PREDICTING ACUTE RECOVERY OF PHYSICAL FUNCTION FOLLOWING TOTAL KNEE JOINT ARTHROPLASTY

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Abstract

The objective was to explore predictors of physical function during acute in-patient rehabilitation within a few days after TKA. Physical function status of participants (n = 72) three days after total knee arthroplasty (TKA) was measured using the Timed Up and Go Test (TUG) and the function subscale of the Western Ontario McMaster Universities Index of Osteoarthritis (WOMAC-function). Potential predictors of physical function were measured day one post-TKA. Their relationship with physical function was examined using backward elimination, multiple regression analyses. Older age and increased comorbidity was associated (R^2 = 0.20) with worse TUG times. Increased pain severity was associated (R^2 = 0.08) with worse WOMAC-function scores. Age, comorbidity, and pain severity should be considered when predicting which patients will struggle with acute recovery post-TKA.

Key Words: knee arthroplasty, physical function, recovery, predictor, osteoarthritis, length of stay

Running Head: Predictors of Acute Physical Function Recovery Post-TKA

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Introduction

Over 600,000 total knee arthroplasties (TKA) were performed in the United States in 2008 representing a 134% increase over ten years [1]. The speed of recovery following TKA varies greatly and many factors influence this recovery [2,3]. It is important to identify patients that will have delayed recovery because they require longer hospital stays, incur additional costs, and impact discharge planning. Supplementary resources, including physiotherapy interventions, can be allocated to these patients immediately post-operatively in an attempt to speed their recovery, improve their physical function, and return them home safely in a timely manner.

Previous studies have examined predictors of physical function recovery after TKA in both subacute (1 to 3 months) and long term (>3 months) stages [3-6]. Physical function was assessed using self-report questionnaires and performance based measures such as the Timed Up and Go Test (TUG). Predictors of decreased physical function in subacute and long term stages included low pre-surgical physical function levels, older age, higher body mass index (BMI), high number of co-morbidities, knee extensor weakness on the non-operated and operated sides, and high pain severity [3,6-10]. Psychological variables also related to physical function including helplessness, self-efficacy, pain catastrophizing, coping ability, and surgical expectations [5,11-15]. These previous studies demonstrate that numerous predictors of long term recovery exist which should inform clinical practice. For instance, addressing the psychological factors could result in improved outcomes although research is needed to examine such interventions.

Although it is important to capture long term recovery from TKA, it is equally important to capture recovery in the acute stages (< 1 month) especially during in-hospital rehabilitation. Studies examining predictors of success in the acute period use hospital length of stay (LOS),

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discharge destination, in-hospital complications, and hospital monetary charges as measures of success [2,16-20]. Predictors associated with negative outcomes include older age, higher BMI, women versus men, being single versus being married, multiple co-morbidities, high pain catastrophizing, and low self-report pre-operative mobility [2,16-20]. These studies provide valuable information on predictors of healthcare resource usage. However, the measures used in the acute setting, such as LOS and discharge destination, are not necessarily related to physical function. They are influenced by factors external to patients' physical function status such as institutional policies and characteristics, discharge planning, experience of the physician, and patient income [2,20]. LOS does not capture patients' physical function status and these variables have only demonstrated a minimal relationship in the post-surgical orthopaedic population [21].

Patients should be functioning adequately prior to discharge home. Thus, physical function in the acute recovery stages should be further investigated and predictors indicative of delayed recovery should be determined. Identifying patients with the potential for delayed physical function recovery will assist with discharge planning and allow additional resources, such as rehabilitation interventions, to be allocated to these patients to speed the recovery process during in-patient rehabilitation. Thus, the primary objective was to explore predictors of physical function during acute in-patient rehabilitation within a few days after TKA. The secondary objective was to explore the relationship between these predictors and LOS.

Materials and Methods

Participants

Individuals following a TKA were recruited using convenience sampling from the acute in-patient unit of a tertiary healthcare center the day after their surgery (day one post-TKA).

