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ORIGINAL ARTICLE

Knee pain during activities of daily living and its relationship with physical activity in patients with early and severe knee osteoarthritis

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Abstract This study aimed to investigate whether knee pain during various activities of daily living (ADLs) is associated with physical activity in patients with early and severe knee osteoarthritis (OA). We hypothesized that the painful ADLs associated with decreased physical activity differ according to disease severity. This cross-sectional study enrolled 270 patients with medial knee OA, assigned to either the *early* (Kellgren Lawrence [K/L] grade 1–2) or the *severe* group (K/L grade 3–4). Physical activity was assessed using a pedometer. Knee pain during six ADLs (waking up in the morning, walking on a flat surface, ascending stairs, etc.) was evaluated using a questionnaire. We performed multiple regression and quantile regression analysis to investigate whether knee pain during each ADL was associated with physical activity. In the early group, the more knee pain they experienced while *ascending stairs*, the lower their physical activity was (75th regression coefficient = −1033.70, $P = 0.018$). In the severe group, the more knee pain they experienced while *walking on a flat surface* or *bending to the floor or standing up*, the lower their physical activity was (unstandardized coefficients = −1850.87, $P = 0.026$; unstandardized coefficients = −2640.35, $P = 0.010$). Knee pain while *ascending stairs* and while *walking on a flat surface* or *bending to the floor or standing up* was a probable limiting factor for physical activity in early and severe knee OA, respectively. These findings suggested that a reduction in task-specific knee pain according to disease severity could improve physical activity levels.

Keywords Knee osteoarthritis · Knee pain · Physical activity · Activities of daily living (ADLs) · Early · Severe

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Introduction

Knee osteoarthritis (OA) is a chronic degenerative joint disorder that affects a large proportion of the population, particularly the elderly [1–5]. It is the 11th leading cause of disability worldwide, with its incidence increasing in the last two decades [6]. Although most patients with knee OA experience severe knee pain, physical dysfunction, depressed mood, and activity restriction [7–10], the recommended conservative treatments for knee OA often include physical activity and lifestyle modifications because walking results in knee pain reduction and improvement in functional ability [11, 12]. In addition, regular physical activity is associated with a lower prevalence of obesity and comorbidities such as diabetes, cardiovascular disease, and hypertension [13]. However, previous reports revealed that the 2008 Physical Activity Guidelines for Americans were met by only 12.9 % of men and 7.7 % of women with knee OA, and a substantial proportion of men and women (40.1 and 56.5 %, respectively) were

inactive [14]. Therefore, it is important to find risk factors for decreased physical activity to maintain or increase this key clinical index.

Most previous studies have focused on the relationship between physical activity and clinical indices such as knee pain and physical function [15–17]. The extent of the influence of physical activity on the improvement of knee pain and physical function has been well established [15, 16]. In contrast, there are few studies on the inhibitors of physical activity [17]. The systematic review conducted by Veenhof reported that physical function is related to a low level of physical activity [18]. Moreover, several studies [19, 20] have identified knee pain as a major limiting factor for physical function. Thomas and colleagues revealed that knee pain was associated with decreased physical activity in patients with knee OA [17]. However, which types of daily activities induce knee pain that significantly affects physical activity remains unknown. Costigan and colleagues reported that mechanical joint loading related to knee pain differs between activities [21]. Accordingly, activities that elicit knee pain may not always be constant. Because managing knee pain is important in an intervention for physical activity, understanding the inhibitory factors of physical activity might be beneficial to design a better approach to increase physical activity more effectively and might help overcome the problem of low adherence to physical activity interventions. Therefore, evaluating the association between knee pain during various activities of daily living (ADLs) and physical activity is an important step in developing effective clinical interventions.

