Activity-pacing and outcomes of total knee arthroplasty: A longitudinal study

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Abstract: Background: Psychological factors may induce chronic pain and lead to inactivity after total knee arthroplasty (TKA). The impact of excessive variations in physical activity on psychological factors remains unclear. Aims/Objectives: This study investigated the impact of wide variations in physical activity during occupational therapy (OT) in the early period after TKA. Materials and Methods: We enrolled 30 TKA patients. Activities were measured postoperatively for 1 week. Patients were assigned to “good-pacing” or “poor-pacing” groups based on the correlation between physical activity and OT day. The outcome indices were Canadian occupational performance measure, pain (resting and walking), pain catastrophizing (rumination, helplessness, and magnification), anxiety, depression, and pain self-efficacy. Results: Twenty (66.6%) patients demonstrated good pacing, while ten (33.3%) showed poor pacing. The good-pacing group showed increased physical activity as the OT day increased. On the contrary, physical activity did not increase with OT day in the poor-pacing group, and these patients exhibited significantly higher walking pain, anxiety, and depression than those in the good-pacing group (p < 0.05). Conclusion: TKA patients with excessive variation in physical activity during OT demonstrated higher pain, anxiety, and depression.

ABOUT THE AUTHOR

The research activities of this group are focused on monitoring the physical activity, functional performance, and psychological factors in real-world settings on occupational therapy. This study of daily physical activity includes monitoring of steps collected using accelerometers for activity diary. The target population includes patients with chronic pain, total knee arthroplasty, high tibial osteotomy, and distal radius fracture. This study investigated the impact of using an activity diary to assess the variation in physical activity during the early period following total knee arthroplasty, and analyze the degree of correlation between physical activity and the number of days of occupational therapy. It was hypothesized that variations in physical activity are associated with pain and psychological factors. Henceforth, it would be possible to alleviate pain, anxiety, and depression by focusing on and managing physical activity even after the surgery. If you have surgery, please try it.

PUBLIC INTEREST STATEMENT

Psychological factors may induce chronic pain and cause inactivity after total knee arthroplasty. However, the impact of excessive variations in physical activity on psychological factors is unclear. We investigated the impact of excessive variations in physical activity during occupational therapy in the early period after surgery. Activities were measured postoperatively for 1 week. Patients were assigned to the “good-pacing” and “poor-pacing” groups based on the correlation between physical activity and occupational therapy day. The outcome indices were Canadian occupational performance measure, pain, and psychological factors. Thirty (66.6%) patients demonstrated good pacing, while ten (33.3%) exhibited poor pacing. The good-pacing group showed increased physical activity as the OT day increased. On the contrary, physical activity did not increase with OT day in the poor-pacing group, and these patients exhibited significantly higher walking pain, anxiety, and depression than those in the good-pacing group (p < 0.05). Total knee arthroplasty patients with wide variation in physical activity during OT demonstrated higher pain, anxiety, and depression.
Significance: Physical activity variations could improve the postoperative outcomes of TKA patients.

Subjects: Rehabilitation Medicine; Disability; Acute phase; Behavioral Medicine

Keywords: total knee arthroplasty; activity diary; activity pacing; occupational therapy

1. Introduction

Chronic pain affects the quality of life and/or the ability to perform basic activities of daily living; therefore, the social consequences of pain have received significantly more attention in recent years (Nakamura et al., 2014). Because of the significant increase in social losses, there is an increasing need to prevent chronic musculoskeletal pain.

