Title:

Contribution of knee adduction moment impulse to pain and disability in Japanese women with medial knee osteoarthritis

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Abstract

Background: An increase in the knee adduction moment is one of the risk factors of medial knee osteoarthritis. This study examined the relationship between knee adduction moment and self-reported pain and disability. We also investigated the influence of pain on the relationships between knee adduction moment and gait performance and disability.

Methods: Thirty-eight Japanese women with medial knee osteoarthritis participated in this study (66.37 years (41–79 years)). Gait analysis involved the measurement of the external knee adduction moment impulse in the stance duration and during 3 subdivisions of stance. The total, pain and stiffness, and physical function Japanese Knee Osteoarthritis Measure scores were determined.

Findings: The pain and stiffness, physical function, and total scores were positively correlated with the knee adduction moment impulses in the stance duration, and initial and second double support interval, and single limb support interval. The knee adduction moment impulse during the stance duration was related to the pain and stiffness subscale and gait velocity. The pain and stiffness subscale was related to the physical function subscale.

Interpretation: Our results suggest that increasing in the knee adduction moment impulse, a proxy for loading on the medial compartment of the knee, is related to increased pain during weight-bearing activities such as walking, thereby restricting walking performance and causing disability by reducing gait velocity. Thus, the reduction in the knee adduction moment

impulse during gait may result in pain relief and may serve as a conservative treatment option with disease-modifying potential.

Key words:

knee osteoarthritis, knee adduction moment impulse, gait analysis, pain, physical function

1. Introduction

The estimated number of individuals with symptomatic medial knee osteoarthritis (knee OA) is approximately 8 million in Japan (Yoshimura, et al., 2009). Knee OA patients experience persistent pain and stiffness in the knees while performing daily weight-bearing activities. Pain is associated with disability due to gait disturbance and functional limitations in mobility and limits carrying out self-care activities. Community-residing older adults, in particular, are at a high risk for disability (Fried and Guralnik, 1997). Therefore, there is an urgent need to reduce the progression and incidence of knee OA in Japan.

The occurrence of dynamic loading on the knee is considerably greater during gait cycles than during any other daily life activity (Schipplein and Andriacchi, 1991). The peak force is higher in the medial compartment of the knee than in the lateral compartment (Shelburne, et al., 2005; 2006). The knee adduction moment has been shown to be a major determinant of not only the total load across the knee joint, but also its distribution between the medial and lateral compartments of the knee; further, an increase in the knee adduction moment would result in an increase in the load on the medial compartment of the knee relative to that on the lateral compartment (Zhao, et al., 2007). Thus, an increase in the magnitude of the knee adduction moment would theoretically contribute to the progression of knee OA (Miyazaki, et al., 2002).

In Japan, many patients with knee OA receive conservative treatment, which consists of exercise, heat therapy, knee orthosis, and the use of lateral heel wedges. Typical exercise regimens for muscle dysfunction might prevent or alleviate some of the problems associated with knee OA (Hurley, 2003). Recently, the use of gait modification retraining for reducing medial compartment contact force has been reported (Fregly, 2008). If gait modification is successful in reducing the peak knee adduction moment, it could serve as a new conservative treatment option with disease-modifying potential. Pain and stiffness in the knee are the primary symptoms for which individuals visit a physician, and these symptoms also lead to behavior which results in physical disabilities. Therefore, it is important that the exercise regimen not only reduces knee adduction moment during walking but also provides pain relief and improves physical mobility.

Some previous studies have reported the relationships between knee adduction moment and clinical features such as pain, stiffness, and physical disability (Maly, et al., 2006; 2008). Maly et al. (2006) reported that there was no relation between knee adduction moment and physical disabilities, as determined by using the 36-item short-form health survey, in patients with knee OA. However, no cross-sectional studies have been conducted in Japan to assess these relationships. Furthermore, differences in the constitutional and mechanical risk factors for knee OA between Western and Oriental populations (e.g., Japanese people tend to be shorter and weigh less than Western people (Yoshimura, et al., 2004)) would imply potentially important differences in the relationships between knee adduction moment and clinical features. In order to develop optimal exercise regimens designed to reduce medial compartment load in the knee and to relieve clinical features of knee OA in Japanese patients, it is necessary to clarify the relationship between knee adduction moment and the clinical features of knee OA.

