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Characteristic Activities of Lower Limbs with Body Weight Support Ratio*

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***Abstract*— In this study, we investigated a lower limbs muscle activity during body weight support treadmill training (BWSTT). Informed consent was obtained from 16 healthy men. Experimental system consists of force plate, treadmill, three-dimensional motion analysis system, electromyograph, and body weight support device. Body weight support (BWS) was set every 15% increase from 0% to 45%. Walking speed was 4.17km/h. The measurement data were reaction forces, joint angles, joint moments and lower limbs muscle activities. The vertical reaction force shows two peaks. Two peaks decreased with increase of BWS together. Joint angles did not show significant changes with BWS. However, only the extension of hip angle was decreased with BWS. The peaks of joint moment were decreased. Decrease of ankle joint moment was greatest compared with other moment. Decrease of peaks of muscle activity by BWS was observed during stance phase, and did not almost change during swing phase.**

I. Introduction

Some previous studies have suggested effectiveness of body weight support treadmill training (BWSTT) [1], [2]. BWSTT make a recovery inter-limbs control of patients with spinal cord injury or stroke, and attracts attention as training to improve walking ability. A kinematic and kinetic analysis is necessary to get more effective setting of BWSTT [3]. However, there are still few reports that quantitatively examined in detail.

In this study, we focused on analysis of reaction force, joint angle, joint moment, and muscle activity in BWSTT. The characteristics were analyzed with such parameters as body weight support ratio (BWS).

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II. Methods

The formal ethics committee of Okayama University of Science approved the study. The subjects were 16 healthy men, in their twenties, and provided informed consent.

A set of 2 treadmills (size: D1225 x W395 x H240mm, walking area: D1000 x W320m, Ohtake Root Kougyou, JPN) was fixed on 2 large force plates (EFP-386A, size: D1800 x W600 x H268mm, Kyowa Electronic Instruments, JPN) (Figure 1). The joint angles during treadmill walking were measured with 3D motion analysis system (VICON 512, Viconpeak, UK). Six set of cameras were used, and the sampling frequency was 120Hz. Ground reaction force was sampled at 1080Hz. Harness for body weight was supported by a constant load spiral spring device (RSB-30, Endo Kogyo, JPN). Walking speed was 4.17km/h when gait cycle was set to 1s in the first subject. Therefore, walking speed was standardized to 4.17km/h. BWS was set statically every 15% increase from 0% to 45%. However, BWS was recalculated from single limb stance of reaction force because an error occurred between a set point and actual values during walking. Lower limbs muscle activities (EMG) were measured from rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), semitendinosus (ST), tibialis anterior (TA), gastrocnemius (Ga), and soleus muscles (Sol). Each measurement data were divided into each stride which based on vertical component of ground reaction force. The data were normalized with each stride time, and were averaged. Amplitude of reaction forces were normalized with body weight (BW). Amplitude of muscle activities were normalized with maximum amplitude. The analysis software was used, FORTRAN and MATLAB.

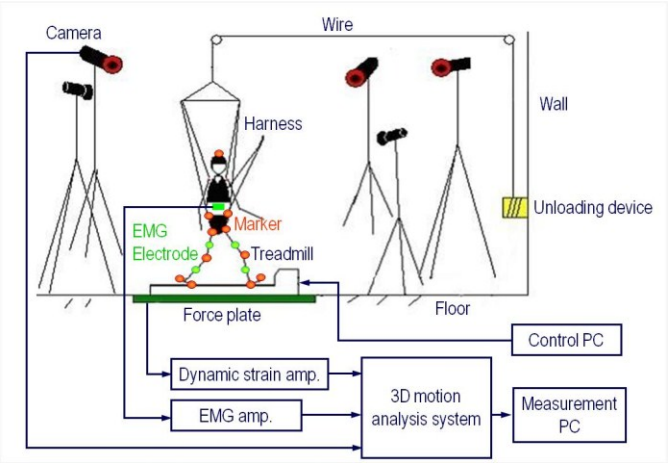

Figure 1 Experimental set up of BWSTT.

