A Comparison of Uphill Walking on a Treadmill and on Overground

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SUMMARY
Recently, treadmills have become important tools for walking analysis and training. However, whether these 2 kinds of walking are identical is unclear. The purpose of this study was to elucidate the differences between uphill walking on a treadmill and on overground through action analysis by using EMG and a video camera. A slope (angle of inclination, 8%) and a concrete pavement were used for uphill and horizontal walking on overground, respectively. In this study, the interval between 2 contacts of the right heel with the ground was regarded as a gait cycle. Surface EMG were recorded from six muscles in lower extremity. The ratios of EMG of the gastrocnemius muscle were greater during uphill walking than during treadmill walking, and the peak levels corresponded to 40–50% of the double-supporting period. Similar phenomena were observed during horizontal walking. During an experiment using a treadmill, a subject walks on a moving belt; hence, the power to move the leg forward must be exercised from a double-supporting period to a swing phase following the takeoff of the leg. This may explain why muscular activity and action pattern during treadmill walking differ from those during walking on overground.

1. INTRODUCTION
Walking is one of the most common and fundamental activities performed everyday by humans. Recently, treadmills have become important tools for walking analysis and training. They are widely used at rehabilitation facilities with the assumption that treadmill walking can be substituted for walking on overground. However, whether these 2 kinds of walking are identical is unclear. Although many studies have been performed to compare treadmill walking and overground walking, there are still differences of opinion. Most of these comparative studies have analyzed horizontal walking; only few studies have compared uphill walking on a treadmill and walking on overground. The purpose of this study was to elucidate the differences between uphill walking on a treadmill and on overground through action analysis by using surface electromyograms (EMG) and a video camera.

2. METHODS
2.1 Subjects

Seven healthy male volunteers participated in this study. Their mean height and weight were 173.4 ± 4.7 cm and 64.6 ± 6.6 kg, respectively. The details of the experiment were explained to them, and the experiment was performed with their consent.

2.2 Experiment
A slope (angle of inclination, 8%) and a concrete pavement were used for uphill and horizontal walking on overground, respectively. During treadmill walking, the angle of inclination was changed according to the slope used for uphill walking on overground. Both uphill and horizontal walking on overground were performed 10 times. Either uphill or horizontal walking on a treadmill were performed for 5 min. Surface EMGs of the rectus femoris muscle, biceps femoris muscle, vastus medialis muscle, vastus lateralis muscle, gastrocnemius muscle, and tibialis anterior muscle were recorded.

2.3 Analysis
In this study, the interval between 2 contacts of the right heel with the ground was regarded as a gait cycle. Time normalization was performed with this interval as 100%. EMGs were recorded with a sampling wavelength of 1,000 Hz. After analog to digital conversion, they were input to a computer. All the waves were rectified by filtering the data through a high-pass filter of 20 Hz. Thereafter, the integral EMG (iEMG) for 1 gait cycle was computed and normalized to 100%. Moreover, the iEMG for every 10% of a gait cycle was determined, and the ratio of this iEMG to iEMG for the full cycle was used as the ratio of EMG.

While analyzing gait characteristics by using a video camera, the area formed by connecting the greater trochanter, lateral epicondyle, and lateral malleolus was defined as the knee joint, and the area formed by connecting the lateral epicondyle, lateral malleolus, and head of the fifth metatarsal bone was defined as the ankle.

3. RESULTS
During overground walking, an angular change of the ankle began to be observed, as a plantar flexion, from approximately 40% of the double-supporting period. During treadmill walking, a greater angular change began to be noticed from approximately 50% of the same period (Fig.1). EMG of the gastrocnemius muscle showed no significant differences in the timing of muscular activity between
overground and treadmill walking (Fig.2). During the double-supporting period, greater magnitudes of muscular activity were recorded during overground walking than during treadmill walking. The ratios of EMGs of the gastrocnemius muscle were greater during overground walking than during treadmill walking, and the peak levels corresponded to 40–50% of the double-supporting period (Fig.3). On the other hand, The ratios of EMG of the biceps femoris muscle were greater during treadmill walking than during overground walking, corresponded to 20–50% of the double-supporting period (Fig4). Similar phenomena were observed during horizontal walking.

**Fig1.** The change of ankle angle in uphill walking

**Fig2.** The change of the gastrocnemius muscle activity in uphill walking

**Fig3.** The change of the EMG rate of the gastrocnemius muscle in uphill walking

**Fig4.** The change of the EMG rate of the biceps femoris muscle in uphill walking

### 4. DISCUSSION

Most electromyographic studies on treadmill walking and horizontal walking have claimed that there are no notable differences in action pattern and timing between the 2 types of walking. This study, however, showed that the magnitude of muscular activity was greater during overground walking than during treadmill walking despite the fact that plantar flexion, ascertained from angular changes of the ankle, occurred faster during treadmill walking. A plausible explanation of this could be that the flow of the treadmill belt caused a delay in plantar flexion precedent to the detachment of the foot from the belt, and thus, a strong takeoff was not necessary. The magnitude of gastrocnemius muscle activity did not correspond to the abrupt angular change of the ankle. It seemed that the biceps femoris, which is a hamstring, was active to compensate for the insufficient activity of the gastrocnemius muscle. During an experiment using a treadmill, a subject walks on a moving belt; hence, the power to move the leg forward must be exercised from a double-supporting period to a swing phase following the takeoff of the leg. This may explain why muscular activity and action pattern during treadmill walking differ from those during walking on overground.