LOWER LIMB DOF CONSTRAINTS AND CHANGES IN WHOLE BODY MUSCLE ACTIVITY DURING STANDING UP IN ACUTE STROKE PATIENTS

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Abstract - Acute stroke patients, whose motor control systems in the central nervous system may not be compensatory for motor paralysis, may be an appropriate model to examine the immediate adaptability of the motor control system to physical changes in the body, such as the addition of assistance. Six acute stroke patients performed a standing movement. Experimental conditions were with and without knee braces. An inertial measurement device and a surface electromyograph were used as the measurement devices. The section of the standing up movement was extracted, and the amount of activity at the time of the moment of the withdrawal and the integral value of the amount of activity up to the moment of the withdrawal were calculated for each muscle. The above parameters were compared between experimental conditions. Results showed that changes in whole-body muscle activity when the distal node force was compensated by the brace differed from patient to patient. Excessive energy expenditure from the trunk muscles was suppressed in patients with good postural control (i.e., trunk in more extended position in the sitting position). On the other hand, patients with poor postural control (i.e., trunk in more flexed position in sitting) had increased trunk muscle activity with distal lateral stability. Changes in whole-body muscle activity in response to lower limb DOF constraints, i.e., control simplification, were expected to vary depending on the trunk function possessed by the patient, as well as changes in the central nervous system motor control system.

Keywords - Stroke, Motion Capture, Orthosis, Motion Control

I. INTRODUCTION

Abnormalities due to stroke begin with network degeneration of brain regions involved in movement, which is expressed as abnormal muscle activity throughout the body via modulation of motor nerves [1]. This disrupts the interaction between the body and the environment, making movement unfeasible. Stroke patients provide a good model of how the motor-related areas of the brain are involved in the interaction between the body and the environment and the mechanisms of motor control. In particular, acute stroke patients, whose motor control systems in the central nervous system have not been compensatory altered in response to motor paralysis, may be an appropriate model to examine the immediate adaptability of motor control systems to physical changes in the body, such as when assistance is provided [2].

However, acute stroke patients are limited in the movements they can perform. Patients are not able to perform walking movements, such as one-leg standing, alternating from left to right, and they must first practice standing up to get out of bed [3]. The patient usually pulls in the handrail or has a caregiver hold his/her hand at his/her side to stand up. However, this kind of assistance increases dependence on the limb without motor paralysis and prevents the reconstruction of the motor control system against motor paralysis (use-dependent plasticity) [1].

Therefore, we attempted to elucidate the adaptability of the injured central nervous system by examining the changes in trunk and paralyzed lower limb muscle activity that occur as a result of simplifying the control of the paralyzed lower limb, i.e., restricting the degree of freedom of the paralyzed lower limb, during the standing movement in acute stroke patients.

II. METHODS

A. Subjects

Six patients were hospitalized with acute cerebrovascular disease.
The patients were defined as those who were within 2 weeks of the onset of the disease as diagnosed by a physician, and who were not yet able to stand up independently. The patients were capable of understanding the research explanations and movement instructions, and verbal consent and signature on the consent form were obtained from the patients themselves.

B. Measurement

A small wireless inertial sensor and a small wireless surface electromyograph (Oisaka Electronics Co., Ltd.), with a measurement frequency of 1000 Hz were used.

The small wireless inertial sensors were affixed to six locations on the body (thorax, pelvis, right and left thighs, and right and left lower legs). Seven muscles (right and left paraspinal erector spinae, paralyzed lateral gluteus maximus, long head of biceps femoris, vastus lateralis, tibialis anterior, and soleus muscles) were used as the derivatives of the small wireless surface electromyography meter.

C. Task

Subjects performed a standing up movement from a platform (Figure 1).



Figure 1: Overview of standing up movement with lower limb orthosis.

The lower limb orthosis was used to prevent the knee joint from flexing more than 90°. Subjects performed standing movements under two conditions: with and without the orthosis.

There were two experimental conditions, with and without braces, and three trials were performed in each condition.

No assistance was provided during any of the trials, and both successful and unsuccessful movements were included in subsequent analyses.

D. Analysis

The stand-up movement section was identified by joint angles. First, the posture of each sensor was identified as a rotation matrix based on acceleration and angular velocity information collected from small wireless inertial sensors. The start of movement was defined as the start of pelvic tilt, and the end of movement was defined as the end of thigh tilt. The point of release was defined as the start of thigh tilt.

Muscle activity was extracted during the standing up movement segment, and the amount of activity at the time of the withdrawal and the integral value of the amount of activity up to the time of the withdrawal were calculated for each muscle.

T-tests were performed for the above parameters with correspondence between experimental conditions.

III. RESULTS

Both the amount of activity at the time of release and the integrated amount of activity up to release were significantly different between experimental conditions only for the soleus muscle ($p < .001$).

For the right and left paraspinal erector spinae and the paralyzed lateral gluteus maximus muscles, the mean activity in the brace condition was greater in subjects with a greater thoracic-pelvic tilt angle in the sitting position (Figure 2), while the mean activity in the brace condition was smaller in subjects with a smaller thoracic-pelvic tilt angle (Figure 3). However, no statistically significant differences existed.