III. Results and Discussions

A. Ground Reaction Force

Figure 2 shows normalized reaction force during 1 stride cycle. The reaction force of vertical component shows two peaks (first peak, second peak) later before the mid stance (a1). These peaks were caused by the upward and downward acceleration of the body's center of mass, respectively [4]. The peaks were decreased with increase of BWS together (a2), (a3). In particular, correlation of second peak was higher than first peak. The reaction force of horizontal component shows two peaks (first peak, second peak) during loading response and terminal stance (b1). These peaks indicate that the deceleration and the acceleration of the body, respectively. The amplitude of these peaks was decreased with increase of BWS together (b2), (b3). The reaction force of lateral component shows a peak (first peak) during loading response (c1). This peak indicates that the center of gravity to move to the outside of the body. The peak was slightly decreased with increase of BWS together (c2).

B. Joint Angle

Joint angles did not show significant changes with BWS. However, only the extension of hip angle was decreased with BWS.

C. Joint Moment

Figure 3 show normalized joint moment during 1 stride cycle. The first peak of hip joint moment was seen during loading response (a1). The peak was decreased with increase of BWS (a2). The second peak of hip joint moment was seen during toe off (a1). The peak did not change (a3). The peaks of knee joint moment were seen during loading response and terminal stance (b1). The amplitude of these peaks was decreased with increase of BWS together (b2), (b3). The peak of ankle joint moment was seen during terminal stance (c1). The peak was decreased with increase of BWS (c2). Decrease of ankle joint moment was greatest compared with other moments.

Based on the above results, at early stance in loading response, joint moment was changed with BWS. On the other hand, at terminal stance in push-off response, the ankle joint moment was subject to the influence of BWS, in the upper hip joint, flexion moment was not affected by BMS.

