Falls after total knee arthroplasty: frequency, circumstances, and associated factors. A prospective cohort study

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Abstract

Background. Individuals with total knee arthroplasty (TKA) often suffer from pain and reduced balance control, which may predispose them to greater fall risk.

Objective. To determine the frequency and circumstance of falls, and fall-related risk factors within a 6-month follow-up period in individuals post-TKA.

Design. Prospective cohort study.

Methods. Knee proprioception, the Balance Systems Evaluation Test (BESTest), knee pain, knee extension and flexion muscle strength, knee range of motion, and balance confidence were evaluated in 134 individuals (39 men, 95 women; mean age: 66.3±6.6 years) 4 weeks post-TKA. Monthly follow-ups, via face-to-face or telephone interviews, were implemented to obtain data on fall incidence over 6 months.

Results. Twenty-three individuals post-TKA (17.2%) sustained at least one fall during the 6-month follow-up period. The median time of the first fall episode was 15 weeks post-TKA. Of the 31 fall episodes, most falls occurred during walking (67.7%). Slipping (35.5%) and tripping (35.5%) were identified as the most frequent causes of falling. Most falls occurred at home (45.2%) or other indoor environments (29.0%). Multivariate binary logistic regression revealed that younger age (odds ratio: 0.91), reduced operated knee proprioception (odds ratio: 1.62), reduced sensory orientation (odds ratio: 0.92), and greater operated knee pain (odds ratio: 1.68) were significantly

associated with more falls during the follow-up period (p<0.05).

Limitations. Results may only be generalizable up to 6 months post-TKA.

Conclusions. Intervention efforts should target deficits in knee proprioception, sensory orientation, and operated knee pain in preventing future falls among individuals with TKA.

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Running title: Factors Associated with Falls in Total Knee Arthroplasty

Introduction

Total Knee Arthroplasty (TKA) is a common intervention for end-stage osteoarthritis (OA) of the knee. OA is among the most prevalent diseases affecting older adults, and is a major contributor to physical disability, morbidity, and utilization of health care resources worldwide.[1-3] Individuals with TKA often suffer from knee pain, reduced knee range of motion and proprioception, quadriceps muscle weakness, as well as balance and gait dysfunction.[4-13] These deficits may predispose individuals with TKA to a high risk of falling. Indeed, an estimated 7-33 % of individuals post-TKA fall between 6 months and one year after surgery.[14-19] Therefore, research dedicated to identifying fall risk factors is especially important in this patient population, in order to improve the quality of life and decrease the burden on the health care system.

Few studies have attempted to identify the risk factors of falls after TKA.[15,16,19] For instance, Matsumoto et al.[15] showed that limited range of motion in post-operative knee flexion and ankle plantar flexion (testing done in a sitting position) were significantly associated with falls during a 6-month follow-up period among 70 individuals with TKA. Alternatively, a cross-sectional study involving a sample of 54 patients with TKA revealed that reduced knee joint range of motion and knee joint pain were significantly associated with falls during a mean period of 39 months after

TKA.[16] More recently, balance confidence and history of falls have been identified as predictors of falls in a 1-year prospective follow-up period among 68 individuals after TKA.[19] Perhaps the discrepancy in these findings may stem from the small sample sizes.[15,16,19] Alternatively, the provision and variety in the length of in- and outpatient therapeutic interventions following TKA surgery may impact fall-related risk factors at different rates; however, previous work is unclear on the existence and details of these programs.[15,16,19] Overall, the available literature on risk factors of falls post-TKA is scarce. Thus, to our knowledge, a comprehensive assessment, including a wide variety of potential important risk factors of falls in a large sample of individuals with TKA, has not been previously reported.

Falls remain an important concern among individuals after TKA; however limited research has explored the incidence of falls, and identified fall risk factors in this population. Accordingly, a 6-month prospective cohort study was undertaken to examine the frequency, circumstances, and risk factors of falls post-TKA. The objectives of this study were: (1) to establish the fall prevalence, as well as to document the circumstances and consequences of falls; and (2) to identify factors that were associated with falls during a 6-month follow-up period in patients post-TKA. Based on the above literature, we hypothesized that more limitation in knee range of motion, more severe knee joint pain, lower knee muscle strength, poorer balance

confidence, and a positive history of falls would be associated with falls during the 6-month follow-up period in individuals with TKA.[15,16,19,20]

Methods

Participants

Individuals who were referred to receive outpatient physiotherapy rehabilitation at a local hospital were recruited during the period between February 2013 and January 2014. The implant used for the TKA surgery was cemented cruciate-substituting prosthesis (Zimmer model: NexGen LPS-Flex, UK). The inclusion criteria were: diagnosis of knee OA for their first primary TKA; aged 50-85 years; able to follow verbal instructions, and provide informed consent. Exclusion criteria were: previous operation on the lower limb; TKA due to rheumatoid arthritis of the knee or traumatic injury; arthroscopy for OA or degenerative meniscal tears on the same limb; and known medical conditions that influenced balance ability (e.g., Parkinson's disease). Participants were formed on a consecutive sampling basis. The study was approved by the Human Research Ethics Subcommittee of the involved university and hospital. All participants provided written informed consent. All experimental procedures were conducted in accordance with the Declaration of Helsinki.

Sample Size Estimation

A sample size estimation was performed using PASS 2011 (NCSS Statistical Software, Kaysville Utah, USA) as a proxy. It was based on a previously reported correlation between post-operative knee range of flexion and extension, and falls post-TKA, with odds ratio value at 3.7 and 2.3 respectively.[15] Therefore, the current study assumed an OR of 3.0 (the average of the two OR values reported above), using post-operative knee range of flexion and extension as a continuous variable of interest. Based on a logistic regression analysis (power=0.8, alpha=0.05), assuming a fall rate of 7 %,[14] and attrition rate of 20%, a minimum of 120 participants was required.

