ABSTRACT. Objective: Knee pain (KP) and low-back pain (LBP) are common sites of pain and major public health issues among older adults. We investigated the combined association of bilateral KP and LBP with objectively measured physical activity (PA) among adults with knee osteoarthritis (OA). Methods: We recruited 150 knee OA adults and measured steps and PA intensity, including sedentary behavior (SB), low PA (LPA), and moderate-to-vigorous PA, using an accelerometer. KP and LBP were measured using a numerical rating scale. They were classified into 4 groups based on the presence of KP and LBP: with the only unilateral KP (UKP), with the combined UKP and LBP (UKP and LBP), with the bilateral KP (BKP), and with the combined bilateral KP and LBP (BKP and LBP). One-way analysis of covariance was performed to compare physical activity variables (intensity or steps) between the four groups. Results: Overall, 126 patients were enrolled. The prevalence of UKP, BKP, UKP and LBP, and BKP and LBP were 29.4%, 23.8%, 18.3%, and 28.6%. The proportion of SB was higher in the BKP and LBP group than in the other groups (F = 6.51, p < 0.01). The proportion of LPA was lower in the BKP and LBP group than in the other groups (F = 6.21, p < 0.01). Conclusions: The proportions of SB and LPA were significantly worse in knee OA adults with BKP and LBP than in those with UKP. Our findings may be a basis for considering knee OA adults for improving PA.

Key words: knee osteoarthritis, knee pain, low-back pain, objectively measured physical activity

Received: March 30, 2020
Accepted: July 11, 2020
Advance Publication by J-STAGE: September 15, 2020

Knee osteoarthritis (OA) is a common orthopedic disease in older adults. There are approximately 25 million adults with knee OA, including the potential population diagnosed by X-ray imaging in Japan1. Knee OA adults are likely to be inactive and do not meet the physical activity (PA) recommendations2. Decreasing PA in knee OA adults not only increases the risk of heart disease and diabetes mellitus but also worsens physical function3,4. Consistent with this, increasing PA in knee OA adults has been shown to improve muscle strength and health-related quality of life5,6. Thus, it is extremely important to improve PA in knee OA adults.

Knee pain (KP) and low-back pain (LBP) are common sites of pain and major public health issues among older adults. The prevalence of KP and LBP were higher in knee OA adults than in healthy adults7,8. Moreover, the knee OA adults are likely to have bilateral KP because of symmetrical varus deformity. KP and LBP are associated with functional limitations and disabilities among knee OA adults9,10. Additionally, previous studies examined the association with KP and PA in knee OA adults11,12. These studies reported that KP was not associated with recommended PA levels12 and steps13 in knee OA adults. However, they could not investi-
gate the association with KP and the intensity of PA such as sedentary behavior (SB), low physical activity (LPA). It is necessary to evaluate the intensity of PA because worsening SB and LPA have been shown to be associated with increasing risk of diabetes mellitus and decreasing motor function in older adults \cite{14,15}. Besides, LBP was associated with disability in knee OA adults \cite{16}. However, little is known of the association with LBP and PA. Considering them, it is clinically significant to investigate the association of objectively measured PA including the intensity of PA with combined bilateral KP and LBP.

Therefore, we aimed to investigate the association of combined bilateral KP and LBP with objectively measured PA (including steps and PA intensity) among knee OA adults.

**Materials and Methods**

**Study design and participants eligibility**

This study used a cross-sectional design. One hundred fifty knee OA adults who received pharmacological therapy and physical therapy at an orthopedic outpatient clinic in Kobe City, Hyogo Prefecture, Japan, were recruited between October 2017 and April 2018. These participants were diagnosed as grade 3 or 4 on the basis of the Kellgren and Lawrence radiographic grading system (K/L grade).

