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The Effect of the EMG Activity of the Lower Leg with Dynamic Balance of the Recreational Athletes with Functional Ankle Instability

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Abstract. [Purpose] The present study investigated the surface electromyographic activity of the lower leg in dynamic balance of recreational athletes with functional ankle instability (FAI) and stable ankles (control). [Methods] Twenty recreational athletes were divided into a functional ankle instability group (10 males) and a stable ankle group (10 males). Their dynamic balance was assessed with the star excursion balance test (SEBT). For all the participants, surface electromyographic (EMG) activities of 7 muscles were evaluated by a Myosystem 1400A unit during the SEBT in 8 directions. [Results] The SEBT scores of the functional ankle instability group (FAIG) were significantly lower than those of the stable ankle group (SAG) during dynamic balance in the anterior, lateral, anterolateral, posteromedial, and posterolateral directions. The EMG activities of TA and PL in the anterior, anteromedial & anterolateral directions, of TP and SE in the posterior, posteromedial and posterolateral directions, and of VL in the lateral direction were significantly lower in FAIG than in SAG. [Conclusion] This study showed that functional ankle stability a affected EMG activity of the lower leg in dynamic balance.

Key words: Functional ankle instability, Electromyographic (EMG) activity, Dynamic balance

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INTRODUCTION

Ankle sprains are among the most common of injuries, Approximately 85% of ankle sprains are due to an inversion injury involving lateral ligament damage[1,2)], and occur in sports with a sudden turn over, cutting, or landing after a jump[3)]. Up to 50% of individuals who sprain their ankles have chronic ankle instability with chronic pain, proprioception deficits, and weakness of the peroneal muscle at the ankle joint[1,2,4)]. And it can be defined as either mechanical instability or functional instability[5,6)]. The mechanical instability can be objectively measured as ligament laxity whereas the functional instability is a subjective feeling of giving way or recurrent sprains[5)]. Functional ankle instability (FAI) might result from one or a combination of the following: muscle strength deficits, delayed muscle reaction time, or proprioception deficits at the ankle joint[7)]. The proprioception and feedback mechanisms of the neuromuscular system, which affect ankle instability are important for maintaining functional stabilization of the ankle joint[8)] and 66% of people who complained of functional ankle instability after ankle sprain showed weakness of the peroneal muscle[9,10)]. Proprioception deficit and delayed reaction time of peroneal muscle makes postural control difficult with ankle instability[7,11)]. Also, a significantly prolonged reaction time of peroneus longus was reported for chronic ankle instability. Therefore, strengthening the peroneal muscle is important in the rehabilitation training for functional ankle instability[12)]. However there is no significant correlation between FAI and the dynamic activity of the peroneal muscle[13)]. Because sensorimotor deficits occur for joint position sense and postural control in FAI, deficits in peroneal muscle reaction time following perturbation are not evident[14)]. Subjects with chronic ankle instability do not have decreased peroneus longus strength but may instead have strength deficits in the invertor[15)].

Muscle strengthening of the tibialis anterior ankle instability should take place first[16)]. Because eversion torque does not affect in FAI, muscle strengthening of the evertor is not needed in the training program[17)]. Moreover, in FAI, a deficit of plantar flexion torque is shown, but deficit of torque in inversion, eversion, and dorsiflexion are not shown[18)]. In ankle instability, deficits of knee flexor and extensor strength could be due to weakness of the plantar flexor[19)]. However as mentioned above, despite several previous studies having investigated the correlation between ankle instability and muscle activity, a consensus is lacking regarding the clinical evidence of the EMG activity of the lower leg during dynamic balance of subjects with functional ankle instability. Therefore, the purpose of this study was to investigate electromyographic activity of the lower leg during dynamic balance of recreational athletes with functional ankle instability. Furthermore, a thorough quantitative analysis would provide basic information regarding dynamic balance of patients with functional ankle instability.