Physical function or daily activity performance is strongly influenced by the severity of the knee OA [22, 23]. Data from the National Health and Nutrition Examination Survey-Epidemiologic Follow-up Study (NHEFS) and the Framingham Study suggest the large impact of radiological knee osteoarthritis on disability in the ADLs related to lower limb function [20, 24]. Thorp and colleagues reported structural and functional differences between mild (K/L grade ≤2) and moderate (K/L grade ≥3) knee OA. Cho and colleagues revealed that patients with K/L grade 3 had more severe symptom (WOMAC Pain and Function) progression compared with K/L grade 2 [23]. Thus, disease severity strongly influences clinical outcome. Generally, radiologic knee OA is defined as having at least a K/L grade of 2 or more [25]. However, a recent study showed the presence of structural damage in the medial compartment of the knee in early-stage OA patients, including stage 1. We therefore included K/L grade ≥1 in the present study [26]. Patients with a K/L grade 1–2 were labeled as the *early group* while patients with a K/L grade 3–4 were labeled as the *severe group*.

The purpose of the present study was to investigate whether knee pain during various ADLs is associated with physical activity in patients with early and severe knee OA.

Materials and methods

Participants

This study had a cross-sectional design. Between February and May 2014, 291 patients aged 56–90 years old with knee OA were recruited by advertisement in community orthopedic clinics in Hiroshima and Kyoto, Japan. Patients with medial tibiofemoral knee OA, with K/L grade ≥1 in one or both knees, who were able to walk independently, and who had the ability to see, hear, and operate a pedometer were included in this study. Individuals were excluded from the present study if they had lateral knee OA, medical conditions causing pain or fatigue that interfered with physical activity such as cardiopulmonary or neurologic disorders, as well as a history of an operation in the knees, periarticular fracture, or cognitive impairment. When a symptom was found to be bilateral, the affected side was defined as having the more severe disease. Written informed consent was obtained from each participant in accordance with the guidelines of the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1995. The ethical committee of the Kyoto University Graduate School of Medicine approved this study.

Measurements

Objective measure of physical activity

Objective physical activity was assessed by measuring the daily, accumulated step counts using a pedometer (Yamax Power Walker EX-300; Yamasa Tokei Keiki Co., Ltd, Tokyo, Japan). We distributed the pedometer and activity calendar to the participants, which were used for recording step counts at the time of a measurement. Participants were asked to wear the pedometer in the pocket of their dominant leg for 14 consecutive days except when sleeping, bathing, and performing water-based activities and were instructed not to perform any unusual activities. Furthermore, the participants were asked to write down the number of steps at the end of each day. The pedometers and activity calendar were sent to our laboratory by mail after 14 consecutive days, and the average amount of step counts was calculated. We restricted our sample to those patients who wore the pedometer for at least 10 valid days, which is enough to meet the minimum number of days needed to reliably estimate physical activity [27]. The pedometers had a 30-day data storage capacity. Previous studies used questionnaires such as Physical Activity Scale for the Elderly (PASE), accelerometer, and pedometer to measure the physical activity of older adults with knee OA [10, 14, 28]. We selected a pedometer, because it is cheap, readily accessible, and more likely to be used in clinical and public health applications.

Radiographic knee OA

Radiographs of the affected side were taken by using an anteroposterior short film, with weight bearing and foot map positioning. The cassette holder was lowered so that the center of the film was at the level of the participant's tibiofemoral joint line. Fluoroscopic guidance with a horizontal anteroposterior x-ray beam was used to properly visualize the joint space. Radiographs taken within 3 months were used. If absent or an acute exacerbation occurs within 3 months, participants were subjected to radiography at the time of our measurement. Radiographs were scored on the basis of the K/L grade, and the scores were used to evaluate the patients' knee OA severity and identified as 0 (normal), 1 (possible osteophytes), 2 (definite osteophytes, possible joint space narrowing), 3 (moderate osteophytes, definite narrowing, some sclerosis, possible attrition), and 4 (large osteophytes, marked narrowing, severe sclerosis, definite attrition) [29]. The intrarater reliability of radiographic evaluation (kappa coefficient = 0.90) was proven in our previous research [30, 31].

Presence or absence of knee pain during several ADLs using the Japanese Knee Osteoarthritis Measure

The Japanese Knee Osteoarthritis Measure (JKOM) was used to assess the presence or absence of knee pain during several ADLs (upon waking up in the morning, walking on a flat surface, ascending stairs, descending stairs, bending to the floor or standing up, and standing still). The JKOM is a self-administered, disease-specific questionnaire for patients with knee OA [32]. Each question is graded on a scale of 0–4 points as *not at all* (0 point), *slight/moderate/quite* (1 to 3 points), and *extreme* (4 point), which indicates no, some, and very severe pain, respectively. The JKOM is one of the most frequently used measures for the treatment of knee OA in Japanese clinical practice and was proven to have sufficient validity and reliability by means of statistical evaluation and comparisons with the Western Ontario McMaster Universities Osteoarthritis Index (WOMAC) [32].

