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Original articles

Effects of Activation of Gluteus Maximus and Abdominal Muscle using EMG Biofeedback on Lumbosacral and Tibiocalcaneal Angles in Standing Position

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Purpose: The purpose of the present study was to determine the effects of activation of gluteus maximus (Gmax) and abdominal muscle using EMG biofeedback on lumbosacral and tibiocalcaneal angles in standing position.

Methods: Fourteen healthy subjects with normal feet participated in the present study. Electromyographic (EMG) biofeedback using visual cue was used to activate the external oblique (EO) and Gmax. The lumbosacral and tibiocalcalcaneal angles were measured by electronic goniometers. All the subjects were instructed to activate the Gmax and EO monitoring increasing amounts of the muscle activities in each muscle. The lumbosacral and tibiocalcaneal angles were collected in three trials during resting and activation of each muscle using EMG biofeedback in standing position. The mean value of three trials was used in the data analysis. A paired-t test was used to compare the lumbosacral and tibiocalcaneal angles between resting and activation of the Gmax and EO using EMG biofeedback.

Results: The lumbosacral and tibiocalcaneal angles were significantly less in the resting compared to activation using EMG biofeedback ($p<0.05$).

Conclusion: The activaition of Gmax and abdominal muscles using EMG biofeedback play role to control the pronation of subtalar joint during the weight-bearing.

Key Words: Abdominal muscles, Gluteus maximus, Pronation, Subtalar joint

Ⅰ. Introduction

The functional structure and alignment of the human foot plays an important role in bipedal standing and locomotion.[1] In normal gait, the movement of subtalar joint allows the foot to change from flexible to rigid structure enabling the foot to adapt to uneven terrain.[2,3] The pronation of the subtalar is characterized by movement in the three planes in a closed kinematic, consisting of the adduction and plantarflexion of talus and eversion of calcaneus. The adduction of the talus causes the internal rotation of the femur as well as tibia.[4] Thus, the amounts or timing of abnormal pronation of the subtalar joint, causing the internal rotation of tibia, is associated to various musculoskeletal disorders such as patellofemoral pain, plantar fasciitis and Achilles tendonitis.[5-7]

In recent years, several studies were reported that eversion of calcaneus affects the alignment of the pelvis. Khamis and Yizhar (2007)[8] reported that the amount of anterior pelvic tilt was increased significantly, when the eversion of calcaneus was increased artificially in bipedal standing. Furthermore, Pinto (2008)[9] determined if bilateral and unilateral increase in eversion of calcaneus affected the pelvic alignment in the coronal and saggital planes during bipedal standing, and reported an increase in anterior pelvic tilting with both bilateral and unilateral eversion of

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calcaneus and a lateral pelvic tilting with unilateral eversion of calcaneus. The excessive eversion of the calcaneus causes the tibia and femur to rotate internally, also this cause to increase the anterior pelvic tilting and the lumbar lordosis.[9,10] The unilateral presence of excessive calcaneal eversion is expected to produce a functional leg length discrepancy and consequently, may produce a lateral tilt of the pelvic to the side with increased pronation subtalar joint, which may cause scoliosis, to some extent.[11] Thus, excessively uinlateral or bilateral eversion of calcaneus may be associated with the occurrence of pathological disorders of the lumbar spine

The tilting of pelvis in the sagittal plane is controlled by various muscles. The posterior pelvic tilting was produced by force–couple, generated by contractions of abdominal muscles and hip extensors. Although the pronation of subtalar joint affects the alignment of the pelvis, it was not known that the activation of lumbo–pevic muscles such as abdominal and gluteal muscles affect the pronation of subtalar joint. In addition, some literatures addressed that lateral rotation of the thigh at the hip joint by the gluteal muscles acts to prevent medial rotation of the thigh and entire lower extremity and thus, the lateral rotation in hip joint by acting gluteus maximus (Gmax) can stabilize the subtalar joint and prevent excessive pronation of the foot.[12] Even the previous literatures addressed that the foot pronation in the distal segment affected the alignment of pelvis of proximal segment, however, it is not quantitative study to determine the effect of contractions of abdominal and gluteal muscles, causing to change the alingment of pelvis, on the amount of foot pronation during the bipedal standing. Thus, in this study, we aimed to determine the effect of activation of gluteus maximus (Gmax) and abdominal muscle using EMG biofeedback on lumbosacral and tibiocalcaneal angles in subjects with normal feet, in bipedal standing.

