MODELING OF THE FOOT-ANKLE SYSTEM IN NATURAL STANDING POSITION USING A FOUR DEGREE-OF-FREEDOM LUMPED PARAMETER MODEL

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Introduction

Models designed to simulate the body’s response to vibration exposure reduce participant exposure times and risk, and are an effective means of testing possible solutions to reduce occupational exposure. Foot-transmitted vibration (FTV) has traditionally been studied in the context of whole-body vibration, but recent literature suggests it warrants separate consideration. It is hoped that improved FTV predictive abilities can one day be used for interventions to reduce the incidence and severity of vibration induced white toes. This study aims to assess whether a three-segment model (two foot segments, one body segment) is capable of predicting the frequency response of the foot and ankle in three standing positions from 10-60Hz (i.e. occupational exposure frequencies).

Methods

The transmissibility responses at the ankle, midfoot, and toes [1, 2], (Goggins et al., 2018; Goggins et al., 2019), from FTV exposure between the frequencies of 10-60 Hz, were used as the reference functions. Three center of pressure (COP) positions were considered: forward, natural, backward. A planar lumped parameter (LP) model with 4 degrees-of-freedom (DOF), which idealized the foot-ankle-system as a truss structure supporting half of the total body mass (Figure 1), was used to replicate the dynamic behaviour [3] (Ji, Zhou and Zhang, 2013). For the full linearised dynamic model, refer to Goggins et al. [4] (Goggins et al., 2021).

Results

The natural COP and forward COP positions resulted in reasonable model results (Figure 2). Unfortunately, the model did not sufficiently capture the backward COP position transmissibility response, particularly the response at the ankle.
Discussion

While the current work represents a useful initial model of the vibration response, further refinements are needed to fully capture the foot’s behaviour under a variety of loading scenarios. These results suggest that properly modelling of the soft tissue of the hindfoot (i.e. the heel fat pad) needs to be a priority. Future LP models could also add segments for the toes, divide the midfoot and ankle into more components, and include segments for the lower limb. Additionally, components can be added to test the effects of various materials underneath the foot (insoles or boots) and determine what thickness, stiffness, and damping characteristics for these materials would be the most effective.

References