Demographic data

Demographic data were obtained through self-reported questionnaires (i.e., age and sex). Body height and weight were assessed in the clinic without shoes or heavy clothing on a calibrated scale using standard techniques. Body mass index (BMI) was calculated by dividing the weight by the square of height.

Motor function

The 10-m gait speed was ascertained by asking the participants to walk 10 m at a self-selected speed. We measured the time required for walking 10 m using a stopwatch and calculated the gait speed (m/s).

Statistical analyses

Participants were divided into the early and severe groups based on K/L grades ≤2 and ≥3, respectively. For continuous (e.g., age, BMI, 10-m gait speed, and step counts) and dichotomous variables (e.g., sex), the characteristics were summarized by using means and standard deviation (SD) in tables or standard error (SE) in figures, and by counts, respectively. The normality of continuous variables was assessed using the Shapiro–Wilk test.

The demographic data, motor function, and physical activity characteristics of both groups were compared using the unpaired *t* (for normally distributed variables) or the Mann–Whitney *U* tests (for non-normally distributed variables) for continuous variables and the chi-squared test for dichotomous variables. The answers to the six individual questions of the pain-related JKOM subcategory were dichotomized into two categories as *not at all* and *slight/moderate/quite/extreme* according to its absence (0) or presence (1). The pain scores 1 to 4 were collapsed into one level because the number of patients with score 2 or more were small. Participants were divided into two groups based on the presence or absence of knee pain during each ADL. The ratios of the number of patients with the presence and absence of knee pain in the early and severe groups were compared by using a chi-squared test. The step counts were compared separately in each group. Furthermore, we performed multiple regression analysis with step counts as a dependent variable. This was conducted to investigate whether knee pain during the ADLs, which showed significant differences in step counts between those with knee pain and those without pain in the univariate analysis, was independently associated with physical activity that was adjusted for age, sex, BMI, and 10-m gait speed. We used 10-m gait speed as an adjustment variable, because a previous study revealed that it influences physical activity [33]. Additionally, because the heterogeneity of the distribution of step counts data as dependent variable was expected, we also performed quantile regression analysis to investigate whether knee pain during the ADLs was independently associated with several levels of physical activity that was adjusted for age, sex, BMI, and 10-m gait speed. We evaluated the 25th to the 75th percentiles of the step counts with increments of 25 percentile points as quantiles. This allowed the comprehensive assessment of the association between knee pain during a certain ADL and step counts across all percentiles.

Statistical analyses were performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, New York) or R (R Foundation for Statistical Computing, Vienna, Austria) programs. The level of statistical significance was set at $P < 0.05$.

Results

Characteristics of patients

Among the 291 participants with medial knee OA in the present study, 11 (3.4 %) and 10 (3.4 %) were excluded because of missing values of the JKOM or step counts, respectively. Among the 270 participants, 207 (76.7 %) were in the early group, whereas 63 (23.3 %) were in the severe group. As shown in Table 1, the Mann–Whitney *U* test showed significant differences between both groups according to age ($P<0.001$), BMI ($P=0.004$), and step counts ($P<0.001$). The step counts of participants in the early group were significantly higher compared to those of participants in the severe group (early group 5146 ± 2630 steps/day; severe group 3969 ± 3004 steps/day). The unpaired *t* test also showed significant differences between both groups according to the 10-m gait speed ($P<0.001$). Chi-square analysis showed no significant differences in sex ($P=0.498$).

Comparison of physical activity based on the presence or absence knee pain during six ADLs

We showed the counts and percentages (%) of the presence or absence of knee pain during the six ADLs in both groups, according to the early and severe groups (Table 2). For all individual questions, there were high ratios of the presence of knee pain in the severe group compared with the early group. However, no significant differences in pain were found between the exercises of *ascending stairs* and *descending stairs*.