The purpose of this study was to examine the relationship between knee adduction moment impulse and self-reported pains and disabilities. We also investigated the influence of pain on the relationship between knee adduction moment impulse and gait performance and disability. We hypothesized that an increase in knee adduction moment impulse is directly related to pain and gait performance, and pain and gait performance will related to disabilities.

2. Methods

2-1. Subjects

We conducted a cross-sectional study with 38 Japanese women. All participants who participated in this study had tibiofemoral OA in at least either side of the knee joints (28 cases of bilateral disease and 10 cases of unilateral disease), and all complained of persistent knee pain. The inclusion criteria were as follows: fulfillment of the American College of Rheumatology classification criteria for symptomatic knee OA (Altman, et al., 1986), chronic knee pain, and the absence of OA in other weight-bearing joints as determined by a clinical examination. Participants were excluded if they had a history of lower extremity joint replacement, had undergone knee surgery or received intraarticular steroid therapy in the 6 months prior to the study, had a systemic arthritic disease or other severe medical conditions, or were receiving physical therapy for knee OA. Participants were screened over the telephone, and those eligible underwent weight-bearing radiography. Participants that fulfilled the eligibility criteria based on radiography findings were enrolled in the study. All procedures were approved by the Hiroshima International University Human Research Ethics Committee and all participants gave their written informed consent prior to enrollment.

2-2. Radiographic analysis.

Anteroposterior weight-bearing radiographs were obtained for all participants. To obtain anteroposterior radiographs and control for the effects of foot rotation on measures of lower extremity alignment, the patients were positioned such that the patellae centered over the femoral condyles with the feet extended straight ahead.

The severity of OA was assessed by using the Kellgren/Lawrence (K/L) grading system (Kellgren and Lawrence, 1957) as follows: grade 0, no abnormalities; grade 1, possible osteophytic lipping; grade 2, definite osteophytes and possible joint space narrowing; grade 3, moderate and/or multiple osteophytes with definite joint space narrowing, sclerosis, and possible bone attrition; and grade 4, large osteophytes, marked joint space narrowing, severe sclerosis, and definite bone attrition.

In the cases of bilateral knee OA, the knee with a higher K/L grade and more pain was recorded as the most affected knee, and this knee was used for data analyses. Of the 38 participants, the left knee was studied in 18 cases, and the right knee, in 20 cases.

2-3. Self-report measures of pain and disability

We used the Japanese Knee Osteoarthritis Measure (JKOM), a new parameter for evaluating knee OA, to assess self-reported pains and disabilities. The JKOM (total 25 questionnaires, maximum 125 points) consists of 4 separate subscales assessing "pain and stiffness in knee (8 questionnaires, maximum 40 points)", "condition in daily life (10 questionnaires, maximum 50 points)", "general activities (5 questionnaires, maximum 25 points)", and "health conditions (2 questionnaires, maximum 10 points)". The score range for each of these subscales was 1 to 5 points, with higher scores indicating worst condition. The JKOM is reliable and valid and can be used in studies to determine the clinical outcomes of knee OA in Japanese people (Akai, et al., 2005). Pain intensity was assessed by using the "pain and stiffness" JKOM subscale. Disabilities were assessed by using the "condition in daily life" subscale.

2-4. Gait evaluation

A 3D motion analysis system that included 8 infrared cameras (VICON MX; Vicon Motion Systems, Oxford, UK) and 8 force plates (AMTI; Watertown, MA, USA) was used to record kinematics and kinetic data at sample frequencies of 100 and 1000 Hz, respectively. The recorded data was low-pass filtered with a second-order recursive Butterworth filter with a cutoff frequency at 6 Hz in accordance with the technique reported by Winter (2005).