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Participants were included if they underwent a primary TKA for knee osteoarthritis the previous day and were between 40 to 85 years of age. Exclusion criteria included TKA revision on the operative leg, bilateral TKA on the same day, fracture sustained during surgery, rheumatoid or other inflammatory arthritis, neurological conditions (i.e. Parkinson's Disease, previous stroke), severe cardiovascular conditions (i.e. unstable angina) and an inability to comprehend English. The study was approved by the local institutional ethics board and informed consent was obtained from participants prior to study enrollment.

A sample size calculation estimated 80 participants would be required for the study [22]. A previous study found the overall explained variance in the TUG and the variance accounted for by contra-lateral knee extensor strength was 49.5 and 4.4% respectively one year post-TKA [3]. To be conservative, these values were rounded down to 40% and 4% for the current sample size calculation. With seven predictors and a significant level of p = 0.05, 68 participants would be required. A 15% drop out rate was also applied and this increased the sample size estimate to 78 participants, which was rounded to 80 participants.

Predictor Variables

The potential predictors chosen for this study have a shown a previous relationship to physical function or LOS post-TKA and could be captured during the initial post-operative physiotherapy assessment. Thus, potential predictors were measured day one post-TKA or were available in medical charts (e.g. pre-operative BMI).

Demographic variables. Age, sex, and BMI (BMI = weight/height^2) were recorded from medical charts. Weight and height were measured during pre-operative screening appointments a few weeks prior to TKA as part of the usual standard of care. Age, sex, and BMI have previously demonstrated a relationship to physical function 6 to 24 months post-TKA [3,6,7].

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Pain Severity. Pain severity on day one post-TKA was measured using the Numeric Pain Rating Scale (NPRS) [23]. Participants were asked to rate their pain on a scale from 0 ("No Pain") to 10 ("Pain as bad as it can be"). Pain severity has been shown to be a predictor of physical function performance post-TKA [9].

Co-morbidity. Participants completed the Self-Administered Comorbidity Questionnaire on day one post-TKA [24]. This questionnaire lists 13 medical conditions with room to add additional conditions. Participants identify if they have the condition, if they are presently receiving treatment for the condition and if the condition limits their activity. Higher scores represent increased co-morbidities. The number of co-morbidities has previously predicted self-report physical function six months post-TKA [7].

Pain catastrophizing. Participants completed the Pain Catastrophizing Scale on day one post-TKA [25]. This measure includes 13 items each rated on a five point scale (0-not at all, 4-all the time). A maximum score is 52 and higher scores represent severe levels of pain catastrophizing. This scale has previously predicted self-report physical function one year post-TKA [15].

Strength. Knee extensor isometric strength of the non-operative leg was measured using a hand-held dynamometer (Lafayette manual muscle test model 01163, Lafayette, IN) on day one post-TKA [26,27]. Participants were positioned in supine with their knee in 60º of flexion supported by a bolster. The dynamometer was placed 1 cm proximal to the superior border of the medial malleolus. The investigator placed one hand on the participant's thigh to stabilize the limb and the other hand on the dynamometer perpendicular to the participant's lower leg. The participants were asked to contract their knee extensors and push into the hand-held dynamometer for five seconds by using a standard phrase: "Keep pushing as hard as you can,

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push, push, push, now relax" [26]. Participants were given a practice trial to become accustomed to the testing protocol and then the test was repeated three times. The maximum value from the three trials normalized to body mass represented the non-operative knee extensor isometric strength (N/kg). Strength measures were not collected on the operative side due to limitations in strength secondary to pain and swelling from the TKA. Knee extensor strength from the non-operative limb has previously shown to predict TUG scores at one month and one and two years post-TKA [3,28].

