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Effects of Long and Short Ankle Destabilization Devices on Muscular Activity while Walking

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Abstract. [Purpose] The aim of this study was to investigate how long and short ankle destabilization devices affect the muscle activities of ankle muscles during ankle stabilization against inversion. [Subjects] Eight healthy people (3 males and 5 females) were instructed to walk on the floor. [Methods] The EMG activities of the tibialis anterior, the peroneus longus, the gastrocnemius lateral, the gastrocnemius medial, and the tibialis posterior were measured. [Results] Differences in TA and PL between unbalance and braking were statistically significant for the long ankle destabilization device. The difference in TA between unbalance and braking was statistically significant for the short ankle destabilization device. [Conclusions] The results suggest that the ankle destabilization device may be beneficial in rehabilitation programs especially for the training of walking.
Key words: Electromyography, Orthosis

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INTRODUCTION

Lateral ankle sprain (LAS) occurs not only in sports activities but also during recreation activities[1)]. The recurrence rate of this injury is estimated at seventy three percent[2)] and accounts for fifteen to forty-five percent of injuries afflicting athletes especially in sports activities requiring jumping, landing, or abrupt change in direction such as soccer[3)]. Moreover, ten to forty percent of persons with LAS may later develop chronic ankle instability (CAI)[4)].

CAI may be related to mechanical instability and could cause changes in the mechanical strength of damaged lateral ankle ligaments and ankle evertor muscles[5)]. Past research in the area of ankle stability suggests the importance of evertor muscles' strength[6)]. Also, Wilkerson et al.[7)] demonstrated that muscular weakness of the muscles which evert the ankle can contribute to the recurrence of the injury following lateral ankle sprain. Moreover, a recent study reported the advantages of specifically training the muscles acting in the stabilization of the ankle against inversion during rehabilitation and prevention programs.

Peroneal muscles are the first muscles to contract in a sudden ankle inversion. As underlined by Hertel[8)], increased magnitude of peroneal muscle activity in response to inversion stress may be a good indicator of restored functional stability. An increase in peroneal muscle function is necessary for the prevention of LAS[9)]. Some authors[4)] have argued that rehabilitation programs should address the restoration of control of volitional contractions of the muscles acting at the ankle. Accordingly, a device that induces a normal pattern of movements related to dynamic conditions such as walking should prove useful.

Forestier et al. exploited a kind of ankle destabilization device worn as shoes and suggested that the ankle destabilization device could be beneficial in rehabilitation programs, especially for the training of walking[10)]. Following that research, we devised and fabricated two kinds of ankle destabilization device and evaluated the effect of the ankle destabilization devices on the ankle muscular activities observed while walking. It was expected that these devices would increase evertor muscle activities.

SUBJECTS AND METHODS

Subjects

Eight healthy (mean age 24.4 ± 2.1 yr; mean weight 57.9 ± 6.7 kg; mean height 166.5 ± 10.9 cm) volunteers without any history of ankle sprain participated in the study. Subjects with any musculoskeletal systemic disease were excluded. Prior to the experiment the subjects were informed about the goal of the study and the general procedure. All subjects provided their written informed consent according to the protocol of our university.

Methods

Electromyographic (EMG) activity was recorded on the left leg. To minimize skin impedance, the skin was shaved and cleaned with skincare and then rubbed with sandpaper.

Surface electrodes were placed 3 cm apart and oriented longitudinally over the tibialis anterior (TA), the peroneus longus (PL), the gastrocnemius lateral (GL), the gastrocnemius medial (GM), and the tibialis posterior (TP). The measured EMG signal was low-pass filtered (8-500Hz), amplified 375 times at the source, and sampled at 1000 Hz (12 bits A/D conversion).

All subjects, wore the ankle destabilization device on their left and right feet. We manufactured two kinds of destabilization device. The destabilization axis deviated by 16° toward the medial side in the sagittal plane. Along the destabilization axis, two wood balls were installed under the heel and hallux, respectively, for the long destabilization device; and for the short destabilization device, the balls were installed under the heel and at the crossing point of the destabilization axis and the peroneus longus. As shown in Fig.1, the device used in the present experiment consisted of an articular device fixed under the foot specifically inducing subtalar joint destabilization during touchdown. The inversion and eversion amplititudes were 5 to 30 deg. With this orthosis, subjects are forced to walk with extra ankle inversion and dorsiflexion or plantar-flexion. Moreover, the inversion and eversion can be braked by a third wood ball fixed under the little toe.

Before testing, the maximal muscle activity of each muscle was recorded for 3 seconds during a maximal isometric voluntary contraction (MVC) test. Measurements were done during resistive ankle plantarflexion, dorsiflexion, pronation and supination movements with the subjects in sitting the position. After a muscular warm-up, all subjects performed 3 MVC trials. The average EMG value (in V) was recorded as the MVC reference value.