The results of the comparison of step counts according to knee pain during the six ADLs are shown in Fig. 1 (the early group) and Fig. 2 (the severe group). The significant differences while *ascending stairs* (presence of pain, mean and SE 4852 ± 216 steps/day; absence of pain 5925 ± 336 steps/day; $P=0.010$), and *descending stairs* (presence of pain 4948 ± 229 steps/day; absence of pain 5715 ± 310 steps/day; $P=0.029$), *bending to the floor or standing up* (presence of pain 4868 ± 221 steps/day; absence of pain 5906 ± 324 steps/day; $P=0.010$), and *standing still* (presence of pain 4829 ± 231 steps/day; absence of pain 5745 ± 299 steps/day; $P=0.016$) were all observed in the early group. On the other hand, significant differences were recognized while *walking on a flat surface* (presence of pain 3456 ± 364 steps/day; absence of pain 5358 ± 940 steps/day; $P=0.014$), *descending stairs* (presence of pain 3560 ± 359 steps/day; absence of pain 5542 ± 1142 steps/day; $P=0.023$), and *bending to the floor or standing up* (presence of pain 3587 ± 333 steps/day; absence of pain 6261 ± 1612 steps/day; $P=0.045$) were observed in the severe group.

Association between knee pain during each ADL and physical activity

The results of multiple regression analysis are shown in Table 3 (early group) and Table 4 (severe group). In the early group, the significant association with physical activity was not recognized in all independent variables (pain in ascending stairs, descending stairs, bending to the floor or standing up, or standing still). However, a tendency toward an association was found between pain in *ascending stairs* and physical activity (unstandardized coefficients = −681.38, 95 % confidence interval (CI), −1407.75, 45.00, $P=0.066$). In the severe group, knee pain while *walking on a flat surface* and *bending to the floor or standing up* were negatively associated with physical activity (unstandardized coefficients = −1850.87,

Table 1 Comparison of characteristics of the early and severe groups

	Early group ($n=207$)	Severe group ($n=63$)	*P* value
Demographic data			
Age (years)[a]	71.4 ± 6.8	75.8 ± 7.1	<0.001**
Sex (men/women)[b]	42/165	16/47	0.498
BMI (kg/cm^2)[a]	23.6 ± 3.9	25.4 ± 4.3	0.005**
Motor function			
10-m gait speed (m/sec)[c]	1.2 ± 0.2	1.0 ± 0.2	<0.001**
Physical activity			
Step counts (steps/day)[a]	5146 ± 2630	3969 ± 3004	<0.001**

Data are shown as mean ± standard deviation

BMI body mass index

****P** values <0.01 were considered to be statistically significant

[a] Mann–Whitney *U* test

[b] Chi-squared test

[c] Unpaired *t* test

Table 2 Distribution of the presence or absence of knee pain during six activities of daily living in the early and severe groups

Individual questions of the pain-related JKOM subscale		Early group ($n=207$)	Severe group ($n=63$)	P value
Do you feel pain in your knees when you wake up in the morning?	Presence	129 (62.3 %)	50 (79.4 %)	0.015
	Absence	78 (37.7 %)	13 (20.6 %)	
Do you have pain in your knees when you walk on a flat surface?	Presence	111 (53.6 %)	46 (73.0 %)	0.008
	Absence	96 (46.4 %)	17 (27.0 %)	
Do you have pain in your knees when ascending stairs?	Presence	141 (68.1 %)	51 (81.0 %)	0.057
	Absence	66 (31.9 %)	12 (19.0 %)	
Do you have pain in your knees when descending stairs?	Presence	140 (67.6 %)	50 (79.4 %)	0.084
	Absence	67 (32.4 %)	13 (20.6 %)	
Do you have pain in your knees when bending to the floor or standing up?	Presence	142 (68.6 %)	54 (85.7 %)	0.009
	Absence	65 (31.4 %)	9 (14.3 %)	
Do you have pain in your knees when standing?	Presence	124 (59.9 %)	49 (77.8 %)	0.011
	Absence	83 (40.1 %)	14 (22.2 %)	

Data are shown as count and percentage (%); chi-squared test

JKOM Japanese Knee Osteoarthritis Measure

95 % CI, −3474.12, −227.63, $P=0.026$; unstandardized coefficients = −2640.35, 95 % CI, −4617.39, −663.32, $P=0.010$).