A total of 28 reflective markers were placed at the following landmarks on both sides: acromion process, lateral epicondyle, ulnar styloid process, top of the iliac crest, anterior superior iliac spine, posterior superior iliac spine, superior aspect of the greater trochanter, medial and lateral femoral condyles, mid-point between the greater trochanter and the lateral femoral condyles, medial and lateral malleoli, mid-point between the lateral knee joint line and the lateral malleolus, head of the first and fifth metatarsal, and the lateral process of the calcaneal tuberosity. These anatomical markers were used to construct anatomical coordinate systems for the pelvis, thigh, shank, and foot segments. In order to calculate the knee adduction moment, the joint centers of the hip, knee, and ankle were approximated as described in previous studies (Andriacchi, et al., 1982; Kurabayashi, et al., 2003). The joint center of the knee on the frontal plane was located by identifying the mid-point of a line which links the medial femoral condyle marker to the lateral femoral condyle marker. The joint center of the ankle was located by identifying the mid-point of a line which links the medial malleoli marker to the lateral malleoli marker. The joint center of the hip was determined as following methods. First, we have calculated a vector which links the both greater trochanter marker. Second, the joint center of the hip was determined at a point interpolated at a distance of 18% of the vector norm from each reflective marker of the superior aspect of the greater trochanter along the vector.

In the walking trials, all participants were instructed to walk barefoot at a self-selected normal speed. Data from 3 walking trials were collected. Three walking trials in which all of the reflective markers could be identified and in which there was clear contact with the force plates were conducted. Kinematic and kinetic calculations were performed using the processing software “BodyBuilder (Vicon Motion Systems; Oxford, UK)”.

Gait speed (m/s) was measured from the center of gravity (COG) averaged over a 3-s data collection period. Step length (m) was measured as anterior-posterior distances between the right and left calcaneal markers in the double support phase. Step length was normalized to body height (%BH).

A 7-link segmental model was developed to calculate hip, knee, and ankle kinematic and kinetic data by using inverse dynamics according to the techniques of Davis et al. (1991) and Vaughan et al. (1992). Anthropometric parameters for mass, center of mass, and moment of inertia for segment were obtained from the report by Okada et al. (1996). We calculated the knee joint moment by using the tibial coordinate system with the origin in the knee joint center. In this study, knee adduction moment was defined as the external knee adduction moment after normalization to the subject's body weight (Nm/kg).

Stance duration was the elapsed time between initial contact and toe-off in the stance phase. Initial contact was assumed to occur when the vertical reaction force exceeded 10% of the individual's body weight, and toe off was assumed to occur in the first frame following initial contact where the vertical force was less than 10% of the individual's body weight. Stance duration was divided into initial double stance interval, single limb support interval, and second double stance interval on the basis of the ground reaction force. The knee adduction moment impulse, the timed integral of all the knee adduction moments, was calculated for stance duration and the subdivisions of the stance duration (**Figure 1**). Thorp et al. (2006; 2007) reported that the knee adduction moment impulse is a useful gait parameter because it is a more sensitive predictor of radiographic disease severity and is a biomechanical component that can be used to distinguish between asymptomatic and symptomatic radiographic OA. All gait parameters and the knee adduction moment impulses during stance and during all and periods of stance duration were individually averaged over 3 trials.

The test-retest reliability of this procedure was found to be excellent in 10 participants tested 1 week apart (intraclass correlation coefficient, 0.92–0.95).

2-5. Statistical analyses

Data are presented as the mean (standard deviation). Statistical significance was set at $p < 0.05$. All data were analyzed with the SPSS 15.0 statistical software (SPSS Japan Inc., Tokyo, Japan).

Participants with radiographic evidence of knee OA were divided into groups depending on the K/L grades: K/L grade 1 or 2, mild knee OA group; and K/L grade 3, moderate knee OA group. There was no participant with K/L grade 4. Unpaired t-tests were used for comparisons of age, body weight, body height, body mass index (BMI), gait speed, step length, stance duration, single limb support duration, and JKOM score (pain and stiffness, physical function, and total score) between groups. Analysis of covariance was used to determine intergroup differences in the knee adduction moment impulse for all periods of stance duration using gait speed as a covariate.

