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DESIGN AND EVALUATION OF A NOVEL PATIENT-SPECIFIC, UNLOADING KNEE BRACE

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INTRODUCTION

Knee Osteoarthritis (KOA) is a degenerative joint disease and, combined with hip osteoarthritis, it is the most frequent cause of walking disability among elderly [1]. Multiple risk factors for the development of KOA, hereunder increased knee joint compressive forces (KJCF), have been identified. For this reason, unloading braces have been investigated, but their effect has not been clearly documented. Many brace designs have focused on reducing the Knee Adduction Moment (KAM) although it does not accurately predict the KJCF. The purpose of this study was, therefore, to develop a novel patient-specific knee brace concept to reduce the KJCF and evaluate its effect in a pilot patient study.

METHODS

The study was divided into three phases: 1) Unloading concept investigation. 2) Prototype development and 3) Evaluation of the brace concept.

Unloading concept investigation

To identify potential mechanisms to unload the knee joint, inverse dynamics-based musculoskeletal models (MSM) were created for ten healthy subjects during gait at self-selected pace in the AnyBody Modeling System (AnyBody Technology, Denmark). On these models, we applied idealized, support moments at the hip, knee and ankle and investigated how these alone and in combination affected the KJCF. The full details of the study can be found in in Stoltze et al. [2] and we found, among other measures, that a knee extension moment applied during early stance can reduce the first peak of the KJCF, whereas an applied ankle plantarflexion moment can reduce the second peak of the KJCF. Based on this, we decided to develop a knee brace prototype to unload the first peak as other studies have already developed a suitable ankle brace for the second peak [3].

Prototype development

Using a combination of strings, springs and a four-bar mechanism, a quasi-passive knee brace was designed to apply a knee extension moment during early stance (Figure 1, left). To apply the knee extension moment only during the early stance, a release mechanism was developed to control whether or not the strings were slack. For brace design details, see Stoltze et al. [4].

Evaluation of the brace concept

Gait data were collected for six KOA patients using motion capture and force plates without the brace.

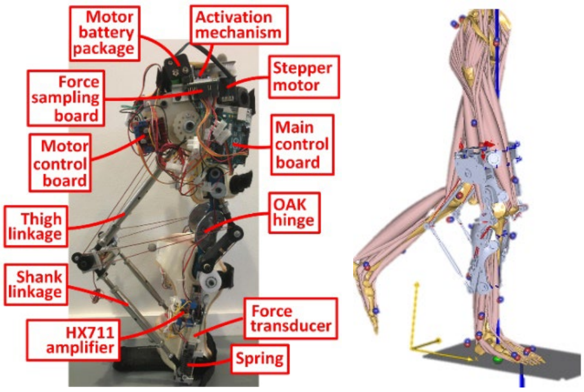

Figure 1 Left: Knee brace prototype. Right: MSM with brace.

For each patient, MSM were created, and an ideal brace model was implemented. Using the model, subject-specific brace parameters (spring stiffness, brace activation etc.) were determined to reduce the KJCF. Subsequently, the prototype brace was manufactured for one patient and the gait mechanics with and without the brace was measured using surface electromyography, marker-based motion capture and force plates. Lastly, the effect from the prototype brace was evaluated with MSM (Figure 1, right).

RESULTS AND DISCUSSION

The simulations with the ideal brace showed a varying reduction of the first peak KJCF between 3.5% to 34% across the six patients. The experiments with the prototype brace reduced the peak vastii muscle activation by 8% and the musculoskeletal models estimated an associated KJCF reduction of 26%. However, the impulse of the KJCF increased by 17%.

CONCLUSIONS

The results with the prototype brace shows promising results in terms of reducing the KJCF through the application of external moments to unload the muscles. However, further studies on large patient cohorts are required to determine the long-term effects on both pain, function and disease progression.

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