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Original Paper

# Electromyographic Analysis of the Activities of the Abdominal Muscles during Gait

**Susumu WATANABE**

*Department of Restorative Science, Physical Therapy Course,*
*Faculty of Medical Professions*
*Kawasaki University of Medical Welfare*
*Kurashiki, 701-01, Japan*
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### Abstract

The purpose of this study was to investigate the electromyographic (EMG) activities of the abdominal muscles during gait. Ten normal male subjects (mean age, 22 years) were examined. The activities of the abdominal muscles were recorded and analyzed with a Muscle Tester ME 3000 P. Bipolar surface electrodes were placed on both sides of the rectus abdominis and the oblique muscles. The rectus abdominis muscles showed two peaks of activity, the first at mid-stance and the second at mid-swing phase. Both sides of the oblique muscles had continuous action. Electromyographic analysis of the activities of the abdominal muscles during gait has been studied by very few investigators. Carlsöö et al. described the activities of the abdominal muscles as well as those of the lower extremities, but they did not analyze their data quantitatively. Our results suggest that the abdominal muscles act along with the pelvic muscles to stabilize the pelvis at both the stance and swing phase. This study will provide a basis for the analysis and treatment of abnormal gait.

## Introduction

Electromyographic analysis of phasic muscle activity during normal human gait has been studied by many investigators. However, most of them have analysed the activities of the lower extremities but not those of the abdominal muscles. Although the gait depends mainly on the muscle activities and movement of the lower extremities, the stability of trunk is also supposed to play an important role. Clinically we observe instabilities of the trunk during abnormal gait: for example, in hemiplegic and ataxic gait. The purpose of this study was to investigate the electromyographic activities of the abdominal muscles during normal human gait to provide a basis of comparison for the analysis and treatment of abnormal gait.

## Subjects and Methods

Ten normal young male students (21.6 ± 2.0

years old) participated in our study. The only criteria for exclusion was a history of abdominal muscle disease. The activities of the abdominal muscles during gait at a comfortable speed were recorded for two mimutes and analyzed with a Muscle Tester ME 3000 P (Fig. 1). Four sets of bipolar surface electrodes were placed on both sides of the rectus abdominis and the oblique abdominis muscles (Fig. 2). Computer quantification involved digital sampling, rectification, and integration of the data. A sampling rate of 1,000 Hz was selected. For statistical analysis the paired Student's t test was used. Differences were judged with statistically significance for $p < 0.05$.

## Results

Fig. 3 shows a typical raw EMG of the right and left rectus abdominis and oblique muscles. Fig. 4 presents the quantitated EMG.

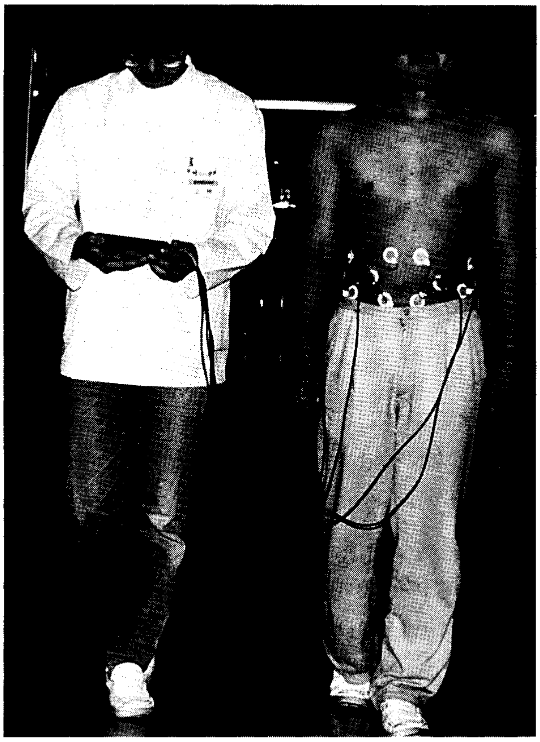

Fig. 1 The activities of the abdominal muscles during gait were measured at a comfortable speed.

The activities of the right and left rectus abdominis muscles were described in Fig. 5. The rectus abdominis muscles showed two peaks of activity, the first at mid-stance phase and the second at the mid-swing phase during a walking cycle. Both abdominal muscles contracted simultaneously. The amplitude of the first peak was $63.7 \pm 18.2 \mu v$ and the second was $47.6 \pm 16.3 \mu v$. There was no significant difference. Fig. 6 showed the activities of both oblique abdominis. The rather continuous activities were recorded throughout a walking cycle. However, the periodicity was noted during the stance and swing phase. The amplitude of the stance phase was $14.5 \pm 3.9 \mu v$, and that of the swing phase was $22.5 \pm 6.4 \mu v$. The mean amplitude during the stance phase was significantly greater than that during the swing phase.