The analysis described in this paragraph was conducted by considering all participants as a single group. Pearson's correlation was performed to examine the associations between JKOM score (pain and stiffness, physical function, and total score) and the knee adduction moment impulse in all periods of stance duration. A step-wise linear regression was performed with pain and stiffness scores, physical function scores, and gait speed as the dependent variables. Independent variables included age, the severity of radiographic OA (K/L grade), BMI and the knee adduction moment impulse in the stance duration. When the physical function score was used as the dependent variable, the pain and stiffness score and gait speed were used as the independent variable. The stepping-method criteria were an F value of ≥ 0.05 for inclusion in the segmental model and ≤ 0.10 for removal from the model.

3. Results

3-1. Baseline characteristics

The mild knee OA group consisted of 20 subjects (3 subjects with K/L grade 1, 17 subjects with K/L grade 2), of which 14 subjects had bilateral knee OA and the left limb was studied in 9 subjects. The moderate knee OA group consisted of 18 subjects with K/L grade 3, of which 14 subjects had bilateral knee OA and the left limb was studied in 9 subjects. The characteristics of the groups are presented in **Table 1**. There were significant differences among the groups with respect to age. The subjects in the moderate knee OA group were older than those in the mild knee OA group ($p < 0.0001$), and the weight, height, and BMI were similar among subjects in both groups.

3-2. Pain and stiffness, physical function, and total JKOM scores

The moderate knee OA group had higher pain and stiffness, physical function, and total JKOM scores than did the mild knee OA group (p = 0.001, 0.001, < 0.0001) (**Table 1**).

3-3. Gait spatio-temporal parameters

No differences in gait speed, step length, stance duration, and single limb support duration were observed between the 2 groups (**Table 1**).

3-4. Knee adduction moment impulses

The knee adduction moment impulses in the stance duration, initial double stance interval, and single limb support interval were higher in the moderate knee OA (p = 0.001, 0.033, 0.001) (**Table 2**). The knee adduction moment impulse in the second double stance interval was not found to be different between the 2 groups (**Table 2**).

3-5. Relationship between JKOM score (pain and stiffness, physical function, and total score) and the knee adduction moment impulse in all periods of stance duration

Pearson's correlation analysis revealed a significant positive correlation between JKOM scores (pain and stiffness, physical function, and total score) and knee adduction moment impulses in the stance duration, initial double stance interval, and single limb support interval (**Table 3**).

The results of the step-wise linear regression analysis are presented in **Table 4**. With regard to the pain and stiffness score, only the knee adduction moment impulse in the stance duration (β = 0.48, $p = 0.002$) exhibited explanatory power in the model (F = 10.74, adjusted $R^2 = 0.23$, $p = 0.002$), and for the physical function score, the pain and stiffness score (β = 0.67, $p < 0.0001$) and gait speed (β = –0.37, $p < 0.0001$) exhibited explanatory power (F = 50.23, adjusted $R^2 = 0.74$, $p < 0.0001$). With regard to gait speed, age (β = –0.45, $p = 0.004$) and the knee adduction moment impulse during gait (β = –0.30, $p = 0.049$) exhibited explanatory power (F = 11.94, adjusted $R^2 = 0.37$, $p < 0.0001$).

4. Discussion

This study examined the relationship between knee adduction moment impulses and self-reports of pain and the degree of disability in Japanese women with knee OA. The study design and analyses had several unique characteristics. First, all participants in this study were women. Yoshimura et al. (2009) reported that the risk of knee OA was significantly higher in women in Japan (odds ratio: 3.4, 95% confidence interval: 2.79–4.06; p < 0.001), and the prevalence of knee OA was significantly higher in women than in men over 40 years of age (men: 42.6%; women: 62.4%). McKean et al. (2007) reported the existence of gender differences with regard to kinetic data of the frontal plane of the knee in patients with knee OA. Debi et al. (2009) reported that spatio-temporal differences between genders may be responsible for the variations in the gait strategies adopted by men and women. It is important to clarify the gender differences in gait characteristics in order to explain the higher incidence of knee OA in females. Additionally, it is possible that hormonal activity affects muscle strength and composition measurements in women. Therefore, we enrolled only women in this study. Secondly, instead of peak knee adduction moment, we measured the knee adduction moment impulse, which incorporates both the knee adduction moment magnitude and duration into a single variable. Both the load and loading time are important variables that have an effect on the articular surface of the knee. It is believed that knee OA progresses more rapidly with an increase in load (Andriacchi, et al., 2004). Load-bearing studies have revealed that the effect of the time integral of load on the articular surface is as important as that the effect of the load magnitude itself (Nuki and Salter, 2007).