SUBJECTS AND METHODS

Subjects

The ankles of 20 male subjects were tested in this study. Subjects were recruited for participation from the student population at a Eulji university. Subjects who qualified for participation were randomly assigned to two groups: 10 subjects with functional ankle instability (FAIG): (age = 21.50 ± 2.36 years, height = 174.90 ± 3.84 cm, weight = 71.70 ± 4.24 kg), and 10 subjects with stable ankles (SAG): (age = 21.90 ± 2.02 years, height = 175.20 ± 5.75 cm, weight = 69.80 ± 4.75 kg).

To meet the criteria for functional ankle instability (FAI), a subject had to meet report a history of a severe ankle sprain injury with at least 3 days of immobilization, at least 2 additional ankle sprains and 2 giving-way sensations with weight-bearing activity within the year before their participation in this study[20,21]. The groups were appropriately matched for age, height, and weight to ensure there were no statistical differences between the groups. All volunteers participated in at least 30 minutes of exercise 3 times per week. Volunteers were excluded if they had experienced an acute ankle sprain within 6 weeks, if they had a history of surgery to or fracture of either lower extremity. Participants in the SAG were free of any history of lower extremity injury. The 20 volunteer participants signed an informed consent form approved by our institution's review board, which also approved the study.

Methods

Dynamic balance was assessed with the Star Excursion Balance Test (SEBT)[6,22,23], and was performed with the subject standing barefoot at the center of a grid laid on the floor with 8 lines extending at 45° increments from the center of the grid. A "crosshairs" was drawn at the center of the grid. The 8 lines were labeled: anterolateral, anterior, anteromedial, medial, posteromedial, posterior, posterolateral, and lateral. The 8 lines were named according to the direction of reach in relation to the stance leg. The subject maintained a single-leg stance while reaching with the contralateral leg to touch as far as possible along the chosen line. The order of reach directions was assigned using a Latin square to avoid order effects affecting the data. Subjects then returned to a bilateral stance while maintaining their equilibrium. The examiner marked the point touched along the line and then manually measured the distance in cm from the center of the grid to the touch point with a tape measure. The average of the 2 reach trials in each direction was calculated as reach distance/non-stance leg length × 100%. Subjects then performed 2 trials in each direction on each limb and EMG activity of lower leg. Thirty seconds of rest were provided between individual reach trials. If the stance foot moved during the trial was rendered invalid. When this occurred, the stance foot was repositioned at the center of the grid for the next trial.

During the SEBT, surface EMG was used to simultaneously record 7 muscles of the dominant leg. The raw surface EMG signals were digitally sampled at 1,000 Hz, and bandpass filtered during data collection from 10 to 500 Hz using a Myosystem 1400A (Noraxon Inc, Scottsdale, AZ, U.S.A)[24,25]. Muscle activity was analyzed for 10 seconds, and the EMG amplitudes (root-mean-square) were rectified and normalized to each respective maximal voluntary isometric muscle contraction (MVC). The rectified and normalized EMG amplitudes were then averaged for all subjects across the 2 trials in each direction of the SEBT and expressed as normalized peak EMG (%). To record EMG activity, we used bipolar, disposable, self-adhesive, Ag/AgCl surface electrodes that were 2 cm in diameter and had an interelectrode distance of 2 cm. The surface electrodes were placed over the muscle bellies of the tibialis anterior (TA), peroneus longus (PL), vastus lateralis (VL), rectus femoris (RF), tibialis posterior (TP), soleus (SE) and biceps femoris (BF) muscles according to guidelines for surface electrode placement. Subjects also performed 15 seconds of muscle contraction of each limb to measure the EMG activities of the lower legs. To reduce anticipatory effects of muscle contraction, thirty seconds of rest were provided between individual reach trials[26].

The mean and standard deviation calculated for all data analyzed in this study using the SPSS/PC 12.0 statistical program for Windows™. The differences of EMG activity with dynamic balance ability between FAIG and SAG, were examined with the independent sample t-test. The level of statistical significance for all variables was chosen as $\alpha=0.05$.

