DEVELOPMENT OF A 2-SEGMENT FOOT MODEL FOR KINEMATIC MEASUREMENT OF MEDICAL GAIT ANALYSIS.

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Introduction

Instrumented gait analysis using optical motion capturing (OMC) represents an essential tool in the prevention, diagnosis, and therapy of a wide range of medical conditions. The ankle and foot are represented by a three segments analysis (Oxford Foot Model (OFM)). However, gait analysis with OMC and OFM is time consuming and requires a large setup.

Inertial measurement units (IMU) could be a time efficient alternative with a good accuracy in the sagittal and moderate accuracy in the coronal and transfers planes [1, 2]. But the foot is only represented by one segment. This oversimplification of the foot does not allow a meaningful analysis for pathologies within the ankle and foot.

The aim of the study was therefore threefold:

1) Development of a 2-segement foot model
2) Assessing a norm data set
3) Evaluation of its reliability

Methods

The study was approved by the local ethics commission (#19-0177).

First, the existing model was amended by an additional IMU placed vertically onto the calcaneus (Fig. 1: 3). The position of the already existing IMUs (forefoot, shank, thigh, pelvis) remained unchanged (Fig. 1: 1, 2). This allowed the assessment of the three three major joint axis (Figure 1: A, B, C).

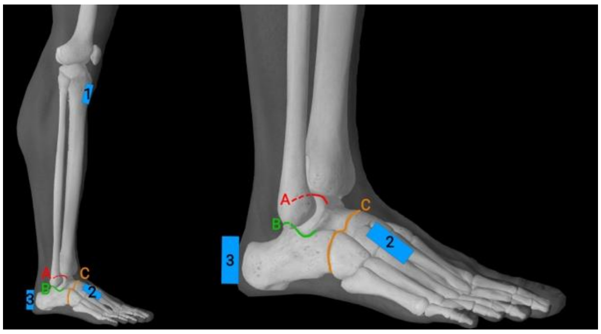

Figure 1: Illustration of the 2-segement foot model including the position of IMU on shank (1), forefoot (2) and hindfoot (3) as well as the three major joint axis: A) Ankle-, B) Subtalar-, C) Chopart-joint;

Second, a norm data set was established by measuring 20 healthy individuals without current or past injuries/pathologies within the foot or ankle.

Third, the intra-rater, inter-rater, and test-retest reliability was assessed on an additional 12 healthy subjects.

The assessment protocol for all subjects was identical. After the standardized application of the IMU sensors, a walking calibration was performed. Following a 2 min treadmill familiarization (4km/h), measurements were recorded for 30 seconds.

All subjects performed a total of 4 gait analysis: Day 1: One measurement by two independent observers; Day 2: Two measurements of each volunteer by one observer.

Data processing was performed in Matlab. Foot kinematics were calculated for tibia-forefoot, tibia-hindfoot, forefoot-hindfoot in sagital, frontal, and transverse planes. All data were averaged over 100% gait cycle for all subjects. Intra-rater, Inter-rater and test-retest reliability was tested with statistic parametric mapping (SPM).

Results

The positioning of the additional sensor has proven to be stable. Figure 2 shows the mean kinematic values for the reference population. The SPM showed no significant differences for inter-rater, intra-rater, test-retest reliability (p>0.05).

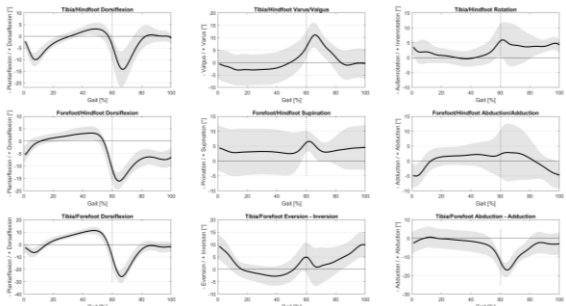

Figure 2: Kinematics of foot for sagittal, frontal, and transversal plane, mean (± 1 SD) values for 20 healthy subjects.

Discussion

The development of a 2-segment foot model seems a valuable extension to the current IMU setup. It allows to generate kinematic curves comparable to the OFM (with OMC) with a good intra-rater, inter-rater and test-retest reliability. A validation of the new model to the OMC is currently in progress. In the future, the IMU technology might proof a cost and time efficient method for a valid clinical gait analysis.

References

1. Park et al., Sensors (Basel), 2021. **21**(11).
2. Rekant et al., SSRN. 2022.