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AFO Changes Leg Muscle Activation During Stairs Descending

This study aims to investigate the effects of ankle foot orthosis(AFO) on the activities of tibialis anterior(TA), soleus(Sol), rectus femoris(RF) and biceps femoris(BF) during stairs descending. The activities of TA, Sol, RF and BF were initially measured while descending 4 stairs without using AFO. The activities of the same muscles were then measured again while descending 4 stairs while using AFO. Wilcoxon signed-rank tests were used to analyze the results in order to examine the differences between the with using AFO and without using AFO. Although the activities of TA, Sol and RF were relatively lower while using AFO than without using AFO, only the differences in Sol and RF activities were significant($p<0.05$). The activity of BF was relatively higher while using AFO compared to the activity of BF observed without using AFO. However, difference was not significant($p>0.05$). Conclusion of this study was observed since AFO's ground reaction force absorption during stairs descending reduced the need to use So and RF that is related to shock absorption. BF activity was increased with AFO than without during standing forward to correct the trunk stability.

Key words: *AFO; Descending stairs; Muscle activation*

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INTRODUCTION

The plastic ankle foot orthosis(AFO) is widely used to provide ankle stability, increase ambulation acceleration, and reduce energy consumption in patients with an ankle joint malfunction or disability(1). An AFO helps the body to develop symmetrically by medially transferring the center of gravity or by transferring the body weight to the lesion(2). However, an AFO can cause decreased adaptability compared to the normal function, and its long-term use can cause muscle disuse atrophy (3,4).

Stairs are frequently encountered in daily life(5), and patients using an AFO should be able to ascend and descend stairs. Stairs require balance and muscle activities that differ from walking on a flat surface. Relative to normal walking, a wider range of movements in the leg joints is required to descend the stairs. Weight bearing is constant while descending stairs, and the muscles regulate weight transfer through eccentric contraction (6,7). In addition, in the down stair gait, the ankle angle differs from the horizontal gait in the swing phase when moving the limbs down(8). Since descending stairs is a common activity in daily life, it can be considered to be a subject worthy of research(9).

Vistamehr et al(2014) evaluated the forward propulsion and dynamic balance of healthy adults that use an AFO(10). Radtka et al(2006) studied the kinematic and kinetic health of adults according to their type of AFO(11).

High risk groups like people with orthosis(12) would benefit from deeper investigation on the stair descent. However, there is a lack of research on the effects of an AFO on muscle activity when descending stairs. This study aims to investigate the changes on the activities of the tibialis anterior(TA), soleus(Sol), rectus femoris(RF), and biceps femoris(BF) while descending the stairs with and without the use of an AFO.

METHODS

All subjects were fully informed of the objectives and methods of the study beforehand, and they gave informed consent to participate in the experiments. Subjects were included if they had no musculoskeletal or neurological disorders affecting the upper or lower extremities, no lesions, no history of spine surgery, or no history of surgery of upper and lower extremities. Subjects received information about the procedures and signed an informed consent form. All subjects signed a consent form before the testing session. The subjects of this study consisted of six males who were approximately 23 to 24 years old. Their mean height was 175.33±3.56 cm, and their mean weight was 71.50±7.06 kg.

An EMG amp (4ch original custom-made EMG amp by ME co., ltd.) was used to measure the muscles' activities. The EMG data of the identified periods were converted to the integrated EMG. A band stopping filter from 49.5 to 50.5 was used to cut off the influence of the alternate current from the Japanese electric power supply. The data were filtered using a band pass filter from 10 to 500 Hz to identify the EMG potentials. Then, the EMG data were commutated to integrate the EMG waves. Attachment of the electrode was according to the reference of Rainoldi et al. (2004); the electrode was attached to the dominant side of subjects (13). A manual muscle test was conducted on each muscle after wearing the AFO to meticulously adjust the parts in contact with the leg. The attachment position of the electrode on each of the muscles are shown in Table 1.

Four stairs were used in this study. The stairs were made of wood coated with an anti-slip coating. Each stair was 15 cm in height and 30 cm in width. The four stairs had identical dimensions.
The activities of the TA, Sol, RF, and BF were initially measured while descending the four stairs without using an AFO. The activities of the same muscles were measured again while descending four stairs while using an AFO. When descending the stairs without wearing the AFO, the participants were asked to descend at a comfortable speed. The travel time was measured, and the speed was expressed as a metronome. When the participants descended the stairs while wearing the AFO, the metronome was activated and the subjects were asked to descend the stairs at the same speed as when they descended the stairs without wearing the AFO.