## Discussion

The schema of Carlsöö[1], which demonstrated the activities of the lower extremities, the erector spinae and the abdominal muscles, is well known (Fig. 7). He described the activities and the functional significances of the lower extremities and these erector spinae but not the abdominal muscles. Waters et al.[2] reported the electrical activity of the

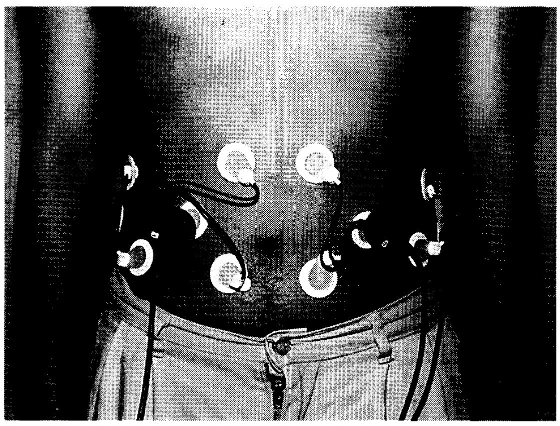

Fig. 2 Four sets of bipolar surface electrodes were placed on both sides of the abdominal muscles.

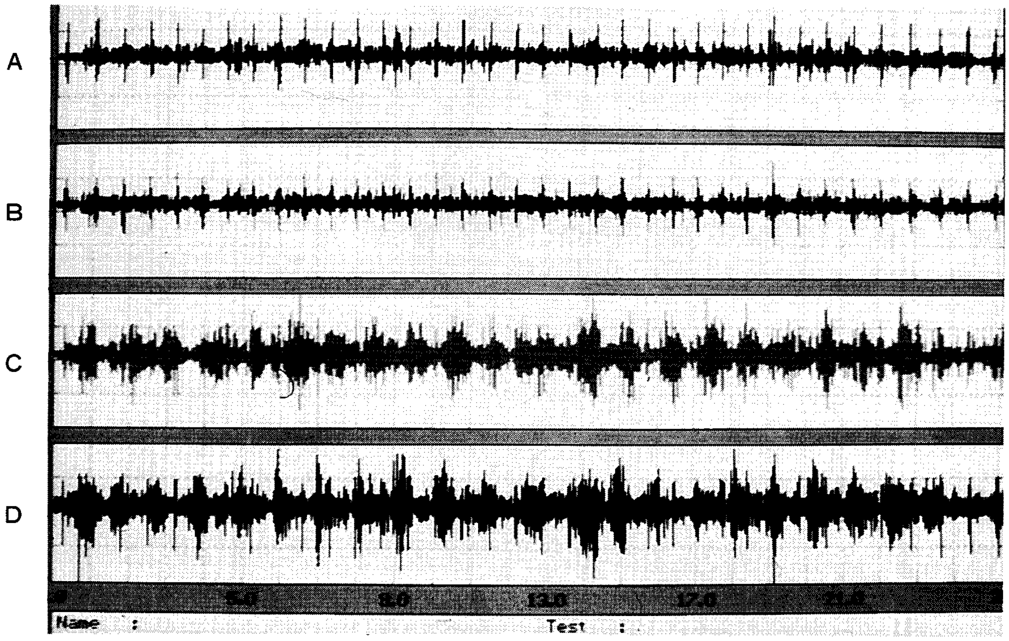


Fig. 3 The raw electromyography of both sides of abdominal muscles.
A: right rectus abdominis
B: left rectus abdominis
C: right oblique abdominis
D: left oblique abdominis

