Original Article

The effects of changes in support and inclined boards on lower-extremity muscle activity

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Abstract. [Purpose] The purpose of this study was to identify the effects of changes in support and inclined boards on lower-extremity muscle activity. [Subjects and Methods] The study subjects were 15 healthy adult males. Aero-Step equipment was used as an unstable support, and an inclined board was used to maintain angles of 0° and 20°. Electromyography was employed to analyze lower-extremity muscle activity. [Results] The vastus lateralis, vastus medialis, rectus femoris, gastrocnemius, soleus, and tibialis anterior muscles showed significant differences according to changes in the support and inclined board. In post-hoc tests the vastus lateralis, vastus medialis, and rectus femoris muscles showed significantly increased activity when exercises were performed on the unstable inclined board (20°) than the stable support (0°), unstable support (0°), or stable inclined board (20°). The gastrocnemius, soleus, and tibialis anterior muscles showed significantly increased activity when exercises were performed on the unstable support (0°), stable inclined board (20°), or unstable inclined board (20°) than on the stable support (0°). [Conclusion] An unstable support and increased slope of the inclined board may increase lower-extremity muscle activity.

Key words: Support, Inclined board, Muscle activity

INTRODUCTION

The knee is the most commonly injured region of the body and occasionally requires long-term rehabilitation depending on the degree of injury1). The most important muscle around the knee joint is the quadriceps femoris. This is the agonist for knee joint extension and plays a crucial role in stabilizing the lower extremities, particularly the knee joint, during standing and walking. A previous study emphasized intervention measures using an unstable support, showing that exercises performed on an unstable support were more effective in improving proprioception than those on a stable support even during weight-shift training; and were effective for promoting sensory-motor feedback by facilitating balance training and the motor control strategy around the ankle, and for enhancing the muscle contraction strategy that strengthens weakened muscles2). Previous studies reported the effects of unstable supports on lower-extremity muscle activity according to differences in air pressure3), the effects of exercises using unstable supports on gait and balance ability4), and the effects of variable bridging exercises on trunk and lower-extremity muscle activity5). However, most of those studies were limited to the effects of unstable supports on flat ground, and there are comparatively few studies on the effects of unstable supports and changes in inclined board angle. Therefore, this study examined the effects of changes in support and inclined boards on lower-extremity muscle activity.

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SUBJECTS AND METHODS

The study subjects were 15 healthy young males in their 20s (mean age 22.0 ± 2.0 years, height 174.0 ± 4.2 cm, weight 64.1 ± 7.7 kg) who were enrolled at U University in Chungcheongbuk-do. The inclusion criteria were lack of pain in the knee joint or ankle joint; exclusion criteria were medical history that could influence the experiment. Ethical approval for the study was granted by the U1 University institutional review board. All subjects read and signed consent forms in accordance with the ethical standards of the Declaration of Helsinki.

The Aero-Step equipment (Aero-step XL, TOGU, Germany) was used as an unstable support, and a wooden inclined board (75 cm × 37 cm) was specially designed to maintain angles of 0° and 20°. The equipment was attached to the unstable inclined board (UIB, 20°) and the unstable support (US, 0°), but was not attached to the stable support (SS, 0°) or the stable inclined board (SIB, 20°). The electromyography (EMG) equipment MP150 (BIOPAC System Inc., Santa Barbara, CA, USA) was used to measure muscle activity, and surface electrodes were attached to the vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF), gastrocnemius muscle (Ga), soleus muscle (So), and tibialis anterior (TA) muscles.

The subjects were instructed to maintain a standing position while extending the knee joint and to maximize isometric contraction of the lower-extremity muscles, and to maintain the contracted position for 10 seconds including the preliminary time necessary for complete contraction during the muscle contraction. Only the EMG signals for four seconds, excluding the first and last three seconds, were selected from the recorded EMG signals to be used as data values. A 30-second break was given between exercises to minimize potential muscle fatigue. The muscular activity values were collected from each subject performing the exercise three times on each support, and the second value of the three measurements on each support was divided by the volume of EMG signals during the maximum voluntary isometric contraction (MVIC) in a position for manual muscle testing.