The results of this study were processed using SPSS 19.0. Wilcoxon signed-rank tests were used to analyze the results in order to examine the differences between the trials using the AFO and without using the AFO; the significance level was set to $p<0.05$.

RESULTS

Although the activities of TA, Sol, and RF were relatively lower while using an AFO than without

Table 1. EMG electrodes attached positions.

Muscle	Attached positions
Tibialis anterior	The 25 percentage distance from the tuberosity of tibia to the inter-malleoli line, starting from the tuberosity of tibia
Soleus	The 50 percentage distance from the tuberosity of tibia to the medial side of the achilles tendon insertion, starting from the achilles tendon
Rectus femoris	The 50 percentage distance from the patella bone, starting from the ASIA
Biceps femoris	The 30 percentage distance from the ischial tuberosity to the lateral side of the popliteus cavity, starting from the ischial tuberosity

Table 2. Changes in leg muscle activation induced by AFO while descending stairs (unit: μv).

	Tibialis anterior	Soleus	Rectus femoris	Biceps femoris
With AFO	24.962±8.643	29.852±9.884	23.192±7.381	18.513±6.671
Without AFO	33.855±20.821	40.156±8.310	28.647±10.887	15.403±3.178
z (p)	−0.943 (0.345)	−2.201 (0.028)*	−1.992 (0.046)*	0.314 (0.753)

*$p<0.05$

using an AFO, only the differences in Sol and RF activities were significant ($p < 0.05$). The activity of BF was relatively higher while using an AFO compared to the activity of BF observed without using an AFO. However, the difference was not significant ($p > 0.05$) (Table 2).

DISCUSSION

This study aims to investigate the changes on the activities of the TA, Sol, RF and BF while descending the stairs with and without the use of an AFO.

The subjects of this study were healthy adults. The effects of an AFO on normal subjects were investigated to determine the effects of an AFO without the confounding effects of neuromuscular impairments (11).

TA and So are activated while descending stairs to provide ankle joint stability, and RF is activated by weight bearing to provide stability and reduce shock. BF places the foot on the next stair after the swing phase and acts on clearance (14). The AFO provides ankle joint stability in the support phase and absorbs the ground reaction force to increase knee joint stability (15). In this study, the activities of TA, So, and RF were relatively lower while using an AFO than without using an AFO. Differences in So and RF activities were significant, and the AFO plays an important role in supplementing weak dorsiflexion. A study by Miyazaki et al (1997) also reported that the activity of TA, a major muscle for dorsiflexion, is higher when an AFO is not worn (16). This also causes the largest difference in stance compared to level walking since a large dorsiflexion is needed to move the body both downward and forward in front of the foot. An AFO would limit the initial plantar flexion, preventing the foot from being put down with its toes first (17).

The AFO causes the accumulation of energy when the foot touches the ground surface and promotes propelling. When descending the stairs, the AFO is expected to absorb the force created by the weight. In other words, since the AFO absorbs shock while descending the stairs, the activities of the BF places the foot on the next stair after the swing phase and acts on clearance (14). plantar flexors and knee extensors, which are used to absorb shock, will be lower. In this study, the activities of So and RF were significantly lower while wearing the AFO.

While descending the stairs, the AFO restricts plantar flexion when the foot with AFO contacts the next stair surface (4,9); this causes the use of hip strategy due to increased mobility (2).
Therefore, it can be inferred that in order to regulate the trunk from slanting forward, BF activity is increased while using an AFO compared to without an AFO (18).

Constant reduction in muscular activity could cause muscle disuse atrophy (14).
Therefore, patients who have worn an AFO for an extended period of time and have used it to descend stairs will need additional energy absorbing and weight shifting training when they stop using their AFO.

CONCLUSIONS

This study aims to investigate the changes on the activities of TA, Sol, RF and BF with and without the use of AFO while descending the stairs. Conclusion of this study was observed since AFO's ground reaction force absorption while descending the stairs reduced the need to use So and RF which is related to shock absorption. And in order to regulate the trunk from slanting forward, BF activity is increased while using AFO than without. Therefore, patients who have worn AFO for an extended period of time and who have used it to descend stairs will need additional energy absorbing and weight shifting trainings when they stop using AFO.

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