VERIFICATION OF A PASSIVE ANKLE-FOOT ORTHOSIS DESIGN METHOD BY USING TRUSS MODELS

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Introduction

Passive ankle-foot orthoses (AFOs) are the most common treatment option for people suffering from foot drop. By holding the foot in a neutral position and thereby preventing its drop, a significant improvement of the patients' gait pattern and comfortable gait speed can be realised [1]. However, the effect is limited and a discrepancy remains compared to the gait of healthy people [2]. Thus, active AFOs driven by motorsand external power supply were developed, which allow for adjustability of the required ankle position. Their disadvantages, as high weight or difficult power supply, have inhibited their use in daily life so far [3]. Therefore, we develop a novel passive AFO that is equipped with supporting structures providing an adjustable assistance for patients. The main requirement for the new design is to provide an appropriate assistance for the patients' needs, i.e. to match the support required by the patient and transfer this support through the product to the patient. A popular tool for investigating the effects of orthoses and similar devices (referred to as wearable assistive devices) are digital human models, allowing to study the biomechanical outcomes of the assistance [4]. In this way, a conceptual method was developed that enables the design of the passive AFO's supporting structures in accordance with the pathological situation of the patients. This contribution aims to verify the method by using truss models of the passive AFO for different patients' conditions.

Material and Methods

The elaborated method enables the integration of finite element models in musculoskeletal human models (MHMs) to design the passive AFO. To save computing time, the design of an AFO was discretized for each patient with beam elements and subsequently the number of beams was minimized by means of topology optimization (see Figure 1). The musculoskeletal human models are created from motion capture recordings of subjects in a gait laboratory. By biomechanical analysis of the gait records, the kinematics and externally applied loads at the truss models during the gait cycle are determined. The resulting stresses and deformations are calculated with these boundary conditions in the truss models and the resulting reaction forces are then applied as external forces to the MHM Thereby, the biomechanical effects of the assistance with a truss model of the AFO can be simulated. By comparing the results, the verification of the method is realized. Therefore, the relation between the provided support to previously determined assistance-as-needed calculations [5] are examined.

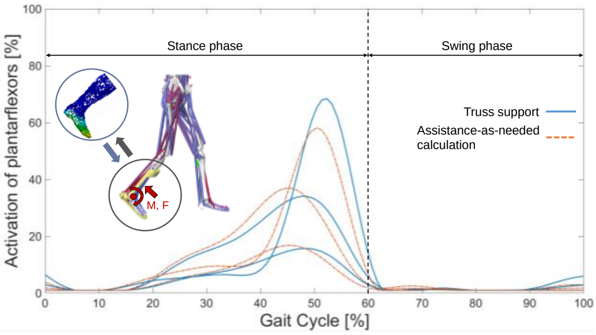

Figure 1: Simulation method for calculating the provided assistance by truss AFO models with resulting muscle activations compared to assistance-as-needed calculations

Results

The results of the truss support show an activation of the plantarflexor muscles from 20 - 60 % of the gait cycle, referred to as the stance phase and no activation after 60 % of the gait cycle, the swing phase (see Figure 1). The supporting forces and torque depict the majority of provided assistance in the stance phase of the gait cycle and a minor part in the swing phase of gait cycle.

Discussion

The good agreement of resulting biomechanical effects of the truss AFO model simulations (muscle activations and provided support torque) compared to data from previous assistance-as-needed calculations (Figure 1) verify the developed passive AFO design method. Thus, the functionality of the method for providing design suggestions and the possibility to depict the interaction between MHM and AFO is proven. In the next validation step, model order reduced finite element models of the AFO will be used to incorporate a more realistic behaviour of the AFO design in the simulation.

References

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