Subjects had a practice period to familiarize themselves with the destabilization device while walking. Then, subjects were instructed to walk. The subjects were asked to perform 3 strides (stance and swing phases). This task was executed with the ankle destabilization mechanism both unbalanced and braking. Subjects performed 5 trials per condition and the order of presentation of the conditions was randomized. The mean muscular activity was expressed as the percentage of the MVC reference value. A video camera allowed us to precisely record the heel-strike occurrence and to synchronize the mechanical events with the EMG signal.

All statistical analyses were performed using the Statistical Package for the Social Sciences Version 12 (SPSS Inc, Japan). Descriptive statistics including mean values ± standard deviation were calculated. We compared the mean muscular activities of 5 muscles (TA vs. PL vs. TP vs. GL vs. GM) under 2 conditions (unbalanced vs. braking) using the paired t-test. The level of significance was chosen as $p<0.05$.

RESULTS

When subjects were wearing the long ankle destabilization device, muscular activation was higher for TA (51.4 ± 21.0% vs 31.7 ± 12.4%), PL (89.4 ± 40.2% vs 38.4 ± 19.0%), GM (71.2 ± 22.5 vs 60.5 ± 22.7), GL (49.3 ± 19.9% vs 42.4 ± 15.9%) and TP (120.5 ± 49.2% vs 90.2 ±

Fig. 1. The lateral view of the long ankle destabilization device. A: The long ankle destabilization device while braking.B: Illustration of the subtalar joint destabilization induced by the device. When the subject steps, the shoes rotates around destabilization axis, eliciting an inversion and dorsiflexion movement of the ankle.

40.5%) in the stance. Differences in TA and PL between unbalanced and braking were statistically significant ($p<0.05$); and for TA (30.0 ± 10.1% vs 20.4 ± 4.2%), PL (38.9 ± 18.6% vs 20.0 ± 9.2%), GM (53.5 ± 33.1 vs 20.8 ± 5.0), GL (41.3 ± 29.2% vs 15.0 ± 4.8%) and TP (62.3 ± 33.9% vs 29.7 ± 15.4%) in the swing.

When subjects were wearing the short ankle destabilization device, muscular activation was higher for TA (28.2 ± 14.0% vs 31.6 ± 15.2%), PL (91.0 ± 59.7% vs 73.7 ± 25.9%), GM (107.6 ± 33.4 vs 97.4 ± 37.0), GL (82.4 ± 32.6% vs 69.7 ± 32.1%) and TP (151.3 ± 69.3% vs 131.2 ± 65.8%) in the stance. Differences in TA between unbalanced and braking were statistically significant ($p<0.05$); and for TA (32.3 ± 7.2% vs 32.7 ± 10.9%), PL (29.4 ± 12.2% vs 29.6 ± 14.6%), GM (23.1 ± 10.1 vs 21.3 ± 10.7), GL (23.8 ± 10.1% vs 19.0 ± 6.2%) and TP (43.4 ± 18.5% vs 41.8 ± 14.5%) in the swing.

DISCUSSION

Inversion ankle sprain has been identified as a common musculoskeletal injury. The incidence of re-injury remains relatively high, between 10–30%[11]. The aim of this study was to evaluate muscular activities in walking while wearing our novel ankle destabilization devices, since it is believed that increased muscular activity could improve ankle stabilization against inversion. Our main result shows that the long ankle destabilization device increased activation of the tibialis anterior and peroneal muscles. TA and PL stabilize the destabilization axis through excess braking of the joint movement[12], increasing the activation of TA and PL.

The recurrence of LAS is caused by a deficit in nerve-muscle control ability[2,13]. TA and PL stabilize the ankle and protect the ankle against inversion movement. The muscular specificity of the destabilization device is illustrated in the results of this study.

The activation of TA decreased while wearing the short ankle destabilization device. The function of TA is to perform dorsiflexion and inversion of the ankle joint. The short ankle destabilization device induced ankle joint inversion and plantar- flexion, and TA didn't need to resist the plantar-flexion of the ankle joint. This may be the reason why TA activity decreased.

The higher muscular activity observed for the medial and lateral gastrocnemius and TP can also be explained by the action of the ankle destabilization device. The ankle destabilization device does not give sufficient support to the foot during the mid-stance and propulsive phases of the walking cycle. Moreover, when wearing the short ankle destabilization device, subjects were forced to walk with extra plantar- flexion; and when wearing the long ankle destabilization device, subjects were forced to walk with extra dorsiflexion.

In conclusion, the results show the potential benefits of the ankle destabilization device for rehabilitation programs. Using this device led to specific muscle strength training of the peroneal and tibialis anterior muscles. A limitation of the present study is that the muscular activity while walking with or without the ankle destabilization device was only assessed in healthy young subjects. It may be interesting to assess the effects of such a device in a population suffering from CAI. It is possible that use of this device could lead to a decrease in the frequency of recurrent ankle sprains. A future study will attempt to assess injury incidence with and without the orthosis and will further examine muscle activities induced by shoe-integrated orthoses during more dynamic functional conditions such as jumping and running.

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