WEARABLE SENSOR AND MACHINE LEARNING ESTIMATION OF KNEE MOMENTS FOR HEALTHY PARTICIPANTS

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Introduction

A major problem following a total knee arthroplasty (TKA) is adaptation of asymmetric gait patterns, which results in higher loads on the non-operated knee often leading to a second surgery [1]. Monitoring motion is crucial for recovery of the knee and helps improve alignment and load distribution. A major challenge is that gait kinetics cannot be accurately measured outside specialized laboratories [2], due to large estimation errors, altered natural gait [3,4] and the use of expensive cumbersome equipment. Thus, the need for a portable system to enable motion and force assessment in healthy and clinical subjects in natural environments. The purpose of this study is to develop a platform for kinetics estimation based on a fused inertial measurement unit (IMU) sensor network and machine-learning (ML) architecture.

Methods

Healthy participants were recruited for this study, with no history of musculoskeletal disorders or orthopedic surgeries or lower limb pain, and with the ability to walk without aids. Participants performed walking trials at a self-selected speed with eight fused IMU sensors (SageMotion, USA) strapped to them, and forty reflective markers placed on anatomical landmarks. Trajectories were tracked using an optical motion capture system (Qualisys, Sweden). Ground reaction force (GRF) was measured using synchronized embedded force plates (AMTI, USA). The inertial and optical motion capture were collected simultaneously and synced in time.

Knee biomechanical measures (knee flexion moment (KFM) and knee adduction moment (KAM, first and second peak) were calculated using gait analysis software (Visual3D, USA) via inverse dynamics. The ML model inputs were body parameters, GRF and distance from knee joint center to center of pressure, used to predict the KFM and KAM.

Results

Biomechanical measures were based on six healthy participants: four females and two males, age 29.00±2.37, mass 67.68±13.63 kg, height 1.68±0.09 m, BMI: 23.93±3.35 kg/m^2.

Results from the musculoskeletal modeling and direct cross product calculations ($\bar{r} X \overline{GRF}$), that were then used as inputs for the ML modeling, are presented in table 1.

Our preliminary best results show an average relative root-mean-square error of 0.119 for KFM and 0.135 for KAM (see figure 1).

Gait Characteristic	Inverse Dynamics	ML Input Data
	Mean±S.D	
Max. Peak of Knee Flexion Moment	0.27±0.10	0.25±0.10
1st Peak of Knee Adduction Moment	0.28±0.06	0.29±0.07
2nd Peak of Knee Adduction Moment	0.17±0.02	0.18±0.04

Table 1: comparison of average knee moment measures (units: Newton·meter/mass·height) of the right knee between musculoskeletal and ML models.

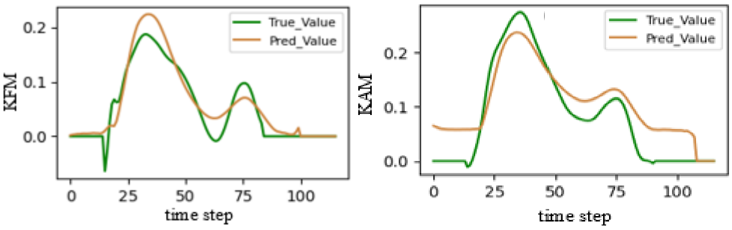

Figure 1: example subject graphs of calculated and predicted values of KFM (left) and KAM (right) of the right knee.

Data of more healthy participants and post-TKA patients (IRB approved, screening in process) is being collected and results will be presented at the conference.

Discussion

This study offers a wearable motion capture system for accurately assessing gait movement patterns and forces, based on a combined IMU-ML approach.

This system has the potential to increase the efficacy, accessibility, and reliability of correcting pathologies post-surgery. In addition, the current IMU network has built-in modules for haptic feedback which can be used in future studies.

References

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