The results of quantile regression analysis are shown in Table 3 (early group) and Table 4 (severe group). In the early group, knee pain while *ascending stairs* was negatively associated with the 75th percentile of the physical activity (75th percentile: regression coefficient = −1033.70, 95 % CI, −1924.27 to −141.73, $P=0.018$). However, other independent variables (pain in descending stair, bending to the floor or standing up, or standing still) were not significantly associated with physical activity. In the severe group, knee pain while *walking on a flat surface* was negatively associated

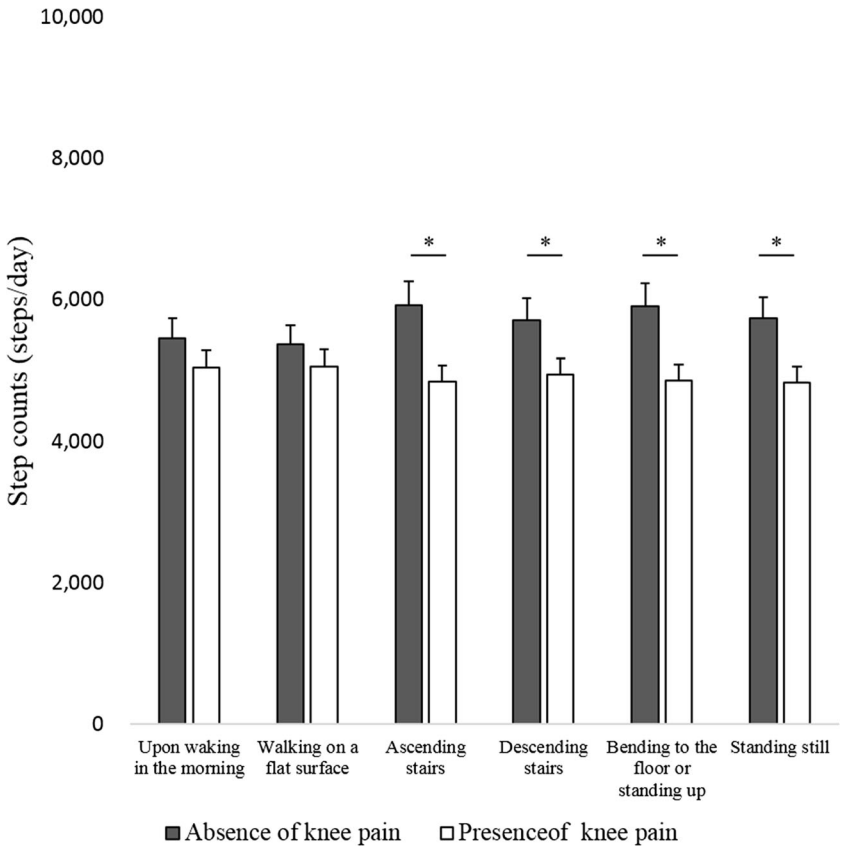

Fig. 1 Comparison of physical activity (step counts) between those without and with knee pain during six activities of daily living in the early group. Differences of physical activity were analyzed by using Mann–Whitney *U* test. *Error bars* show standard error. **P* values <0.05 were considered to be statistically significant