Study Design

This was a prospective cohort study. The participants typically attended their first outpatient physiotherapy treatment 2 weeks after their TKA, during which the knee staples were removed. The physiotherapy treatment (i.e., electrotherapy for pain and edema control, mobilizing and strengthening exercises, gait and balance training) was provided once or twice a week for 8 to 10 weeks (mean number of treatment sessions=11.3, SD=3.0). On average, the last outpatient physiotherapy session took place at 94.0 days (SD=25.5) after TKA. The initial assessment took place in person

at 4 weeks after TKA. The participants were then followed up for 6 months in order to collect data on falls. The initial assessment took place during the period between February 2013 and January 2014, whereas the collection of prospective fall data from the last participant was completed in July 2014.

Procedures

Demographic information was collected from medical records and face-to-face interview in the initial assessment session. The number of falls in the last year prior to TKA also was obtained in the same session through face-to-face interview.

In the assessment session, the measurements were performed independently by one of the three raters 4 weeks post-surgery. All three independent raters were physiotherapists with more than 10 years of relevant experience and were well trained to administer all the assessment tools used in the current study. Both the choice of rater and the sequence of test administration (balance, knee pain, knee range of motion, muscle strength and proprioception, balance confidence) were randomized by a computer program. The therapists providing the rehabilitation were blinded to the assessment data.

Measurements

Balance ability: The Balance Evaluation Systems Test (BESTest) contains 36 performance-based items in six specific balance sub-sections.[21] Each item was rated by a therapist on an ordinal scale from 0 to 3, with 3 representing no impairment of balance and 0 representing severely impaired balance or inability to complete a task, with a possible score range of 0-108.[21] Higher scores were indicative of better balance ability. The six sub-sections are section 1: Biomechanical Constraints (5 items, maximum score=15), Section 2: Stability Limits/Verticality (7 items, maximum score=21), section 3: Anticipatory Postural Adjustment (6 items, maximum score=18), section 4: Postural Responses (6 items, maximum score=18), section 5: Sensory Orientation (5 items, maximum score=15) and section 6: Stability in Gait (7 items, maximum score=21). The total score and subsection scores were converted to percentages (0-100%) for subsequent analysis.[21] The validity and reliability of the BESTest was good when administered in individuals with TKA.[6]

Balance confidence: The Activity-specific Balance Confidence Scale (ABC) is a 16-item questionnaire that evaluates self-perceived balance confidence while attempting various activities of daily living on a scale from 0-100% (0%: no confidence; 100%: complete confidence), and had been previously validated in the Chinese elderly population.[22] The average score of the 16 items was used for analysis.

Pain: The intensity of knee pain on the operated side experienced during

maximal active knee flexion was measured by the previously validated 11-point Numerical Pain Rating Scale (NPRS; 0: no pain; 10: worst imaginable pain).[23] One practice trial was completed wherein the therapist passively guided the limbs to show the participants the knee flexion motion. Participants began with both tested leg extended, and asked to perform a maximal active knee flexion movement once. The level of pain experienced was rated by the NPRS.

Knee range of motion: Two trials were performed of the maximal active flexion and extension range of motion (ROM) on both knees, measured with a 1-degree-increment long arm goniometer (Baseline® 180º Goniometer, Stainless steel. 14"L, NexGen Ergonomics Inc., Quebec, Canada). For knee flexion, larger values were indicative of greater range of motion. For knee extension, larger positive values denoted more restriction in range of motion, while negative values were indicative of hyperextension. The normal value of knee flexion and extension post-operatively is 106.3±11.1 ° and 1.4±3.1 °, respectively.[24] If the difference in ROM between the two trials was more than 5 degrees, a third trial was performed and the mean of the two closest ROM values was used for subsequent analysis. The criterion validity, as well as the inter- and intra-tester reliability of data obtained with the goniometer have been demonstrated to be high.[25]

Knee muscle strength: The previously validated maximum isometric knee

extension and flexion strength assessment was measured by a handheld dynamometer (DFE2-500 Chatillon Force Gauge, Largo, FL), with the operated knee stabilized at 60° flexion.[26] Maximal voluntary isometric contraction of the knee extensors and flexors was measured by a force transducer, which was placed around the anterior (for isometric knee extension) and posterior (for isometric knee flexion) regions of the lower leg, 2 cm above the proximal pole of the lateral malleolus. During testing, the participants were instructed to keep the tested knee joint stationary while gradually increasing the force of the contraction until the maximal force was reached, without performing sudden kicking or pulling motions. The participants were asked to maintain the maximal contraction for 5 seconds. The assessor met the resistance of the contraction and the strength value (N) was registered by the dynamometer. Larger values represented greater muscle strength. Trials were repeated up to three times, with 1 minute of rest between trials. The trial with the largest maximal volitional isometric force output was used for data analysis.[27] The strength value (N) was normalized to each participant's body weight and expressed as N/kg. The reference values of isometric knee flexion strength for older adults aged 60-70 years were 1.86 and 2.16 N/kg for women and men respectively.[28] The corresponding reference values for isometric knee extension were 3.83 and 4.72 N/kg respectively.[28] Hand-held dynamometry was also used to measure knee muscle strength in in previous research

on TKA.[15]

Knee joint proprioception: The testing of knee proprioception was adopted from one of the test items in the validated Physiological Profile Assessment.[29] Participants began with their eyes closed in a seated position. The center of the medial aspect of the first metatarsal joint on both sides was marked with a marker pen to indicate the matching reference points. A vertical clear acrylic sheet (60×60×1 cm) inscribed with a protractor was placed between the legs (Figure 1). During testing, participants were asked to extend the knees together to a certain position near mid range while keeping the ankles and feet relaxed, and attempt to match the position of the big toes. The degree of radial disparity (in degrees) between the two reference points was measured using the protractor. Smaller values depicted greater accuracy. The same test was conducted five times, each at slightly different knee joint angles near mid range. One practice trial was given prior to actual recording. The data obtained from the five experimental trials were averaged, and the mean score was used for analysis as per the standard protocol.[29,30] The normative values for women and men aged 64-69 years were 0.5-2.1°, and 0.5-2.4° respectively.[31]