Dependent Variables

Timed Up and Go Test. Physical function performance on day three post-TKA was measured using the TUG. Participants began seated in a standard chair (seat height 49.5 cm, seat width 51 cm) with armrests (height from floor 68.5 cm). Standard instructions included: "When I say 1,2,3 go, please stand up from the chair, walk with your assistive device at a comfortable pace to the line, return to the chair and sit down." The line was 3 m from the chair and they used the gait aid they planned to use upon discharge (e.g. standard walker or standard crutches) which was recorded. The participants were timed to the nearest 1/10 s using a digital stopwatch. The TUG was completed twice and an average score calculated. This procedure has previously demonstrated good test-retest reliability (intraclass correlation coefficient = 0.80) in patients following orthopaedic surgery [21].

Western Ontario McMaster Universities Index of Osteoarthritis physical function subscale. Self-report physical function on day three post-TKA was captured using the function subscale of the Western Ontario McMaster Universities Index of Osteoarthritis (WOMAC-function). The subscale consists of 17 items each representing a functional task (i.e. descending stairs) with a five point scale rating the difficulty of the activity (0-no difficulty, 4-extreme

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difficulty). The WOMAC-function score is calculated by summing the item scores (minimum = 0, maximum = 68) with higher scores representing increased difficulty performing functional tasks. The WOMAC-function has previously demonstrated reliability and construct validity with other self-report physical function outcome measures [29,30].

Length of stay. LOS on the acute in-patient unit was recorded. Day one represented the day after TKA surgery. Upon discharge from the acute in-patient unit, participants either returned home, were admitted to another in-patient rehabilitation hospital, or were admitted to assisted living.

Data Collection Protocol

Participants were recruited by a physiotherapist or physiotherapy assistant during the initial post-operative physiotherapy assessment that is part of the usual standard of care. Predictor variables were collected on day one post-TKA including age, sex, pain severity, co-morbidity, pain catastrophizing, and strength. Pre-operative height and weight were collected from medical charts in addition to descriptor variables including a history of previous lower extremity arthroplasty and weight bearing status post-TKA. All participants underwent standard rehabilitation from this initial assessment until discharge consisting of mobility training, range of motion exercises, and strengthening exercises (e.g. anti-gravity end range knee extension). TUG and WOMAC-function were measured on day three post-TKA by a physiotherapist or physiotherapy assistant. This day was chosen because an institutional goal was to discharge patients on day three post-TKA if they are safe and able to return home. Some participants were discharged earlier and thus dependent variables were measured on day two post-TKA for these participants. LOS was determined upon discharge from the acute in-patient unit and discharge destination was recorded for descriptive purposes. The physiotherapists and physiotherapy

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assistants that collected data underwent standard training prior to the commencement of the study to ensure consistent data collection procedures.

Data Analysis

Descriptive statistics were calculated for dependent and predictor variables. Bivariate relationships between continuous variables were examined using Pearson correlation coefficients. The correlation between the dichotomous variable, sex, and the continuous variables were examined using point biserial correlation coefficients. Step-wise, backward elimination, multiple regression analyses examined the relationship between the dependent variables and predictors. Three separate analyses were conducted, one analysis for each dependent variable (TUG, WOMAC-function, LOS). All predictors (age, sex, BMI, pain severity, co-morbidity, pain catastrophizing, strength) were entered into the analysis. Predictors were removed in steps such that the predictor remaining in the analysis that accounted for the smallest, non-significant ($P > 0.10$) amount of the variance in the dependent variable was removed. After eliminating all non-significant predictors, the remaining predictors in the regression analyses each accounted for a significant portion of variance. The appropriateness of the regression analyses were evaluated by examining data normality, residuals, and multicolinearity.

Results

Eighty participants were recruited for the study. Seven participants dropped out of the study including four for medical complications and three participants refused to complete the day three post-TKA data collection. Additionally, data from one participant were excluded due to collection errors during the strength test. The remaining participants (n = 72; 40 women, 32 men) had data from at least one dependent variable. From this sample, the number of participants that had complete data for the TUG, WOMAC-function, and LOS were 68, 69 and 72 respectively.