II. Methods

1. Subjects

In this study, fourteen healthy adults (male: ten, female: four) participated in this experiment. We selected the subjects in normal feet alignment. Normal alignment of the foot was considered to measure the resting calcaneal stance position (RCSP) and navicualr drop test.[13–15] The RCSP and navicular drop test was measured using a gravity goniometer and ruler, respectively. The RCSP was quantified by measuring the posterior bisection line of the heel in relation to the ground. The height of navicular drop was measured as difference in navicular height between standing with subtalar joint in a neutral position and with relaxed foot posture. A normal foot type alignment was defined as having a RCSP between 2° of inversion and 2° of eversion, and as navicular drop between 5 and 9 mm. Subjects who met both RCSP and navicualar drop criteria were selected for possible participation in in this study. The exclusion criteria included current orthopaedic or neurological conditions and lower extremity contracture or deformity that would prevent a normal standing. All subjects signed an informed consent form. General information of the subjects is presented in Table 1.

2. Experimental methods

1) Instrumentation

In this study, The wireless TeleMyo DTS (Noraxon, Scottsdale, AZ, USA), was used for EMG biofeedback in order that monitor the amount of activation of Gmax and abdominal muscle and for measuring the tibiocalcaneal angle. The sampling rate of EMG signals for each muscle was 1000 Hz. EMG data were processed into the root mean square (RMS), which was calculated from 50–ms data points of windows. The tibiocalcaneal angle analyzed using MyoResearch Master Edition 1.07 XP software (Noraxon, Scottsdale, AZ, USA). The electronic goniometer (DUALER IQ, J–TECH, USA) with two inclinometers was used to measure the lumbosacral angle.

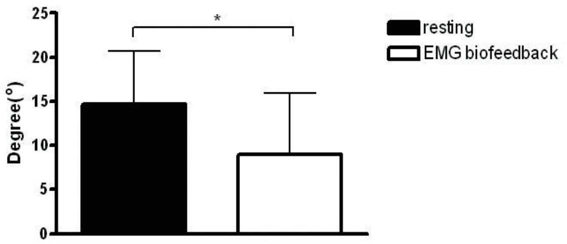
2) Procedures

Before running this experiment, subjects were fully explained to the experimental procedure. We positioned the subject supine on a table with hips and knees flexed and both feet flat on the table. We instructed the subject

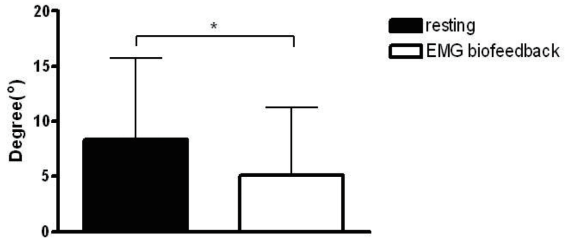
Table 1. Characteristics of the subjects. (N=14)

	Age (yr)	Height (cm)	Mass (kg)	ND (mm)	RCSP(o)
Mean ± SD	22.07 ± 1.27	173.57 ± 4.89	69.29±5.34	7.07±0.92	0.80±0.83

SD = Standard deviation, ND = Navicular drop, RCSP = Resting calcaneal standing position.