IV. DISCUSSION

The joint moments during the standing up motion reach their peak value at the point of seat-off, which poses a challenge to motor control [4]. In a previous study, we found that the sum of joint moments in the whole body at this time was the same in chronic stroke patients and healthy adults [5]. However, we have shown that joint moments increase at the hip joint and decrease at the knee joint in a compensatory relationship, and that the mechanical energy supply from the lumbar extensor muscles is responsible for this increase in hip joint moment [5]. This is the result of the proximal segment compensating for the strong motor paralysis in the distal segment.

In the present study, changes in whole-body muscle activity varied from patient to patient when the distal node force was compensated by the brace. Excessive energy expenditure from the trunk muscles was suppressed in patients with good postural control (i.e., trunk in more extended position in the sitting position). On the other hand, patients with poor postural control (i.e., trunk in more flexed position in sitting) had increased trunk muscle activity with distal lateral stability.

V. CONCLUSION

Changes in whole-body muscle activity in response to lower limb DOF constraints, i.e., control simplification, would be different depending on the trunk function possessed by the patient, and changes in the central nervous system motor control system

would also be expected to be different.

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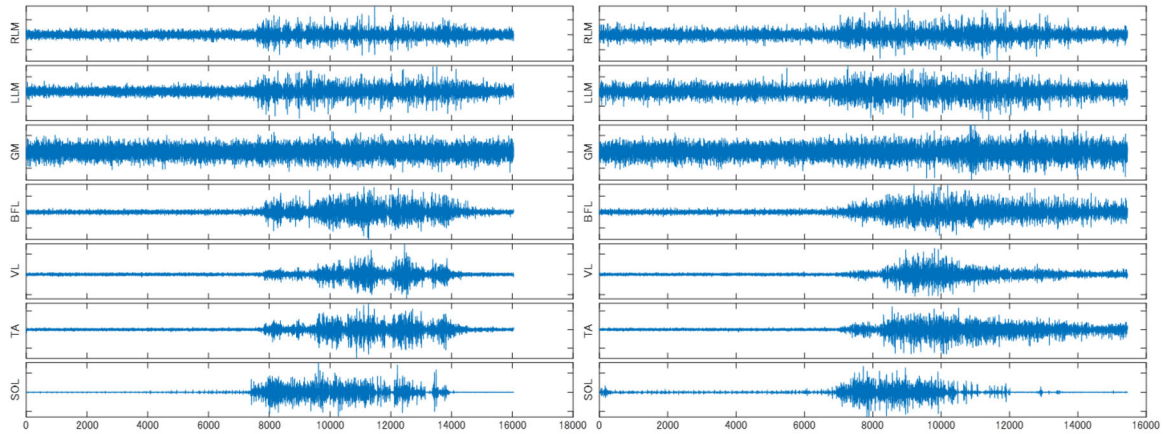


Figure 2: Muscle activity changes during the stand-up movement of a patient in a sitting position with the trunk in a more flexed position (representative example).

Left column: without brace; right column: with brace. RLM: right paraspinal erector spinae; LLM: left paraspinal erector spinae; GM: gluteus maximus; BFL: biceps femoris paralyticus; VL: vastus lateralis; TA: tibialis anterior; SOL: soleus; and SOL: soleus ostialis. The muscles are aligned cephalad to caudal from the upper to the lower row. Left and right paraspinal erector spinae and paralyzed lateral gluteus maximus muscles are more active under orthotic conditions.

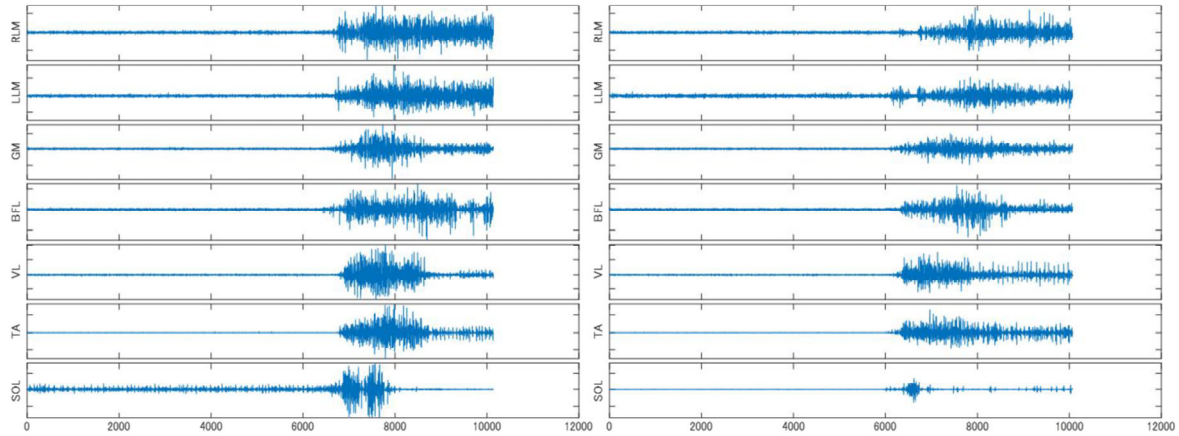


Figure 3: Muscle activity changes during the standing up movement of a patient in a sitting position with the trunk in a more extended position (representative example).

The left column is without braces and the right column is with braces. The abbreviations and order of the muscles are the same as in Figure 2. The left and right paraspinal erector spinae muscles and the paralyzed lateral gluteus maximus muscle are less active under the orthotic condition.

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