Prediction of Knee Osteoarthritis by Simple Gait Recognition Using a Depth Camera and Machine Learning

Ken Kadoya[1], Kentaro Homan, Masatoshi Miyake, Kengo Ukishiro[2], Ryosuke Fukami, Yoshito Nejime, Yasumitsu Ohkoshi[2], Norimasa Iwasaki[3]
[1]Hokkaido Univ School of Med, [2]Hakodate Orthopedic Clinic, [3]Hokkaido University School of Medicine

INTRODUCTION: Gait is whole-body movement potentially reflecting various disease conditions including knee osteoarthritis (KOA). Due to recent advancements of technology, a depth camera can capture whole-body movement during gait, and numerous gait-related features can be calculated. Further, machine learning can make algorithms to predict a certain condition from numerous features accurately. Thus, we hypothesized that KOA might be predicted by the comprehensive analysis of whole-body movement during gait with machine learning.

METHODS: Ninety-one patients consisting of early- to late-stage KOA and 15 healthy subjects walked for 5 meters underneath the camera, which identified 3-dimensional positional information of 25 joint points in a subject (Fig.1). Based on the 300 segments determined by two joint points, 2,700 features were generated (300 segments × 3 axes × 3 statistics). By 4 statistical analysis, 4 sets of the top 20 features related to KOA were selected, and they were applied on 20 kinds of machine learning, resulting in the generation of 80 algorithms. For validation of the algorithms, the leave-one-out cross validation method was used. Algorithm performance was evaluated by area under the curve of receiver operating characteristics (AUC of ROC), Matthew's correlation coefficient (MCC), and accuracy. Lastly, to address the issue caused by imbalanced data of KOA and control subjects, an additional analysis was performed with 78 new control data artificially generated by the synthetic minority oversampling technique (SMOTE).

RESULTS: The top 20 features related to KOA used the positional information of joint points in the upper extremities more than those in the lower extremities and trunk (Fig. 2), suggesting that movements in the upper extremities reflect the gait characteristics caused by KOA. The highest AUCs of ROC, MCC, and accuracy were 0.949 (0.745 ± 0.159, average ± standard deviation), 0.691 (0.423 ± 0.140), and 0.927 (0.875 ± 0.032) respectively (Fig.3). An additional analysis of balanced data with SMOTE increased all of them, especially MCC, the highest of which was 0.938 (0.802 ± 0.087), supporting the findings of the initial analysis.

DISCUSSION AND CONCLUSION: KOA could be predicted with high accuracy by an analysis of whole-body movement during gait with machine learning. The gait characteristics of KOA were detected not only in the lower extremities but also in the upper extremities, suggesting the importance of comprehensive analysis of whole-body movement during gait. These findings suggest that this method may contribute to the development of a novel prediction system for KOA as well as other diseases that affect gait function.

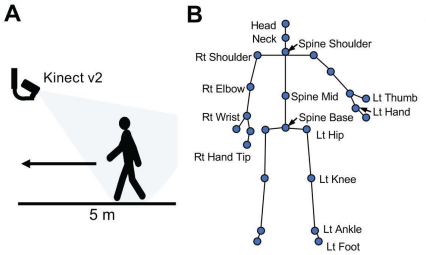

Figure 1: Gait recognition system by Kinect.
(**A**) Shema of the gait recognition system.
(**B**) Locations of Joint points generated by Kinect.

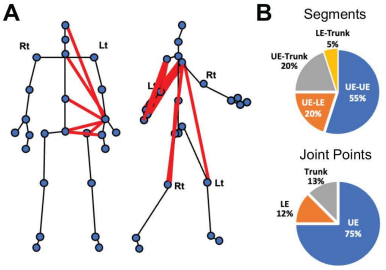

Figure 2: Representative example of the top 20 features of KOA.
(**A**) Identified KOA related segments were illustrated with red lines in frontal (Lt) and lateral (Rt) views.
(**B**) Anatomical locations of the selected segments and joint points. UE: upper extremity, LE: lower extremity.

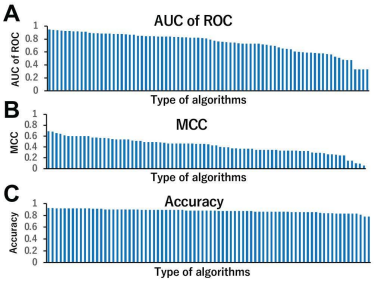

Figure 3: Performance of 80 algorithms
(**A**) AUC of ROC. Each bar represents each algorithm.
(**B**) MCC.
(**C**) Accuracy.