The inclusion criteria were as follows: (i) the numerical rating scale during walking is more than 4 at the worse side of the knee, (ii) over 65 years old, (iii) able to walk freely or with assisting gait tools, and (iv) no symptoms in the hip and ankle joint during walking. The exclusion criteria were as follows: (i) neurological conditions affecting gait ability, such as Parkinson’s disease or cerebrovascular disease, (ii) total joint arthroplasty in the lower joints, and (iii) invalid data on the accelerometer (details described later). The ethics committee of the Anshin Hospital approved all procedures before commencing the study (approval protocol number: No.61), and all participants provided written informed consent in accordance with the Declaration of Helsinki before participating.

**Measurements of physical activity**

We measured steps and PA intensity by using an accelerometer (Active Style Pro HJA-350IT; Omron Healthcare, Kyoto, Japan). The algorithm and validity of the accelerometer device have been previously described \cite{17-19}. The device was used to measure anteroposterior (x-axis), mediolateral (y-axis), and vertical (z-axis) acceleration signals. Patients were instructed to wear the accelerometer on their waist for ≥7 days, except when sleeping or during water-based activities such as bathing, showering, and swimming. The device estimates the intensity of activity by metabolic equivalents (METs). The algorithm for the prediction of METs was established using the Douglas bag method in a controlled laboratory setting \cite{8,19}. The intensity of PA was classified into 3 categories based on METs: SB (≤1.5 METs), LPA (>1.5 to <3.0 METs), and moderate-to-vigorous physical activity (MVPA) (≥3.0 METs). The data were collected in 60-s epochs. Non-wear time was defined as at least consecutive 60 min of 0 counts per minute (cpm), with allowance of up to 2 min of some limited movement (<50 cpm) within those periods \cite{20}. To provide a sufficient estimation of PA on the basis of the accelerometer, patients needed to wear the accelerometer for ≥4 valid days, with ≥10 wear hours per day \cite{20}.

**Knee pain and low-back pain**

We used the numerical rating scale to evaluate KP and LBP. Numerical rating scale is a valid and reliable instrument used in clinical practice because of its sensitivity \cite{21}. KP and LBP were evaluated by the average pain in the last month on a scale ranging from 0 to 10, with 0 representing no pain and 10 representing the worst pain imaginable. Patients were classified by whether they have KP or LBP. Patients who provided a numerical rating scale score of ≥4 were defined as having pain, and that score was used as the cut-off point in terms of pain-related interference with functioning in patients with chronic musculoskeletal pain \cite{21}.

**Physical function**

**Knee extensor strength**

The maximal isometric strength of knee extensors was measured using a hand-held dynamometer (μTas F1; ANIMA, Chofu, Japan). Details of the measurements have been described previously \cite{22}. The peak torque (N m) was estimated as the product of force and lever-arm length. Two attempts at maximal contraction were performed, and the greater value was recorded and normalized according to the body weight (N m/kg).

**Knee range of motion**

The range of motion (ROM) of the knee joint, during flexion and extension, was measured using a standard two-arm plastic goniometer. Measurement of knee flexion and extension ROM followed the methods recommended by the Japanese Orthopedic Association and the Japanese Association of Rehabilitation Medicine. Passive ROM of the involved limb was measured every 5 degrees in the supine position. All measurements were performed twice by trained physical therapists and were selected a value of the good one.

**Knee-specific functional outcomes**

The new knee society score (KSS) questionnaire was used to assess knee-specific functional outcomes \cite{21}. The new KSS consists of four categories: symptoms (3 items, 25 points), patient satisfaction (5 items, 40 points), patient
expectations (3 items, 15 points), and functional activities (19 items, 100 points). High scores represent less pain and greater patient satisfaction, expectations, and physical functioning. The new KSS is a validated and reliable instrument used before and after TKA\textsuperscript{26}.

*Gait function*

The timed-up-and-go (TUG) test was used to evaluate the time taken to rise from a chair, walk 3 meters, turn around, and return to a seated position. Participants were instructed to walk as fast as possible, and they completed two trials each; the fastest time was used for analysis\textsuperscript{27}.

