0.11m/s), lower levels of preoperative Short-Form-36 physical function (0.066m/s), greater body mass (0.046m/s), and the preoperative use of a walking aid (overall $P<0.001$). Patients who reported that they limited their daily activities due to a fear of falling also had poorer gait speed (0.033m/s and 0.054m/s slower gait speed for "Occasional" and "Often" categories, respectively, vs. "None").

Conclusions: Gait speed recovery post TKA is driven by both physical and psychological factors, suggesting that identifying and treating the underlying physical and cognitive causes of gait speed limitations may be crucial to optimize functional recovery.

Key words: knee; replacement; walking; correlates

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INTRODUCTION
In patients with end-stage, symptomatic knee osteoarthritis, although a total knee arthroplasty (TKA) substantially improves *self-reported* physical function\(^1,2\), *performance-based* physical function such as gait speed improves more slowly and gait speed limitations may persist at one year or beyond post surgery\(^3,4\). As this mismatch was already evident in the first 3 months post TKA\(^5-8\), identifying the factors associated with gait speed recovery in the acute post-TKA phase could open up opportunities to provide effective preventive care for at-risk patients.

Despite this, few longitudinal studies have comprehensively evaluated the factors associated with gait speed although both physical and psychological factors are probably involved. Previous small studies\(^7,9,10\) have examined, with mixed results, the associations of individual or selected sets of physical factors - namely, knee range-of-motion, postural balance, and quadriceps strength - with gait performance, but no studies of adequate size and statistical power have examined the simultaneous associations of all the aforementioned physical factors with gait speed. With regard to psychological factors, 2 recent systematic reviews\(^11,12\) concluded that preoperative psychological distress, commonly indexed by the Short Form-36\(^13\), was associated with post-TKA physical function; however, all studies on which the reviews were based focussed on self-reported physical function. Furthermore, no studies, to our knowledge, have examined the clinical significance of fear-induced activity limitation (FIAL), which is defined as the avoidance or curtailment of daily activities because of a fear of falling. This is surprising given the awareness and prevalence of FIAL in community-living older adults and several clinical populations\(^14\) and its cascading negative impact on future physical functioning and fall risk\(^15,16\). To the extent that the TKA population has an increased risk of fall-related hip fracture\(^17\), the study of FIAL in TKA takes on even more clinical relevance.
Thus, we conducted a prospective longitudinal study to identify the factors associated with acute post-TKA gait speed. We hypothesized that physical factors - namely, postoperative knee and balance impairments - and psychological factors, indexed by preoperative SF-36 mental health and FIAL, would be independently associated with gait speed, after adjustment for preoperative clinicodemographic factors.
METHODS

Our study cohort comprised patients from an ongoing longitudinal study that aimed to identify risk factors for functional disability in TKA. Details of the study design have been published previously \(^\text{18}\). Between July 2013 and July 2015, we identified 2130 patients age ≥50 years who underwent a primary TKA and postoperative outpatient physiotherapy at Singapore General Hospital - the largest tertiary teaching hospital in Singapore which performed half (51.1\%) of all knee arthroplasties in the nation\(^\text{19}\). All patients underwent TKA with a tourniquet. Post TKA, all patients underwent daily inpatient rehabilitation and at discharge, they were given a booklet with advice on ice therapy, the outpatient rehabilitation process, and home exercises. All patients were routinely referred for outpatient physical therapy rehabilitation at our institution within 2 weeks following discharge, and patients who attended rehabilitation would receive exercises, patient education, manual therapy and other modalities that were prescribed and progressed at the physical therapist’s discretion. We excluded patients who had a history of rheumatoid arthritis \((n=27)\) and patients with stroke or Parkinson disease \((n=34)\). For patients with consecutive admissions for TKA, only data from the first admission were analyzed to meet the statistical assumption of independence. Of the remaining 2069 patients who were evaluated within a month preoperatively, and were scheduled for 4-, 8-, 12-, and 16-week postoperative assessments as part of routine clinical care, we selected a cohort of 1765 patients with at least one follow-up gait speed value. All data were collected by technicians \((n=3)\) and physical therapists \((n=16)\) trained (and audited) in the testing procedures. The institutional review board approved the study with a waiver of informed consent (SingHealth CIRB 2014/2027, Singapore).
Baseline Measures

