Key Determinants of Knee Adduction Moment in Patients with Knee Osteoarthritis During Gait

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Disclosures: T.N. is the founder and shareholder of iMU, Co., Ltd. (Tokyo, Japan). T.N., K.H are patent holders for the processing device, program, method, and processing system.

INTRODUCTION: The knee adduction moment (KAM) reflects the mechanical load on the medial compartment of the knee during gait and serves as a biomechanical and clinical digital marker of knee osteoarthritis (KOA)[1]. However, conventional KAM measurement requires motion capture systems, which are time-consuming and equipment-intensive, limiting their clinical utility. To address this, we previously demonstrated the reproducibility and accuracy of a wearable system (iMUone) that estimates KAM using a single accelerometer and artificial intelligence.[2] In this study, we utilized the iMUone system to analyze gait in KOA patients undergoing treatment at affiliated medical facilities, aiming to identify key factors associated with KAM. Estimated KAM values obtained from the wearable device are referred to as iKAM.

METHODS: A total of 194 patients (133 females, 61 males; mean age: 72 ± 7.18 years) diagnosed with medial knee osteoarthritis and scheduled for surgery at Keiyu Orthopaedic Hospital were included. Patients with comorbid lumbar spine or hip disorders or with severe deformities causing gait difficulty were excluded. An accelerometer was attached to the tibial tuberosity, and gait was measured three times over a 5-meter walkway at a self-selected comfortable speed using the iMUone wearable system.The following background variables were collected: sex, age, height, weight; radiographic measurements (KL grade, FTA, LDFA, mMPTA); gait parameters (gait speed, stance time); pain scores (JKOM, pain at rest, during walking, and during knee flexion); and range of motion (extension and flexion on the affected side). Normality was assessed, and logarithmic transformation was applied where necessary. Correlation analyses were performed for all variables. Stepwise multiple regression analyses were conducted with either KAM impulse or peak KAM as the dependent variable and the background factors as independent variables.

RESULTS SECTION: A strong negative correlation was observed between gait speed and stance time. Strong positive correlations were found between height and weight, and between LDFA and FTA. Moderate positive correlations were observed between KL grade and FTA, pain during walking and pain during knee flexion, LDFA and knee extension range of motion (ROM), as well as between total JKOM score and walking pain.
In the multiple regression analysis with peak iKAM as the dependent variable, the model showed R = 0.771, adjusted R^2 = 0.584, and a significant F change (p = 0.013). For the model with iKAM impulse as the dependent variable, R = 0.725, adjusted R^2 = 0.513, and a significant F change (p = 0.019) were observed.The significant predictors of peak iKAM, in descending order of influence, were: body weight, stance time, gait speed, knee extension ROM, and height. For iKAM impulse, the predictors were: stance time, body weight, gait speed, FTA, and height.The relative contribution of each explanatory factor was as follows: in the peak iKAM model — gait-related factors contributed 28%, height and weight 24%, and knee extension ROM 6%. In the iKAM impulse model — gait-related factors contributed 25%, height and weight 20%, and lower limb alignment (FTA) 6%.

DISCUSSION: This study identified body weight, gait speed, and stance time as key determinants of knee KAM in 194 patients with knee osteoarthritis. These findings align with prior evidence that slower gait speed reduces KAM and faster gait shortens stance time, both influencing medial knee loading. Multivariate analysis showed that anthropometric and gait parameters mainly affected peak iKAM and iKAM impulse. Additionally, varus alignment (FTA) was associated with increased peak iKAM, while limited knee extension correlated with higher iKAM impulse, highlighting the importance of addressing alignment and joint mobility. Although regression models demonstrated adequate explanatory power, some variance remains due to factors not measured in this study. Although previous studies have suggested associations between KAM and pain, no significant correlation with pain was observed in our analysis. This discrepancy might be explained by several limitations, including non-simultaneous timing of pain assessment and gait measurement, and the lack of standardized analgesic use due to the observational study design.Wearable inertial measurement units enabled practical, dynamic KAM assessment, supporting real-time personalized interventions. Given the advanced disease stage of most participants, further research including early and moderate KOA cases is necessary to validate these findings and the clinical utility of KAM as a biomechanical marker.

SIGNIFICANCE/CLINICAL RELEVANCE: (1-2 sentences): Identifying the primary contributors to knee adduction moment (KAM) during gait in patients with knee osteoarthritis using wearable devices is essential for incorporating dynamic factors into clinical assessment and intervention. This study demonstrates that body weight and stance time are key modifiable factors influencing KAM, supporting clinical strategies to reduce joint loading and potentially slow disease progression.

