A NEW SYNERGY-BASED FOOT MODEL: DESCRIPTION OF ARCHES MOBILITY IN HEALTHY AND FLAT FEET DURING GAIT

Michele Conconi (1), Nicola Sancisi (1), Claudio Belvedere (2), Alberto Leardini (2)

1. Dept. of Industrial Engineering, University of Bologna, Italy; 2. Movement analysis Laboratory, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy

Introduction

Internal mobility of the foot in gait analysis is usually addressed by multi-segment foot models (MFMs) [1]. These did prove clinical applicability, though cannot show measures of motion within the segments. Also, several markers are needed. Using Principal Component Analysis, we recently showed that the foot joint mobility can be represented with only four modes, or synergies [2]. Differently from the concept of degrees-of-freedom (DOF) in ideal joints such as revolute or spherical pairs, each synergy implies all bone motion components, thus establishing the coupling among them. The aim of this work is to test a synergy-based approach to reconstruct the foot joint motion during gait. In particular, the variation of foot arches in healthy and flat feet were compared, resorting only to three markers on the tibia and three on the foot.

Methods

Gait data were collected for 3 healthy and 3 flat foot volunteers during level walking, using a state-of-the-art experimental protocol [3]. Reference synergies and bones, featuring virtual markers and anatomical reference systems [4], were scaled on each subject based on foot length. Bone motion was reconstructed through synergy-based multi-body kinematic optimization, tracking the shank (6 DOF) and the foot posture as the linear combination of 4 bone synergies (4 DOF) at once, resorting to 3 markers on the shank and 3 markers on the foot, namely CA, FMH, VMH as in [3]. The angles characterizing the 3 arches of the foot (Fig.1) were also measured. T-test ($p \leq 0.05$) identified differences between the two populations.

Results

Healthy feet showed considerable MLA and TA excursion, while arches were more open and less mobile in flat feet (Fig. 2). TA revealed almost the same capability to separate the two populations than the traditional MLA.

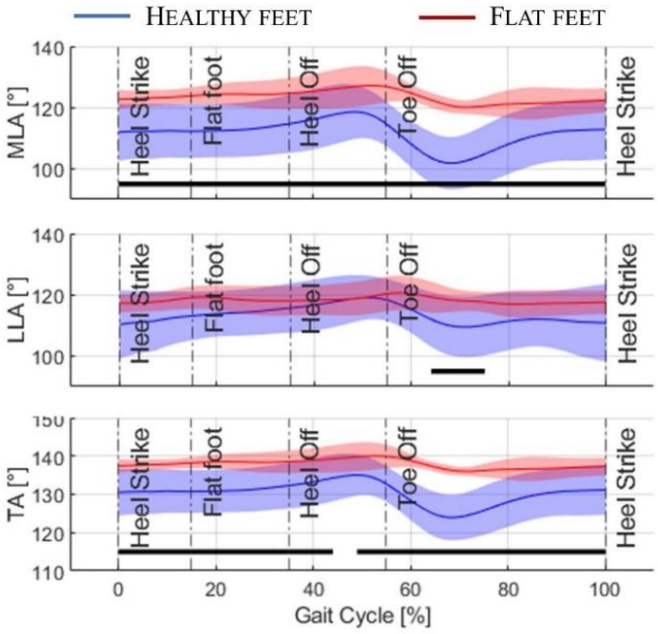

Figure 2: Time-history of arch angles during gait cycle. Black lines show statistically significant differences between healthy (blue) and flat (red) feet.

Discussion

The proposed synergy-based foot model worked successfully in the present initial clinical exploitation. With respect to standard MFMs, only three markers are needed on the foot, highly simplifying data collection and elaboration. Moreover, it allows the tracking of all bone motions, thus providing information about the complex foot behavior, such as the mobility of the longitudinal and transverse arches during walking.

References

1. Leardini et al, Gait&Post., 69:50-59, 2019.
2. Pompili et. al, ESB congress 2022.
3. Leardini et al., Gait&Post., 25, 453-462, 2007.
4. Conconi et al., J Foot Ankle Res, 20;14(1):66, 2021.

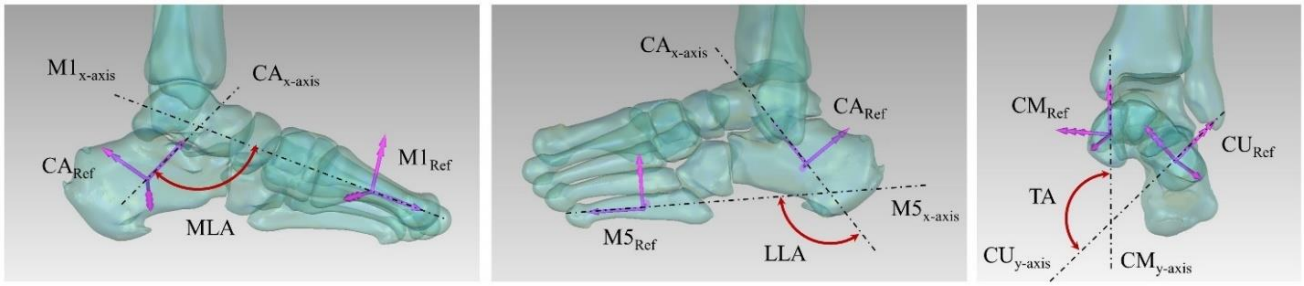

Figure 1: Definition of the medial longitudinal (MLA), lateral longitudinal (LLA), and transverse (TA) arch angles, all measured as the spatial angle between the axes of the reported bone anatomical reference systems. CA = calcaneus; M1 = first metatarsus; M5 = fifth metatarsus; CM = medial cuneiform; CU = cuboid.