Patients were evaluated preoperatively using a standardized clinical interview and assessment. From it, we used subject-matter expertise and the literature to identify variables potentially associated with self-reported or performance-based physical function (Table 1). Specifically, the presence of contralateral knee pain was measured by the “Patient Category” item (response choice b) from the Knee Society Clinical Rating System\textsuperscript{20}. The presence of hypertension was determined by patient self-reported and it was chosen given its association with gait speed decline in older adults\textsuperscript{21}. For the type of walking aids used preoperatively, we coded the responses into 4 categories: (i) 'None', (ii) 'Walking stick or umbrella', (iii) 'Quadstick', and (iv) 'Walking frame or two-canes or crutches'. For type of surgeons (specialist or general orthopaedic surgeon), our patients were cared for by 42 orthopaedic surgeons, 7 of whom were adult reconstruction specialists. We used the English and Chinese Short Form 36 (SF-36) health survey\textsuperscript{13} to assess preoperative levels of mental health (mental health subscale), bodily pain, and physical functioning. Of note, the English and Chinese SF-36 scores have previously been shown to be internally consistent and equivalent in a Singapore Chinese sample\textsuperscript{13}.

Information about preoperative falls history and FIAL was obtained from patients by their treating physical therapists within 2 weeks post-surgery and patients were instructed to provide responses from the preoperative perspective. For falls history, the number of falls in the one year prior to TKA was collected via retrospective recall and we defined a fall as “an event which results in a person coming to rest inadvertently on the ground or other lower level and other than as a consequence of the following: sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in a stroke, or an epileptic seizure.”\textsuperscript{22} We classified patients into 1 of 3 groups:
non-fallers (no fall), single fallers (one fall), and recurrent fallers (2 or more falls). To assess FIAL, patients were asked whether, preoperatively, they had avoided or cut down on certain activities because they were afraid of falling. Three response options were offered: 'No/Never', 'Occasionally', and 'Often'.

**Follow-up Measures**

At 4, 8, 12, and 16 weeks postoperatively, knee range-of-motion, postural balance, quadriceps strength, and gait speed were obtained. A long-arm goniometer was used to measure active-assisted knee flexion and extension range-of-motion with the patients in supine position. To measure knee flexion, patients were asked to slide their heels toward the buttocks and to flex their knees maximally with the assistance of a belt. Knee extension range of motion was measured with the patient’s heel elevated on a firm wedge. Two sets of flexion and extension range-of-motion measurements were taken, and the higher measurement was recorded. Postural balance was measured using computerized posturography on a Wii Balance Board (Nintendo, Kyoto, Japan)\(^{23, 24}\). Patients stood quietly on the Balance Board for 30 seconds and centre-of-pressure velocity along the antero-posterior plane was recorded\(^{25}\). All patients performed two trials and the mean of the 2 was taken. Quadriceps strength was assessed isoinertially\(^{26}\) using a seated knee extension machine (Cybex VR3, Medway, USA). Given concerns about patellofemoral pain in TKA\(^{27}\), the knee range-of-motion for the strength test was set from 90° to 40° of knee flexion. Quadriceps strength was determined using the one repetition maximum test, which is the maximum load the patient could lift once in good form\(^{26}\). To allow patients to gain confidence with the testing protocol, we tested the contralateral knee before the ipsilateral (operated) knee. Thirty-second rest periods were given between trials, and most patients reached
their one repetition maximum load between the third and fifth (the maximum number of trials allowed) trials.

