Immediate Effect of the Toe Spreader on Tibialis Anterior and Peroneus Longus Muscle Activities: a Pilot Study

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Abstract [Purpose] This study investigated how the toe spreader affects muscle activities during gait in order to enhance the clinical decision-making process regarding the different characteristics of toe spreader materials. [Subjects] Twenty healthy participants were recruited. [Methods] Repeated measures of tibialis anterior (TA) and peroneus longus (PL) EMG activities (%RVC) were evaluated with and without toe separators made of two different materials (i.e., soft and hard). [Results] Compared to walking without a toe spreader, TA activity was significantly increased by the soft toe spreader and was decreased by the hard one. PL activity was significantly decreased by the soft toe spreader. [Conclusion] The altered TA and PL activities observed in this study may be the result of the toe spreader providing medio-lateral foot support during walking.

Key words: Toe spreader, Tibialis anterior, Peroneus longus

INTRODUCTION

Ankle instability has several causes, including trauma, peripheral nerve damage or central nerve system problems, and patients with ankle instability may have a strength deficit in the ankle joint invertor muscles, or impairment of proprioceptive sense, or neuromuscular or postural control. The muscular control of the ankle and foot plays an important stabilizing role by offering dynamic restraint against external forces1). The tibialis anterior (TA) is a foot dorsiflexor that controls excessive pronation and maintains the medial longitudinal arch during weight-bearing activities as an extrinsic foot muscle2). Ankle dorsiflexion muscles allow foot clearance from the ground during the swing phase by playing the role of agonists, and control the foot plantar flexion during heel strike in the stance phase by playing the role of antagonists3). Decrease in dorsiflexor strength would affect movement of the foot and ankle at the beginning of the swing phase. The peroneus longus (PL) is dynamically worked in the stabilization of the ankle and foot against inversion injury movement4). Various foot orthoses that have the advantage of non-surgical intervention are available as a standard option in the treatment of foot injuries. Foot orthoses are commonly used to prevent deformity, restore the anatomic foot alignment and mechanism, and facilitate normal foot function5, 6) in several disorders, such as hallux valgus7), arthritis8), plantar fasciitis9) and excessive foot pronation10). In previous research, the toe spreader has been used to control the abnormal tonic toe flexion reflex in the stance phase of gait, which is caused by cutaneous and proprioceptive stimulation of the plantar surface of the foot11). Abduction of the toes of patients with hemiplegia by a toe spreader is restricted to toe clawing and extensor spasticity of the entire lower extremity12). The toe spreader pushes the metatarsophalangeal joints into a neutral position and supports the interphalangeal joints in a slightly extended position to prevent extreme flexion13). It may also provide additional mechanical support and stability to the foot during the stance phase. In a clinical setting, we have used a toe spreader to improve functional limitations of the lower extremity. Although we observed that the toe spreader improves the gait pattern, there remain unexplained positive effects of the toe spreader, including activities of the muscles. The aim of this study, therefore, was to investigate the muscle activities of TA and PL during walking while wearing a soft or hard toe spreader and compare them with those of the barefoot condition, to help guide its use.

SUBJECTS AND METHODS

Twenty healthy male subjects (mean age 25.08±2.12 years, mean height 176.57±4.20 cm, mean weight 69.77±5.60 kg) who responded to flyers posted at Hanseo University and Kyungsung University, Republic of Korea volunteered to participate in this study. Subjects were introduced to the testing procedures before the pretest. After providing their informed consent prior to participation, each subject was given two toe spreaders of different textures, soft and hard (Foot Smart, Memphis, TN, USA), (Fig. 1). We asked each subject about their physical activity level and exclude those...
who engaged in regular exercises. Participants were able to perform the exercise and ambulation without pain, but were excluded if they had a history of injury or surgery to the low back or lower limbs within the past year. The exclusion criteria included past or current inflammatory arthritis, and foot deformities such as hallux valgus, hammer toe and claw toe.