(A) Lumbosacral angle



(B) Tibiocalcaneal angle

Figure1. Electrogoniometer for tibiocalcaneal angle.

to contract abdominal and gluteal muscles simultaneously and to press the lumbar spine firmly against the table. We judged the subject as correctly completing the posterior pelvic tilt when the tester could not place his hand between the subject's lumbar spine and the surface of the table during three consecutive posterior pelvic tilting. Then, the surface electrodes were attached to external oblique (EO: obliquely approximately 45°(parallel to a line connecting the most inferior point of the costal margin of the ribs and the contralateral pubic tubercle) superior to the anterior superior iliac spine, near the level of the umbilicus) and Gmax (midpoint of a line running from the last sacral vertebrae to the greater trochanter). The electrogoniometer's sensors were placed on each tested leg and calcaneus by the same examiner. The goniometer was placed in a frontal plane. One end was placed along the midline of the dorsal side of the distal lower leg above the line joining the two malleoli and the other goniometer end was placed on the dorsal side of the calcaneal bone below the line joining the two. The tibiocalcaneal angle was defined as the angle between the midline of the calcaneus in the frontal plane and the bisection line of gastrocnemius. The lumbosacral angles was measured by placing the primary sensor at spinous process in T12 and secondary sensor at scaral midpoint.

The subject was instructed to maximally tighten his abdominal muscles while squeezing his buttocks together to complete a posterior pelvic tilting in a standing position and then sustained an contraction by monitoring visually the bar graphs using EMG biofeedback for 5 second. The tibiocalcaneal and lumbosacral angles were measured during the resting and activation relaxation of EO and Gmax by using the EMG biofeedback.

3) Statistical analysis

To determine the intrarater reliability of lumbosacral and tibiocalcaneal angles, intraclass correlation coefficients (ICCs) were used. The $ICC_{3, 1}$ model was selected to test

Figure2. Lumbosacral and tibiocalcaneal angle in resting and muscle activation using EMG biofeedback(*p<0.05).

the intrarater reliability. The average data were used from 3 repeated measurements of the lumboscacral and tibiocalcaneal angles for data analysis. SPSS, Version 15.0 for Windows (SPSS, Inc., Chicago, IL) was used for data analysis. The pared-t tests were used to compare the lumboscacral and tibiocalcaneal angles between pre- and post-activation. The statistical significance was set at $p = 0.05$.

III. Results

The measure of the lumbosacral (ICC3,1 = 0.94; 95 %CI: =0.86~0.98) and tibiocalcaneal (ICC3,1=0.99; 95 %CI:=0.97~0.99) angles showed good intrareliability. In this study, the measured lumboscacral and tibiocalcaneal angles was very high reliability, thus, it is possible to generalize the results. The mean±standard deviation of lumbosacral angle was 14.69°±6.00° during the resingpre and 8.95°±6.95° during activation of EO and Gmax using EMG biofeedback (Figure 1A). The mean±standard deviation of tibiocalcaneal angle was 8.33°±7.41° forduring the resting and 5.12°±6.12° during activation of EO and Gmax using EMG biofeedback (Figure 1B). The lumbosacral and tibiocalcaneal angle were significant difference between the resting and and activation of EO and Gmax using EMG biofeedback ($p<0.05$)(Figure, 1A, 1B).