**Assessment of gait speed**

For the fast gait test, patients stood directly behind the start line and were clocked from the time the first foot crossed the start line until the lead foot crossed the 10-meter finish line. Patients were instructed to “walk as quickly as you can, but safely” and to finish at least 2 meters past the finish line to eliminate the deceleration effects from stopping the walk. Each patient performed a familiarization trial (at a comfortable pace) before the actual trial. Immediately after the fast gait test, participants were asked to rate their (ipsilateral) knee pain intensity using an 11-point numeric pain scale, with 0 indicating ‘no pain’ and 10 indicating ‘worst pain ever experienced’.

In the present study, although habitual and fast gait speeds were measured, we have focused on fast gait speed because it has been shown to correlate more closely with functional decline than does habitual gait speed in older adults\textsuperscript{28, 29}

**Statistical Analysis**

Continuous variables were presented as means with SDs and medians with interquartile ranges (IQRs) whilst categorical variables were presented as frequencies with percentages. As our baseline covariates were missing at low levels (0.51\% to 4.52\% for individual covariates and 6.3\% of patients had missing covariate data), we used the transcan function developed by Harrell\textsuperscript{30} to singly impute missing values.
We modeled the time course of fast gait speed using a generalized least-squares model, and we accounted for within-patient correlation over time using a first order autoregressive covariance structure, as determined by the (lowest) Akaike Information Criterion\textsuperscript{31}. Generalized least squares regression uses a full likelihood approach which assumes that missing data are missing at random (MAR\textsuperscript{32}). To avoid assuming linear time trends, actual assessment dates were used and time (weeks since TKA) was modeled flexibly as a restricted cubic spline\textsuperscript{30}. We graphically displayed the gait trajectory curve, showing data for patients at 3 age levels: 55, 65, and 75 years.

To characterize the independent clinicodemographic, physical, and psychological factors associated with gait speed, we included all variables listed in Table 1 as independent variables in the model, with post-TKA physical factors modelled as time-varying variables. Given that the various independent variables were quantified on different scales, we scaled the regression coefficients to the IQR of each continuous variable to provide a more standardized and clinically meaningful distinction than the conventional one-unit change in predictor values. To assess clinical significance, we compared the regression results with a minimum meaningful difference of 0.050m/s in gait speed\textsuperscript{33}. To evaluate the relative contribution of the predictors in the multivariable regression model, we computed the partial Wald $\chi^2$ of each predictor minus its degree of freedom ($\chi^2 - df$)\textsuperscript{30}. To relax the linearity assumption, we modeled all continuous variables as restricted cubic splines\textsuperscript{30} unless there was insufficient evidence against the null assumption of linearity ($P>0.20$). To evaluate whether the associations of psychological and post-TKA physical factors with gait speed changed over time, we considered their first-order interactions with time. Finally, to explore the possibility that the post-TKA factors could be
mediators for the baseline factors, we compared our model with one without the follow-up physical factors.

We assessed the appropriateness of all models using residual plots and quantile–quantile plots. All model assumptions were met adequately. We used R software, version 3.2.2 (http://www.r-project.org), for all analyses and graphing.
RESULTS

Table 1 shows the baseline characteristics of the total sample. Mean age was 67.1 years (SD, 7.5) and women accounted for nearly three-quarters (74%) of the sample. Mean body mass index (BMI) was 27.4kg/m² and based on recommended BMI cut-offs for the Asian population, 42% of our sample was overweight (BMI 23 to <27.5 kg/m²) and 43% was obese (BMI ≥27.5 kg/m²). All patients were assessed at least once during the 4 postoperative assessment time points with 68%, 17%, and 1% assessed at least 2, 3, and 4 times, respectively. Table 2 shows the mean and median knee impairment, postural balance, and gait speed values at the 4 time points, while Figure 1 shows the smoothed model-predicted gait speed over time at 3 age levels. Overall, fast gait speed improved nonlinearly over time, with a steep improvement rate observed in the first 8 to 10 weeks post-TKA, beyond which the improvement over time was more gradual.