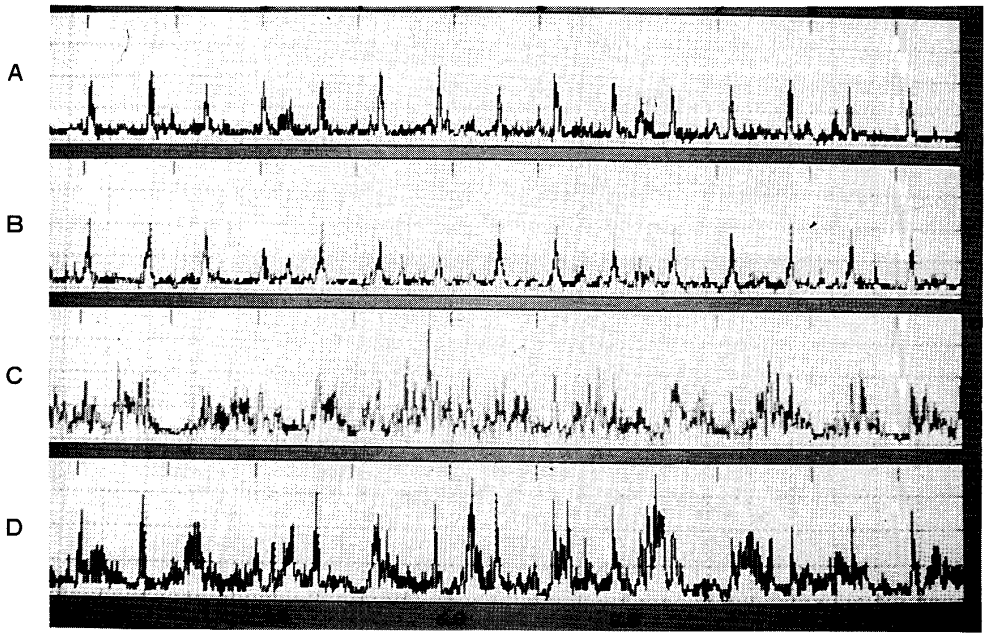


Fig. 4 The quantitated electromyography of both sides of the abdominis muscles.
A: right rectus abdominis
B: left rectus abdominis
C: right oblique abdominis
D: left oblique abdominis

A

B

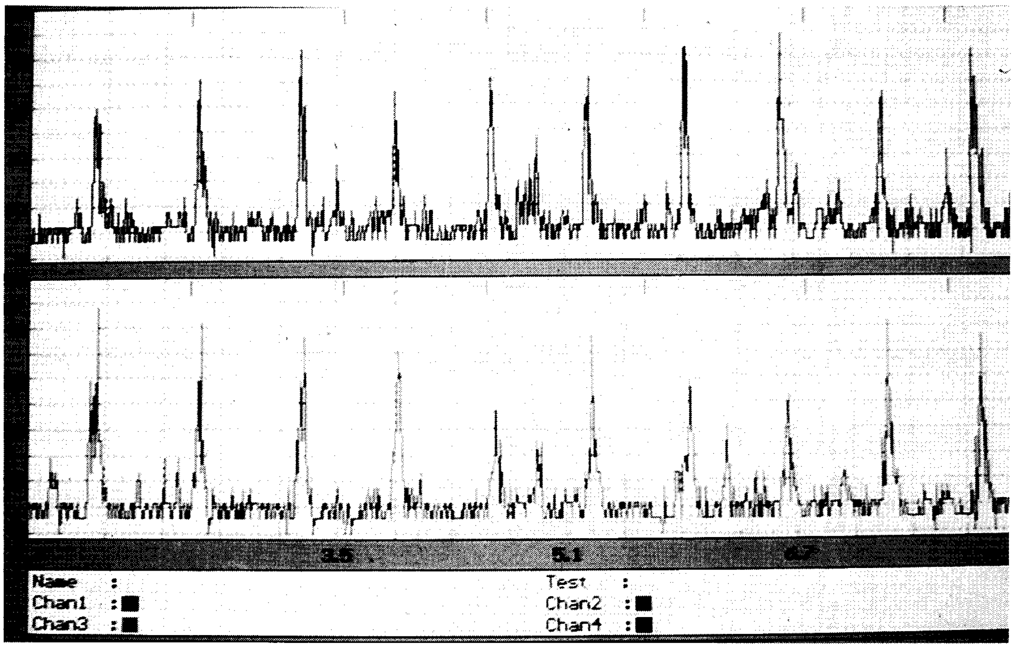


Fig. 5 The rectus abdominis showed two peaks of activity, the first at mid-stance and the second at mid-swing.
A: right rectus abdominis
B: left rectus abdominis