Total knee arthroplasty (TKA) is an effective treatment for patients with knee osteoarthritis, as it aims to reduce pain and improve disability, functional outcomes, and physical activity (Kurtz et al., 2007). In approximately 15% of cases, chronic pain may result from TKA (Ackerman et al., 2005). Despite surgery, urgent countermeasures are needed to prevent chronic pain and reduced physical activity. Previously, bed rest was a common approach for acute musculoskeletal pain; however, more recently, controlled exercise has been recommended to reduce pain and improve the quality of life (Murphy et al., 2010). Early postoperative exercise, involving getting out of bed and walking as soon as possible after the operation, is similarly recommended for patients who underwent TKA (Taniguchi et al., 2017). Appropriate pacing of physical activity is reported to be effective in reducing the severity of musculoskeletal pain (Nijs et al., 2009). Appropriate pacing of physical activity eliminates variations in activity patterns, facilitates maintenance of a steady pace of activity throughout the day by the patient, and helps prevent a drastic increase in physical activity (Birkholtz et al., 2004).

Recent studies have reported interventions where patients with chronic pain wore pedometers to self-manage physical activity, which assists in preventing increased pain and enabling them to participate in daily activities (Hirase et al., 2018; McDonough et al., 2013). A non-randomized controlled study reported that the use of an activity diary alongside occupational therapy (OT) practices resulted in decreased pain and improvement in psychological factors and levels of physical activity; specifically, the protocol encouraged self-management of walking and pain (Hiraga et al., 2019). Recently, the importance of step-by-step pacing throughout the day has equally been highlighted (Hayashi et al., 2018); postoperative physical activity increased daily. Another study investigated chronic pain and total hip arthroplasty for more than 3 and 6 months after surgery in stable patients (Kinkel et al., 2009); in the early postoperative period, patients recovered more rapidly. Nevertheless, the impact of variations in physical activity using an activity diary throughout the day has not been investigated in TKA patients.

Therefore, the present preliminary study aimed to investigate the impact of using an activity diary to assess the variation in physical activity during the early period following TKA, and analyze the degree of correlation between physical activity and the number of days of OT. In another study of patients with chronic pain, variations in physical activity were associated with pain (Andrews et al., 2012). It was hypothesized that patients with wide variation in physical activity would develop more severe pain than those with a gradual increase in physical activity.

2. Materials and methods

2.1. Study design

This preliminary longitudinal cohort study included TKA patients at our hospital. Patients were classified into two groups: good-pacing group and poor-pacing group, depending on the correlation between physical activity and OT day (1 week).
2.2. Ethical considerations
All study patients provided written informed consent to participate in the study. The study design was approved by the appropriate Ethics Review Board at Fukuoka Rehabilitation Hospital (FRH2016-R-041).

2.3. Participants

2.3.1. Power analysis
The G*Power 3 (Faul et al., 2007) was used to perform preliminary test force analysis and estimate the required sample size. The power (1–β) and significance level (α) were set at 0.6 and 0.05, respectively (De Bekker-Grob et al., 2015; Cohen, 1992). The effect size was set at 0.8, which constitutes a large standard for two-group analysis. Power analysis indicated that a sample size of 30 patients was required for pre- and post-OT evaluations.

2.3.2. Target participants
Patients who underwent TKA between September 2016 and August 2018 at our hospital were included; 35 patients met this criterion. Exclusion criteria included the diagnosis of dementia or other apparent mental illness (e.g., depression) that would interfere with the completion of the questionnaire and the refusal to participate in OT. Additional exclusion criteria included post-operative complications (e.g., nerve injury and deep vein thrombosis), other significant medical diseases interfering with postoperative rehabilitation, previous TKA (such as TKA of the opposite limb or revision TKA), and TKA performed for causes other than degenerative diseases (e.g., rheumatoid arthritis and bone necrosis). Based on these criteria, 2 of the 35 patients were excluded, resulting in a total of 33 TKA patients comprising two cohorts (good-pacing group, n = 22, poor-pacing group, n = 11).

All patients received general anesthesia, and non-steroidal anti-inflammatory drugs were administered at a dose of 60 mg (dosage: three tablets per day) for 2 weeks postoperatively. All patients followed the same physical therapy and OT protocols after surgery. All patients began physical therapy, including knee joint range of motion exercises (flexion-extension) and stretching, on the first postoperative day. OT commenced 1 week postoperatively for the purpose of improving everyday life. Patients were discharged at the approval of the physician or on the request of patients 4 weeks postoperatively.