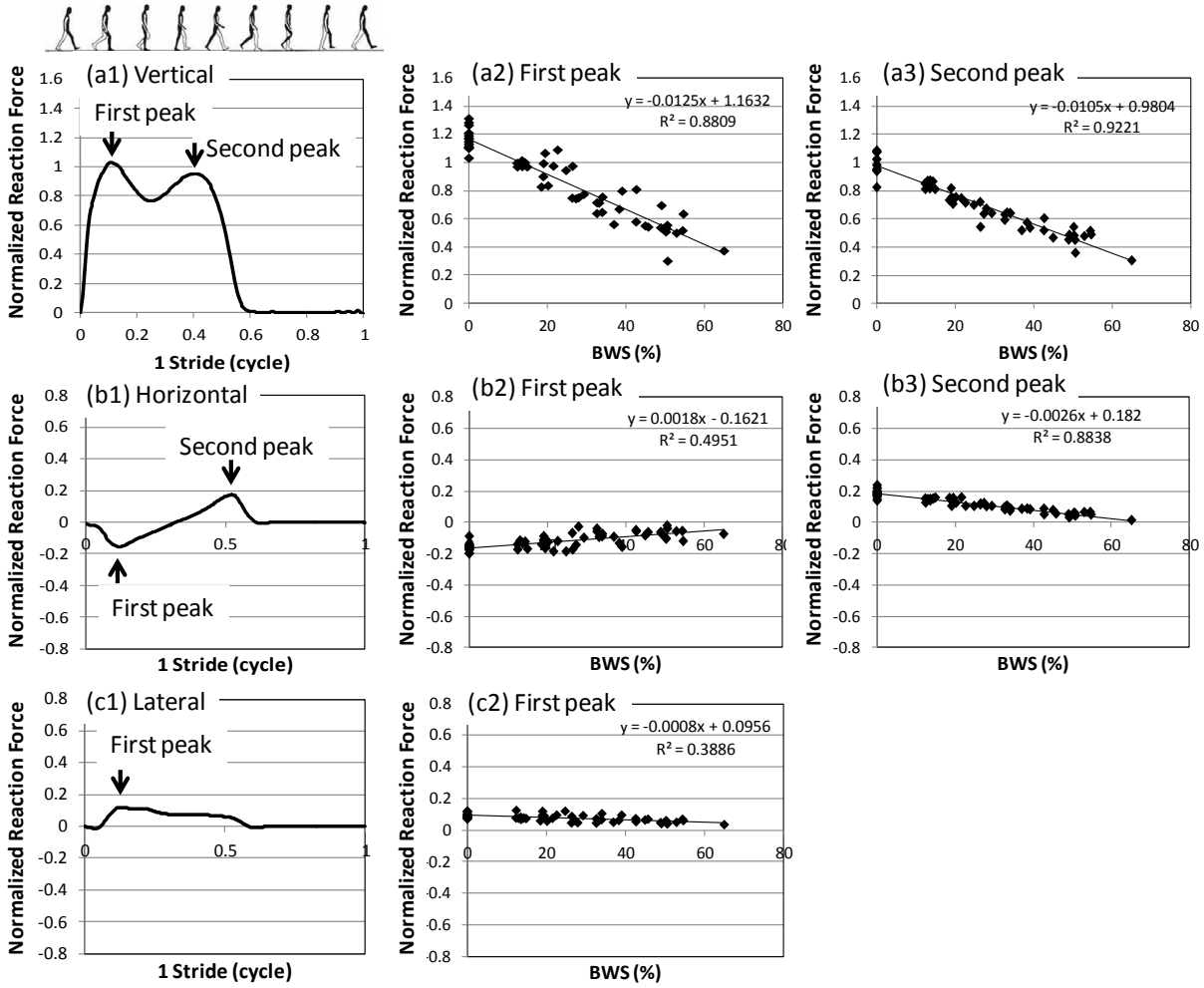

Figure 2 The change of normalized reaction force. (a1): Vertical reaction force. (b1): Horizontal reaction force. (c1): Lateral reaction force. (a2), (a3): First and second peak of vertical reaction force. (b2), (b3): First and second peak of horizontal reaction force. (c2): First peak of lateral reaction force.

