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Human hip joint center analysis for biomechanical design of a hip joint exoskeleton

Key words: Hip joint exoskeleton, Hip joint center, Compatible joint, Human-machine interaction force

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Motivation

- With rapid progress in mechatronics and robotics, anthropomorphic exoskeletons have been widely studied for rehabilitation applications and for general walking assistance.
- Although exoskeletons can assist or guide the motions of humans, especially patients, there is potential for discomfort and injury if the designs are not compatible with human biomechanics.
- Without the ability to fully sense discomfort, paraplegic or post-stroke patients may even suffer from serious injuries during repeated rehabilitation, where comfort is far from ideal when wearing traditional exoskeletons.

Main idea

- We focus on the lower body and present a human-biomechanics-based exoskeleton for providing support to the hip joint in a natural way.

- Based on the human anatomical experimental data, the designed mechanical hip joint center (HJC) can follow naturally occurring motions as the flexion angle varies.

Method

1. We design an experimental task including static and dynamic sections to get the human hip joint center.
    - Static section: a functional method is used to calculate the static HJC and the distance between the static HJC and markers pasted on the thigh surface during a limited range of hip motions.
    - Dynamic section: the thigh moves freely in the reachable space and specific optimization methods based on the results from the static tests are used to calculate the dynamic motion of the HJC.
2. The three hip joint orthogonal axes, the flexion/extension axis, the abduction/adduction axis, and the internal/external rotation axis are split and followed up with translations of the flexion/extension axis and the abduction/adduction axis.

Major results

- The optimal mechanical hip joint center sphere can well cover the human anatomical hip joint center.

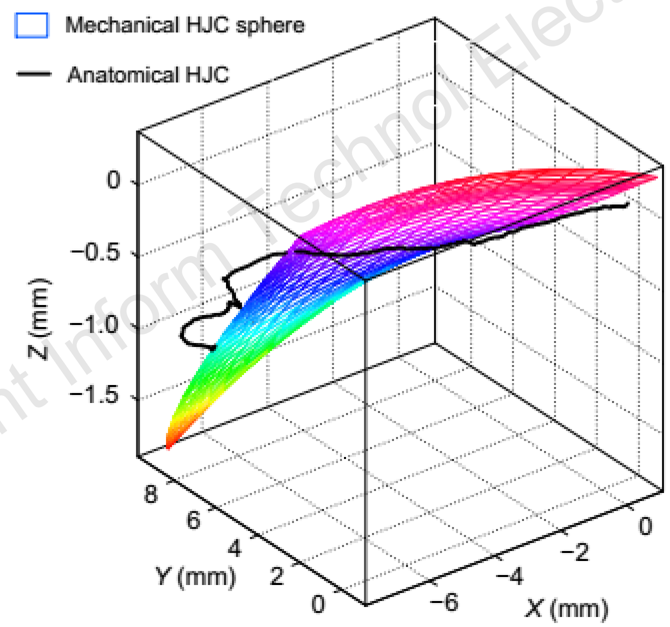

Fig. 5 Optimal mechanical HJC sphere and anatomical HJC

Major results (Cont'd)

- The internal force F_r with the biocompatible joint is lower than the F_r obtained using the traditional jointed exoskeleton during flexion and abduction motions.

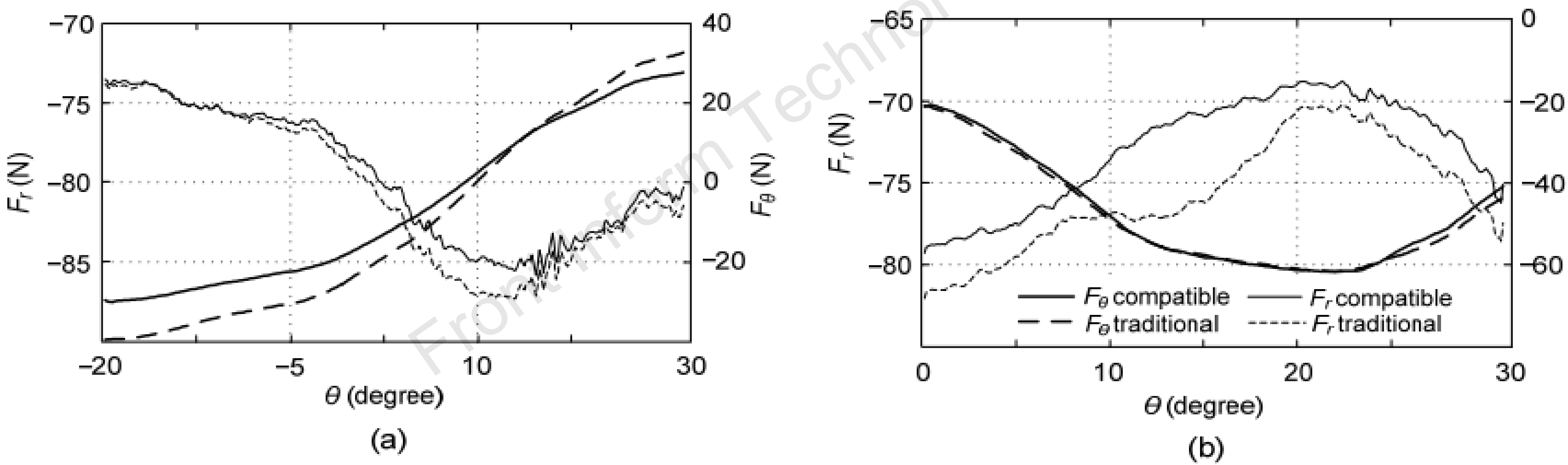

Fig. 10 Hip joint internal force during flexion (a) and abduction (b)

Conclusions

- The dynamic HJC motions were calculated based on the functional method and specific optimization. The results provide evidence for that the hip joint does not constitute a simple ball-and-socket mechanism.
- The mechanical hip joint was designed with its HJC best covering the anatomical one by translation of the flexion/extension and abduction/adduction axes under the SFTR system.
- The human-exoskeleton interaction force experiments show that the average force decreases by 24.1% and 76.0% during hip flexion and abduction, respectively, when applying the new design method.