REFERENCES: Include references here. (References are Optional)

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2. Akiba A, Harato K, Yoshihara H, Iwama Y, Nishizawa K, Nagura T, et al. Development of a wearable system to estimate knee adduction moment of patients with knee osteoarthritis during gait using a single inertial measurement unit. J Joint Surg Res. 2025;12(2):e100058.

ACKNOWLEDGEMENTS: We thank all the patients who participated in this study and the clinical staff, Azusa Miyamoto at Keiyu Orthopedics Hospital for their support during data collection.

IMAGES AND TABLES:

Table 1

Measure unit		Mean (standard deviation)
iKAM_impulse	N-m-s	9.076 ± 0.238
Peak_iKAM	N-m-s	26.909 ± 0.538
SEX		F133/M61
KL		KL 1/2/3/4 : 6/38/91/59
age	y.o	72.01 ± 0.52
hight	cm	155.93 ± 0.59
waight	kg	63.61 ± 0.77
BMI	kg/m²	26.09 ± 0.24
FTA	°	182.95 ± 0.42
LDFA	°	82.91 ± 0.15
mMPTA	°	83.45 ± 0.20
gait_speed	m/s	0.95 ± 0.01
stance_time	sec	0.67 ± 0.01
JKOM(total)	(25-125)	49.91 ± 1.10
pain(rest)	(VAS:0-10)	2.05 ± 0.17
pain(walk)	(VAS:0-10)	5.26 ± 0.18
pain(flex)	(VAS:0-10)	4.70 ± 0.20
ROM(flex)	°	119.12 ± 0.99
ROM(extend)	°	-7.38 ± 0.41

Table 2

2a

explanatory variable	coefficient	standardization coefficient β	significant probability
constant	-2.157		<0.001
weight	0.919	0.550	<0.001
stance time	0.668	0.452	<0.001
gait speed	0.694	0.351	<0.001
ROM extension	0.168	0.155	0.002
height	0.827	0.154	0.013

R	0.771
adjusted R-squared	0.584

2b

explanatory variable	coefficient	standardization coefficient β	significant probability
constant	-8.214		<0.001
stance time	0.978	0.521	<0.001
weight	1.009	0.475	<0.001
gait speed	0.674	0.268	0.003
FTA	2.289	0.204	<0.001
height	1.070	0.157	0.019

R	0.725
adjusted R-squared	0.513

Fig 1

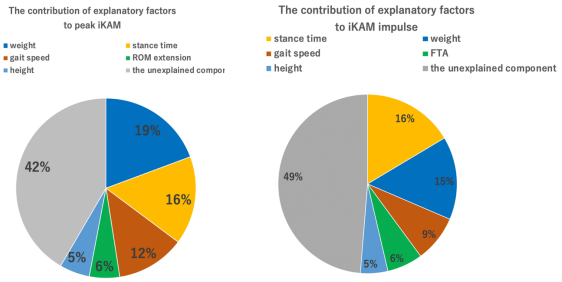

Table 1. Baseline demographic and clinical characteristics of the participants (n = 194). Values are expressed as mean ± standard deviation(SD). SEX: Female 133, Male 61. KL: Grade distribution according to the KL grade (KL 1/2/3/4 = 6/38/91/59). iKAM_impulse / peak_iKAM: Estimated knee adduction moment values obtained from a wearable device. BMI: Body Mass Index. FTA: Femorotibial angle. LDFA: Lateral distal femoral angle. mMPTA: Mechanical medial proximal tibial angle. JKOM: Total score of the Japanese Knee Osteoarthritis Measure (JKOM). pain: Self-reported pain evaluation using the Visual Analog Scale (VAS) at rest, during walking, and during flexion. ROM: Range of motion (flex: flexion, extend: extension).

Table 2. Multiple Regression Analysis Results 2a: Results with peak_iKAM as the dependent variable. This table presents the results of the multiple regression analysis, highlighting the significant explanatory variables when Peak_iKAM is used as the dependent variable. The coefficients, standard errors, and p-values for each significant variable are shown.
2b: Results with iKAM_impulse as the dependent variable. This table presents the results of the multiple regression analysis, highlighting the significant explanatory variables when iKAM_impulse is used as the dependent variable. The coefficients, standard errors, and p-values for each significant variable are shown.

Figure 1. Distribution of the explanatory contribution of each factor to iKAM, based on the adjusted coefficient of determination in the multiple regression model.
3a: factor to peak_iKAM Gait-related factors (gait speed and stance time) accounted for 28%, body constitution (weight and height) for 24%, and range of motion (knee extension limitation) for 6% of the explained variance. 3b: factor to iKAM impulse Gait-related factors (gait speed and stance time) accounted for 25%, body constitution (weight and height) for 20%, and lower limb alignment (FTA) for 6% of the explained variance.