Sequential changes in lower extremity function after total knee arthroplasty

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Research article

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Abstract

**Background**: The effectiveness of total knee arthroplasty for recovering ambulation and balance function has not been investigated in detail. The present study aimed to measure functional changes in the lower limb before and after TKA by measuring ambulation function with the 3 meters Timed Up and Go test and balance function using one-leg standing time.

**Methods**: The study included 137 patients (116 women and 21 men) with osteoarthritis of the knee who underwent primary total knee arthroplasty. The mean age of the patients was 74.4 years. The mean postoperative hospital stay for rehabilitation was 23.9 days. The Timed Up and Go test and standing time were performed preoperatively, 2 weeks postoperatively, at discharge, and 3, 6, and 12 months postoperatively. These results from these 6 measurements were also compared using one-way analysis of variance. We also separated the patients into 3 groups by the length of hospital stay: 3 weeks or less (early discharge group), 3 to 4 weeks (standard discharge group), and over 4 weeks (late discharge group). The Timed Up and Go test and standing time among the 3 groups were evaluated at 6 measurement points.

**Results**: Ambulation and balance function were significantly improved at 3 months after surgery. However, ambulation and balance function did not improve further from 3 months to 6 months postoperatively or from 6 months to 1 year postoperatively. Ambulation function in the early and standard discharge group were significantly lower than those in the late discharge group at all measurement points. Balance function in the early and standard discharge groups were significantly longer than those in the late discharge group preoperatively.

**Conclusions**: Total knee arthroplasty is useful for restoring lower limb function, as both ambulation and balance function were significantly improved 3 months after surgery. Although a longer hospital stay with rehabilitation not always affected ambulation and balance function, preoperative ambulation and balance function may predict the length of hospital stay after surgery. No further improvement in ambulation or balance was recognized beyond 3 months, suggesting that further rehabilitation after hospital discharge is needed.

**Background**

Osteoarthritis (OA) of the knee joint is the most common indication for total knee arthroplasty (TKA). The incidence and prevalence of OA is likely to continue increasing owing to factors such as the aging population in developed countries [1]. Furthermore, OA is an important risk factor for falls. Falls are among the most common causes of injury and hospitalization in elderly individuals [2]. TKA aims to relieve pain, restore motor abilities, correct lower limb deformities, and improve quality of life [3]. However, patients undergoing TKA owing to knee OA often have residual functional deficits, such as ambulation and balance deficits, which increase the risk of falls [4].
There is a concept of musculoskeletal ambulation disability symptom complex (MADS) that indicates the elderly population with a high risk of falls and ambulation deficits caused by musculoskeletal disorders. The diagnosis of MADS is composed of two parts: (1) a musculoskeletal disorder must be diagnosed, which includes deteriorating ambulation and balance function, and (2) the degree of independence in the activities of daily living must decrease to the point of requiring support or nursing care, or a functional decline in ambulatory function must be observed (Table 1) [5]. The functional evaluation involves 2 simple performance tests; MADS is diagnosed if the 3 meters Timed Up and Go (TUG) test time [6] is not less than 11 seconds and/or the one-leg standing time (ST) with open eyes [7] is less than 15 seconds [8].

Rehabilitation with a particular emphasis on physiotherapy and exercise is widely promoted after TKA [9]. Physiotherapy targets mobilization and achievement of functional goals relating to hospital discharge. Length of hospital stay after TKA varies widely from country to country [10, 11], and these differences may depend on each institute’s capacity to perform postoperative inpatient rehabilitation. Our institution allows patients to determine the length of their hospital stay and to receive rehabilitation everyday, taking into consideration uncontrolled pain and unstable transfer.

Some papers have reported the effect of TKA on postoperative ambulation and balance [12]. However, there have been no detailed reports on how TKA affects perioperative and postoperative ambulation and balance or differences in ambulation and balance due to the length of the hospital stay. The present study aimed to quantitatively evaluate changes in ambulation and balance before and after TKA based on the evaluation criteria of MADS by performing the TUG test and the ST. It was hypothesized that ambulation and balance would improve after TKA and that a longer hospital stay with rehabilitation would improve ambulation and balance.