*Other measurements*

We collected demographic data such as sex, age, weight, height, body mass index, and the K/L grade in bilateral side from medical records. Patients answered whether they ever diagnosed as the depression.

*Statistical analysis*

Continuous variables were expressed as mean ± standard deviation, and nominal variables were expressed as number (%).

The patients were classified into 4 groups based on the presence of KP and LBP: with the only unilateral KP (UKP group), with the combined UKP and LBP (UKP and LBP group), with the bilateral KP (BKP group), and with the combined bilateral KP and LBP (BKP and LBP group). One-way analysis of variance was performed for continuous variables, and the $\chi^2$ test was performed for categorical variables to compare demographic data, physical function, and pain parameters. For physical activity variables (intensity or steps), one-way analysis of covariance (ANCOVA) was performed to compare the variables between the four groups. Age, body mass index, sex, and K/L grade on the bilateral side were considered potential confounders. When significance was determined by one-way analysis of variance and covariance, the Bonferroni test was performed for post-hoc comparisons.

The statistical significance level was set at $p < 0.05$ for all analyses. All analyses were performed using SPSS for Windows 21.0.0 version (IBM, Tokyo, Japan).

**Results**

Of the 150 patients, 11 underwent total arthroplasty in other lower joints, and 13 were missing the accelerometer PA data. These patients were excluded from the study. Finally, a total of 126 patients were enrolled in this analysis (figure1). We confirmed that the measured baseline characteristics and physical function of our remaining participants and those of the dropouts were not significantly different (Supplemental Table).

Patient characteristics, physical function, and pain among the four groups are summarized in Table 1. The prevalence of UKP, UKP and LBP, BKP, and BKP and LBP were 29.4%, 23.8%, 18.3%, and 28.6%, respectively. The KSS in the BKP group, and BKP and LBP groups, were lower than those in the UKP group and the UKP and LBP group ($F = 4.47$ vs UKP group, $P < 0.01$ vs UKP and LBP group, $P < 0.01$, separately).