Participants in the moderate knee OA group had larger knee adduction moment impulses in the stance duration, initial double stance interval, and single limb support interval. Further peak knee adduction moment has been reported to be significantly higher in patients with more severe OA than in those with less severe knee OA (Sharma, et al., 1998; Mundermann, et al., 2004; 2005). Thorp et al. (2006) evaluated the adduction moment impulse in the stance phase in 117 patients with radiographic knee OA and found that the adduction moment impulse differed between subjects with moderate knee OA and those with mild knee OA; our results were consistent with these findings. The differences between mild and moderate symptomatic radiographic knee OA are not only structural but also functional due to the load magnitude at the medial knee joint.

Surprisingly, the knee adduction moment impulse in the second double stance interval was not found to be different between the 2 groups. This is in contrast to findings reported by Thorp et al. (2006) who found that the knee adduction moment impulse during terminal stance may be an important gait parameter. There are a few potential explanations for our findings. Participants in the moderate knee group have adopted altered gait pattern that reduce the knee adduction moment. These include toeing out (Guo, et al., 2007), walking more slowly (Mundermann, et al., 2004), walking with increased medial-lateral trunk sway (Mundermann, et al., 2008). In this study, we had not examined in the altered gait pattern. Clearly, more research is needed to test a relationship the altered gait pattern and the knee adduction moment impulse during terminal stance.

There are conflicting reports on the relationships between knee adduction moment during gait and clinical symptoms such as pain and disability. Thorp et al. (2007) observed a positive association between knee pain and the magnitude of external knee adduction moments in subjects with symptomatic radiographic knee OA (K/L grade 2). Another study observed a strong significant correlation between single limb stance knee adduction moment and the pain, function, and total WOMAC scores in subjects with symptomatic radiographic knee OA (Kim, et al., 2004). On the contrary, a negative linear association between knee adduction moment and knee pain would indicate the possibility that subjects experiencing knee pain adopt a compensatory gait pattern to reduce knee adduction moment and thereby reduce medial tibiofemoral load (Mundermann, et al., 2004). A reduced gait speed and a toe-out gait pattern influence knee adduction moment variability (Guo, et al., 2007; Mundermann, et al., 2004). In the present study, positive correlations were found between the knee adduction moment impulses in all periods of stance duration and the JKOM score (pain and stiffness, physical function, and total score). Our results were consistent with the results of Kim et al. (2004) and Thorp et al. (2007).

The knee adduction moment may relate strongly to pain and physical disability, but the relationship is a matter of debate. Maly et al. (2006) suggested that pain was not related to the knee adduction moment, and therefore studies on the influence of pain on the adduction moment, performance, or disability were not carried out. In contrast, the results of the step-wise linear regression analysis in the present study indicated that the knee adduction moment impulse in the stance duration was related to self-reported pain and stiffness in the knee. Increased medial tibiofemoral load during weight-bearing activities such as walking may result in pain due to intraosseous pressure, effusion, and ischemia (O'Reilly, et al., 1998). Local mechanical stress at the articular surface is a risk factor for the development of incidental knee pain or symptomatic knee OA (Segal, et al., 2009). In addition, the present study has identified that the intensity of self-reported pain and stiffness in the knee (positive effect) and gait speed (negative effect) were factors that were related to self-reported physical disability in daily life, and that age (negative effect) and the knee adduction moment impulse during stance duration (negative effect) were factors that were related to gait speed. The knee adduction moment impulse during the stance duration was not found to directly affect physical disability in this study. Nevertheless, our results raised the possibility that intense pain and stiffness in the knee and gait speed mediated the relationship between medial loading and physical disability. Taken together, these results suggest that the knee adduction moment impulse, a proxy for loading on the medial compartment of the knee, would induce pain during weight-bearing activities such as walking, thereby limiting walking performance and leading to disability by reducing gait velocity. The discrepancy between the results of our study and that of Maly et al. (2006) can be attributed to the fact that the number of participants with moderate or severe knee OA was higher in our study. Further, our study included only women, but their study included both men and women. We measured the knee adduction moment impulse in the stance duration, but they had measured the peak knee adduction moment during gait. Finally, differences in the constitutional and mechanical risk factors for knee OA between the Western and Oriental populations may also be responsible.