Table 3 shows results of the generalized least squares models of gait speed. To facilitate the interpretation and comparison of the results, the effect sizes for all continuous variables are expressed in terms of an increase of one interquartile range (IQR) in the value of the variable. Figure 2 complements Table 3 by showing the relative contribution of the factors ($\chi^2 - df$) associated with gait recovery. None of the factor-by-time interactions were statistically significant whilst 2 factors – namely, age and ipsilateral quadriceps strength – showed significantly nonlinear association with gait speed (Figure 3). In the full model, based on a minimum meaningful difference of 0.050m/s in gait speed, strong baseline clinicodemographic factors associated with gait speed included age (patients aged 73 years [75th percentile] had, on average, 0.11m/s [0.096 to 0.13] slower gait speed compared with patients aged 62 years [25th percentile]), preoperative SF-36 physical function (0.066m/s [0.045 to 0.086] greater gait speed per IQR increase in SF-36 scores), preoperative use of a gait aid (the use of gait aids was
associated with slower gait speed; overall $P<0.001$), and body weight (0.046 m/s [0.031 to 0.061]
slower gait speed per IQR increase in body weight). Post-TKA physical factors were among the
most explanatory determinants, with knee flexion range-of-motion (IQR-β, 0.055 m/s [0.042 to
0.068]) and quadriceps strength strongly associated with gait speed over time (IQR-β values,
0.084 m/s [CI, 0.071 to 0.098] and 0.064 m/s [CI, 0.049 to 0.079] for ipsilateral and contralateral
quadriceps strength, respectively).

Preoperative SF-36 mental health ranked second last in explanatory importance (IQR-β, -0.003 [-
0.015 to 0.009]) whilst there was a consistent gradient in association between FIAL and gait
speed recovery (0.033 m/s [CI, 0.010 to 0.056] and 0.054 m/s [CI, 0.023 to 0.086] slower gait
speed for the "Occasional" and "Often" categories, respectively; $P<0.001$). In exploratory
analyses (Table 3, Model 2), when post-TKA physical factors were removed from the model,
point estimates for sex and FIAL improved and achieved clinical significance, indicating
potential partial mediation. In contrast, the association of gait speed with preoperative SF-36
mental health scores did not become more evident.
Table 1: Preoperative characteristics of patients

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Patients (N=1765)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>61.7 66.8 72.6 (67.1±7.5)</td>
</tr>
<tr>
<td>Women</td>
<td>74% (1313)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.51 1.55 1.61 (1.56±0.08)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58 65 73 (67±13)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.3 26.9 29.8 (27.4±4.4)</td>
</tr>
<tr>
<td><strong>Clinical characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>66% (1166)</td>
</tr>
<tr>
<td>Adult reconstruction specialist</td>
<td>55% (974)</td>
</tr>
<tr>
<td>Contralateral knee pain</td>
<td>58% (1013)</td>
</tr>
<tr>
<td>Preop walking aids</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>72% (1259)</td>
</tr>
<tr>
<td>Stick</td>
<td>23% (394)</td>
</tr>
<tr>
<td>Quadstick</td>
<td>3% (53)</td>
</tr>
<tr>
<td>Walking Frame</td>
<td>2% (36)</td>
</tr>
<tr>
<td>Falls history</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>89% (1525)</td>
</tr>
<tr>
<td>Once</td>
<td>7% (125)</td>
</tr>
<tr>
<td>Recurrent</td>
<td>4% (71)</td>
</tr>
<tr>
<td>SF-36 bodily pain</td>
<td>22 32 51 (36±18)</td>
</tr>
<tr>
<td>SF-36 physical function</td>
<td>20 40 55 (40±22)</td>
</tr>
<tr>
<td><strong>Psychological factors</strong></td>
<td></td>
</tr>
<tr>
<td>SF-36 mental health</td>
<td>72 84 92 (81±17)</td>
</tr>
<tr>
<td>Fear-induced activity limitations</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>61% (1055)</td>
</tr>
<tr>
<td>Occasional</td>
<td>27% (460)</td>
</tr>
<tr>
<td>Often</td>
<td>12% (211)</td>
</tr>
</tbody>
</table>