RESULTS

The Star Excursion Balance Test (SEBT) was performed to test dynamic balance. SEBT scores of FAIG were significantly lower than those of ASG in the anterior, lateral, anterolateral, posteromedial, and posterolateral directions ($p<0.05$). SEBT scores of FAIG were slightly significantly lower than those of SAG in the posterior, medial and anteromedial directions but not significantly (Table 1).

In SEBT in the direction of the principal axes, the muscle activities of FAIG were significantly lower than those of SAG the tibialis anterior, peroneus longus, and biceps femoris in the anterior direction ($p<0.05$). Similarly, the EMGs of the tibialis anterior and soleus of FAIG were lower than those of ASG in the posterior direction ($p<0.05$), and that of the vastus lateralis in the lateral direction. However, in the medial direction the muscle activities of the lower limb of FAIG were slightly but not significantly less than those of SAG (Table 2).

In SEBT in the directions of the diagonal axes, the muscle activities of the tibialis anterior and peroneus longus of

Table 1. The SEBT score with dynamic balance in 8 directions

Direction	SEBT score (%)	
	FAIG (n=10)	SAG (n=10)
Anterior	69.59 ± 1.29*	80.35 ± 0.67
Posterior	81.33 ± 1.25	84.27 ± 0.80
Medial	84.13 ± 1.28	86.41 ± 1.64
Lateral	83.29 ± 1.17*	91.75 ± 1.51
Anteromedial	81.16 ± 1.73	85.12 ± 0.82
Anterolateral	73.77 ± 2.94	82.76 ± 1.15
Postermedial	81.55 ± 1.98*	87.88 ± 1.55
Posterolateral	72.92 ± 1.55*	83.93 ± 1.28

Data=Mean ± SE.*p<0.05 between FAIG and ASG. SEBT score: reach length/leg length×100. FAIG: Functional Ankle Instability Group SAG: Stable Ankle Group.

FAIG were significantly lower than SAG in the anterolateral and anteromedial directions ($p<0.05$). EMGs of the tibialis posterior, and soleus of FAIG were significantly lower than those of SAG in the posterolateral and posteromedial directions ($p<0.05$) (Table 3).

DISCUSSION

In this study We evaluated the EMG activity of each muscle of the lower leg of FAI subjects in dynamic balance to provide basic data for rehabilitation training. We measured dynamic balance ability with the star excursion balance test (SEBT) and EMG activity in order to measure the muscle strength of the lower leg as in previous studies[6,22,23]. The SEBT scores in the anterior, lateral, anterolateral, posteromedial, and posterolateral directions were significantly lower in FAIG than in SAG. In patients with chronic ankle instability, it has been reported that the dynamic balance in the SEBT decreased significantly in the anterior, posteromedial and posterolateral directions[6,27], and the SEBT score decreased in the medial and posteromedial directions and, in particular, the decrease in the posteromedial direction was clinically useful[23]. Also, in this study, the similar result is shown, but every directions of SEBT, except posterior, medial, anteromedial direction, are decreased in FAI.

In the SEBT, the EMG activity of lower limb is measured for the muscle strength of lower limb. The result show that the EMG activities of tibialis anterior, rectus femoris, and bicep femoris in anterior direction are significantly lower FAIG than SAG.

This result was similar to the reports of study[22,28] that, in patients with chronic ankle instability, the angles of hip and knee flexion decrease due to the low muscle performance of the lower leg during SEBT, and the ankle joint instability is affected by the deficit in knee joint neuromuscular adaptations caused by decreased in the ankle plantar flexor, the knee flexor and extensor torque as the previous study[19]. Also, The result as similar with previous studies show that when the sound leg is moved forward under ankle instability, the center-of-gravity (COG) line near the knee is moved toward the hip joint and, as a result, muscle strength applied to the quadriceps femoris and the tibialis anterior of the affected leg is weak and this lowers the ability to maintain the posture, moreover, the muscle performance of the biceps femoris as an antagonist to the hip joint and as an

Table 2. The EMG activity with dynamic balance in directions of the principal axes

