Development of a new approach with less mechanical restraint for measuring strength of toe plantar flexion at the distal part of foot

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Toes allow posture stability and propulsion of body in human gait. The strength of toe plantar flexion (STPF) correlates positively with walking speed and negatively with the occurrence of falling events. The alteration of STPF due to aging, foot deformity, foot disease, etc., is a well-studied phenomenon. It is therefore recommended to measure STPF regularly in order to prevent falling event. The conventional seated approach requires restraint of the lower limb. Since long toe flexors, such as the flexor hallucis longus and flexor digitorum longus attach beyond the ankle joint and the metatarsophalangeal joint (MTP joint), the contraction of the long toe flexors affects these joints. It is required for the experimenters to hold the foot in order not to rise the heel, and is also required for the participants a skillful movement such as to plantar flex the toes with the ankle joint at a right angle as well. In an effort to improve the STPF measurement conditions and promote its usage, we proposed a new approach featuring a custom-made device allowing "less restrained" measurements in standing by raising a leg.

Chapter 1.

The background is presented. The toe is defined as the anatomical segment going from the MTP joint to the most distal phalanges. The biomechanics and functional role of the toe are also discussed. Toe plantar flexion is caused by the contraction of flexor muscles and STPF is defined as the strength generated by toe plantar flexion at the MTP joint. We also introduced the measurement approaches used in previous studies. The purpose of this study is described, which is to develop a new approach to solve the problems in the seated approach, to design and manufacture a new device, and to evaluate them through participant experiments comparing the seated approach.

Chapter 2.

The new STPF measurement approach adopted in this study was explained. The original feature of our new STPF measurement approach lies in the fact that measurements can be carried out in less restrained conditions, with the distal end of the foot being unfixed. The specs of measurement device are described. The device was made of an a plate (acrylic resin) and straps. It is lightweight and easy-to-wear allowing the new approach for STPF measurement. In addition, an “analysis by finite element method” (CADENAS WEB2CAD Inc.) was used to determine the appropriate materials used to build the device. The properties of the materials, such as strength and thickness are also clarified.

Chapter 3.

The results of an experiment using the new STPF measurement approach are reported. Measurements performed with our new device were compared to the one performed with the seated approach. The

participants were 13 adult women, who performed measurements with both approaches. The inter-subject coefficient of variation was found to be smaller with the new approach, thus pointing to the validity of our approach for measuring STPF.

Chapter 4.

The concept of the strength of hallux plantar flexion (SHPF) is explained. The SHPF data is obtained from the pressure distribution at the maximum STPF. The ratio of SHPF to STPF is calculated. We found a smaller ratio when using the new measurement approach. This result indicates that the strength of the phalanges other than the hallux contributes more to the maximum STPF in the new approach than in the seated approach.

Chapter 5.

We considered the social implementation of this method. Regarding interventions for the elderly, we discussed the improvement of the measurement method and the measurement equipment with reasonable prices. Then, the technical specifications were evaluated. We created a roadmap for impact (social change) in the logic model.

Chapter 6.

Conclusions are presented. The development of the new approach and device points to the possibility to perform less restrained STPF measurements. The new approach presented in this thesis is easy to perform, the device is lightweight and the data collected through the experiment are reliable. However, improved measurement approaches for the elderly intervention and ameliorating the existing devices would be required. We hope that the present study will contribute to the prevention of falling events and a longer walking life.