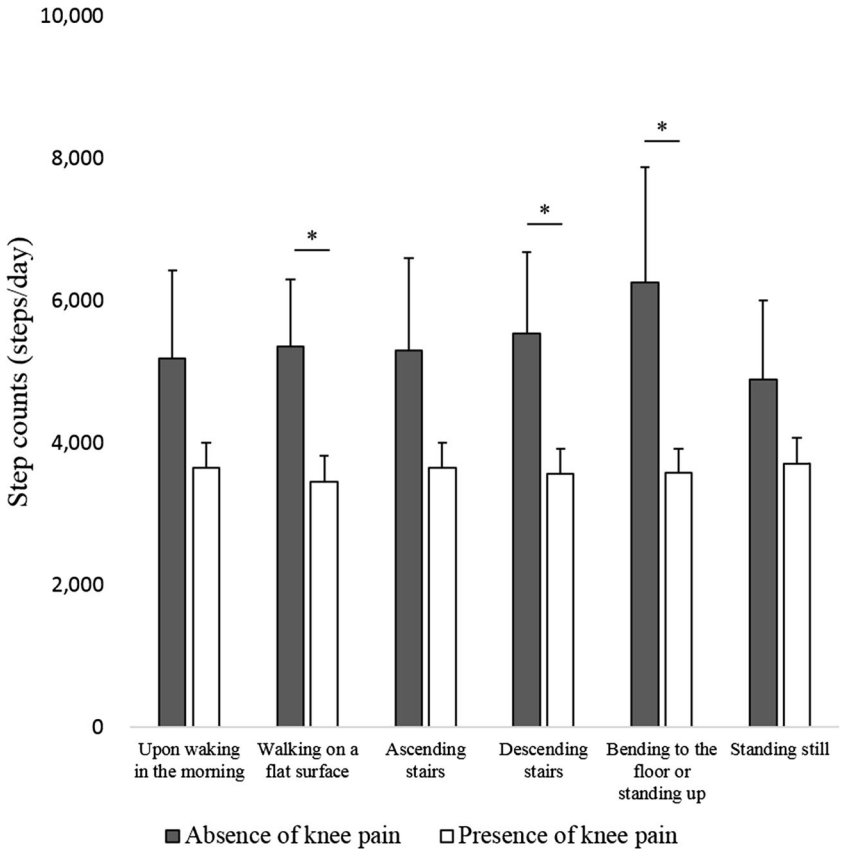

Fig. 2 Comparison of physical activity (step counts) between those without and with knee pain during six activities of daily living in the severe group. Differences of physical activity were analyzed by using Mann–Whitney *U* test. *Error bars* show standard error. **P* values <0.05 were considered to be statistically significant

with the 50th percentile of the physical activity (50th percentile: regression coefficient = −1771.84, 95 % CI, −3455.07 to −86.93, $P = 0.039$). However, knee pain while *descending stairs* or *bending to the floor or standing up* was not significantly associated with physical activity.

Discussion

This cross-sectional study revealed that the painful activities associated with decreased physical activity differed according to disease severity. In the early group, knee pain while *ascending stairs* was negatively associated with physical activity in a high activity layer, revealing that the more pain the participants experienced while *ascending stairs*, the lower their level of physical activity was. In the severe group, knee pain while *walking on a flat surface* or *bending to the floor or standing up* was negatively associated with physical activity, demonstrating that the more pain the participants experienced during these activities, the lower their level of physical activity was. Vignon and colleagues reported that healthy subjects, as well as knee OA patients in general, can pursue a high physical activity, provided the activity is not painful and does not predispose to trauma [34]. Furthermore, previous studies have demonstrated that the pain coping strategy, or *avoidance of activities*, is associated with activity limitations in persons with knee OA [35–37]. Therefore, it is desirable to manage knee pain when designing an intervention for physical activity. Our present data suggested that while knee pain during basic movements such as walking or standing up should be paid attention to in severe knee OA, focusing on knee pain during advanced movements such as ascending stairs is more important in early knee OA to find a strategy to increase physical activity.

During univariate analysis in the early group (Fig. 1), significant differences were recognized in physical activity between those with and without knee pain while ascending stairs, descending stairs, bending to the floor or standing up, and standing still. Although no significant relationship was found between any independent variables and physical activity in multiple regression analysis, knee pain while *ascending stairs* was negatively associated with the 75th percentile of physical activity in quantile regression analysis. Quantile regression is an analysis that considers non-homogeneity of physical activity as a dependent variable. As seen in Table 3, the regression coefficient for knee pain while *ascending stairs* decreases gradually every 25th percentile and shows a prominent low value in the 75th percentile (25th percentile = −653.18, 50th percentile = −672.17, 75th percentile = −1033.70). Therefore, non-significance on multiple regression analysis can probably be attributed to the non-homogeneity of physical activity data in the

Table 3 The coefficients from multiple regression analysis and quantile regression analysis are provided to characterize association between knee pain during several activities of daily living and physical activity (step counts) in the early group