2.4. OT using the activity diary for good-pacing and poor-pacing groups
An activity diary developed by the hospital was used for intervention in TKA patients (Hiraga et al., 2019). The activity diary was configured to record 11 items, such as the date, number of steps, and degree of pain, each day; this diary aimed to facilitate the achievement of activity goals while encouraging active self-management. A pedometer (Pleasure Walker PZ-150; Yamasa Co., Ltd., Tokyo Japan) was used to record the number of steps per day and was attached to the foot of the non-operative side. A previous study reported that the attachment of the pedometer to the foot is optimal for detecting activity amount and step count (Rhudy & Mahoney, 2018). In addition, we focused on improving activity, rather than solely evaluating pain. Therefore, pain levels and steps were equally recorded in the activity diary. Such interventions were incorporated into the OT program, which lasted 40 minutes per day. The use of the activity diary commenced at the start of the OT program (Figure 1). Notably, patients were not preoperatively instructed.

Patients with a significant correlation (P < 0.05 and r > 0.7) between physical activity (steps per day) and OT practice day, as determined by a single regression test, were classified in the “good-pacing group.” On the contrary, patients with no correlation (P ≥ 0.05 and r < 0.7) between these variables were classified in the “poor-pacing group” (Hayashi et al., 2018). Figure 1 illustrates higher physical activity per day as the days of OT increased in a representative case of the good-pacing group. Conversely, in the poor-pacing group, increases and decreases in physical activity were observed over the course of the OT program.
2.5. **Assessment**
Assessments were performed before OT (1 week postoperatively [PO1W]) and after OT (4 weeks postoperatively [PO4W]).

2.6. **Canadian occupational performance measure**
In the implementation procedure, five target goals were listed, and their priority was determined using the Canadian occupational performance measure (COPM) (Law et al., 1990). After determining the priority order, the performance of each goal was evaluated with a 10-point scale (ranging from 1: not possible to 10: very good). Satisfaction was similarly evaluated on a 10-point scale (ranging from 1: not satisfied to 10: very satisfied). In addition, performance and satisfaction scores were determined for each group.

2.7. **Pain**
The numerical rating scale (NRS) (Jensen et al., 1994) was used to evaluate pain on an 11-point scale (ranging from 0: no pain to 10: worst imaginable pain). Resting and walking pain were both assessed on the NRS.

2.8. **Pain catastrophizing**
The pain catastrophizing Scale (PCS) (Sullivan et al., 1995) was used to evaluate pain catastrophizing. The PCS comprises 13 items and uses self-evaluation on three subscales: rumination, helplessness, and magnification. The patient evaluated the time spent on the condition on a five-point scale (ranging from 0: not at all to 4: all the time). Notably, a high score indicated strong pain catastrophizing.

2.9. **Anxiety and depression**
The hospital anxiety and depression scale (HADS) (Zigmond & Snaith, 1983), comprising 14 questions, was used in the evaluation of anxiety and depression. Using a four-point scale (ranging from 0: not at all to 3: most of the time), the patient evaluated anxiety and depression, and how much time was spent in that state. Similarly, HADS subscale scores were obtained.

2.10. **Pain self-efficacy**
The pain self-efficacy questionnaire (PSEQ) (Adachi et al., 2014) was used in the evaluation of self-efficacy for pain. The PSEQ used self-entry of scores for 10 items on a seven-point scale (ranging from 0: not at all confident to 6: completely confident).
2.11. Statistical analysis
All continuous variables were expressed as mean ± standard deviation (SD). Differences between the good-pacing and poor-pacing groups were analyzed using the chi-square test and the unpaired t-test for categorical and continuous variables, respectively. Data were analyzed using JMP software (version 14.0 for Microsoft Windows; SAS Institute Co., Ltd). A P-value<0.05 was considered statistically significant.