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The missing TUG and WOMAC-function data were due to participants being discharged from the healthcare center prior to collection of these dependent variables. Only one TUG trial was collected for one participant, as opposed to averaging two trials, and this participant's data were still used in the analysis. Descriptive statistics for the sample (n = 72; 40 women, 32 men) are provided in Table 1. Pearson and point biserial correlation coefficients are provided in Table 2 for the dependent variables and predictors.

All participants were full weight bearing post-TKA. The majority of participants were discharged home (n=63) from the healthcare center while some were transferred to a rehabilitation hospital for additional therapy (n = 8) or to assisted living (n = 1). Most participants (n = 45) had no history of previous knee or hip arthroplasty on the operative or non-operative leg. The remaining participants had a previous TKA (n = 16) or total hip arthroplasty (n = 8) on the current non-operative leg, combined TKA and total hip arthroplasty on the non-operative leg (n = 2), and total hip arthroplasty on the operative leg (n = 1).

The majority (n = 62) of the TUG and WOMAC-function scores were collected on day three post-TKA. Two participants were collected on day two post-TKA due to early discharge. Eight participants were collected after day three post-TKA because of other complications (n = 4) or the treating physiotherapist did not feel the participant could safely complete the testing (n = 4). During the TUG, participants either used a 4-point standard walker (n = 58) or standard crutches (n = 10). The type of gait aid was not recorded for four participants.

The TUG regression analysis revealed that age and co-morbidity were the only predictors explaining 20% of TUG variance (Table 3). An increase in age and co-morbidities were associated with worse physical function performance demonstrated by increased TUG times

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(Table 2 and 3). The unstandardized regression coefficients (Table 3) revealed that an increase in age by 1 year would increase the TUG between 0.36 to 1.66 s and an increase in the Self-Administered Comorbidity Questionnaire by 1 point would increase the TUG between 0.41 to 3.64 s.

The WOMAC-function regression analysis revealed that pain severity was the only predictor and it captured a small amount (8%) of WOMAC-function variance (Table 3). An increase in pain severity was associated with worse self-report physical function demonstrated by increased WOMAC-function scores (Table 2 and 3). The unstandardized regression coefficients (Table 3) revealed that an increase in pain severity by 1 point would increase WOMAC-function by 0.19 to 1.94 points.

For the LOS regression analysis, the residuals had a non-normal distribution (Kolmogorov-Smirnov = 0.15, $p < 0.01$) violating the normality assumption. The LOS was transformed using the natural logarithm (LOS-natural log) which resulted in normally distributed residuals (Kolmogorov-Smirnov = 0.08, $p = 0.20$). Age and co-morbidity were the only significant predictors explaining 17% of LOS-natural log variance (Table 3). Increased age and increased co-morbidities were associated with increased LOS-natural log (Table 3). Examining the unstandardized regression coefficients (Table 3), patients with the ages of 50 and 69 years would have a predicted LOS of three and four days respectively assuming a Self-Administered Comorbidity Questionnaire score of seven (i.e. sample mean for this study) for both patients. Similarly, patients with a Self-Administered Comorbidity Questionnaire score of five and ten points would have a predicted LOS of three and four days respectively assuming an age of 67 years (i.e. sample mean for this study) for both patients.

Discussion

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The current findings demonstrate predictors of physical function recovery during the acute, inpatient rehabilitation phase following primary TKA. The majority of previous studies have measured long-term physical function recovery (i.e. greater than six months). Predicting recovery during the typical discharge day from acute inpatient rehabilitation will help identify patients with the potential for delayed physical function recovery thus assisting with discharge planning and resource allocation. Increased age and increased co-morbidities resulted in poor functional performance post-TKA. Thus, older patients with multiple co-morbidities should receive supplemental resources, such as additional therapy or time in the hospital, to ensure they have adequate physical function prior to discharge. Also, increased pain severity day one post-TKA related to poorer self-report physical function demonstrating the need for effective pain control early post-TKA.