Incidence of falls: During the initial assessment session, each participant was given a log book to record any future fall incidents and related circumstances (e.g., time of the day, location, etc.). Participants were followed-up monthly for 6 months

post-operatively by a blinded research assistant during physiotherapy treatment visits, or through telephone interviews if the individual was no longer receiving outpatient physiotherapy service. A fall was defined as unintentionally coming to rest on the ground, or at some lower level, and not as a result of a major intrinsic event (e.g., stroke).[32]

Data Analysis

IBM SPSS software (version 23.0) was used to analyze the data (Armonk, NY). Based on the prospective fall data, the participants were categorized as fallers (at least 1 fall during the follow-up period) and non-fallers. Separate independent t-tests and Chi-square tests compared fallers, non-fallers, and dropouts 4 weeks post-TKA. Univariate binary logistic regression analyses were used to determine the association of each outcome variable measured at 4 weeks post-TKA with fallers identified during the 6-month follow-up period. Next, multivariate stepwise binary logistic regression analysis (backward method) was performed, using the significant factors identified in the aforementioned univariate analysis as the independent variables and to generate the predicted probability value of fall for each individual. Next, a receiver operating characteristic (ROC) curve analysis was done, using the predicted probabilities generated above to identify fallers. The area under curve (AUC) value was reported.

The above analyses were repeated with the inclusion of the dropouts. An alpha ≤0.05 was defined as statistically significant.

Results

Participant Characteristics

A total of 146 individuals were recruited, and none of these individuals declined to participate. Twelve participants withdrew during the course of the study, therefore 134 participants had complete data (Figure 2). One of these participants withdrew before 4 weeks post-TKA and thus the baseline data for clinical variables were not available. Twenty-three fallers (17.2%) were identified during the 6-month follow-up period post-TKA. None of the dropouts had experienced any falls during the follow-up period up to the time of withdrawal. Participant characteristics (fallers and non-fallers) at 4 weeks post-TKA (initial assessment) are summarized in Table 1. At 4 weeks post-TKA, the fallers were significantly younger, showed greater pain on the NPRS, greater error in knee proprioception, less operated and non-operated knee flexion strength, as well as less operated knee extension strength (p<0.05; Table 1). A greater proportion of the non-fallers required a walking aid post-operatively than the dropouts (p<0.05; Table 1). No adverse events occurred during testing.

Fall Episodes

Thirty-one fall episodes were reported among the 23 fallers. Sixteen fallers (69.6%) fell once, 6 fallers (26.1%) fell twice, and 1 faller (4.3%) reported 3 falls during the follow-up period. The median time of the first fall episode was 15 weeks post-TKA (interquartile range: 7-24 weeks). The mean fall rate (i.e., (number of patient falls/number of patient days)×1000) was 1.22 (CI: 0.99, 1.51). Among the 23 fallers identified during the follow-up period, only two (8.7%) had a positive history of falls within 1 year prior to TKA.

Circumstances and Consequences of Falls

For the 31 fall episodes, most of the falls occurred in the afternoon (58.0%; Figure 3a) and during walking (67.7%; Figure 3b). Among the known causes, slipping (35.5%) and tripping (35.5%) were mentioned most frequently (Figure 3c). The majority of falls were in the forward direction (51.6%; Figure 3d). Additionally, most falls occurred at home (45.2%) or other indoor environments (29.0%). Most of the participants (87.1%) were not using a walking aid when the fall occurred. Four (12.9%) falls had led to mild injuries (bruising). No major injuries (e.g., fractures) were reported.

Factors Associated with Falls

Univariate binary logistic regression indicated that age, knee proprioception, section V (Sensory Orientation subsection) of the BESTest, pain intensity, and operated knee extension strength, were significantly associated with falls post-TKA (Tables 2). A correlation analysis was then performed for these five variables before the multivariate logistic regression analysis was conducted. The results exposed that there was no or little relationship (correlation coefficient $\leq$0.25) among these variables. Therefore, these variables were entered into the same multivariate analysis model without concerns with multicollinearity. After removing the insignificant operated knee extension strength (p=0.13), the multivariate stepwise logistic regression analysis ($\chi^2_{(4)}$=19.39, p<0.05) indicated that younger age, more severe deficit in knee proprioception, poorer sensory orientation, and more severe pain intensity remained significantly associated with falls (p<0.05, Table 3). The model revealed a 98.2 % correct classification of non-fallers, and 21.7 % correct classification of fallers, with an overall correct classification of 85.1 %. Using the predicted probabilities generated by the above multivariate logistic regression model, a ROC curve analysis was done to identify fallers. The resulting AUC value was 0.78 (95%CI: 0.68, 0.89).

The above logistic regression analyses were repeated with the inclusion of

dropouts. As none of the dropouts had experienced any falls during the follow-up period up to the time of withdrawal, these participants were considered as non-fallers in this analysis (Supplementary Table 1 and 2). After removing the insignificant operated knee extension strength (p=0.08), the multivariate stepwise logistic regression analysis ($\chi^2_{(3)}$=17.40, p<0.05) indicated that younger age, poorer knee proprioception, and more severe pain intensity remained significantly associated with falls (p<0.05, Supplementary Table 2). The model revealed a 98.4% correct classification of non-fallers, and 17.4% correct classification of fallers, with an overall correct classification of 85.5%. The ROC curve analysis yielded an AUC value of 0.75 (95%CI: 0.65, 0.85).

Discussion

Main Findings

Our results revealed that 17.2% of individuals sustained at least one fall during the follow-up period after TKA. The majority of falls occurred at home during locomotion. Lastly, the factors associated with falls post-TKA were: younger age, reduced operated knee proprioception, a lower score on the sensory orientation subscale of the BESTest, and more severe operated knee pain.

Incidence of Falls

The proportion of fallers during the 6-month follow-up period post-TKA in our study was 17.2%. Previous studies have reported values ranging from 7-32.9%.[14,15,17] Differences in follow-up periods, participant characteristics, and self-reported falls data compared to regular follow-ups by the researchers may have contributed to the discrepancies in findings. Overall, our results assert that falls remain an important concern among individuals who have undergone TKA. Thus, clinicians should consider performing a fall-risk assessment in order to identify those at a greater risk for falls in order to provide a targeted intervention.