**Methods**

This prospective study included 137 patients (116 women and 21 men) with knee OA who underwent primary TKA between March 2013 and July 2016 and were followed up for 1 year. The mean age of the patients was 74.4 years (range, 49–88 years), and the mean body mass index was 25.8 (range, 16.0–35.7). The postoperative mean hospital stay for rehabilitation was 23.9 days (range, 16–45 days). The exclusion criteria were a lack of follow-up data from all evaluation periods, rheumatoid arthritis or arthritis due to infection, and secondary knee OA. The hospital ethics committee approved the study protocol, and the patients provided informed consent for participation. All operations were performed by a single surgeon (H.M.). TKAs were performed with a medial parapatellar arthrotomy approach. Inpatient rehabilitative treatment was started on the day after surgery, and the rehabilitation was performed everyday. The patients remained in the hospital until they were ready to leave. Regular rehabilitation after discharge was not performed except for regular hospital visits.

*Evaluation of ambulation and balance (Fig. 1) and the timing of measurements*

The TUG test was used to evaluate the patients’ ambulation ability in order to diagnose MADS. The TUG test was performed preoperatively, 2 weeks postoperatively, at discharge, and 3, 6, and 12 months
postoperatively. This test measures the time taken to rise from a chair, walk straight for 3 meters, turn around, walk back, and sit down on a chair. The time is measured from the seated position with a stopwatch starting on the command “ready go” and is stopped when the participant sits down. The fastest time of three trials was chosen, and the time was recorded to the nearest 0.1 second.

The ST was also used to evaluate balancing ability in order to diagnose MADS. The ST on the operative side was also performed preoperatively, 2 weeks postoperatively, at discharge, and 3, 6, and 12 months postoperatively. The test measures the duration that the participants can stand on one leg with eyes open, hands placed on the hips, and the other foot raised at least 5 cm. The longest time of three trials was chosen, and the time was recorded to the nearest 0.1 second.

The TUG test and ST were individually performed face-to-face with patients by physical therapists in the physiotherapy room. We documented the importance of these tests to the patients and maintained fidelity for these tests. These tests were performed in all patients that we were able to follow up for 1 year postoperatively.

**Diagnosis of MADS**

MADS is diagnosed if the 3 meters TUG test time is not less than 11 seconds and/or the one-leg ST with open eyes is less than 15 seconds. The percentage of patients with MADS was calculated at each measurement point. We calculated the percentage of mergers of reduced ambulation and balance ability at each measurement point.

**Statistical analysis**

All values were expressed as the mean ± standard error. The results were analyzed statistically using the Statview statistical software package (ver. 5.0; Abacus Concepts, Inc., Berkeley, CA, USA). The TUG test and ST results were compared among the 6 time periods using one-way analysis of variance. We separated the patients into 3 groups by the length of hospital stay: 3 weeks or less (early discharge group), 3 to 4 weeks (standard discharge group), and over 4 weeks (late discharge group). The TUG test time and ST among the 3 groups were evaluated using a repeated measures analysis of variance with a Fisher’s probable least-squares difference post hoc test for multiple comparisons of paired samples. P < 0.05 was set statistically significant. A statistical power analysis was performed prior to the study, which was expected to require a power of 0.8, based on a prespecified significance level of α<0.05 and assuming a medium effect size (0.25) using G power 3 [13]. The estimated sample size was 93 patients.

**Results**

**Changes in ambulation (TUG) and balance (ST) function**

The mean TUG test times were 12.6 ± 0.4, 16.9 ± 0.6, 13.0 ± 0.3, 11.1 ± 0.3, 10.4 ± 0.3, and 10.2 ± 0.3 seconds when measured preoperatively, 2 weeks postoperatively, at discharge, 3, 6, and 12 months postoperatively, respectively. The mean TUG test time was significantly higher 2 weeks after TKA than it
had been preoperatively; however, the mean time was significantly lower at discharge than 2 weeks after TKA. There was no significant difference between the mean TUG test time when measured preoperatively and at discharge. The mean TUG test times at 3 months, 6 months, and 1 year after TKA were significantly improved when compared to the preoperative time. However, there was no significant improvement from 3 months to 6 months postoperatively or from 6 months to 1 year postoperatively (Fig. 2a).