Although these relationships were significant, only a small portion of variance in physical function was captured including 20% for physical function performance (TUG) and 8% for self-report physical function (WOMAC-function). Previous studies have captured 34 to 57% of TUG variance at one month to two years post-TKA [3,8,31] and 16 to 36% of WOMAC-function variance at six weeks to two years post-TKA [4,5,11,12,14,15,32-35]. There are two possible explanations for the lower explained variance in the current study. Firstly, it might be more difficult to predict recovery in the acute, short term stages of recovery than long term recovery. Stevens-Lapsley et al. (2010) were able to explain 33% of the TUG variance at one month post-TKA and this increased to over 50% at three and six months post-TKA [31]. Secondly, pre-operative measures of the TUG and WOMAC-function are the strongest predictors of these measures post-operatively over different time points [3,31,32]. The current study did not collect pre-operative measures because we were interested in predictors that could be measured day one

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post-TKA during the initial post-operative physiotherapy assessment. Measuring the TUG and WOMAC-function during a pre-operative visit would likely provide useful information on which patients will have delayed recovery and thus aid with discharge planning; however, additional research is needed to examine the strength of pre-operative and acute post-operative physical function measures.

Previous predictors of physical function recovery post-TKA were not significant in the current study. For instance, pain catastrophizing and knee extensor strength on the non-operative leg have both been shown to predict recovery in WOMAC-function at one year post-TKA but were not significant predictors of acute recovery in the current study [3,15]. Predictors of physical function likely vary during the different stages of recovery. For instance, Sullivan et al. (2009) found that pain catastrophizing was not a significant predictor of WOMAC-function at six weeks post-TKA [4]; however, the same author found that pain catastrophizing was a significant predictor at one year [15]. Again, it is likely that predicting physical function recovery is more difficult in the early stages and significant predictors vary throughout the different recovery stages.

The predictors of physical function differed between the self-report (WOMAC-function) and performance (TUG) measures (Table 2). Low to moderate correlations (r=0.29 to 0.56) have been found between self-report and performance physical function measures in patients undergoing hip or knee arthroplasty which is comparable to the current results (r=0.28) [36-38]. Self-report physical function measures tend to overestimate patients' ability to move around after arthroplasty and they have a stronger relationship with pain severity than with measures of performance (e.g. TUG times) [28,38]. It is suggested that self-report and performance measures capture different aspects of physical function and should be used together to provide

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complementary information [28,38,39]. Given that WOMAC-function and TUG measure different aspects of physical function, it is not surprising that the predictors of these measures post-TKA also differ.

Longer LOS was associated with older age and increased co-morbidities; however, the external validity of this finding should be questioned. LOS does not provide a true reflection of how patients are functioning after TKA. LOS is influenced by institutional factors that are external to the patients. For instance, shorter LOS after TKA has been associated with the physician of record being a resident rather than an attending surgeon [20]. Also, increased hospital and surgeon volume have been associated with shorter LOS [2]. In the current study, the goal of the department was to have patients ready for discharge day three post-TKA and 63% of participants reached this goal. Considering that LOS is influenced by institutional factors and policies, the external validity of this measure should be questioned. Using standardized outcomes that are not influenced by institutional policies, such as the TUG and WOMAC, would allow findings to be generalized to similar populations across institutions.

Limitations include not collecting pre-operative measures of physical function as these have been shown to be the strongest predictors of post-TKA physical function [3,31]. The current study was interested in predictors that could be captured day one post-TKA either from the participant or the participant's chart and pre-operative physical function is not measured at our institution. Additionally, other variables that have previously predicted physical function recovery, such as patient expectations and self-report pre-operative walking distance [12,16], were not studied. The number of predictors studied was limited by sample size and the feasibility of measuring all possible predictors.