There are some limitations to the present study. First, this cross-sectional study showed that the knee adduction moment impulse in the stance duration is a factor that is related to the clinical features of knee OA, but we were unable to identify the causative factor of pain and physical disability. Further longitudinal studies are needed to determine the pathomechanical factors underlying the clinical features of knee OA. Second, some participants had bilateral disease, and this may have influenced the gait characteristics observed and their JKOM score. Third, factors related to pain and physical disability have been reported in many studies. All factors related to pain and physical disability were not used as independent factors in this study. For instance, knee instability was a limiting factor in the ability to perform functional tasks (Fitzgerald, et al., 2004). Further studies are required to determine the effects of factors that were not analyzed in this study. In addition, the cross-sectional design of this study is a limitation.

Nevertheless, we believe that the findings of this study point to the importance of developing certain types of therapeutic exercises for knee OA. The exercise regimens currently used for treating knee OA focus on pain reduction and muscle strengthening, but this study highlights the importance of treatments aimed at gait modification exercise to reduce the knee adduction moment impulse during gait. The reduction in the knee adduction moment impulse during gait may result in pain relief and improve walking ability and reduce physical disability, and may thus serve as a conservative treatment options with disease-modifying potential.

5. Conclusion.

We found that the knee adduction moment impulse in the stance duration was related to pain and stiffness and gait velocity and was not related to physical disability, although self-reported pain and stiffness were related to physical disability. Our results suggest that the knee adduction moment impulse, a proxy for loading on the medial compartment of the knee, would induce pain during weight-bearing activities such as walking, thereby limiting walking performance and contributing to disability by reducing gait velocity.

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Appendix.

The content of Condition in daily life in the Japanese Knee Osteoarthritis Measure (JKOM)

Condition in daily life

Here are a couple of questions regarding your ability to perform daily routines during the last few days. Choose one answer and mark an X in the box next to it. [Options: Not at all, a little, moderately, quite, extremely]

1. How difficult is ascending or descending stairs?
2. How difficult is bending to the floor or standing up?
3. How difficult is standing up from sitting on a western style toilet?
4. How difficult is wearing pants, skirts, and underwear?
5. How difficult is putting on socks?
6. How long can you walk on a flat surface without taking a rest? [More than 30 min, about 15 min, around my house, can hardly walk]
7. Have you been using a walking stick (cane) recently? [Not at all, hardly, sometimes, often, always]
8. How difficult is shopping for daily necessities? [Not at all, a little, moderately, quite, extremely]
9. How difficult is doing light housework (cleaning the dining room after eating, etc.)? [Not at all, a little, moderately, quite, extremely]
10. How difficult is doing heavy housework (using the vacuum cleaner, etc.)? [Not at all, a little, moderately, quite, extremely]