The results of comparing the physical activity variables among the four groups are summarized in Table 2. The proportion of SB was higher in the BKP and LBP group than in the other groups ($F = 6.51$ vs UKP group, $P < 0.01$ vs UKP and LBP group, $P = 0.03$ vs BKP group, $P = 0.03$). The proportion of LPA was lower in the BKP and LBP group than in the other groups ($F = 6.21$ vs UKP group, $P = 0.01$ vs UKP and LBP group, $P = 0.01$).
Table 1. Patient characteristics, physical function, and pain among the four groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>All patients (n = 126)</th>
<th>UKP group (n = 37)</th>
<th>UKP + LBP group (n = 23)</th>
<th>BKP group (n = 30)</th>
<th>BKP + LBP group (n = 36)</th>
<th>F value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (female), n (%)</td>
<td>98 (78.0)</td>
<td>29 (78.4)</td>
<td>18 (78.3)</td>
<td>23 (76.7)</td>
<td>28 (77.8)</td>
<td>-</td>
<td>0.63</td>
</tr>
<tr>
<td>Age, years</td>
<td>72.3 ± 6.2</td>
<td>71.5 ± 7.1</td>
<td>69.1 ± 5.8</td>
<td>74.3 ± 4.4</td>
<td>72.5 ± 6.3</td>
<td>2.41</td>
<td>0.07</td>
</tr>
<tr>
<td>Height, cm</td>
<td>153.0 ± 7.7</td>
<td>152.9 ± 8.2</td>
<td>151.5 ± 8.0</td>
<td>152.2 ± 5.7</td>
<td>154.4 ± 8.6</td>
<td>0.75</td>
<td>0.53</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>60.4 ± 13.0</td>
<td>60.5 ± 11.4</td>
<td>57.5 ± 8.9</td>
<td>63.4 ± 18.6</td>
<td>60.0 ± 9.2</td>
<td>0.91</td>
<td>0.44</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>25.8 ± 5.9</td>
<td>25.8 ± 4.1</td>
<td>25.2 ± 3.9</td>
<td>27.7 ± 9.6</td>
<td>24.7 ± 4.2</td>
<td>1.4</td>
<td>0.25</td>
</tr>
<tr>
<td>The presence of depression, n</td>
<td>1 (0.8)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>1 (2.8)</td>
<td>-</td>
<td>0.9</td>
</tr>
<tr>
<td>Grade of knee OA in the involved limb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>grade 3, n (%)</td>
<td>38 (30.2)</td>
<td>13 (35.1)</td>
<td>8 (34.8)</td>
<td>8 (26.7)</td>
<td>9 (25.0)</td>
<td>-</td>
<td>0.56</td>
</tr>
<tr>
<td>grade 4, n (%)</td>
<td>88 (69.8)</td>
<td>24 (64.9)</td>
<td>15 (65.2)</td>
<td>22 (73.3)</td>
<td>27 (75.0)</td>
<td>-</td>
<td>0.12</td>
</tr>
<tr>
<td>Grade of knee OA in the uninvolved limb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>grade 1, n (%)</td>
<td>17 (13.5)</td>
<td>7 (18.9)</td>
<td>5 (21.7)</td>
<td>3 (10.0)</td>
<td>2 (5.6)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>grade 2, n (%)</td>
<td>40 (31.7)</td>
<td>12 (32.4)</td>
<td>8 (34.8)</td>
<td>9 (30.0)</td>
<td>11 (30.6)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>grade 3, n (%)</td>
<td>38 (30.2)</td>
<td>9 (24.3)</td>
<td>6 (26.1)</td>
<td>11 (36.7)</td>
<td>12 (33.4)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>grade 4, n (%)</td>
<td>31 (24.6)</td>
<td>9 (24.3)</td>
<td>4 (17.4)</td>
<td>7 (23.3)</td>
<td>11 (30.6)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Range of motion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion, degree</td>
<td>120.1 ± 13.8</td>
<td>120.5 ± 17.0</td>
<td>124.7 ± 11.7</td>
<td>118.8 ± 11.6</td>
<td>118.5 ± 12.0</td>
<td>0.87</td>
<td>0.46</td>
</tr>
<tr>
<td>Extension, degree</td>
<td>−10.2 ± 6.8</td>
<td>−8.5 ± 5.6</td>
<td>−11.8 ± 10.6</td>
<td>−10.0 ± 7.6</td>
<td>−11.3 ± 5.6</td>
<td>1.27</td>
<td>0.29</td>
</tr>
<tr>
<td>Knee extensor strength, N/m/kg</td>
<td>0.82 ± 0.36</td>
<td>0.76 ± 0.23</td>
<td>0.97 ± 0.30</td>
<td>0.74 ± 0.25</td>
<td>0.88 ± 0.51</td>
<td>2.23</td>
<td>0.09</td>
</tr>
<tr>
<td>New knee society score, score</td>
<td>79.7 ± 29.0</td>
<td>87.3 ± 32.6</td>
<td>90.6 ± 17.9</td>
<td>73.0 ± 26.3*</td>
<td>70.6 ± 26.3*</td>
<td>4.47</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Timed up and go test, s</td>
<td>10.4 ± 3.7</td>
<td>9.5 ± 2.8</td>
<td>9.5 ± 2.9</td>
<td>10.5 ± 2.6</td>
<td>11.7 ± 3.6</td>
<td>2.38</td>
<td>0.08</td>
</tr>
<tr>
<td>Knee pain, NRS</td>
<td>5.9 ± 2.1</td>
<td>4.9 ± 2.7</td>
<td>5.0 ± 2.0</td>
<td>6.5 ± 1.8*</td>
<td>6.9 ± 2.0*</td>
<td>6.2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Knee pain (contralateral side), NRS</td>
<td>3.1 ± 2.5</td>
<td>0.9 ± 0.8</td>
<td>1.1 ± 0.8</td>
<td>5.1 ± 2.2*</td>
<td>5.2 ± 1.8*</td>
<td>63.44</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Low-back pain, NRS</td>
<td>2.3 ± 2.6</td>
<td>0.5 ± 0.8</td>
<td>5.2 ± 2.2*</td>
<td>0.7 ± 0.9</td>
<td>5.0 ± 1.7*</td>
<td>94.69</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Continuous variables are expressed as mean ± standard deviation, and ordinal variables are expressed as number (%). One-way analysis of variance was performed for continuous variables and the χ² test was performed for categorical variables.