Continuous variables are summarized as 25<sup>th</sup> 50<sup>th</sup> 75<sup>th</sup> percentiles and $\bar{X} \pm 1$ SD. Categorical variables are summarized as percentages and frequencies (N).
Figure 1: Natural spline-smoothed predicted fast gait speed over time at 3 age levels: 55, 65, and 75 years. Model 1 (Table 3) was used to generate model-predicted data.

Table 2: Knee Range-of-motion, Postural Balance, Quadriceps Strength, and Gait Speed 4, 8, 12, and 16 weeks post TKA

<table>
<thead>
<tr>
<th></th>
<th>4 Weeks</th>
<th>8 Weeks</th>
<th>12 Weeks</th>
<th>16 Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexion range-of-motion (°)</td>
<td>97 (105 ± 13)</td>
<td>101 (120 (109 ± 12)</td>
<td>105 (120 (112 ± 12)</td>
<td>105 (113 120 (111 ± 12)</td>
</tr>
<tr>
<td>Knee extension range-of-motion (°)</td>
<td>0.0 (5.0 8.0 (4.8 ± 5.2)</td>
<td>0.0 (5.0 5.0 (3.7 ± 5.1)</td>
<td>0.0 (5.0 5.0 (3.1 ± 4.6)</td>
<td>0.0 (5.0 5.0 (2.7 ± 4.2)</td>
</tr>
<tr>
<td>Postural balance (cm/s)</td>
<td>0.71 (0.91 1.18 (1.02 ± 0.45)</td>
<td>0.71 (0.90 1.13 (0.99 ± 0.43)</td>
<td>0.70 (0.90 1.12 (0.97 ± 0.38)</td>
<td>0.69 (0.88 1.16 (0.96 ± 0.38)</td>
</tr>
<tr>
<td>Ipsilateral quadriceps strength (lbs)</td>
<td>10 (15 20 (17 ± 11)</td>
<td>15 (25 30 (25 ± 13)</td>
<td>20 (25 35 (20 ± 14)</td>
<td>30 (30 35 (30 ± 13)</td>
</tr>
<tr>
<td>Contralateral quadriceps strength (lbs)</td>
<td>25 (35 45 (37 ± 16)</td>
<td>25 (35 45 (30 ± 16)</td>
<td>30 (35 50 (40 ± 16)</td>
<td>30 (35 45 (30 ± 15)</td>
</tr>
<tr>
<td>Knee pain (10)</td>
<td>0 (0 0 (0.5 ± 1.34)</td>
<td>0 (0 0 (0.3 ± 1.10)</td>
<td>0 (0 0 (0.6 ± 0.75)</td>
<td>0 (0 0 (0.0 ± 0.57)</td>
</tr>
<tr>
<td>Fast gait speed (m/s)</td>
<td>0.67 (0.65 0.65 (0.05 ± 0.30)</td>
<td>0.64 (1.06 1.25 (1.04 ± 0.31)</td>
<td>0.95 (1.14 1.31 (1.33 ± 0.39)</td>
<td>0.96 (1.16 1.32 (1.13 ± 0.29)</td>
</tr>
</tbody>
</table>

Continuous variables are summarized as 25th and 75th percentiles and X ± 1SD.
Figure 2: Relative contribution of variables in the multivariable generalized least squares model predicting fast gait speed (Model 1, Table 3), measured by the Wald $\chi^2$ statistics minus the $df$ for each variable.
Figure 3: Multivariable-adjusted differences in gait speed (and 95\%CIs) associated with age and ipsilateral quadriceps strength relative to (hypothetical) patients with the reference values for age (65 years) and ipsilateral quadriceps strength (25 lbs). Predicted values were calculated in a multivariable generalized least squares model using restricted cubic splines and adjusted for variables listed in Model 1 (Table 3). For both predictors, there was strong evidence for both an overall trend ($P<0.001$) and nonlinearity of the association ($P<0.001$).
DISCUSSION