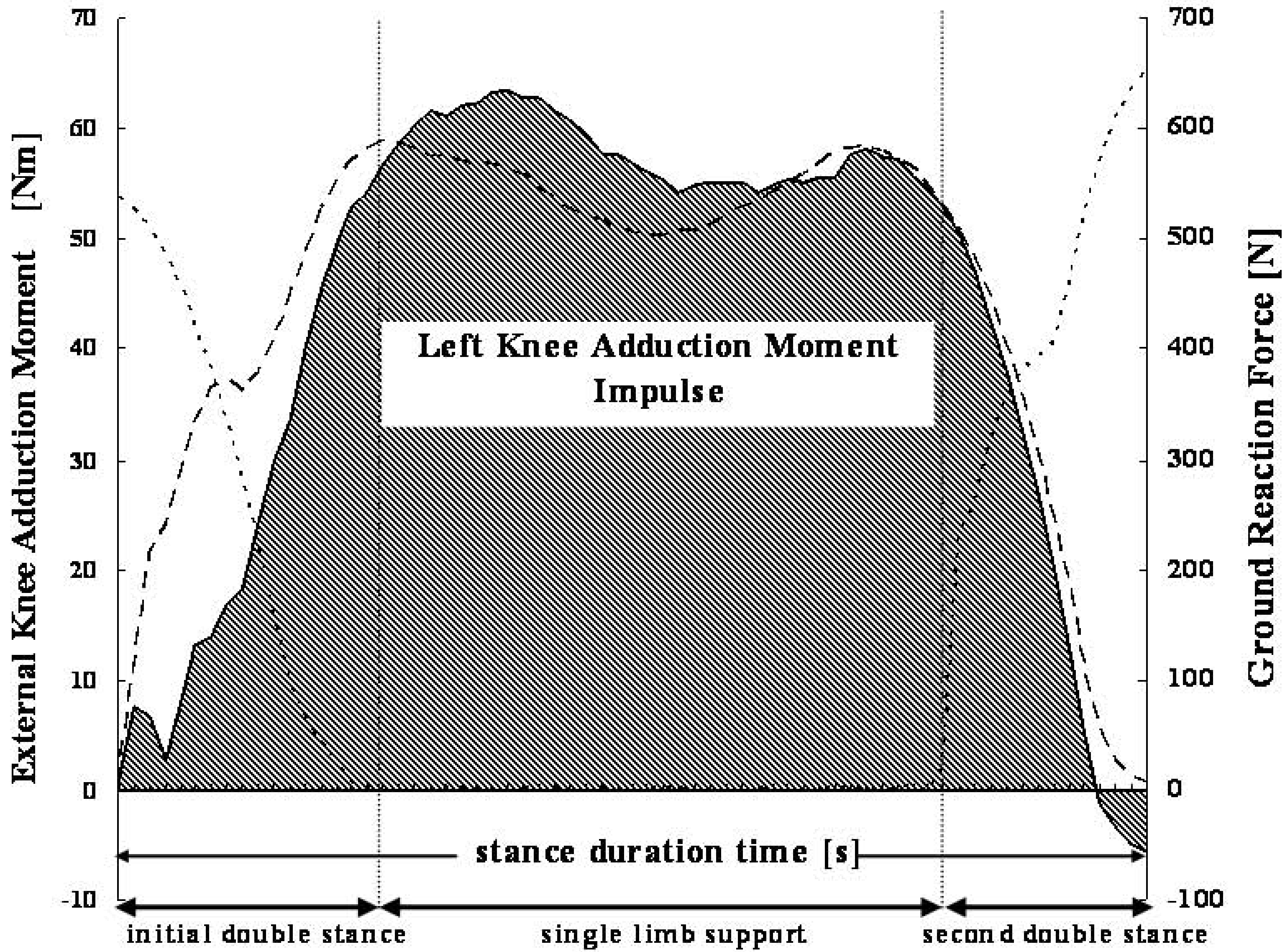

Fig. 1. Graphic representation of a Left knee adduction moment from initial contact to toe off. Stance duration was divided into initial double stance interval, single limb support interval, and second double stance interval on the basis of the ground reaction force. The solid line corresponds to the Left knee adduction moment. Left knee adduction moment impulse is represented by the shaded area. The dashed line corresponds to Left lower limb ground reaction force, while Right lower limb ground reaction force is indicated by the dotted line.