Circumstances of Falls

Our study confirms the work by Tsonga et al. that most falls occurred during walking and that the major causes were tripping and slipping in patients with TKA.[19] Among the 20 falls reported by 15 patients during their 1-year follow-up period, 95.0% occurred during walking.

In the current study, most falls occurred at home (45.2%) or other indoor environments (29.0%). This was in contrast with Tsonga et al., who reported that the majority of falls occurred in an outdoor environment (65.0%) at the 1-year follow-up.[19] The discordance in results may have stemmed from differences in follow-up

duration. Their participants may have engaged in more outdoor activities as they progressed to the later stages of recovery after surgery. Our findings highlight the importance in reducing hazards in the home that could cause slipping or tripping, especially in the early stages of recovery from TKA.

Fall-Related Risk Factors

Our results showed that the combination of younger age, poorer operated knee proprioception, a lower score on the sensory orientation subscale of the BESTest, and more severe operated knee pain, were independently associated with increased risk of falls. Interestingly, younger age was associated with increased risk of falls. Although it is well known that aging combined with inactivity can gradually lead to decreased physical performance, and thus increased fall risk,[33] the critical factor that remains is whether balance capacity matches individual demands. Our younger participants may have been more physically active and subsequently more likely to engage in risky behaviors compared with older counterparts; however, this cannot be confirmed as we did not measure physical activity, hence this should be considered in future work.

We are the first to identify knee proprioception as a significant predictor of falls post-TKA. This was consistent with our finding that the Sensory Orientation subsection score of the BESTest exhibited an association with falls. It is known that

306 sensory information from the somatosensory, visual, and vestibular systems must be
307 integrated for balance control. However, the relative contribution of each system is
308 dependent on different sensory contexts. For example, when standing on an unstable
309 surface, there is an increased dependency on visual and vestibular inputs to keep an
310 upright position.[34] The ability to reweight sensory information is important for all
311 populations, but this becomes increasingly difficult for those with compromised
312 sensory systems, as they may exhibit increased risk of falls.[35] Previous research
313 demonstrated that in response to support surface translations, individuals with
314 vestibular or proprioceptive loss exhibited unfavorable changes in muscle onset
315 latency and amplitude.[36,37] Therefore, deficits in knee proprioception, coupled with
316 age-related declines in vestibular and somatosensory function, may challenge the
317 ability to effectively reweight information from different sensory subsystems that
318 maintain body equilibrium, thereby increasing the fall risk in individuals with TKA.[36]
319 In line with previous work, greater pain intensity was associated with increased
320 risk of falls.[16] In the current study, we measured the operated knee pain on maximal
321 knee flexion only, but not during other activities. A systematic review suggests that
322 between 19-31 % of individuals had an unfavorable pain outcome after TKA, which
323 may place these individuals at risk for falls post-operatively.[38]
324 Surprisingly, while knee extensor muscle strength of the operated leg was

associated with falls in the univariate logistic regression, but its effect was diminished in the multivariate analysis. Compromised quadriceps strength has been identified as a significant predictor of increased postural sway in patients with knee OA.[20] In a systematic review and meta-analysis, Moreland et al.[39] indicated that lower extremity weakness was a clinically important risk factor for falls in older adults. In addition to muscle weakness, there are a multitude of deficits in physical function specific to TKA, such as knee pain,[19] impairment in knee proprioception,[9] and balance,[6] which may further contribute to falls. Moreover, the relationship between muscle weakness and falls is probably modified by multiple characteristics of the individual, task, and environment.[40]

In contrast to Tsonga et al.,[19] the history of falls was not a significant predictor of prospective falls during the follow-up period. The insignificant results may be explained by the low proportion of fallers pre-operatively (4.5%; Table 1), compared to other studies (23.3-63.2%).[9,17-19] Underreporting may have occurred because the data on pre-operative falls were collected retrospectively. The low incidence of falls in the pre-operative period also may be due to the relatively good physical mobility among our participants, as only 30 out of 134 participants (22.4%) required walking aids pre-operatively.

Interestingly, when the dropouts were included in the factors associated with falls

analysis, only younger age, knee proprioception and greater pain intensity remained significantly associated with falls (Supplementary Tables 1 and 2). Section V of the BESTest (sensory orientation), which was identified as a significant fall-related factor in the original analysis, did not reach statistical significance. These findings indicate that dropouts may diminish the effects of this factor on fall risk, and should be considered in future work.

Clinical Implications

The results indicate that individuals with TKA who are of younger age, more impairment in knee proprioception, more severe pain in the operated knee, and probably poorer sensory orientation, are contributors to falls. As such, these factors should be considered in the overall fall-risk assessment and educational programs in this patient group. The latter three factors are modifiable and should be addressed in fall prevention programs.

Limitations and Future Research Directions

Given that the data on fall history within the last year prior to TKA was obtained retrospectively, participants may have underestimated the number of falls. We did not measure physical activity level, and if participants reduced their physical activity

363 during recovery, they may have been less subject to fall-inducing situations.
364 Participants were only followed for a period of 6 months; thus, it is possible that other
365 predictive factors may have emerged with a longer follow-up period. Our results
366 revealed good specificity of the regression model, but the sensitivity was relatively
367 low. Further research is needed to identify potential fall-related risk factors that were
368 not evaluated in the study (e.g., physical activity, dual-task balance and mobility
369 function, etc.). From a clinical perspective, there may be limitations in how the
370 findings might translate into clinical practice or patient education because the cutoff
371 scores for the various fall-related factors were not identified. The development of an
372 algorithm in patient screening in identifying patients with low/medium/high fall risks
373 awaits further investigations.

374 Our power analysis was based on previous findings on the relationship between
375 falls and knee range of motion. The study may be underpowered for other
376 independent variables. There are potential concerns that the tester may not be able to
377 overcome the maximal muscle force generated by some patients. However, as
378 described in the Methods section, participants were asked to gradually build up the
379 force until maximal effort was reached. The muscle strength values attained by our
380 participants were also lower than the age-matched reference values, indicating muscle
381 weakness.[28] Taken together, it is unlikely that the assessor was unable to overcome the

force generated by the participants. Moreover, muscle torque (Nm) may be a better representation of muscle strength. However, we did not measure leg length and thus unable to calculate the muscle torque values.