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In summary, it is important to predict physical function during the inpatient, acute stages of rehabilitation post-TKA to help determine which patients might struggle with physical function recovery. Increased age and increased co-morbidities were related to decreased physical function performance. Older patients with multiple co-morbidities should receive additional resources after TKA to ensure they are functioning adequately prior to discharge. Increased pain severity was related to decreased self-report physical function demonstrating the importance of pain control in the early stages of recovery. Predictors only accounted for a small amount of variance in post-operative physical function. Routinely including measures of physical function during pre-operative screening would likely lead to improved predictions of physical function in the acute stages of rehabilitation post-TKA.

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Table 1. Mean, Stand Deviation and Range of the Dependent and Predictor Variables for the Sample (n = 72); Frequency is Provided for Length of Stay.

Variable		Mean (SD)	Range
Age (y)		67 (9)	48, 84
BMI (kg/m^2)		32.1 (7.2)	20.5, 53.4
Pain Severity		4 (3)	0, 9
Co-morbidity		7 (4)	1, 20
Pain catastrophizing		11 (11)	0, 46
Non-operative knee extensor isometric strength (N/kg)		2.51 (0.94)	0.80, 6.40
Timed Up and Go Test (s)[a]		63.5 (27.3)	15.6, 135.0
WOMAC-function[b]		33 (9)	13, 59
Length of stay (d) Frequency	2 days	3	
	3 day	42	
	4 days	19	
	5 days	4	
	> 5 days	4	

SD, standard deviation; WOMAC-function, Western Ontario McMaster Universities Index of Osteoarthritis physical function subscale.

[a]TUG data for 68 participants. [b]WOMAC-function data for 69 participants.

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Table 2. Correlation Coefficients between Study Variables.*

Variable	2	3	4	5	6	7	8	9	10
1. TUG	0.28†	0.35†	0.35†	-0.09	-0.08	0.00	0.29†	-0.05	-0.23
2. WOMAC-function	-	0.45†	0.09	-0.10	-0.03	0.28†	0.09	0.11	-0.08
3. LOS		-	0.34†	0.11	-0.04	0.12	0.21	0.12	-0.15
4. Age			-	0.08	-0.47†	0.04	0.01	-0.29†	-0.09
5. Sex				-	-0.01	0.09	0.15	0.13	0.20
6. BMI					-	0.07	0.19	0.16	-0.28†
7. Pain Severity						-	0.07	0.03	-0.11
8. Co-morbidity							-	0.14	-0.14
9. Pain Catastrophizing								-	-0.04
10. Strength									-

*Point biserial correlation coefficients were used between the dichotomous variable (sex) and continuous variables; Pearson correlation coefficients were used between continuous variables;

$^{\dagger}p < 0.05$, two-tailed

TUG, Timed Up and Go Test; WOMAC-function, Western Ontario McMaster Universities Index of Osteoarthritis physical function subscale; LOS, length of stay; BMI, body mass index

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Table 3. Regression Analyses Results.

Dependent Variable	R^2	Constant	Significant Predictor	b[a] (95% CI)	β[a]	*P* value[b]
Timed Up and Got Test	0.20	-18.02	Age	1.01 (0.36, 1.66)	0.34	<0.01
			Co-morbidity	2.03 (0.41, 3.64)	0.28	0.02
WOMAC-function	0.08	28.43	Pain severity	1.06 (0.19, 1.94)	0.28	0.02
Length of stay-natural log	0.17	0.47	Age	0.01 (0.00, 0.02)	0.36	<0.01
			Co-morbidity	0.01 (0.00, 0.03)	0.20	0.08

CI, Confidence interval; WOMAC-function, Western Ontario McMaster Universities Index of Osteoarthritis physical function subscale.

[a] b and β represent the unstandardized and standardized coefficients respectively.

[b] *P* value for the coefficients

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