3. Results

3.1. Patient characteristics
Patient characteristics are shown in Table 1. The mean age of all patients was 77.0 ± 5.6 years, and the study included 7 males and 26 females.

3.2. Differences in the good-pacing and poor-pacing groups
Differences in the PO1W and PO4W variables between the good and poor-pacing groups are shown in Table 2. The number of TKA patients with good pacing and poor pacing was 20 (66.6%) and 10 (33.3%), respectively.

![Figure 2](image)

Figure 2 shows the group correlation between physical activity and OT practice day. In the good-pacing group, physical activity increased as the number of days of OT practice increased. Conversely, in the poor-pacing group, physical activity did not increase with the number of days of OT.

Among the PO4W variables, the poor-pacing group demonstrated a significantly higher postoperative average walking pain (NRS; P = 0.002, 95% confidence interval [CI] = 1.14 to 3.22) and higher postoperative anxiety (HADS; P = 0.003, 95% CI = 1.24 to 5.55), and depression (P = 0.005, 95% CI = 0.36 to 7.11) than the good-pacing group.

### Table 1. Baseline patient characteristics

| Variable                      | TKA patients (n = 33) |
|-------------------------------|-----------------------|
| Age (years)                   | 77.0 ± 5.6            |
| Female, n (%)                 | 26 (78.8)             |
| BMI                           | 24.9 ± 3.8            |
| Nonworker (%)                 | 27 (81.8)             |
| Nonsmoker (%)                 | 26 (78.7)             |
| Nondrinker (%)                | 30 (90.0)             |
| COPM performance (points)     | 3.5 ± 2.4             |
| COPM satisfaction (points)    | 3.4 ± 2.2             |
| NRS rest pain (points)        | 2.3 ± 1.9             |
| NRS walk pain (points)        | 4.1 ± 1.8             |
| PCS total score (points)      | 21.9 ± 9.9            |
| Rumination score (points)     | 11.3 ± 4.8            |
| Helplessness score (points)   | 6.8 ± 4.3             |
| Magnification score (points)  | 3.6 ± 2.7             |
| HADS anxiety (points)         | 7.1 ± 3.5             |
| HADS depression (points)      | 6.6 ± 3.6             |
| PSEQ total score (points)     | 35.0 ± 13.3           |

Values are expressed as means ± standard deviation or as numbers (%).
BMI: body mass index; COPM: Canadian Occupational Performance Measure; HADS: Hospital Anxiety and Depression Scale; NRS: numeric rating scale; PCS: Pain Catastrophizing Scale; PSEQ: Pain Self-Efficacy Questionnaire.

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## Table 2. Differences between good-pacing and poor-pacing groups