The EMG signals were collected by the Pro Comp Infiniti™ (Thought Technology Ltd., Montreal, Canada) instrument. A triode Ag/AgCl surface electrode, which consists of three electrodes (positive-ground-negative), was placed on each site after preparation consisting of shaving, and scrubbing the skin with alcohol, to reduce skin impedance. Surface electrodes were placed and recorded the activities of TA and PL over each muscle belly of the dominant extremity. The dominant extremity was defined as the one preferentially used to kick a ball. For TA, the surface electrode was placed at approximately 20% of the distance from the tibial tuberosity to the inter-malleoli line. The electrode for PL was placed at approximately 20% of the distal distance from the fibular head. The reference electrode was placed over the lateral malleolus of the same extremity. The EMG signals were band-pass filtered between 20 to 500 Hz and sampled at a frequency 1024 Hz. The root mean square (RMS) of each muscle activity was calculated for five seconds in the anatomical position. The muscle activation during gait was expressed as the relative voluntary contraction (%RVC), the relative muscle contraction of the 100% average EMG signals of the three seconds in the middle of 5 seconds of data, excluding the data of the first and last one seconds, and expressed as %RVC measured over 3 gait cycles. The normalized mean EMG amplitude data (%RVC) were analyzed using SPSS Version 12.0 (SPSS Inc., Chicago, IL, USA) and are presented as means ± standard deviation. One-way ANOVA was used to identify differences in normalized mean EMG data of each muscle during the gait cycle among the three conditions. Confidence intervals were used to evaluate multiple pairwise comparisons with Tukey’s post hoc t-test. The level of significance was chosen as p<0.05.

RESULTS

Significant differences were observed in the muscle activity of TA among the conditions (p<0.05). The result of the post hoc test showed that TA activity significantly increased when the soft toe spreader was used compared to the hard one. PL activity significantly decreased when the soft toe spreader was used compared with walking without a toe spreader (p<0.05). The results of this study are shown in Table 1.

DISCUSSION

In a clinical setting, we found that enhanced muscle activity of the lower extremity when a toe separator was used may lead to better ankle stability in patients with ambulation problem. The study by de Saca et al. found that a toe spreader increased gait velocity and cadence of individuals with hemiparesis. However, the relationship was not clear, and very few studies have addressed muscle activities during ambulation with a toe spreader. Therefore, this study was conducted to determine whether a toe spreader immediately affects TA and PL activities during walking. The tibial muscle and triceps surae complex act antagonistically at the ankle to perform preparatory foot positioning before initial contact, and to absorb high impact loads in the contact phase. On the other hand, the peroneal muscle may play a role in controlling subtalar joint motion, providing mediolateral stability during midstance-propulsion through load-induced eccentric contraction. Peroneal muscle also helps to control the degree of eccentric rear foot eversion, a component of foot pronation during the stance phase. Increased PL activity is observed in subjects with functional ankle instability during the post-heel strike period of gait. An increase in eversion displacement of the subtalar joint seems to be associated with overuse injury. We hypothesized that the toe spreader would affect TA and PL muscle activities. TA amplitude is increased when it resists ankle planar flexion during the contact phase of gait. In this study, the soft toe spreader facilitated TA activity by altering the load of weight-bearing or the stance time. It was explained the additional mechanical stability as an extrinsic support. PL showed a significant decrease in peak EMG amplitude immediately after insertion of the soft toe spreader. PL assists with medio-lateral stability. The explanation of reduced PL activity was supported by a similar result found in an investigation of the standard flexible shoe or stable running shoe. The hard toe spreader did not result in heightened TA activity compared with the soft toe spreader.

Table 1. The %RVC of muscles activity with different toe separators

<table>
<thead>
<tr>
<th>Group</th>
<th>without toe spreader (%RVC)</th>
<th>soft toe spreader (%RVC)</th>
<th>hard toe spreader (%RVC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td>793.7 ± 93.9</td>
<td>1093.9 ± 123.0*</td>
<td>662.7 ± 90.4*</td>
</tr>
<tr>
<td>PL</td>
<td>526.7 ± 97.8</td>
<td>395.4 ± 47.2*</td>
<td>525.9 ± 74.9</td>
</tr>
</tbody>
</table>
It was unclear why this was so, but we speculate that use of the hard toe spreader might disturb the ankle and foot movement during walking because of the decreased toe contact area that it offers. Besides, the participants had no experience walking with increased irritation of the toe. Thus, further research is needed to substantiate these findings and the long-term effects of toe spreader use. It will also be necessary to investigate the kinematic and kinetic data, including center of pressure measurement, joint moments and power, and changes of impact force during “toe spreader walking” performed by patients with chronic ankle instability or impaired neuromuscular control.

REFERENCES

9) Seligman DA, Dawson DR: Customized heel pads and soft orthotics to treat heel pain and plantar fasciitis. Arch Phys Med Rehabil, 2003, 84: 1564–1567. [Medline] [CrossRef]