BKP, bilateral knee pain; BMI, body mass index; LBP, low-back pain; NRS, numerical rating scale; OA, osteoarthritis; UKP, unilateral knee pain.

* p < 0.01 vs UKP group.
† p < 0.01 vs UKP and LBP group.
‡ p < 0.01 vs BKP group.

The proportion of MVPA and number of steps were not significantly different among the 4 groups.

Discussion

In this study, we investigated the association of combined bilateral KP and LBP with PA, including steps and PA intensity in knee OA adults. The main findings showed that the proportions of SB and LPA were significantly worse in knee OA adults with combined bilateral KP and LBP than in those with UKP, UKP and LBP, and BKP, even after adjusting for potential confounders. This study is the first to clarify the association of combined bilateral KP and LBP with objectively measured PA in knee OA adults.

This study showed that PA in the BKP group or the UKP and LBP group was not worse than that in the UKP group, which supports the results of previous research in community-dwelling adults. These studies have reported an insignificant association of PA with KP or LBP. However, interestingly, PA was significantly worse in the BKP and LBP group than in the other groups, which suggests that combined bilateral KP and LBP had a negative effect on PA. A potential explanation for these results is the effect of multisite pain on PA. Murata et al. reported that chronic musculoskeletal multisite pain was negatively associated with PA. However, further research is needed to confirm these findings.
Table 2. Results of comparing physical activity among the four groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>All patients (n = 126)</th>
<th>UKP group (n = 37)</th>
<th>UKP and LBP group (n = 23)</th>
<th>BKP group (n = 30)</th>
<th>BKP and LBP group (n = 36)</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid days (days)</td>
<td>9.3 ± 2.1</td>
<td>9.2 ± 2.6</td>
<td>9.6 ± 1.8</td>
<td>9.6 ± 2.3</td>
<td>8.9 ± 2.3</td>
<td>0.76</td>
<td>0.55</td>
</tr>
<tr>
<td>Waking wear time (min/day) SB</td>
<td>811.4 ± 107.4</td>
<td>809.6 ± 91.0</td>
<td>812.8 ± 106.0</td>
<td>837.6 ± 126.2</td>
<td>790.9 ± 111.6</td>
<td>0.44</td>
<td>0.82</td>
</tr>
<tr>
<td>Time (min/day)</td>
<td>446.3 ± 118.9</td>
<td>424.8 ± 119.3</td>
<td>436.5 ± 130.7</td>
<td>442.0 ± 140.4</td>
<td>487.2 ± 134.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Time/waking wear time (%) SB</td>
<td>55.3 ± 11.4</td>
<td>52.5 ± 11.3</td>
<td>53.7 ± 10.9</td>
<td>53.9 ± 9.7</td>
<td>61.6 ± 9.3</td>
<td>6.51</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>MVPA</td>
<td>331.9 ± 94.7</td>
<td>345.7 ± 110.6</td>
<td>338.4 ± 84.8</td>
<td>366.1 ± 97.2</td>
<td>279.2 ± 105.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Time/waking wear time (%) MVPA</td>
<td>40.9 ± 10.4</td>
<td>43.0 ± 10.9</td>
<td>41.8 ± 10.8</td>
<td>43.1 ± 8.8</td>
<td>35.3 ± 8.8</td>
<td>6.21</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Step counts (number/day)</td>
<td>4019 ± 2692</td>
<td>4735 ± 2942</td>
<td>4179 ± 2656</td>
<td>3357 ± 2585</td>
<td>3660 ± 2364</td>
<td>1.13</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Data are expressed as means ± standard deviations. One-way analysis of covariance was performed to compare physical activity variables between the 4 groups. Age, body mass index, sex, and K/L grade on the bilateral side were considered as potential confounders. SB: sedentary behavior; LPA: light physical activity intensity; MVPA: moderate-to-vigorous physical activity intensity