In this longitudinal study of 1765 patients with TKA, we found that the physical and psychological factors associated with lower post-TKA fast gait speed over time included lower quadriceps strength, lower knee range-of-motion, poorer postural balance, and greater severity of FIAL. We also identified several clinicodemographic factors that were clinically and statistically significantly associated with lower gait speed: older age, lower preoperative SF-36 physical function, greater body mass, the use of a walking aid, and female sex (with its effects mediated by post-TKA physical factors). To our knowledge, this study is the first comprehensive evaluation of the factors associated with gait speed recovery in a large cohort of patients with TKA.
Clinicodemographic Factors

In our analyses, the association between age and fast gait speed over time was negative and nonlinear (Figures 1 and 3). Our results extend previous efforts to (i) compare functional outcomes in often variedly defined "young" and "old" patients with TKA\(^{35}\) and (ii) examine possible nonlinear associations between age and functional outcomes\(^{36}\). Our approach, however, differs from previous studies in that we avoided age categorization\(^{37}\) and used cubic spline regression to model age as a continuous variable. In 1096 patients from the same cohort, we used similar analyses and observed that the association of age with the risk of self-reported walking disability was J-shaped, with both lower and higher age levels associated with higher risk\(^{38}\). Thus, taken together, we believe that our results are internally consistent and to our knowledge, this is the first time it has been formally shown that the association between age and post-TKA functional outcomes may be nonlinear. Whether this nonlinear association is a result of less-than-ideal fast gait speed amongst younger patients or severe gait speed limitations amongst older-old patients, are intriguing, important questions yet to be answered – and particularly so when the indications for TKA have, in recent years, rapidly expanded to include patients of a wider age range.

Physical Factors

Collectively, knee impairments and postural balance are powerful, independent predictors of fast gait recovery and our study supported and extended previous analyses by linking multiple longitudinal physical factors and fast gait speed in a multivariable model. Of interest, ipsilateral quadriceps strength was the strongest predictor and its association with gait speed was
significantly nonlinear. Specifically, a steep rise in gait speed with increasing quadriceps strength was observed up to an approximate value of ~25 lbs, above which there was a more gradual – but still quantitatively important – rise. While quadriceps weakness is generally attributed to disuse muscle atrophy, severe weakness may represent a more complex aetiology, including quadriceps activation failure due to multiple factors. Given the strong influence of severe quadriceps weakness on gait speed limitations, further investigation of its pathophysiology is warranted and our results support calls to address quadriceps impairments aggressively and early in the rehabilitation process.

Similarly, we observed a substantial association between contralateral quadriceps strength and fast gait speed over time. This finding agrees with one prior study and indicates that contralateral quadriceps strength may be a proxy indicator of the functional status of the non-operated knee which, in turn, could independently influence physical function. Given also that the contralateral quadriceps may weaken over time, our findings suggest that to optimize functional outcomes, the contralateral knee should not be overlooked in rehabilitation. Besides contralateral quadriceps strength, the influence of knee flexion range-of-motion on gait speed was clinically important and relatively linear. Prior limited studies evaluating the association of knee flexion with gait performance have been conflicting but our large sample size and comprehensive adjustment for confounders increase confidence in our results. As walking is usually performed with the knees flexed, at a maximum, to 67°, why greater levels of knee flexion (>90°) are linearly associated with faster gait speed is uncertain but may be related to a radiographically well-aligned prosthesis or to a greater participation in daily and physical activities that demand high knee flexion. Regardless, our findings suggest that exploring how
best to improve knee flexion range-of-motion, be it via better implant design or rehabilitation planning, may constitute a worthy endeavour.