Muscle	Functional Ankle Instability Group (n=10) Stable Ankle Group (n=10) Normalized peak EMG activity (%)			
	Anterior	Posterior	Medial	Lateral
TA	53.79 ± 1.62* 65.06 ± 2.66	65.10 ± 1.55 65.32 ± 2.31	63.02 ± 1.91 67.72 ± 4.74	65.07 ± 3.19 67.95 ± 1.73
PL	65.80 ± 1.54* 74.06 ± 1.37	59.82 ± 1.58 63.09 ± 2.49	65.84 ± 1.28 69.03 ± 1.85	71.33 ± 3.11 75.55 ± 2.09
VL	68.84 ± 2.24 73.94 ± 1.82	72.43 ± 2.70 73.57 ± 2.82	74.59 ± 1.32 74.59 ± 1.61	58.33 ± 1.15* 64.24 ± 1.01
RF	50.79 ± 1.62 55.98 ± 2.03	68.13 ± 2.51 70.45 ± 2.98	74.69 ± 2.00 77.50 ± 1.61	68.64 ± 2.64 72.57 ± 3.45
TP	62.32 ± 1.99 66.58 ± 2.36	49.96 ± 1.85* 58.51 ± 1.84	71.16 ± 2.42 72.95 ± 1.88	69.18 ± 1.33 71.55 ± 1.15
SE	65.23 ± 1.75 69.24 ± 2.05	63.52 ± 1.17* 71.00 ± 1.34	72.05 ± 2.09 75.73 ± 1.65	69.73 ± 2.25 68.78 ± 1.98
BF	64.27 ± 2.40* 74.68 ± 2.37	72.67 ± 1.97 75.07 ± 2.21	76.59 ± 0.88 79.48 ± 1.25	74.06 ± 2.21 75.18 ± 1.37

Data=Mean ± SE. *p<0.05 between Functional ankle instability group and Stable ankle group. TA: Tibialis Anterior. PL: Peroneus Longus. VL: Vastus Lateralis. RF: Rectus Femoris. TP: Tibialis Posterior. SE: Soleus. BF: Biceps Femoris. EMG activity: Electromyographic activity.

Table 3. The EMG activity with dynamic balance in directions of the diagonal axes

Muscle	Normalized peak EMG activity (%)			
	Anteromedial	Anterolateral	Posteromedial	Posterolateral
TA	62.58 ± 1.87* 67.80 ± 0.82	60.80 ± 1.64* 66.02 ± 1.13	73.11 ± 3.08 76.31 ± 0.99	63.62 ± 2.77 66.28 ± 2.05
PL	62.70 ± 0.83* 68.14 ± 1.16	59.56 ± 1.38* 66.81 ± 1.43	58.34 ± 1.48 62.01 ± 1.64	67.92 ± 3.18 71.05 ± 2.47
VL	68.42 ± 2.57 74.82 ± 3.45	70.54 ± 1.53 74.88 ± 2.96	71.75 ± 1.07 74.45 ± 1.55	75.25 ± 1.09 78.37 ± 1.06
RF	68.55 ± 2.70 72.06 ± 3.24	70.79 ± 1.16 73.68 ± 1.11	71.63 ± 2.57 75.06 ± 1.82	71.09 ± 2.94 74.98 ± 2.77
TP	72.73 ± 1.88 75.17 ± 2.66	68.05 ± 2.88 72.18 ± 2.51	68.93 ± 1.46* 74.19 ± 1.20	51.98 ± 1.71* 58.62 ± 1.61
SE	64.91 ± 3.13 70.49 ± 2.35	71.99 ± 1.57 73.57 ± 2.31	61.45 ± 1.93* 67.77 ± 1.65	74.52 ± 1.15* 80.03 ± 1.51
BF	67.66 ± 1.86 71.67 ± 3.04	67.62 ± 2.57 71.40 ± 1.91	77.13 ± 1.99 78.47 ± 1.81	60.80 ± 2.75 67.16 ± 2.55

Upper values: Functional Ankle Instability Group (n=10); lower values: Stable Ankle Group (n=10)

Data=Mean ± SE. *p<0.05 between Functional ankle instability group and Stable ankle group.
TA: Tibialis Anterior. PL: Peroneus Longus. VL: Vastus Lateralis. RF: Rectus Femoris.
TP: Tibialis Posterior. SE: Soleus. BF: Biceps Femoris. EMG activity: Electromyographic activity.

agonist to the knee joint in knee flexion is lowered.

