2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

# Novel load indicator for knee osteoarthritis during gait movement

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***Abstract*— Gait analysis using a musculoskeletal model was conducted with 3,000 cases of open-gait database. We propose a product of knee joint reaction force and angular velocity of knee joint as a knee load index (KLI) during gait movement. Greater KLI values were observed with subjects of bended knee joint.**

***Clinical Relevance*— A mechanical factor for estimation of developing osteoarthritis of the knee was proposed based on numerical analysis using a musculoskeletal model.**

## I. INTRODUCTION

Osteoarthritis of the knee (knee OA) is a major locomotive disorder causing physical inactivity which is a common determinant of adult mortality from non-communicable diseases [1]. Mechanical factors around joints are strongly related to the development of osteoarthritis. In particular, shear stress of the cartilage on the stiffer subchondral bone is believed as a cause of cartilage failures [2]. Although detailed mechanisms of damaging cartilages are not clearly understood yet, knee loads combined compression and shear can be assumed as a key factor of developing knee OA [3]. This study presents a hypothetical factor of knee loads based on a numerical analysis using a musculoskeletal model.

## II. METHODS

A total of 3,000 gait data were obtained from 300 subjects in an opened gait database [4]. A musculoskeletal model and biomechanical multibody dynamics software, OpenSim ver.4.1 [5] were applied to biomechanical analysis such as scaling body dimensions, inverse kinematics, inverse dynamics, and muscle force estimations. Dynamic knee loads were expressed on the local coordinate system of the bones. Since mechanical cause of cartilage damages can be assumed as effects of compression and shear stress around knee joint cartilage [2, 3], we assumed a knee load index (KLI) as an indicator of mechanical damage on cartilage tissues. To avoid body weight effects, the KLI were expressed as follows:

$$\text{normalized } KLI(t) = \left| \left(F_y(t)/W\right) * \left|\omega_k(t)\right| * \Delta t \right|, \quad (1)$$

where $F_y$ is an axial reaction force on the tibia, $W$ is body weight, $\omega_k$ is an angular velocity of knee joint, and $\Delta t$ is a time step, respectively. This study conducted a survey of relationship among the KLI, joint angle, and muscle forces normalized by body weight with bended (AIST0054) and stretched (AIST0068) knee joint angle subjects during the gait movement.

*Research supported by KYOCERA Corporation.

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## III. RESULTS

Peak values of joint reaction force normalized by the body weight on the knee were observed in the begging of the gait cycle. The first force peak $f_1$ in Fig. 1 was appeared by the effect of ground reaction force, and the second one $f_2$ was generated by muscular contraction force of quadriceps. In particular, the normalized KLI indicated higher value during knee joint movement with greater joint reaction force. However, zero angular velocity of knee joint with great joint reaction force at such time of $t_3$ did not develop any KLI value.

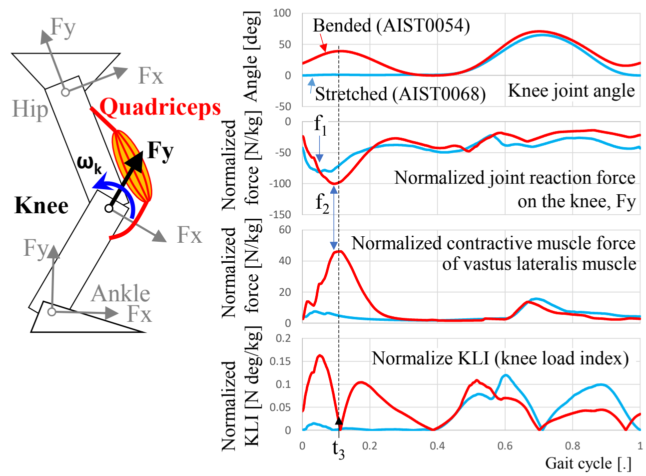


Figure 1. Knee joint angle, normalized joint reaction force, and normalized contractive force of vastus lateralis muscle, and normalized knee load indicator (KLI) by the subject body weight of bended (AIST0054) and stretched (AIST0068) knee joinst angle subjects during a single gait cycle.

## IV. DISCUSSION & CONCLUSION

This study shows that various gait movement may generate wide range joint reaction forces and the KLI values. Even though all gait data utilized in this study were obtained from healthy human subjects, relationships between body kinematics and joint knee load data may provide us mechanisms of knee OA development during gait movement.

## ACKNOWLEDGMENT

The authors thank Dr. Edwardo A.Y. Murakami and Mr. Takashi Nagatomo of Kyocera Corporation for their kind assistance with this research.

## REFERENCES

[1] M. Ishijima, et al., *Clinic Rev BoneMiner Metab*, 2016, 14:77-104.
[2] J. M. Mansour, "Biomechanics of cartilage," in Kinesiology: the mechanics and pathomechanics of human movement, 2003, pp.69-83.
[3] K. S. Halonen, et al., J Biomechanical Eng. 138(7), 2016
[4] Y. Kobayashi, et al., AIST Gait Database 2019.
[5] A. Seth et al., *Plos Comput. Biol.*, 14(7), 2018, Art. no. 1006223.