**Psychological Factors**

Of note, based on previous systematic reviews, we have expected preoperative SF-36 mental health to be associated with post-TKA gait recovery, yet we found no association. Furthermore, we reran our analyses excluding FIAL, history of falls, and post-TKA factors to address concerns that the null associations for preoperative SF-36 mental health may relate to its correlation with these factors: the null findings persisted in these sensitivity analyses (data not shown). Previous studies demonstrating an association may have done so because they have focussed on self-reported – and not performance-based – measures of physical function. In the study by Turcot et al. on 79 patients with TKA, only a weak cross-sectional correlation ($r=0.29$) between Week-12 gait speed and SF-12 mental health scores was observed. That said, in contrast to the extensive research on the impact of SF-36 mental health on post-TKA self-reported function, we acknowledge that direct supporting (or disconfirming) evidence for our findings is sparse and that the SF-36 mental health is a generic measure. Thus, our null findings cannot completely rule out the association of gait recovery with psychological distress, and future research focusing on more specific measures (for example, the Depression Anxiety Stress Scale and the Hospital Anxiety and Depression Scale) may help clarify whether this is the case.

Besides SF-36 mental health, our study uniquely examines the association between FIAL and fast gait speed, which is important to consider given that patients with end-stage, symptomatic knee osteoarthritis awaiting a TKA tended to be women, older, and to have substantial physical...
disability – all of which are robust risk factors for FIAL in community-dwelling older adults. Two studies have examined the association of gait speed with avoidance coping and self-efficacy – putative correlates of FIAL - but none have studied FIAL. In our study, we observed that ~12% of patients reported that they often limited their daily activities due to a fear of falling and that greater severity of FIAL predicted lower post-TKA gait speed over time. More important, exploratory analyses suggest that the longitudinal post-TKA physical factors may partially mediate the association between FIAL and gait speed. Based on the prototypical "avoidance model" and some preliminary data suggesting that FIAL was not uncommon after a TKA, we speculate that many patients with FIAL may remain fearful and physically inactive after surgery, making them prone to deconditioning, knee stiffness, muscle weakness, and decreased balance performance - a plausible causal pathway that warrants further study. Nevertheless, our data not only support current management guidelines that recommend muscle strengthening and balance training to address knee and balance impairments in patients with TKA, but they also suggest that identifying and treating the underlying cognitive causes of physical impairments may be crucial to augment the effects of conventional physical rehabilitation.

**Limitations**

Our study has limitations. First, although our study provides a detailed analysis of the time course of acute gait recovery post TKA, our missing data rate increased over time, as also observed in similar previous studies. Whilst we used a full-likelihood approach to reduce the potential biases caused by missing data, the dropout leading to relatively fewer patients assessed at the final follow-up remains a study limitation. Second, we did not have comparative normative
data from healthy controls which would allow us to develop alternative indices of gait speed recovery and further our understanding of post-TKA gait speed. Third, although the present study has examined several preoperative clinicodemographic factors, we acknowledge that more detailed or joint-specific factors – for example, physical activity levels, knee radiographic severity, and preoperative quadriceps strength – should be considered. Fourth, although preoperative FIAL and falls history were assessed before the follow-up gait assessment, they were retrospectively collected and were thus subject to recall bias. Also, FIAL was assessed with a single item which may not capture the complexity of the FIAL construct. Nevertheless, the one-item measure is widely used in previous large-scale studies\textsuperscript{14} and its use would facilitate the recognition of FIAL in clinical practice.

**Conclusion**

In conclusion, potentially modifiable physical and psychological factors, including quadriceps strength, knee range-of-motion and FIAL, are significant factors associated with fast gait speed post TKA, independent of clinicodemographic factors such as age, preoperative SF-36 physical function, and body mass. This knowledge will be critical for the identification of at-risk patients and the results also suggest that treating the underlying physical and cognitive causes of gait speed limitations may be crucial to optimize functional recovery.
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Conflict of interest

The authors declare that they have no conflicts of interest.

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