A

B

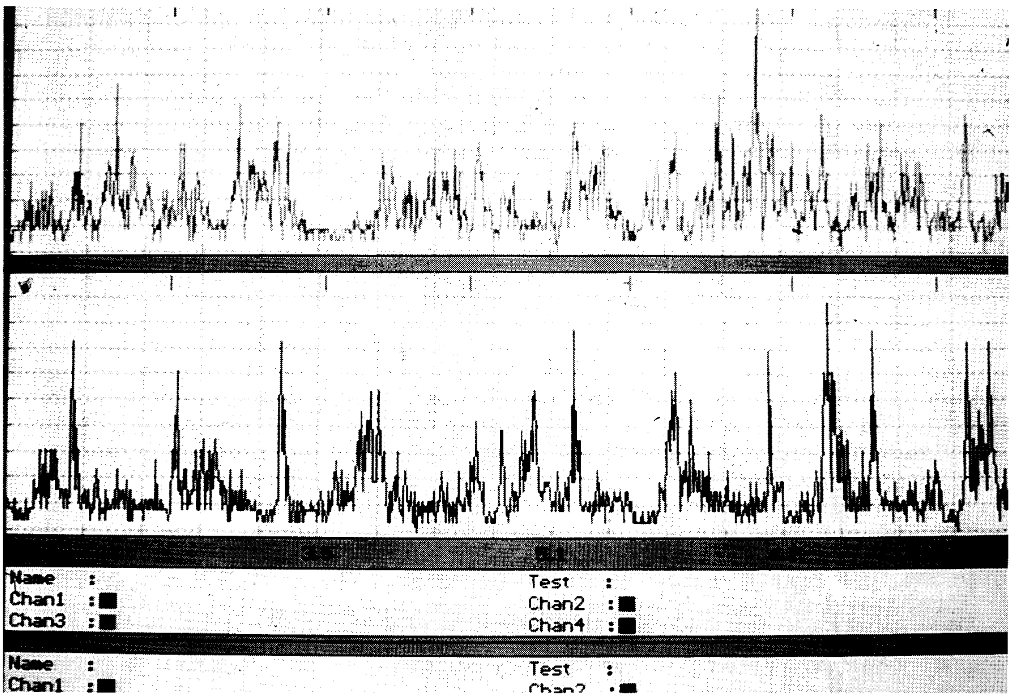


Fig. 6 The oblique abdominis had continuous action.
A: right oblique abdominis
B: left oblique abdominis

trunk during walking (Fig. 8). In the rectus abdominis, five of ten subjects displayed electrical activity. When present, it occurred just before right and left heel contact. In the obliquus internus abdominis and obliquus externus abdominis muscles, continuous electrical activity was recorded throughout the walking cycle. Perry et al.[3] reported that the rectus abdominis had a low level of continuous action and activity of the obliquus externus muscle was intermittent with a low-intensity pattern throughout stance. In any case, there have been few studies regarding the activities of the trunk muscles during

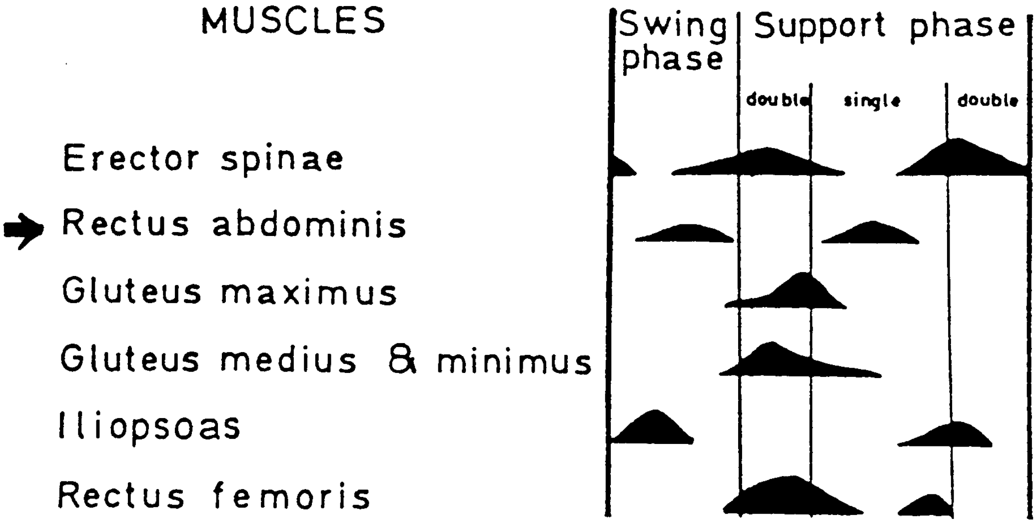


Fig. 7 The muscle co-ordination in ordinary gait: schematic representation following electromyogrphic registrations. (1972, Carlsöö)