Tne plantar flexion with supination is an important factor in the adjustment of the ankle, and it clinically contributes to prevention of recurrence in the athletes' ankle injury[5].

In this study, The EMG activity of soleus on posterior direction is significantly lower FAIG than SAG. In the previous study[25], the activation of plantar flexor was reported with the anterior-posterior movement on the sagittal plane in the standing posture and the eccentric plantar flexion strength was needed to strengthen in FAI[18]. Therefore in this study, the plantar flexor in FAIG is more weakened than in SAG, as the injury of lateral ligament with the most ankle sprain is due to the internal force with the plantar flexion. The EMG activities of tibialis anterior and peroneus muscle in the direction of anteromedial, anterolateral, posteromedial, and posterolateral was significantly lower FAIG than SAG.

Our results indicate that because EMG activity of peroneus longus, which had a role with controlling ankle inversion, the peroneous longus acted as the deceleration in FAIG . and it is caused when the deceleration mechanism did not function in full capacity as expected during the dynamic balance. Also, The results show that EMG amplitude appeared on FAI caused by inversion away, this is based on subjects with FAI which the peroneal latency was slower caused by electromechanical delay (EMD)[13].

In the case of the ankle instability, The internal velocity and directional control were decreased in the rhythmic weight shift, so the sway in the lateral-posterior direction was occurred. In the recurrence of ankle sprain, the dynamic neuromuscular ability is decreased with delaying the acceleration time (ACC-TIME) of evertor, so the ankle instability is induced. Moreover, the dynamic activity of peroneal muscle is decreased, so FAI is occurred[7,13,29]. However, in the case of the chronic ankle instability, the tibialis posterior should be strengthened instead of strengthening peroneus longus[15]. Therefore, strengthening invertor as well as evertor should be required for preventing the ankle instability. These results suggest that recurrent ankle injuries can be prevented by strengthening muscles contributing to the stabilization of the ankle in each direction and activating feed-forward motor control through the analysis of muscle activities involved according to dynamic balance in FAI. Further research is required to objectification and scale difference in the muscle activity of the lower leg in various age groups with FAI.

In conclusion, the dynamic balance should be affected with the EMG activity in lower leg along the each direction. In addition, We can plan and resource initial documents on rehabilitation program that will include selective muscle strengthening during the training in support of patients with FAI.

REFERENCES

1) Ekstrand JH, Tropp: The incidence of ankle sprains in soccer: Foot Ankle. 1990, 11: 41–44.
2) Karlsson J, Lansinger O: Lateral instability of the ankle joint. Clin Orthop, 1992, 276: 253–261.
3) Garrick JG, Requa RK: The epidemiology of foot and ankle injuries in sports. Clin Podiatr Med Surg. 1989, 6: 629–637.
4) Lentell G, Baas B, Lopez D, et al.: The contributions of proprioceptive deficits, muscle function, and anatomic laxity to functional instability of the ankle. Orthop Sports Phys Ther, 1995, 21: 206–215.