Only individuals who were referred to receive outpatient physiotherapy were recruited for this study. It is therefore possible that post-surgery complications could have occurred in other patients who were not referred to outpatient services, which may have skewed our data towards a healthier TKA population. Our participants received outpatient physiotherapy treatment for an average of 94.0 ± 25.5 days post-TKA. Accordingly, our results may only be generalizable to individuals with TKA receiving similar outpatient rehabilitation. Because there were only a few recurrent fallers in our data, we did not perform any sub-group analysis to compare the fall-related risk factors between recurrent fallers and single fallers. Future research should determine whether recurrent fallers exhibit different fall-related risk factors relative to single fallers post-TKA.

Conclusion

A substantial proportion (17.2%) of individuals sustained at least one fall within the 6-month follow-up period after TKA. The falls predominantly occurred at home, and during locomotion. Younger age, poorer knee proprioception, severe operated

401 knee pain and difficulty with sensory orientation were important factors related to
402 falls after TKA. These factors should warrant greater attention in clinical assessment
403 and intervention settings in this patient population.
404
405 **Conflict of Interest Statement**
406 The authors have no conflict of interest to declare.
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Table 1. Participant characteristics

Variable	All Participants (*n*=146)		Fallers (*n*=23)		Non-Fallers (*n*=111)		Dropouts (*n*=12)	
	Mean (SD) or *n (%)*	Range	Mean (SD) or *n (%)*	Range	Mean (SD) or *n (%)*	Range	Mean (SD) or *n (%)*	Range
Basic demographics (N=146)								
Age (year)	66.7 (6.7)	(50.0-80.0)	63.6 (6.4)	(50.0-76.0)	66.8 (6.6)	(52.0-80.0)	71.6 (4.9)*†	(63.0-80.0)
Gender (female) (*n, %*)	102 (69.9%)		18 (78.2%)		77 (69.4%)		7 (58.3%)	
Side of TKA (left) (*n*, %	62 (42.5%)		8 (34.8%)		48 (43.2%)		6 (50%)	
Number of Participants Who Had At Least One Fall in the Last 12 Months (*n*, %)	6 (4.1%)		2 (8.7%)		4 (3.6%)		0 (0%)	
Required Walking Aid Pre-Operatively (*n, %*)	86 (58.9%)		11 (47.8%)		65 (58.6%)		10 (83.3%)	
Requiring Walking Aid Post-Operatively (*n, %*)	137 (93.8%)		22 (95.7%)		106 (95.5%)		9 (75%)†	
Number of Outpatient Sessions (*n*)	11.3 (3.0)	(1.0-26.0)	11.1 (2.8)	(7.0-19.0)	11.6 (2.9)	(7.0-26.0)	9.3 (4.1)	(1.0-16.0)
Outpatient Physiotherapy Treatment Period (days)	94.0 (25.5)	(123.0-172.0)	95.5 (19.7)	(77.0-156.0)	93.7 (21.6)	(65.0-172.0)	93.8 (55.6)	(1.0-168.0)
Body Mass Index (kg/m^2)	26.7 (3.8)	(18.3-37.8)	26.6 (3.1)	(20.1-32.1)	26.7 (4.0)	(18.3-37.8)	27.1 (4.9)	(23.2-32.7)

Clinical variables measured at 4 weeks post-TKA (N=145)‡

	All Participants (*n*=145)		Fallers (*n*=23)		Non-Fallers (*n*=111)		Dropouts (*n*=11)	
BESTest Total Score (0-100%)	74.8 (12.1)	(12.0-96.2)	74.2 (12.0)	(50.0-91.5)	76.3 (9.5)	(50.0-96.2)	60.1 (23.2)*†	(12.0-82.4)
BESTest: Section I (0-100%)	51.3 (17.4)	(13.3-93.3)	48.2 (15.2)	(20.0-73.3)	52.8 (17.5)	(13.3-93.3)	41.7 (17.3)	(20.0-66.6)
BESTest: Section II (0-100%)	88.9 (7.2)	(42.8-100.0)	90.0 (6.1)	(81.0-100)	89.7 (5.6)	(71.4-100)	79.2 (14.0)*†	(42.8-90.4)
BESTest: Section III (0-100%)	75.8 (18.6)	(5.5-100.0)	77.3 (16.4)	(44.4-100)	77.5 (16.6)	(38.9-100)	55.0 (28.7)*†	(5.5-88.8)
BESTest: Section IV (0-100%)	64.8 (22.8)	(0.0-100.0)	63.5 (26.5)	(22.2-100)	67.1 (20.1)	(0-100)	45.5 (32.1)†	(0.0-94.4)
BESTest: Section V (0-100%)	97.1 (10.4)	(0.0-100.0)	95.9 (9.6)	(66.7-100)	98.6 (3.9)	(80.0-100)	84.8 (31.4)*†	(0.0-100)
BESTest: Section VI (0-100%)	68.2 (18.7)	(0.0-100.0)	68.1 (17.0)	(23.8-90.5)	69.8 (16.8)	(6.7-100)	52.4 (32.0)†	(0.0-90.4)
ABC Score (0-100%)	65.1 (18.0)	(19.4-96.9)	64.7 (16.1)	(35.0-96.9)	66.2 (17.4)	(20.0-96.9)	54.6 (25.6)	(19.4-91.9)
Pain Intensity (NPRS) (0-10)	1.7 (1.1)	(0.0-6.0)	2.3 (1.0)†	(0.0-5.0)	1.7 (1.0)	(0.0-6.0)	1.2 (1.0)	(0.0-3.0)
Operated Knee Proprioception (º)	1.7 (1.0)	(0.0-5.2)	2.1 (1.3)†	(0.4-5.2)	1.5 (1.0)	(0.0-4.8)	1.9 (0.8)*	(0.8-3.5)
Operated Knee Flexion ROM (º)	108.6 (9.7)	(70.0-130.0)	107.8 (9.1)	(90.0-120.0)	108.5 (10.0)	(70-130)	110.9 (7.3)	(100.0-120.0)
Non-Operated Knee Flexion ROM (º)	117.3 (12.1)	(80.0-140.0)	119.6 (12.2)	(95.0-140.0)	117.2 (12.1)	(80-140)	114.5 (11.7)	(90.0-130.0)
Operated Knee Extension ROM (º)	-3.5 (5.0)	(-25.0-0.0)	-3.5 (5.5)	(-20.0-0.0)	-3.6 (5.0)	(-25-0.0)	-3.2 (5.1)	(-15.0-0.0)
Non-Operated Knee Extension ROM	-2.0 (5.3)	(-30.0-0.0)	-1.7 (6.0)	(-25.0-0.0)	-1.8 (4.8)	(-30-0.0)	-3.6 (7.8)	(-25.0-0.0)
Operated Knee Flexion Strength	1.8 (0.5)	(0.6-3.4)	1.6 (0.5)	(0.9-3.0)	1.8 (0.5)	(0.6-3.4)	1.7 (0.5)	(0.8-2.6)
Non-Operated Knee Flexion Strength	2.2 (0.5)	(1.2-4.0)	2.0 (0.5)	(1.3-3.3)	2.2 (0.5)	(1.2-4.0)	2.0 (0.5)	(1.4-2.8)
Operated Knee Extension Strength	2.1 (0.7)	(0.8-4.0)	1.8 (0.7)†	(0.8-3.7)	2.2 (0.7)	(0.8-4.0)	1.9 (0.6)	(1.1-3.0)
Non-Operated Knee Extension	2.9 (0.7)	(1.5-4.7)	2.6 (0.8)	(1.5-4.0)	2.9 (0.7)	(1.6-4.7)	2.9 (1.0)	(1.6-4.6)