| Variable                     | Good-pacing group (n = 20) | Poor-pacing group (n = 10) | P-Value (95% CI) | Mean difference |
|------------------------------|-----------------------------|-----------------------------|------------------|-----------------|
| Age (years)                  | 75.6 ± 5.3                  | 79.0 ± 5.2                  | 0.055            | 4.31 (−0.12 to 8.75) |
| Female, n (%)                | 16 (80.0)                   | 8 (80.0)                    | 0.741            |                 |
| BMI                          | 24.5 ± 4.0                  | 25.7 ± 3.2                  | 0.435            | 1.25 (−1.93 to 4.44) |
| Nonworker (%)                | 15 (75.0)                   | 7 (70.0)                    | 0.771            |                 |
| Nonsmoker (%)                | 15 (75.0)                   | 6 (60.0)                    | 0.398            |                 |
| Nondrinker (%)               | 18 (90.0)                   | 9 (90.0)                    | 0.748            |                 |
| COPM performance (points)    | 3.3 ± 2.4                   | 3.9 ± 2.6                   | 0.529            | 0.64 (−1.57 to 2.86) |
| COPM satisfaction (points)   | 3.1 ± 3.8                   | 3.8 ± 2.3                   | 0.460            | 0.69 (−1.31 to 2.70) |
| NRS rest pain (points)       | 2.5 ± 1.8                   | 2.1 ± 2.0                   | 0.637            | 0.38 (−2.06 to 1.28) |
| NRS walk pain (points)       | 3.2 ± 1.7                   | 4.5 ± 2.0                   | 0.472            | 0.55 (−1.01 to 2.12) |
| PCS total score (points)     | 23.0 ± 8.2                  | 19.5 ± 13.1                 | 0.395            | 3.49 (−4.81 to 11.81) |
| Rumination score (points)    | 11.9 ± 4.6                  | 10.1 ± 6.7                  | 0.361            | 1.83 (−2.22 to 5.89) |
| Helplessness score (points)  | 7.1 ± 4.3                   | 6.3 ± 4.5                   | 0.648            | 0.82 (−2.84 to 4.49) |
| Magnification score (points) | 3.9 ± 2.6                   | 3.1 ± 3.0                   | 0.458            | 0.83 (−1.44 to 3.11) |
| HADS anxiety (points)        | 7.3 ± 3.8                   | 6.7 ± 2.7                   | 0.685            | 0.59 (−2.37 to 3.55) |
| HADS depression (points)     | 6.5 ± 3.9                   | 6.6 ± 3.3                   | 0.954            | 0.08 (−3.21 to 3.30) |
| PSEQ total score (points)    | 33.7 ± 11.7                 | 37.5 ± 16.8                 | 0.497            | 3.76 (−7.47 to 15.00) |
| Age (years)                  | 79.0 ± 5.2                  | 7.1 ± 2.1                   | 0.275            | 0.82 (−2.35 to 0.70) |
| Female, n (%)                | 8 (80.0)                    | 7.1 ± 2.0                   | 0.131            | 1.11 (−2.57 to 0.35) |
| NRS rest pain (points)       | 1.6 ± 1.0                   | 1.6 ± 1.0                   | 0.481            | 0.50 (−0.95 to 1.97) |
| NRS walk pain (points)       | 3.5 ± 1.8                   | 3.5 ± 1.8                   | 0.002            | 2.18 (1.14 to 3.22) |
| PCS total score (points)     | 19.4 ± 10.6                 | 15.7 ± 9.2                  | 0.361            | 3.65 (−5.23 to 12.54) |

(Continued)
| Variable                        | Good-pacing group (n = 20) | Poor-pacing group (n = 10) | P-Value (95% CI) | Mean difference |
|--------------------------------|-----------------------------|----------------------------|------------------|-----------------|
| Rumination score (points)      | 8.4 ± 4.6                   | 9.2 ± 4.2                  | 0.665            | 0.80 (--2.96 to 4.57) |
| Helplessness score (points)    | 5.0 ± 4.0                   | 6.3 ± 4.3                  | 0.430            | 1.33 (--2.08 to 4.47) |
| Magnification score (points)   | 2.3 ± 2.3                   | 3.8 ± 2.8                  | 0.148            | 1.52 (--0.57 to 3.61) |
| HADS anxiety (points)          | 2.2 ± 2.1                   | 5.6 ± 3.1                  | 0.003            | 3.40 (1.24 to 5.55) |
| HADS depression (points)       | 2.2 ± 2.2                   | 6.0 ± 4.2                  | 0.005            | 3.73 (0.36 to 7.11) |
| PSEQ total score (points)      | 42.2 ± 9.8                  | 39.8 ± 10.3                | 0.563            | 2.37 (--5.96 to 10.71) |

Values are expressed as means ± standard deviation or as numbers (%).

All continuous variables were expressed as mean and standard deviation. Differences between the two groups were analyzed using the χ² test for the categorical variables and the unpaired t-test for the continuous variables, respectively.