5) Eils E, Rosenbaum D: A multi-station proprioceptive exercise program in patients with ankle instability. Med Sci Sports Exerc, 2001, 33: 1991–1998.
6) Hubbard TJ, Kramer LC, Denegar CR, et al.: Correlations among multiple measures of functional and mechanical instability in subjects with chronic ankle instability. J Athl Train, 2007, 42: 361–366.
7) Mattsson E, Broström LA: The increase in energy cost of walking with an immobilized knee or an unstable ankle. Scand J Rehabil Med. 1990, 22: 51–53.
8) Lephart SM, Pincivero DM, Rozzi SL: Proprioception of the ankle and knee. Sports Med. 1998, 25: 149–155.
9) Bernier JN, Perrin DH, Rijke A: Effect of unilateral functional instability of the ankle on postural sway and inversion and eversion strength. J Athl Train, 1997, 32: 226–232.
10) Pontaga I: Ankle joint evertor-invertor muscle torque ratio decrease due to recurrent lateral ligament sprains. Clin Biomech, 2004, 19: 760–762.
11) van Cingel RE, Kleinrensink G, Uitterlinden EJ, et al.: Repeated ankle sprains and delayed neuromuscular response: acceleration time parameters. J Orthop Sports Phys Ther, 2006, 36: 72–79.
12) Tropp H: Pronator muscle weakness in functional instability of the ankle joint. Int J Sports Med, 1986, 7: 291–294.
13) Palmieri-Smith RM, Hopkins JT, Brown TN: Peroneal activation deficits in persons with functional ankle instability. Am J Sports Med, 2009, 37: 982–988.
14) Munn J, Sullivan SJ, Schneiders AG: Evidence of sensorimotor deficits in functional ankle instability: a systematic review with meta-analysis. J Sci Med Sport, 2010, 13: 2–12.
15) Hertel J, Braham RA, Hale SA, et al.: Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability. J Orthop Sports Phys Ther, 2006, 36: 131–137.
16) Ebig M, Lephart SM, Burdett RG, et al.: The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in the chronically unstable ankle. J Orthop Sports Phys Ther, 1997, 26: 73–77.
17) Kaminski TW, Buckley BD, Powers ME, et al.: Effect of strength and proprioception training on eversion to inversion strength ratios in subjects with unilateral functional ankle instability. Br J Sports Med, 2003, 37: 410–415.
18) Fox J, Docherty CL, Schrader J, et al.: Eccentric plantar-flexor torque deficits in participants with functional ankle instability. J Athl Train, 2008, 43: 51–54.
19) Gribble PA, Robinson RH: Alterations in knee kinematics and dynamic stability associated with chronic ankle instability. J Athl Train, 2009, 44: 350–355.
20) Brown CN, Mynark R: Balance deficits in recreational athletes with chronic ankle instability. J Athl Train, 2007, 42: 367–373.
21) Kaminski TW, Perrin DH, Gansneder BM: Eversion strength analysis of uninjured and functionally unstable ankles. J Athl Train, 1999, 34: 239–245.
22) Gribble PA, Hertel J, Denegar CR, et al.: Chronic ankle instability and fatigue create proximal joint alterations during performance of the Star Excursion Balance Test. Int J Sports Med, 2007, 28: 236–242.
23) Gross M: Effect of recurrent lateral ankle sprains on active and passive judgement of joint position. Phys Ther, 1987, 67: 1505–1059.
24) Lewis NL, Brismée JM, James CR, et al.: The effect of stretching on muscle responses and postural sway responses during computerized dynamic posturography in women and men. Arch Phys Med Rehabil, 2009, 90: 454–462.
25) Wagner JM, Dromerick AW, Sahrmann SA, et al.: Upper extremity muscle activation during recovery of reaching in subjects with post-stroke hemiparesis. Clin Neurophysiol, 2007, 118: 164–176.
26) Delagi EF, Perotto A, Iazzetti J, et al.: Anatomic Guide for the Electromyographer (2nd ed). Springfield: Charles C. Thomas, 1980.
27) McKeon PO, Ingersoll CD, Kerrigan DC, et al.: Balance training improves function and postural control in those with chronic ankle instability. Med Sci Sports Exerc, 2008, 40: 1810–1819.
28) Wikstrom EA, Tillman MD, Chmielewski TL, et al.: Dynamic postural stability deficits in subjects with self-reported ankle instability. Med Sci Sports Exerc, 2007, 39: 397– 402.
29) Holmes A, Delahunt E: Treatment of common deficits associated with chronic ankle instability. Sports Med, 2009, 39: 207–224.