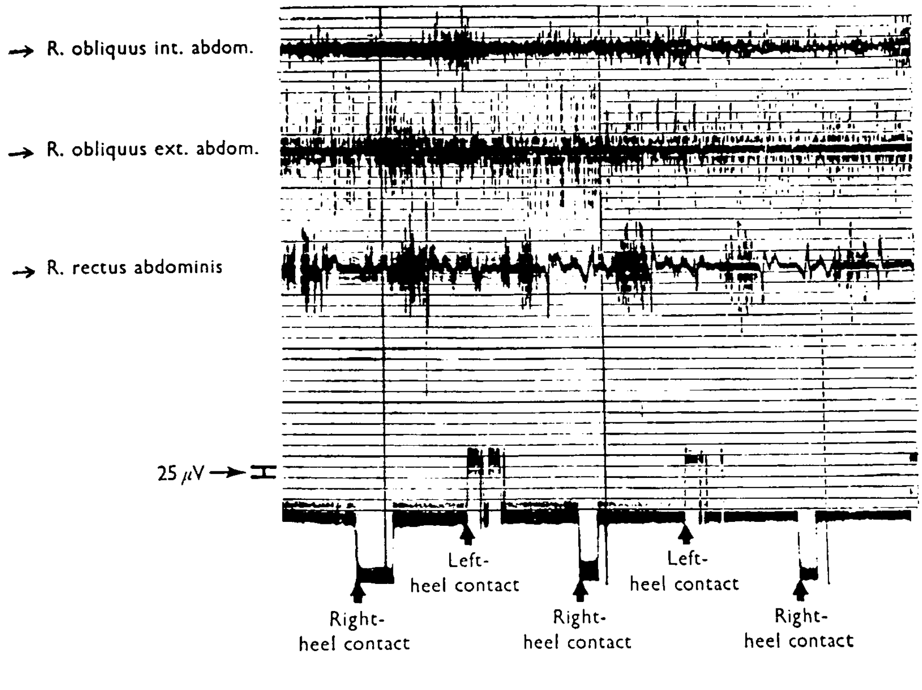


Fig. 8 Electromyographies of the trunk during walking. (1972, Warters)

gait. The purpose of our study was to measure quantitatively the electromyographic activities of the abdominal muscles during gait and to investigate the significance of these activities. The author was able to confirm that the rectus abdominis acted during mid-stance and mid-swing as Carlsöö had shown. We concluded that the erector spinae acted to prevent the trunk from flexing forward by inertia immediately after heel contact, while the rectus abdominis acted in order to stabilize the trunk and the pelvis to prevent their hyperextension during mid-stance. The mid-stance of one lower extremity corresponds to the mid-swing of the other one. Therefore, the synchronous contraction of the opposite side of the rectus abdominis helps the swing of the lower extremity by stablizing the pelvis backward to the trunk. As Waters et al. reported, both sides of the oblique muscles showed continuous action during gait. In our study, the period activities were observed during both the stance and swing phases. The mean amplitude during the swing phase was greater than that during the stance phase. The obliquus externus abdominis originates from the lower eight ribs and inserts into the linear alba and the pubic tubercle, while the obliquus internus abdominis originates from iliac crest and the inguinal ligament and inserts into lower four ribs and the lateral border of the rectus abdominis. Synchronous action of both sides flex the trunk, whereas the action of one side rotates and bends the trunk laterally. Therefore, we suppose that the oblique abdominis muscles, along with the gluteus medius at the frontal plane stabilizes the pelvis and the trunk during the stance phase and helps the swing of the lower extremity by connecting the pelvis with the trunk synchronized with the rectus abdominis. During gait, displacement and acceleration of the axial segments reflect the action of the limbs in swing and stance. Conseqently, the greatest motion occurs at the pelvis. Two mechanisms are working, the impact of limb loading and the drag of contralateral swinging limb. Pelvic motion is initiated by the base of the trunk mass which is eccentric to the center of the supporting hip joints. Movement of the pelvis is restrained by the hip muscles, while the back and abdominal musculatures control the alignment of the trunk over the pelvis. Activity of the erector spinae during limb loading and the later action of the abdominal muscles decelerate the passive forces reflected to the trunk. Our results suggest that in spite of poor movement of the pelvis and the trunk, the abdominal muscles were very important in stabilizing them. This study should provide a basis of comparison for the analysis and treatment of abnormal gait.

## References

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