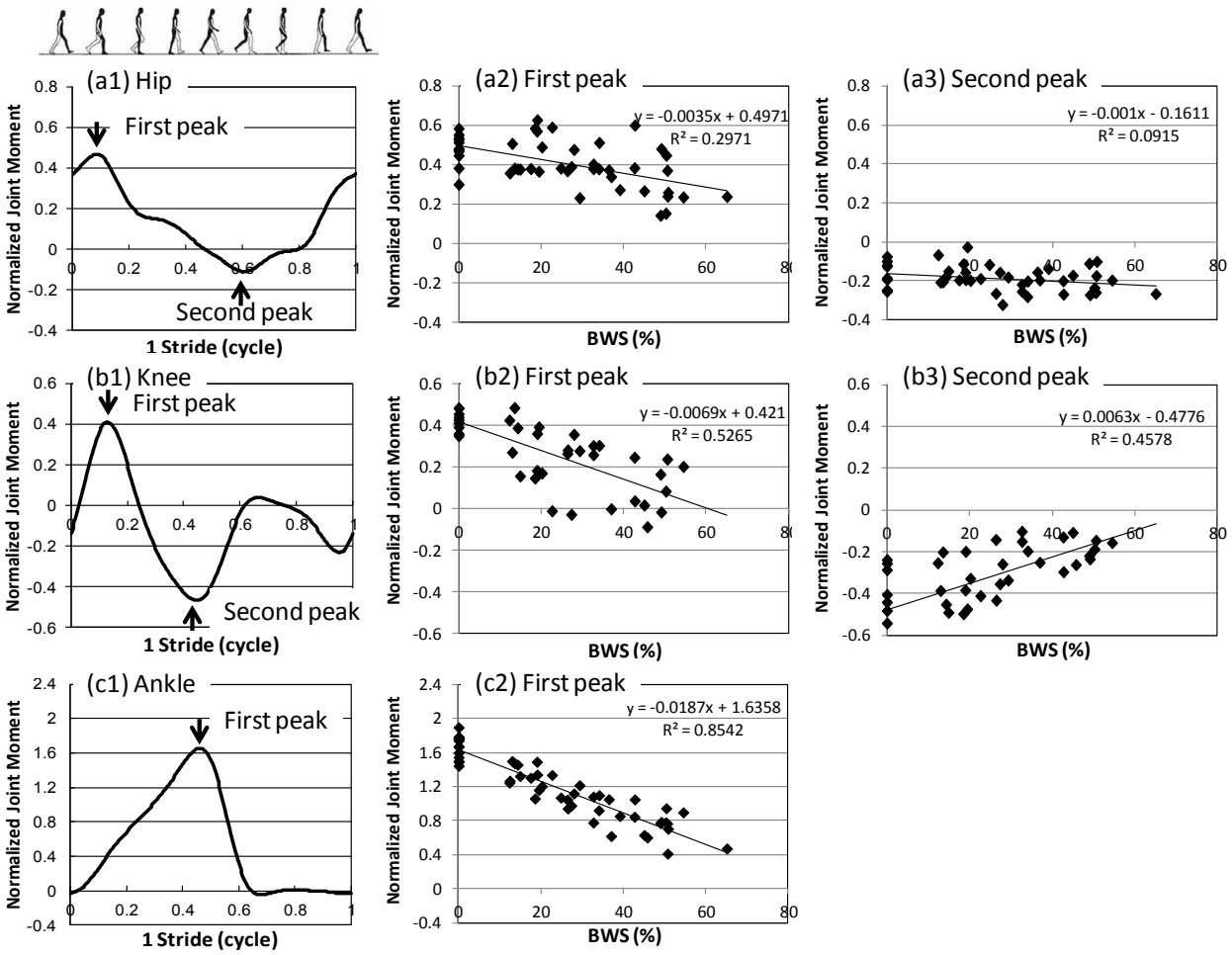

Figure 3 The change of normalized joint moment. (a1): Hip joint moment. (b1): Knee joint moment. (c1): Ankle joint moment. (a2), (a3): First and second peak of hip joint moment. (b2), (b3): First and second peak of knee joint moment. (c2): First peak of ankle joint moment.

D. Muscle Activity

Figure 4 shows lower limbs normalized EMGs during 1 stride cycle. Activity of biceps femoris muscle was observed during initial contact and terminal swing (a1). The first and second peaks were slightly decreased with increase of BWS (a2), (a3). Activity of vastus lateralis muscle was observed during initial contact and terminal swing (b1). The first peak was decreased with increase of BWS (b2). The second peak was slightly decreased with increase of BWS (b3). Activity of tibialis anterior muscle was observed initial contact and initial swing (c1). In initial contact, it is thought that the activity was to prepare for shock absorption of heel contact. In initial swing, it was thought that the activity was to maintain toe clearance when a toe off. The first peak was decreased with increase of BWS (c2), but the second peak did not change (c3). Activity of gastrocnemius muscle was observed terminal stance (d1). The first peak was decreased with increase of BWS (d2). Activity of soleus muscle was observed terminal stance (e1). The first peak was decreased with increase of BWS (e2). Decrease of peaks of muscle activity by BWS was observed during stance phase, and did not almost change during swing phase.

IV. CONCLUSION

In this study, we investigated a lower limbs activity during BWSTT. According to the results, vertical and horizontal reaction force, extension of hip joint angle, joint moment, muscle activity of stance phase were decreased with increase of BWS. According to the results, a load-related change was especially shown around the ankle joint moment, and as shown in flexion moment of the hip, there may be a scheme for motion control of the leg, which is not related to load.