ABC: Activities-specific Balance Confidence Scale; BESTest: Balance Evaluation Systems Test; NPRS: Numeric Pain Rating Scale; ROM: Range of Motion; TKA: Total Knee Arthroplasty

*significantly different from fallers ($p<0.05$)

† significantly different from non-fallers ($p<0.05$)

‡One participant dropped out before 4 weeks post-TKA. Thus, the data for these variables were based on 145 participants only.

Table 2. Univariate binary logistic regression analyses for factors associated with fallers (participants with complete dataset; N=134)

Variable	Cox-Snell R^2 for each predictor	Regression coefficient (B)	*P* value	Odds ratio	95% CI for odds ratio	
					Lower	Upper
Age	0.03	-0.75	0.03*	0.93	0.86	0.99
Proprioception	0.04	0.48	0.02*	1.61	1.08	2.41
Pain Intensity (NPRS)	0.04	0.53	0.01*	1.70	1.09	2.63
BESTest Section V	0.02	-0.07	0.04*	0.93	0.87	0.99
Operated Knee Extension Strength	0.04	-0.95	0.01*	0.38	0.17	0.84
Non-Operated Knee Extension Strength	0.02	-0.63	0.07	0.52	0.26	1.06
Operated Knee Flexion Strength	0.03	-0.99	0.05	0.36	0.13	1.00
Non-Operated Knee Flexion Strength	0.03	-0.98	0.05	0.37	0.14	1.00
Falls in the Last 12 months	0.00	0.92	0.30	2.52	0.43	14.68
BESTest Total Score	0.00	-0.02	0.34	0.97	0.93	1.02
BESTest Section I	0.01	-0.01	0.23	0.98	0.95	1.01
BESTest Section II	0.00	0.01	0.78	1.01	0.93	1.09
BESTest Section III	0.00	-0.00	0.95	0.99	0.97	1.02
BESTest Section IV	0.00	-0.00	0.46	0.99	0.97	1.01
BESTest Section VI	0.00	-0.00	0.65	0.99	0.96	1.02
Operated Knee Extension ROM	0.01	-0.04	0.26	0.95	0.88	1.03
Non-Operated Knee Extension ROM	0.00	-0.02	0.58	0.97	0.90	1.05
Operated Knee Flexion ROM	0.00	0.01	0.59	1.01	0.96	1.06
Non-Operated Knee Flexion ROM	0.00	0.00	0.69	1.00	0.97	1.04
ABC score	0.00	-0.00	0.71	0.99	0.96	1.02
Number of Outpatient Sessions	0.00	-0.06	0.49	0.94	0.78	1.12
Outpatient Physiotherapy Treatment Period	0.00	0.00	0.70	1.00	0.98	1.02

*Significantly associated with fallers (p<0.05).

ABC: Activities-specific Balance Confidence Scale; BESTest: Balance Evaluation Systems Test; NPRS: Numeric Pain Rating Scale; ROM: Range of Motion; TKA: Total Knee Arthroplasty; CI: Confidence Interval.

Table 3. Multivariate binary logistic regression analysis for identifying factors associated with fallers (participants with complete dataset; N=134)

Variable	Cox-Snell R^2 for model	Regression Coefficient (B)	*p* value	Odds Ratio	95% CI for Odds Ratio	
					Lower	Upper
	0.14					
Age	-	-0.08	0.02*	0.91	0.84	0.99
Proprioception	-	0.48	0.02*	1.62	1.05	2.50
Pain Intensity (NPRS)	-	0.52	0.02*	1.68	1.07	2.64
Subsection V of BESTest: Sensory orientation	-	-0.08	0.04*	0.92	0.86	0.99
Constant	-	9.86	0.05		-	-

*significantly associated with fallers ($p<0.05$)

†Knee extension strength on the operated side was removed from the stepwise regression model ($p=0.13$)

BESTest: Balance Evaluation Systems Test; NPRS: Numeric Pain Rating Scale; CI: Confidence Interval.

Figure captions

Figure 1.

Assessment of knee proprioception.