BMI: body mass index; COPM: Canadian Occupational Performance Measure; CI: confidence interval; HADS: Hospital Anxiety and Depression Scale; NRS: numeric rating scale; PCS: Pain Catastrophizing Scale; PSEQ: Pain Self-Efficacy Questionnaire.
Figure 2 shows the group correlation between physical activity and OT practice day. In the good-pacing group, physical activity increased as the number of days of OT practice increased. Conversely, in the poor-pacing group, physical activity did not increase with the number of days of OT.

Figure 2. Correlation between step count (physical activity) and occupational therapy practice day for (A) the good-pacing group and (B) the poor-pacing group.
4. Discussion

The good-pacing group showed increased physical activity with an increase in OT practice days; however, the poor-pacing group demonstrated no increase in physical activity with an increase in OT practice days. The patients in the poor-pacing group equally showed significantly higher walking pain, anxiety, and depression than those in the good-pacing group. This study is the first to indicate that patients with variations in physical activity during OT develop postoperative walking pain. Moreover, based on the pain associated with the variation in physical activity, it has been shown that the prevalence of anxiety and depression may similarly increase.

Previous research has shown that variations in physical activity are associated with increased pain, psychological disturbances, and physical disability (Andrews et al., 2012). The fear-avoidance model of chronic pain demonstrates that pain amplifies catastrophic thinking and anxiety and causes over-avoidance (Vlaeyen & Linton, 2000). Furthermore, the poor-pacing group supposedly demonstrated an incomplete expansion in gradual physical activity, which amplifies the pain. In addition, it was reported in previous studies that the improvement in physical functions such as muscle strength was not observed by conducting the intervention to gradually expand the activity (Hirase et al., 2018). Therefore, it can be deduced that underactivity, which prolongs pain and leads to disability, is due to the fear of pain and avoidance of activity. Until now, the effects of activity pacing during OT using an activity diary have not been investigated in TKA patients.

This study showed that TKA patients in the good-pacing group exhibited significantly lower degrees of walking pain, anxiety, and depression than those in the poor-pacing group. Physical activity improved postoperative psychological factors (Andrews et al., 2012). In addition, this study showed that variation in physical activity during OT (when using the activity diary throughout the day) was similarly significant in TKA patients.

However, no difference in COPM was observed between the groups. Previous reports have demonstrated an improvement in COPM using the activity diary during OT practice (Hiraga et al., 2019). However, there is a possibility that COPM may improve in both groups with the continuation of postoperative analyses.

Severe postoperative pain can be predicted by the PCS (Quartana et al., 2009). Pain catastrophizing is one of the fear-avoidance variables, which refers to the avoidance of movements or activities due to fear. PO4W PCS showed no significant difference between the poor-pacing and good-pacing groups in this study. Variation in physical activity was associated with postoperative walking pain, independent from the PCS score. The regulation of physical activity during OT using the activity diary might be effective against pain even among patients with the highest pain catastrophizing.

There were several limitations to this study. First, a power calculation was used in the determination of adequate sample size; however, larger multicenter studies would supposedly be beneficial. Second, this study investigated only the early postoperative period. The long-term effects of variation in physical activity during OT using the activity diary on pain, goal achievement, psychological factors, and quality of life were not analyzed. Third, the effect of wearing and looking at a pedometer has not been investigated. A pedometer might increase the motivation to exercise and result in more physical activity. Fourth, physical activity was exclusively measured using the pedometer (Pleasure Walker PZ-150; Yamasa Co., Ltd., Tokyo Japan). The consistency of the results with those obtained using different motion counters could not be confirmed. Future studies involving a longer follow-up period are necessary to investigate the variation in physical activity during OT using the activity diary, and assessing its impact on improving pain, goal achievement, psychological factors, and quality of life.

This study showed that TKA patients with variation in physical activity during OT using the activity diary exhibited severe walking pain, anxiety, and depression. Desirable variations in
physical activity during OT using the activity diary in the early postoperative period could improve pain and psychological factors in TKA patients.

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Data availability
The clinical trial registration information of this research is available online. The documents can be viewed at UMIN id number UMIN000036561.

Competing interests
The authors declare that there is no conflict of interest.

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