KINEMATIC AND ELECTROMYOGRAPHIC PROPERTIES OF ROBOT-ASSISTED WALKING WITH A UNILATERAL KNEE EXOSKELETON

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SUMMARY

KNEXO has been developed to study the effects of compliant assistance during treadmill gait. Kinematic and electromyographic (EMG) data show that the device has its shortcomings (unilateral, 1 DoF, 1 joint) when assisting healthy gait, yet it gives opportunities to study the effects of assistance-as-needed on gait biomechanics.

INTRODUCTION

Automated locomotor training allows for monitoring and assessment of gait training, long training sessions, high accuracy of desired gait patterns, and a reduced workload for physical therapists [4]. Yet, a monotonous repetition of the exact same gait pattern could result in learned disuse [5]. Determinants of gait training do not only involve task-specificity and repeatability, but also variability, intensity and self-initiative [7]. It seems to be primarily the effort of the patient that drives mechanisms of neuroplasticity [6]. A robotic gait orthosis should therefore be a compliant device that is able to interact with the subject to provide assistance-as-needed. To reduce the scale and complexity of the problem of compliant and safe human-robot interaction, a unilateral knee exoskeleton powered by pleated pneumatic muscles (KNEXO; at right leg) has been developed with built-in compliance [1,2,3]. This prototype was used to study the effects of compliant human-robot interaction on kinematics and muscle activity during gait in healthy subjects.

METHODS

Unassisted (ZF) and assisted walking (with KNEXO in low (LC) and high compliance (HC) with and without resistance (R) from the subject, i.e., walk with a stiff knee) on a treadmill were induced by KNEXO in 10 healthy male subjects. Gait kinematics were evaluated during five consecutive gait cycles by means of motion capturing (VICON 612 motion analysis system). EMG activity of m. tibialis anterior (TA), m. gastrocnemius medialis (GM), m. biceps femoris (BF), m. rectus femoris (RF) and m. vastus lateralis (VL) of the right leg was registered by Megawin ME6000 Biomonitor. Synchronisation of data occurred through detection of right heel strike with a foot contact sensor.

RESULTS & DISCUSSION

Raw EMG data of 5 consecutive gait cycles were averaged, rectified, smoothed and time normalized to one averaged gait cycle. From the kinematic data, rotations in the sagittal plane will be discussed. Joint angles were averaged and time normalized to one gait cycle. Data are given for one healthy subject but are comparable for all 10 subjects.
Figure 1: RMS smoothed, averaged EMG (+/- stdev) data of 5 muscles of the right leg of a healthy subject during walking with KNEXO in ZF, LC no R, LC R, HC no R and HC R

![Chart showing EMG data comparison]

Figure 2: Comparison of the averaged and time normalized hip, knee and ankle joint angle trajectories of the left and right leg during walking without KNEXO and with KNEXO in ZF, LC no R, LC R, HC no R and HC R

When comparing walking without KNEXO and with KNEXO in ZF (unassisted), EMG data of the right leg showed increased activity of VL, RF and TA during initial contact, loading response and the end of swing, while the activity of BF during terminal stance and pre swing and the activity of GM during stance and initial swing are significantly reduced when walking with KNEXO in ZF (Figure 1). This could be in order to compensate the incomplete knee extension during swing, while the decreased activity of BF and GM are because of a limitation in the natural range of motion of the leg joints. Muscle activity during walking with KNEXO in LC no R and HC no R approaches muscle activity during walking with KNEXO in ZF. Right knee excursion is reduced and right hip flexion increased when walking with KNEXO in ZF compared to walking without KNEXO (Figure 2). This could be due to the inertia of the exoskeleton or to misalignments between the human joints and the robotic knee joint. Changes in kinematics of one joint also influence other joints. When comparing walking with KNEXO in LC and HC, joint kinematics are more pronounced when walking with KNEXO in LC. The subject is more forced into a specific gait pattern when walking in the LC mode.

CONCLUSIONS

Overall, walking within KNEXO, which is a 1 DoF, 1 joint, unilateral device that limits the natural degrees of freedom of the leg, leads to asymmetric kinematics and changes in naturally occurring muscle activity. Walking without KNEXO and with KNEXO in unassisted mode is difficult to compare as the device is unilateral and the pneumatic muscles give, although weight-compensated, a certain amount of inertia to the movement. Walking with KNEXO in high compliance resembles walking with KNEXO in unassisted mode.

REFERENCES