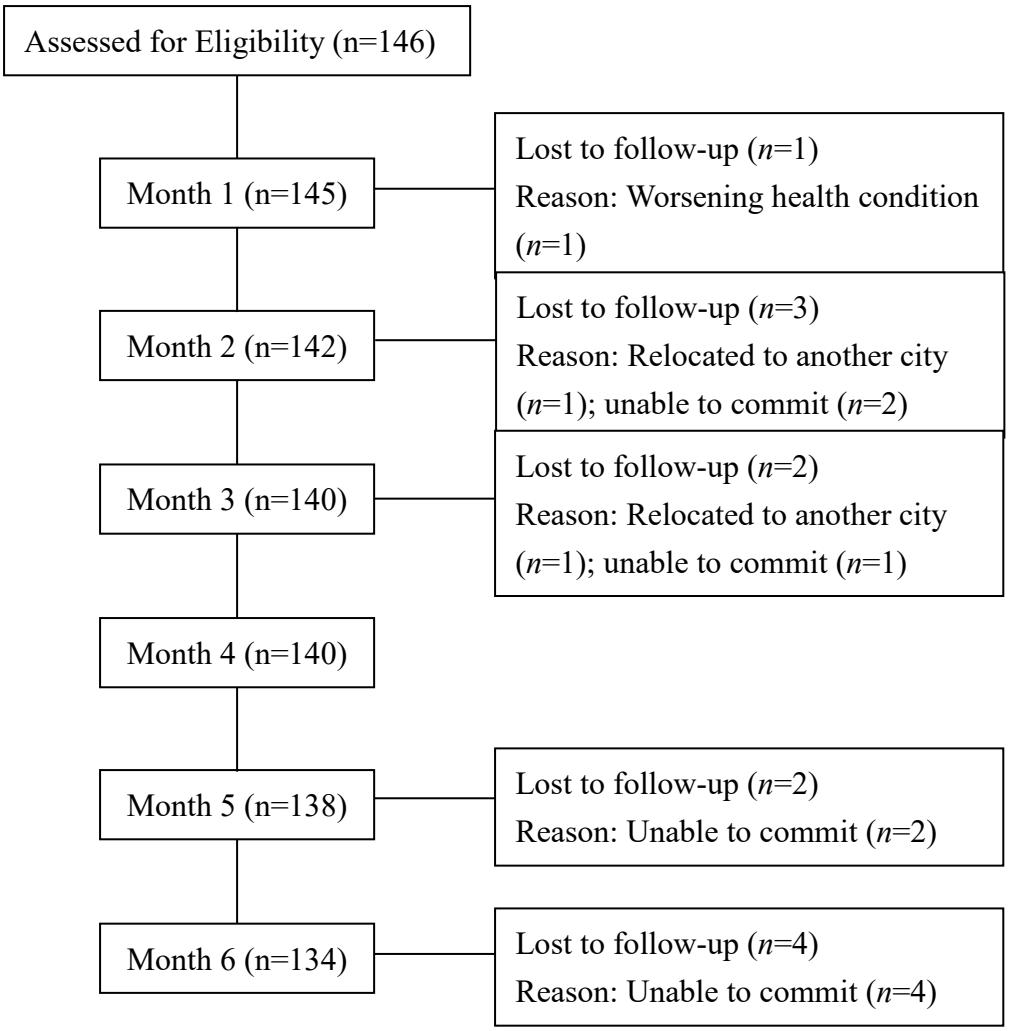
Figure 2.

Flow diagram of participant recruitment, adherence, and attrition.

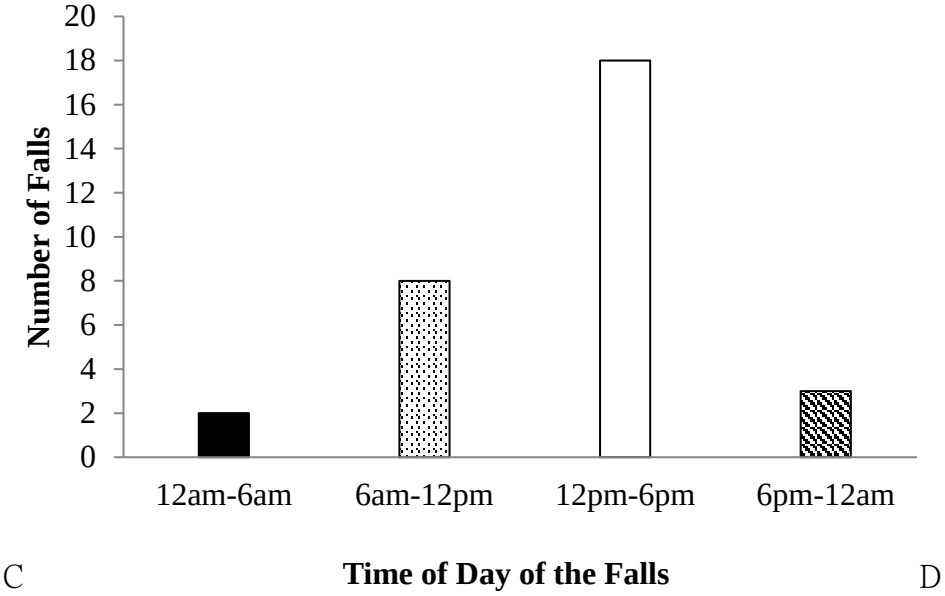
Figure 3.

Fall-related circumstances are illustrated with respect to: (a) Time of day of the falls; (b) Activity completed during the falls; (c) Causes of the falls, (d) Direction of the falls.