The mean STs on the operative side were 17.6 ± 2.1, 15.3 ± 1.8, 20.9 ± 2.4, 27.9 ± 2.9, 28.5 ± 2.7, and 25.9 ± 2.6 seconds when measured preoperatively, 2 weeks postoperatively, at discharge, and 3, 6, and 12 months postoperatively, respectively. There was no significant difference in the mean ST when measured preoperatively, 2 weeks postoperatively, and at discharge. The mean ST at 3 months after TKA was significantly improved compared to the preoperative ST, similar to the TUG test time. However, there was no significant improvement from 3 months to 6 months postoperatively or from 6 months to 1 year postoperatively (Fig. 2b).

**Changes in the percentage of mergers of MADS**

The percentages of patients with MADS were 79.6%, 91.2%, 80.3%, 64.2%, 59.9%, and 61.3% when the patients were evaluated preoperatively, 2 weeks postoperatively, at discharge, and 3, 6, and 12 months postoperatively, respectively. The percentages of mergers of reduced ambulation ability (TUG ≥ 11 seconds) and balance ability (ST < 15 seconds) were 59.6% and 65.7%, 83.9% and 68.8%, 67.2% and 59.9%, 37.2% and 56.2%, 34.3% and 52.6%, and 30.7% and 56.9% when the patients were evaluated preoperatively, 2 weeks postoperatively, at discharge, and 3, 6, and 12 months postoperatively, respectively (Fig. 2c).

**TUG test time and ST according to length of hospital stay**

The 137 patients included in the current study were separated into the early discharge group (49 patients; mean age, 73.7 years (range, 49–88 years); mean postoperative hospital stay, 19.2 days (range, 16–21 days)), standard discharge group (63 patients; mean age, 74.9 years (range, 49–86 years); mean postoperative hospital stay, 24.0 days (range, 22–28 days)), and late discharge group (25 patients; mean age, 74.6 years (range, 64–88 years), and mean postoperative hospital stay, 33.1 days (range, 29–45 days)). The mean TUG test times and STs on the operative side are listed in Table 2. The mean TUG test times in the early and standard discharge group were significantly lower than those in the late discharge group at all measurement points. The mean TUG test time in the early discharge group was significantly lower than that in the standard discharge group 2 weeks after TKA. The mean STs in the early and standard discharge groups were significantly longer than those in the late discharge group preoperatively. There was no significant difference in the mean ST between the early and standard discharge groups (Table 3).

**Discussion**
We hypothesized that ambulation and balance would improve after TKA and that a longer hospital stay with rehabilitation would improve ambulation and balance. The most important finding in this study was that ambulation and balance were significantly improved at 3 months after TKA, thus supporting our hypothesis. However, ambulation and balance did not improve from 3 months to 6 months postoperatively or from 6 months to 1 year postoperatively, thus contradicting our hypothesis. Furthermore, a longer hospital stay did not improve ambulation and balance, thus contradicting our hypothesis. These results suggest that patients with poor preoperative ambulation and balance might have a longer hospital stay and that a longer hospital stay with rehabilitation might not affect ambulation and balance after discharge.