IV. Discussion

In normal gait, the pronation of subtalar joint occurs immediately after the initial contact to allow flexibility of the foot for adaptation of the foot and shock absorption in the weight-bearing surface[2] Also, the maximal amount of pronation in the subtalar joint is 6.3° in 37.9% of the stance phase, changing in range of the position of it in single-limb support and neutral position of subtalar joint.[16] The most common pathomechanics of foot problem is the excessive pronation of the subtalar joint.[17] The excessive pronation of the subtalar joint causes various overuse injuries and syndromes of lower extremity. The pronation of the subtalar joint is controlled by passive and active structure of the lower extremity.[18–22] The passive structures are the locking of the first metatarsal bone and cuneiform, plantar ligament, and plantar fascia. The active structures are the foot extrinsic and intrinsic muscles, such as tibialis anterior and posterior, abductor hallucis, flexor digitorum brevis, and interosseous, during weight bearing in stance and gait. Although previous studies reported that the pronation of the subtalar joint is controlled by various passive and active structures of the lower extremity, it was no study to determine that the muscles around proximal segments such as pelvic and femur may control the pronation. Therefore, the purpose of this study was to determine that the contraction of Gmax and abdominal muscles using EMG biofeedback can affect the tibiocalcaneal and lumbosacral angles in bipedal stance. Khamis and Yizhar (2007)[8] reported that when applying the lateral wedges under the foot in bipedal stance, the angle of calcaneal eversion increased by 6.5° and the angle of anterior pelvic tilting increased by 1.2°. Also, Pinto et al (2008)[9] reported that when applying the lateral wedges under the foot in bipedal and unilateral, the angle of calcaneal eversion increased by 7.81° and 11.68° and the angle of anterior pelvic tilting increased by 1.57° and 1.41°. Although difference of lumbosacral angle cannot estimate difference of angle of anterior pelvic tilting, in this study, differences of lumboscacral and tibiocalcaneal angles between the resting and activation of Gmax and abdominal muscles using EMG biofeedback were 5.74° and 3.21°, respectively. Previous studies demonstrate the relationship between lumbosacral angle and anterior pelvic tilting[10,23]. Levine and Whittle (1996) reported that angle of pelvic tilting and lumbosacral angle decreased by 8.7° and 9.0°, respectively during maximal posterior pelvic tiling. In this study, the mean of lumbosacral angle was 8.95° for activation of Gmax and abdominal muscles using EMG biofeedback. Compared with previous studies, in this study, the angle of posterior pelvic tilting may be similar with that in previous study. Thus, Compared with Pinto et al (2008)[9] and Khamis와 Yizhar (2007)'s[8] study, tibiocalcaneal angle increased more than that previous studies. We speculate that reason is that the motion of pelvic and hip of proximal segments is more effective to increase the motion of tibial and foot of the distal segments in transverse plane.

The dysfunction of lumbopelvic–hip complex is associated with overuse injuries of lower extremity. Especially, previous studies demonstrated that the neuromuscular changes of gluteus medius were ankle hypermobility, ankle injury, iliotibial band friction syndrome, patellofemoral pain syndrome.[24–25] Thus, in previous studies, the strengthening of gluteus medius was recommended to prevent and manage the various injuries of lower extremity related to excessive pronation of the subtalar joint. In this study, activation of Gmax and abdominal muscles using EMG biofeedback significantly increase the angle of lumbosacral and tibiocalcaneal angle related to the pronation of subtalar joint. Therefore, we assert that the posterior pelvic tilting by activaition of Gmax and abdominal muscles play role to to control the pronation of subtalar joint during the weight–bearing. Further study is needed to determine if the strengthening of Gmax and abdominal muscles can prevent the excessive pronation of subtalar joint and manage the various overuse injuries related to the excessive pronation of subtalar joint.

The first limitation of this study is that other muscles was not monitored using the EMG biofeedback. However, the subjects were instructed and practiced to contract selectively Gmax and abdominal muscles. The second limitation is to measure tibiocalcaneal angle only in standing. In further study, it is needed to determine that the contraction of Gmax and abdominal muscles can affect the tibiocalcaneal and lumbosacral angles during functional activities such as stair–up or gait. In this study, it was determine if contraction of Gmax and abdominal muscles effects on lumbosacral and tibiocalcaneal angles in standing position. The lumbosacral and tibiocalcaneal angle were significant difference between resting and activation of Gmax and abdominal muscles using EMG biofeedback. Thus, the activaition of Gmax and abdominal muscles using EMG biofeedback play role to control the pronation of subtalar joint during the weight–bearing.

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