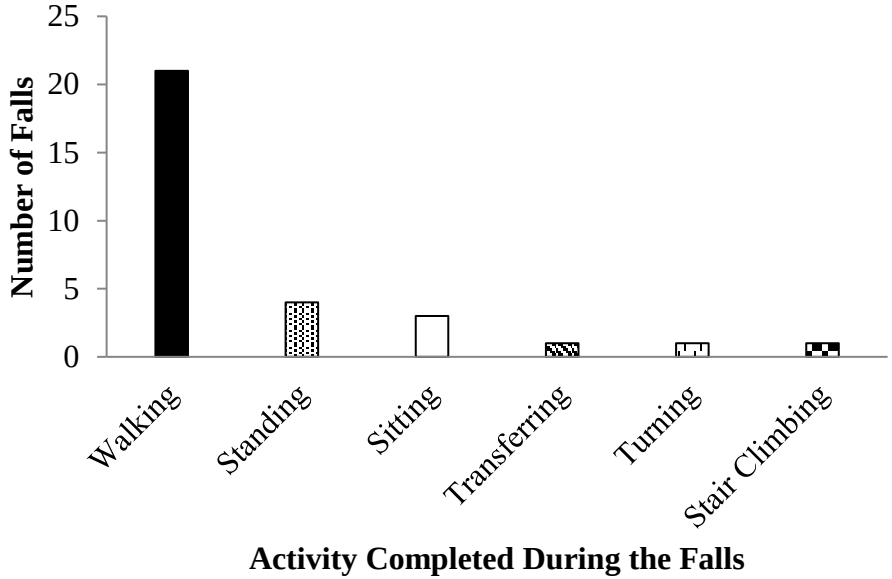

0
10
20
30
40
50
60
70
80
90
100
110


Assessed for Eligibility (n=146)
Month 1 (n=145)
Lost to follow-up (n=1)
Reason: Worsening health condition (n=1)
Month 2 (n=142)
Lost to follow-up (n=3)
Reason: Relocated to another city (n=1); unable to commit (n=2)
Month 3 (n=140)
Lost to follow-up (n=2)
Reason: Relocated to another city (n=1); unable to commit (n=1)
Month 4 (n=140)
Month 5 (n=138)
Lost to follow-up (n=2)
Reason: Unable to commit (n=2)
Month 6 (n=134)
Lost to follow-up (n=4)
Reason: Unable to commit (n=4)

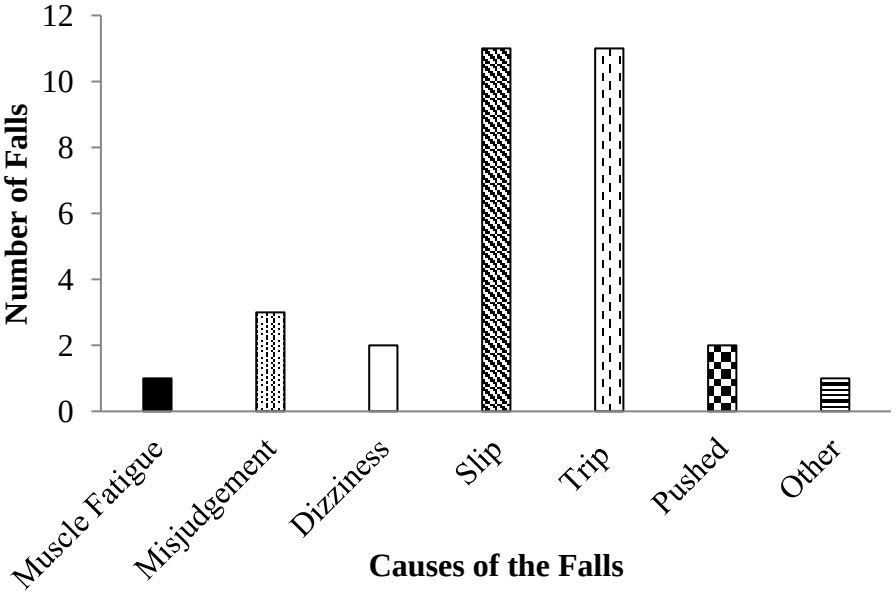
A


Number of Falls
20
18
16
14
12
10
8
6
4
2
0
12am-6am
6am-12pm
12pm-6pm
6pm-12am
Time of Day of the Falls

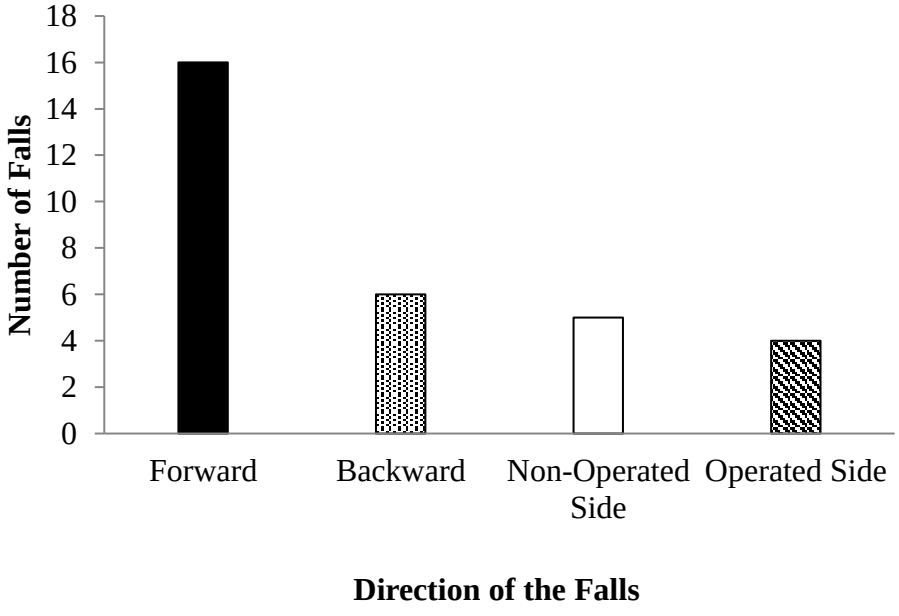
B


Number of Falls
25
20
15
10
5
0
Walking
Standing
Sitting
Transferring
Turning
Stair Climbing
Activity Completed During the Falls

C


Number of Falls
12
10
8
6
4
2
0
Muscle Fatigue
Misjudgement
Dizziness
Slip
Trip
Pushed
Other
Causes of the Falls

D


Number of Falls
18
16
14
12
10
8
6
4
2
0
Forward
Backward
Non-Operated Side
Operated Side
Direction of the Falls