MADS is defined as a condition where elderly individuals have a high risk of falls and have ambulatory disabilities caused by musculoskeletal disorders [5]. MADS is also diagnosed if the 3 meters TUG test time is not less than 11 seconds and/or the one-leg ST with open eyes is less than 15 seconds. The TUG test is a modified, timed version of the “Get-Up and Go” test first reported by Mathias et al. [14]. It is a simple and inexpensive method to assess basic mobility with daily movements [15]. The TUG test includes sit-to-stand and stand-to-sit chair transitions, turning, straight-ahead gait, balance control, and the ability to perform tasks in sequence [12]. The ST is also a widely used clinical tool to evaluate postural steadiness in the standing position for elderly people. Previous reports suggest that ST is associated with age, self-assessment of their health status, body mass index, mortality, and the risk of falls [16]. The ST involves standing on one foot, placing the hands on the hips, and raising the other foot more than 5 cm, while keeping the eyes open [17]. The TUG test and ST are simple to score, requiring minimal training and no expertise in mobility analysis. In the current study, approximately 80% of the patients preoperatively had MADS, and this number decreased to about 65% at 3 months postoperatively. Our results indicate that only about 15% of patients no longer had MADS at 3 months after surgery. The percentage of mergers of reduced ambulatory function (TUG ≥ 11 seconds) improved from 59.6% preoperatively to 37.2% at 3 months postoperatively and 30.7% at 1 year postoperatively, indicating that the percentage improved at 3 months after TKA. However, the percentage of mergers of reduced balancing function (ST < 15 seconds) improved from 65.7% preoperatively to 56.2% at 3 months postoperatively but did not improve from 3 months postoperatively to 1 year postoperatively (56.9%).

Rehabilitation with an emphasis on physiotherapy and exercise is widely promoted after TKA [9]. During the hospital stay, physiotherapy targets mobilization and achievement of functional goals relating to hospital discharge. The length of hospital stay after TKA was recently reported to range widely from 3.8 days to 35.1 days by each country [10, 11]. Therefore, in countries with a short hospital stay, outpatient, community, or home-based physiotherapy and exercise-based interventions are important after hospital discharge [9]. In the current study, patients were discharged at their request, with inpatient rehabilitation continuing daily until discharge. As a result, the mean TUG test time and ST at 3 months after TKA were significantly improved compared to the preoperative TUG test time and ST. However, there was no significant improvement from 3 months to 6 months postoperatively or from 6 months to 1 year postoperatively for either the TUG test time or the ST. Considering these results and that no regular
rehabilitation after discharge was performed in this study, we suggested that continued rehabilitation after discharge might be necessary to restore lower limb function beyond 3 months after TKA.

This study has some limitations. First, the data were obtained for posterior-stabilized and cruciate-retaining TKA; therefore, the results for each type of TKA may differ. Second, we did not evaluate patients by OA stage. Third, the TUG test and ST were only performed until 1 year after TKA. Longer-term investigation of the changes in the TUG test and ST are necessary. Fourth, we did not consider the influence of range of motion and activity on preoperative or ambulation and balance ability. These should be investigated in a future study.

Conclusions

TKA is a useful treatment for restoring lower limb function, as both ambulation and balance were significantly improved at 3 months after TKA. A longer hospital stay with rehabilitation not always affected ambulation and balance, and preoperative ambulation and balance ability may also predict the length of hospital stay after surgery. Furthermore, an improvement in ambulation and balance was not recognized beyond 3 months after TKA, suggesting that further intervention with rehabilitation after hospital discharge is needed.

List Of Abbreviations

osteoarthritis (OA)
total knee arthroplasty (TKA)
musculoskeletal ambulation disability symptom complex (MADS)
Timed Up and Go (TUG)
standing time (ST)

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Steel Memorial Hirohata Hospital. Written, informed consent was obtained from each participant.

Consent for publish

Not applicable.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

Not applicable.

**Authors’ contributions**

All authors have made substantial contributions to (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content; and (3) final approval of the version to be submitted.

The specific contributions of the authors are as follows:

Conception and design of the study: MT, HMuratsu, RK, TM.

Analysis and interpretation of the data: TM, KT, YK, TK, SH, AM, HMiya

Drafting of the article: MT, HMuratsu, TM.