Independent variables	Multiple regression analysis				Quantile regression analysis		
	B[a]	95 % CI	Beta[b]	*P* value	25th (95 % CI)	50th (95 % CI)	75th (95 % CI)
Knee pain while							
Ascending stairs	−681.38	(−1407.75 to 45.00)	−0.12	0.066	−653.18 (−1362.86 to 56.86)	−672.17 (−1510.03 to −166.03)	−1033.7 (−1924.27 to −141.73)*
Descending stairs	−383.29	(−1107.92to 341.35)	−0.07	0.298	−351.12 (−1009.59 to 307.59)	−514.12 (−1361.89 to 333.89)	−285.00 (−1031.33 to 463.33)
Bending to the floor or standing up	−618.58	(−1347.23 to 110.06)	−0.11	0.096	−631.81 (−1329.03 to 67.03)	−393.19 (−1319.76 to 533.76)	−1033.70 (−2174.69 to 108.69)
Standing still	−374.41	(−1080.53 to 331.71)	−0.07	0.297	−368.27 (−995.04 to 259.04)	−96.12 (−898.54 to 706.54)	−269.33 (−1020.27 to 482.27)

In quantile regression analysis, data are shown as percentile (95 % confidence interval), adjusted for age, sex, body mass index, and 10-m gait speed

**P* values <0.05 were considered to be statistically significant

[a] In multiple regression analysis, data are shown as unstandardized coefficients (95 % confidence interval) adjusted for age, sex, body mass index, and 10-m gait speed

[b] In multiple regression analysis, data are shown as standardized coefficients, adjusted for age, sex, body mass index, and 10-m gait speed

Table 4 The association between knee pain during several activities of daily living and physical activity (step counts) in the severe group

Independent variables	Physical activity (step counts)				Quantile regression analysis		
	B[a]	95 % CI	Beta[b]	*P* value	25th percentile (95 % CI)	50th percentile (95 % CI)	75th percentile (95 % CI)
Knee pain while							
Walking on a flat surface	−1850.87	(−3474.12 to −227.63)	−0.28	0.026*	−891.29 (−2004.3 to 222.37)	−1771.84 (−3455.07 to −86.93)*	−1637.41 (−3963.87 to 689.87)
Descending stairs	−1552.69	(−3335.96 to 230.58)	−0.21	0.087	−862.39 (−1863.23 to 139.23)	−1446.3 (−2953.86 to 61.86)	−1548.02 (−6057.55 to 2961.55)
Bending to the floor or standing up	−2640.35	(−4617.39 to −663.32)	−0.31	0.010*	−767.77 (−3250.06 to 1716.06)	−2103.39 (−5755.50 to 1549.50)	−4004.09 (−10,522.03 to 2514.03)

In quantile regression analysis, data are shown as percentile (95 % confidence interval), adjusted for age, sex, body mass index, and 10-m gait speed

[a] In multiple regression analysis, data are shown as unstandardized coefficients (95 % confidence interval) adjusted for age, sex, body mass index, and 10-m gait speed

[b] In multiple regression analysis, data are shown as standardized coefficients, adjusted for age, sex, body mass index, and 10-m gait speed

**P* values <0.05 were considered to be statistically significant

early group. Considering these results, knee pain while *ascending stairs* can be a limiting factor for physical activity for patients with early knee OA and relatively high activity corresponding to the 75th percentile of step counts. According to the pain coping strategy [35–37], patients tend to reduce their ambulation because they want to avoid activities that involve stairs.

Stair climbing is a common and frequent dynamic ADL that is biomechanically and physiologically more challenging than typical walking tasks and is considered one of the most difficult tasks for the elderly [38, 39]. Costigan and colleagues revealed that stair climbing was reported as the first complaint in patients with knee OA [21]. Furthermore, knee pain is most likely to appear for the first time during weight-bearing activities involving bending of the knee, such as using the stairs [40]. Consistent with these previous studies, the prevalence of knee pain while ascending or descending stairs did not significantly differ according to disease severity in the present study. Knee pain during ascending stairs probably occurs easily at the early stage of knee OA. In a biomechanical study, stair climbing results in approximately six times more compressive load transmitted through the knee joint compared to walking on level ground [41]. Thus, knee pain while climbing stairs can be a functional and psychological barrier for daily activity in patients with early stage knee OA. However, *ascending stairs* and *descending stairs* should be discussed separately. In the present study, pain while *ascending stairs* was associated with physical activity by quantile regression. Although the percentage of patients with pain is similar between ascending and descending stairs (Table 2), the regression coefficients for pain while *descending stairs* did not show a low value in the 75th percentile. Some patients maintain relatively high activity despite knee pain while descending the stairs.