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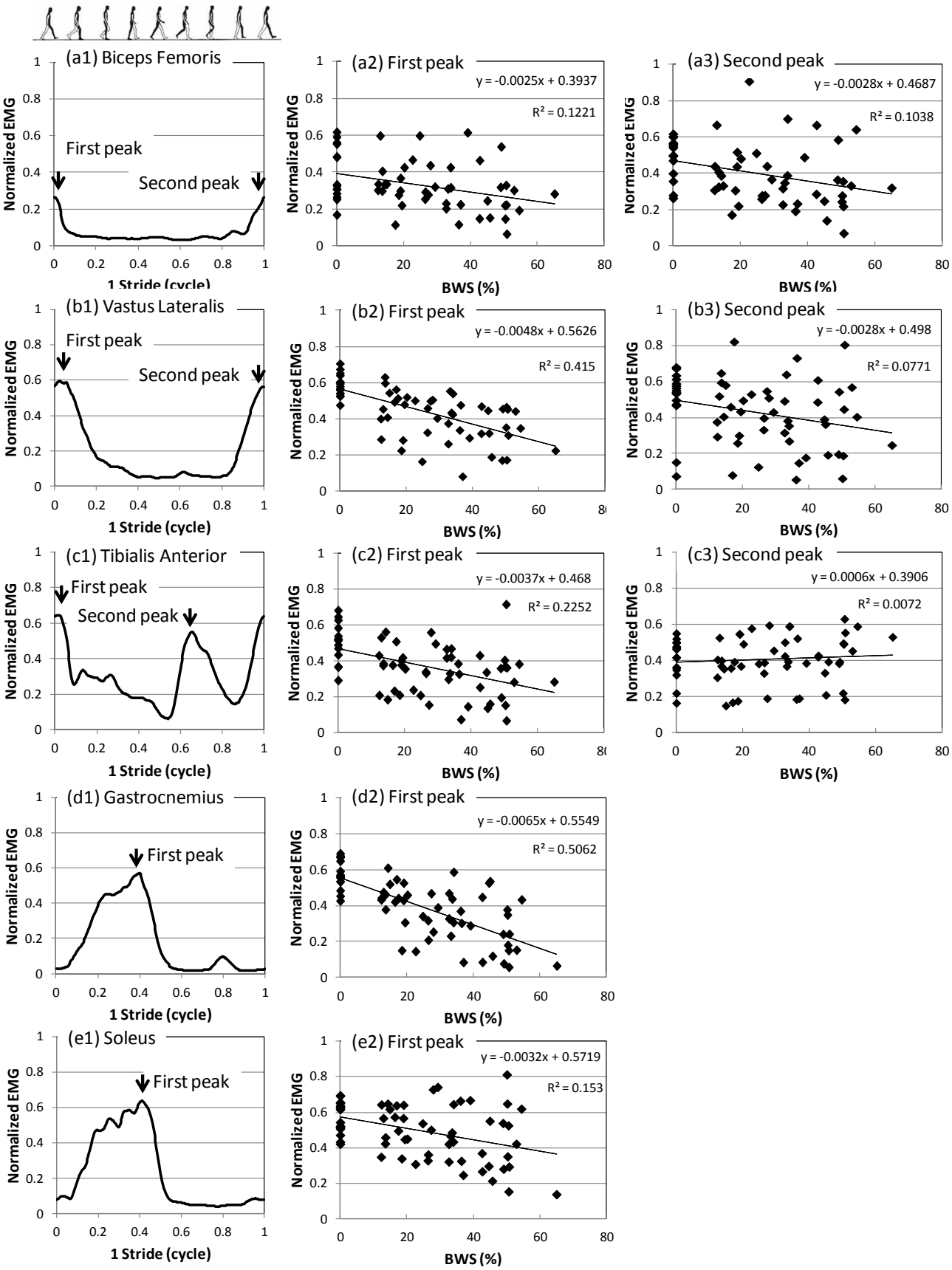

Figure 4 The change of normalized EMG. (a1): Biceps femoris. (b1): Vastus lateralis. (c1): Tibialis anterior. (d1): Gastrocnemius. (e1): Soleus. (a2), (a3): First and second peak of biceps femoris. (b2), (b3): First and second peak of vastus lateralis. (c2), (c3): First and second peak of tibialis anterior. (d2): First peak of gastrocnemius. (e2): First peak of soleus.