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**References**


Tables

Table 1: The diagnosis criteria of MADS.
Diagnosis of MADS requires fulfillment of (2) or (3) in addition to (1)

(1) Eleven orthopedic disorders or conditions that impair movement

1. Vertebral compression fracture and various spinal deformities (kyphotic spine, severe lumbar kyphosis and scoliosis etc.)
2. Lower extremity fracture (femoral neck fracture etc.)
3. Osteoporosis
4. Osteoarthritis (hip joint, knee joint etc.)
5. Lumbar spinal canal stenosis
6. Spinal disorder (cervical myelopathy, spinal cord injury etc.)
7. Neuromuscular disease
8. Rheumatoid arthritis or other arthritis due to infections
9. Lower limb amputation
10. Musculoskeletal wasting after prolonged immobility
11. High frequency of falls

(2) Decreased independence, with need for support or nursing care

(3) Functional decline, as evaluated with ST and TUG

1) One-leg standing time with eyes open (ST): less than 15 seconds
2) 3 meters Timed Up and Go test (TUG): not less than 11 seconds

Table 2: The mean TUG test times and STs on the operative side.

<table>
<thead>
<tr>
<th></th>
<th>TUG / ST</th>
<th>Preoperatively</th>
<th>2 week-PO</th>
<th>At discharge</th>
<th>3 month-PO</th>
<th>6 month-PO</th>
<th>1 year-PO</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDG</td>
<td>TUG</td>
<td>11.8 ± 0.4</td>
<td>14.1 ± 0.6</td>
<td>12.0 ± 0.5</td>
<td>10.2 ± 0.4</td>
<td>10.0 ± 0.5</td>
<td>9.6 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>20.7 ± 3.6</td>
<td>19.1 ± 3.6</td>
<td>23.2 ± 4.3</td>
<td>30.2 ± 4.8</td>
<td>30.1 ± 4.7</td>
<td>26.3 ± 4.0</td>
</tr>
<tr>
<td>SDG</td>
<td>TUG</td>
<td>11.9 ± 0.4</td>
<td>16.7 ± 0.8</td>
<td>12.5 ± 0.4</td>
<td>10.7 ± 0.5</td>
<td>9.8 ± 0.3</td>
<td>9.9 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>20.6 ± 3.3</td>
<td>15.7 ± 2.6</td>
<td>24.2 ± 3.6</td>
<td>29.9 ± 4.4</td>
<td>30.9 ± 4.1</td>
<td>28.6 ± 4.2</td>
</tr>
<tr>
<td>LDG</td>
<td>TUG</td>
<td>15.9 ± 1.9</td>
<td>23.2 ± 1.9</td>
<td>16.2 ± 1.0</td>
<td>13.9 ± 0.9</td>
<td>12.7 ± 0.7</td>
<td>12.3 ± 0.8</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>7.7 ± 2.5</td>
<td>9.9 ± 2.8</td>
<td>17.1 ± 4.6</td>
<td>22.5 ± 6.4</td>
<td>19.1 ± 5.5</td>
<td>17.8 ± 4.8</td>
</tr>
</tbody>
</table>

Mean ± standard error (seconds)
TUG: 3 meters Timed Up and Go, ST: one-leg standing time
PO: Postoperatively
EDG: Early discharge group, SDG: Standard discharge group, LDG: Late discharge group

Table 3: The relationships of mean TUG test times and STs according to length of hospital stay.
Mean ± standard error (seconds)

p<0.05 statistically significant

TUG: 3 meters Timed Up and Go, ST: one-leg standing time
PO: Postoperatively
EDG: Early discharge group, SDG: Standard discharge group, LDG: Late discharge group

**Figures**

![Figure 1](image-url)
Figure 1

The TUG test and ST with open eyes. TUG: 3 meters Timed Up and Go, ST: one-leg standing time

Figure 2

Figure 2a: Changes in ambulation (the 3 meters Timed Up and Go test time: TUG).
Figure 2b: Changes in balance (the one-leg standing time with open eyes: ST).
Figure 2c: Changes in the percentage of mergers

Figure 2

Figure 2a: Changes in ambulation (the 3 meters Timed Up and Go test time: TUG). Figure 2b: Changes in balance (the one-leg standing time with open eyes: ST). Figure 2c: Changes in the percentage of mergers
of musculoskeletal ambulation disability symptom complex (MADS).