One-way repeated measures analysis of variance (ANOVA) was performed to examine changes in lower-extremity muscle activity according to changes in support and inclined board, and the Bonferroni post-hoc test was employed. SPSS (version 12.0 for Windows) was used for statistical processing and the statistical significance level was set at α=0.05.

RESULTS

Changes in the support and inclined board led to significant differences in the VL, VM, RF, Ga, So, and TA readings (p<0.05). In the post-hoc test, the VL, VM, and RF showed significantly higher levels of activity when exercises were performed on the UIB (20°) than on the SS (0°), US (0°), or SIB (20°) (p<0.05). The Ga, So, and TA showed significantly higher activity when exercises were performed on the US (0°), SIB (20°), or UIB (20°) than on the SS (0°) (p<0.05) (Table 1).

DISCUSSION

The results showed significantly higher levels of muscular activity in the VL, VM, and RF when exercises were performed on the UIB (20°) than on the SS (0°), US (0°), or SIB (20°), and significantly higher activity in the Ga, So, and TA when exercises were performed on the US (0°), SIB (20°), or UIB (20°) than on the SS (0°). This might be because increased slope of the inclined board with an unstable support led to a corresponding increase in sole flexion, subsequently increasing VL, VM, RF, Ga, So, and TA activity as the result of a compensatory action to move the trunk backward in order to prevent falling forward. Joseph and Nightingale6) reported that an increase in heel height resulted in a significant increase in gastrocnemius muscle activity, and that wearing high-heeled shoes shifts the center of gravity forward, and thus increases the activity of the gastrocnemius to prevent the body from tilting forward at the ankle. In addition, Choe and Sin7) reported that the calf and hamstring muscles increased activity in order to correct imperfect posture.

Table 1. Comparison of lower-extremity muscular activity according to changes in support and inclined board (Units: %)

|                  | SS (0°) | US (0°) | SIB (20°) | UIB (20°) |
|------------------|---------|---------|-----------|-----------|
| VL**             | 55.5 ± 10.8 | 58.7 ± 11.1 | 72.3 ± 10.7 | 84.7 ± 9.6 |
| VM**             | 56.5 ± 11.3 | 58.7 ± 10.0 | 73.5 ± 11.5 | 87.5 ± 8.8 |
| RF**             | 55.4 ± 16.3 | 57.1 ± 14.5 | 64.9 ± 16.2 | 77.8 ± 16.2 |
| Ga**             | 33.5 ± 13.8 | 58.3 ± 16.5 | 61.2 ± 20.1 | 61.9 ± 17.2 |
| So**             | 44.7 ± 11.1 | 68.8 ± 12.1 | 63.5 ± 19.7 | 65.4 ± 19.5 |
| TA**             | 43.1 ± 14.2 | 62.9 ± 13.5 | 59.7 ± 17.2 | 63.8 ± 18.7 |

SS: stable support; US: unstable support; SIB: stable inclined board; UIB: unstable inclined board; VL: vastus lateralis; VM: vastus medialis; RF: rectus femoris; Ga: gastrocnemius; So: soleus; TA: tibialis anterior. *p<0.05, **p<0.01
In the present study, increased lower-extremity muscle activity when performing exercises on the unstable support compared with the stable support might be a consequence of the unstable support increasing external perturbation more than the stable support, resulting in the use of the ankle strategy to maintain postural stability and increased use of the hip strategy. A more unstable support leads to a corresponding increase in co-contraction of the muscles that pass through the body segments to maintain physical balance; this is improved through the gamma motor neurons, and this action for improvement eventually influences joint stability. Sagong and An9) also reported that increased heel height on an unstable support correspondingly increased muscular activities of the rectus femoris and the erector spinae. The results of these previous studies support the findings of the present study.

This study has some limitations. Firstly, it involved a small number of subjects. Secondly, it included only adults resident in Chungcheongbuk-do, which makes the generalization of the findings problematic. Future studies may be required to investigate the effects of changes in support and inclined board on lower-extremity activity among other populations groups, such as elderly people.

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