* p < 0.01 vs UKP group.
† p < 0.05 vs UKP and LBP group.
‡ p < 0.05 vs BKP group.
§ p < 0.01 vs BKP group.

with PA[^10]. Therefore, it was considered that the BKP and LBP group, which had multisite pain, had significantly worse PA than the other groups. For this reason, it was considered that PA was significantly worse in the combined BKP and LBP group than in other groups.

Other important findings were that the proportion of MVPA and step counts were not associated among 4 groups, whereas increasing the proportion of SB and decreasing the proportion of LPA were negatively associated with combined bilateral KP and LBP. One possible reason for these results is that participants were inactive and had more severe knee OA. Our participants had severe knee OA classified as K/L grade 3 or 4 at worse side of KP, and the proportion of MVPA and step counts were relatively small (3.8 ± 3.0%, 3688 ± 2736 steps/day, respectively). The severity of knee OA in our study was higher (the KL grade of our participants was III-IV) and the step counts were lower (the mean step count of our participants was 3688 ± 2736) than those in the study by Chmelo et al. (KL grade: II-III; mean step count: 6209 ± 2554[^11]). The proportion of MVPA was not found because no information about total wear time in that previous study was available; therefore, it was difficult to compare that study with ours. Our results suggest that the influence of knee OA severity at the worse side of KP on MVPA and step count was higher than that of KP and LBP.

Future research that studies knee OA adults with mild knee OA and a high proportion of MVPA is needed to clarify the association of combined bilateral KP and LBP with MVPA or step count.

The results of one-way analysis of covariance indicated that the proportion of SB was 8.9% higher in knee OA adults with combined bilateral KP and LBP than in those with UKP, UKP and LBP, and BKP. Mitchell et al. reported that a 1-h increase in total sedentary time was associated with a 35%-44% increase in the odds of metabolic syndrome in older adults[^12]. Additionally, Mekary et al. reported that a 1-h increase in SB was associated with an 18% increase in the odds of depression[^13]. The 10% of total waking wear time in our study was equal to more than 1 hour. Therefore, a 10% increase in SB could be a clinically meaningful effect size in terms of the health of knee OA adults.

Several limitations were identified in our study. First, we used a cross-sectional study design; therefore, we were unable to explain the cause and effect relationship. Future longitudinal studies are needed to clarify the cause and effect relationship between combined bilateral KP and LBP with PA. Second, we cannot evaluate the periods of pain. The periods of pain may affect physical activity. Third, the accelerometer used in this study could not capture water-based activities such as bathing, swimming, and underwater walking. These activities may have affected our results by causing the underestimation of PA. Finally, we did not evaluate depression status, which can be a confounding factor. Previous study has reported the association of depression with PA and pain[^14]. Further research should investigate the influence of depression on PA and pain perception.
Conclusion

This study explored the association of PA with combined bilateral KP and LBP in knee OA adults. The proportions of SB and LPA were significantly worse in knee OA adults with combined bilateral KP and LBP than in those with UKP, UKP and LBP, and BKP, even after adjusting for potential confounders.

Our findings may be a basis for considering knee OA adults about for improving PA and developing strategies for relieving pain in sedentary knee OA adults.

Conflict of Interest: None.

Acknowledgments: We acknowledge all subjects and all staff members who participated in this study.

References
27) Shumway-Cook A, Brauer S, et al.: Predicting the probability for falls in community-dwelling older adults using the Timed
Physical activity in knee osteoarthritis adults with pain


Appendix
baseline characteristics and physical function between the patients who remained and those who dropped out.