Table 1

Characteristics of the mild knee OA group and the moderate knee OA group

variable	mild knee OA group (n = 20)	moderate knee OA group (n = 18)	t-value	*p*-value	Mean difference (95% CI *)	Power
Age (years) †	61.90 (8.11)	71.33 (6.79)	3.87	< 0.0001	9.43 (4.48 ~ 14.38)	0.96
Height (m)	1.49 (0.05)	1.48 (0.07)	0.29	0.771	0.0059 (–0.03 ~ 0.05)	0.06
Weight (kg)	56.62 (5.51)	59.14 (8.34)	1.11	0.275	2.52 (–7.13 ~ 2.09)	0.19
BMI (kg / m^2)	25.37 (2.47)	26.74 (2.61)	1.66	0.105	1.37 (–3.04 ~ 0.3)	0.37
Japanese Knee Osteoarthritis Measure: JKOM						
Total †	46.15 (7.76)	63.00 (15.88)	4.22	< 0.0001	16.85 (8.76 ~ 24.94)	0.98
Pain, stiffness †	16.95 (3.38)	22.56 (5.83)	3.67	0.001	5.61 (2.51 ~ 8.7)	0.95
physical function †	16.75 (4.08)	23.61 (6.78)	3.83	0.001	6.86 (3.23 ~ 10.5)	0.96
Gait spatio-temporal parameters						
Gait velocity (m/s)	1.04 (0.15)	0.95 (0.17)	1.77	0.086	0.09 (–0.03 ~ 0.19)	0.41
Step length (%BH)	0.49 (0.06)	0.47 (0.06)	1.16	0.255	0.02 (–0.02 ~ 0.06)	0.2
Stance time (s)	0.61 (0.05)	0.64 (0.08)	1.39	0.173	0.03 (–0.07 ~ 0.01)	0.27
Single support time (s)	0.36 (0.04)	0.38 (0.04)	1.28	0.21	0.02 (–0.04 ~ 0.009)	0.24

Value: mean (Standard deviation: SD)

*: confidence interval

†: significant difference ($p < 0.05$)

Table 2

The knee adduction moment impulses in stance duration, initial and second double stance interval, and single limb support interval (the mild knee OA group vs the moderate knee OA group)

Knee adduction moment impulse (Nm・S / kg)	**mild knee OA group (n = 20)**	**moderate knee OA group (n = 18)**	**F-value**	***p*-value**	**Power**
Stance duration *	0.31 (0.06)	0.41 (0.09)	12.54	0.001	0.93
Initial double stance interval *	0.04 (0.01)	0.06 (0.02)	4.94	0.033	0.58
Single limb support interval *	0.24 (0.04)	0.31 (0.07)	13.22	0.001	0.94
Second double stance interval	0.04 (0.02)	0.04 (0.02)	0.003	0.958	0.05

Values: mean (Standard deviation: SD)

*: significant difference ($p < 0.05$)

Table 3

Pearson's correlation analyses between the JKOM score (pain and stiffness, physical function, and total score) and the knee adduction moment impulses (stance duration, initial double stance interval, and single limb support interval).

	knee adduction moment impulses		
	stance duration	**initial double stance interval**	**single limb support interval**
JKOM * Total score	0.54 (0.27 ~ 0.73, 0.001) †	0.54 (0.27 ~ 0.73, < 0.0001) †	0.47 (0.18 ~ 0.69, 0.003)†
Pain and stiffness score	0.46 (0.17 ~ 0.68, 0.004) †	0.53 (0.25 ~ 0.73, 0.001)†	0.40 (0.09 ~ 0.64, 0.012)†
physical function score	0.53 (0.25 ~ 0.73, 0.001)†	0.57 (0.31 ~ 0.73, < 0.0001)†	0.45 (0.15 ~ 0.67, 0.005)†

Value: Pearson correlation coefficients (95% confidence interval, *p*-value)

*: Japanese Knee Osteoarthritis Measure: JKOM

†: correlation is significant ($p < 0.05$).

Table 4

Models of “pain and stiffness” score, physical function score, and gait speed (m / s) by the forward stepwise regression analysis (n = 38)

Dependent variable	**Independent variable**	**Unstandardized Coefficient (95% IC)**	**Standardized coefficient**	***p*-value**	**Adjusted R^2**
pain and stiffness score [*]	Knee adduction moment impulse in stance duration (Nm・s / kg)	29.09 (11.10 ~ 47.10)	0.48	0.002	0.23
Physical function score [*]	pain and stiffness scores [a]	0.80 (0.58 ~ 1.02)	0.67	< 0.001	0.62
	Gait speed (m / s)	–15.04 (–22.41 ~ –0.77)	−0.37	< 0.001	0.74
Gait speed (m / s)	age	–0.008 (–0.013 ~ –0.003)	−0.45	0.004	0.34
	Knee adduction moment impulse in stance duration (Nm・s / kg)	–0.53 (–1.058 ~ –0.003)	−0.30	0.049	0.41

*: subscale of the Japanese Knee Osteoarthritis Measure: JKOM