On univariate analysis in the severe group (Fig. 2), significant differences were recognized in physical activity between those with and without knee pain while walking on a flat surface, descending stairs, and bending to the floor or standing up. In addition, multiple regression analysis showed that knee pain while *walking on a flat surface* and while *bending to the floor or standing up* were negatively associated with physical activity as a general tendency. However, by quantile regression analysis, knee pain while *walking on a flat surface* was negatively associated with only the 50th percentile of physical activity. As can be seen from the regression coefficients in Table 4, data distribution of physical activity tends to be more linear in the severe group compared to the early group. Therefore, the discussion will be based mainly on the multiple regression results in the severe group.

The present study suggested that the limiting factors for physical activity differ according to disease severity. In addition, as demonstrated by the unstandardized coefficients of the multiple regression analysis, the negative association between knee pain and physical activity was stronger in the severe group than in the early group. NHEFS and the Framingham Study showed the large impact of radiological osteoarthritis of the knee on disability in the ADLs related to lower limb function [20, 24]. Knee pain while *walking on a flat surface* and *bending to the floor or standing up* were negatively associated with physical activity in the severe group probably because these basic functions are more affected by advances in radiographic severity, and any limiting factors influence physical activity more drastically with disease progression. Several previous studies have demonstrated that the pain coping strategy or *avoidance of activities* is associated with activity limitations in persons with knee OA [35, 36]. Therefore, because patients with symptomatic knee OA tend to avoid knee pain that occurs during a walk and when standing up, it is believed that knee pain while walking and standing up was negatively associated with physical activity.

Our results suggest that improvements in task-specific knee pain according to disease severity may improve physical activity. In the early group, the reduction of the knee pain when *ascending stairs* may lead the patients to go out more frequently and to expand their activity area. In the severe group, knee pain when *bending to the floor or standing up* is possibly more important as an initial target for improving physical activity because the unstandardized coefficients are larger. The patients in the severe group who did not experience pain when *bending to the floor or standing up* showed similar physical activity with those in the early group (Fig. 2). Therefore, our findings suggest the necessity of an evaluation of pain-inducing movement and an intervention for reducing pain to improve physical activity. Because the relationship between knee pain and physical activity is bidirectional [15–17], intervention utilizing physical activity is an important option to reduce knee pain. However, it is difficult to increase physical activity while feeling knee pain, because patients tend to avoid the movement accompanying knee pain [35–37]. Therefore, managing knee pain is an important consideration when designing interventions for physical activity [42].

This study has several limitations. First, we could not evaluate intensity, durations, and variety of physical activity, because we used a pedometer. The US Department of Health and Human Services 2008 Physical Activity Guidelines for Americans outline the minimal recommendations for evaluating the intensity and duration of physical activity [43]. Second, although the pedometer is an acceptable tool for measuring physical activity, the pedometer that we used has been validated only in a healthy population. Third, because this study was cross-sectional in nature, a cause–effect relationship between knee pain during the six ADLs and physical activity remains unknown.

In conclusion, we investigated the association between knee pain during the six ADLs (upon waking up in the morning, walking on a flat surface, ascending stairs, descending

stairs, bending to the floor or standing up, and standing still) and physical activity in patients with early and severe knee OA. We found a significant association between knee pain while *ascending stairs* and physical activity in a high activity layer in early knee OA. Furthermore, the association between knee pain while *walking on a flat surface* or *bending to the floor or standing up* and physical activity reached significance in severe knee OA. Additional studies, particularly on the influence of task-specific knee pain on longitudinal decline of physical activity, as well as the evaluation of the effects of interventions on knee pain to improve physical activity are needed.

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Compliance with ethical standards Written informed consent was obtained from each participant in accordance with the guidelines of the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1995. The ethical committee of the Kyoto University Graduate School of Medicine approved this study.

Conflict of interest The authors did not receive financial support or other benefits from commercial sources or any other financial interests that could create a potential conflict of interest or the appearance of a conflict of interest with regard to the work.

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