COMPARISON OF SELECTED MUSCULAR ACTIVITY OF LOWER EXTREMITIES IN YOUNG WOMEN'S WALKING ON SUPINATED, PRONATED AND NORMAL FOOT

Hamideh Khodaveisi[1], Heydar Sadeghi[1], Raghad Memar[1] and Mehrdad Anbarian[2]

[1] School of Physical Education and Sport Sciences, Kharazmi University, Tehran, Iran
[2] School of Physical Education and Sport Sciences, Bu-Ali Sina University, Hamadan, Iran

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Abstract

Change in anatomical structure of foot, reduces the foot ability for normal performance. This study aims to compare selected muscles of lower extremities during walking for individuals on supinated, pronated and normal foot. 45 female students were selected through foot posture index and X-ray under the specialist physician in three foot structural groups consisting of normal, pronated and supinated foot. Electromyography activities were recorded from muscles of tibialis anterior, peroneus longus, medial gastrocnemius, and biceps femoris in three groups while walking in determined path with self-selected walking speed. Each effort simultaneous with electromyography registration was recorded with camera. One-Way ANOVA test was used to compare the groups at significance level of 0.05. The activity of muscle of tibialis anterior, medial gastrocnemius was greater in pronated foot group than that in supinated and normal groups. The muscle activity of peroneus longus was greater in supinated foot group than that of two other groups while there was seen no significant difference between muscle activity of biceps femoris. Regarding the findings of this research, the muscular performance change in pronated and supinated foot group is more noticeable than that in normal foot group.

Key words: *muscle activity, walking, normal foot, pronated foot, supinated foot*

Introduction

In walking foot bears the performance of absorbing contact forces with the ground, balancing, and adaptation to ground surfaces and transmission of forces efficiently, which are obtained through mutual activities of foot joints, (Barwick, 2012). The important movements occur at the talocrural, subtalar, talonavicular, calcaneocuboid and navicular-cuboid joints during walking (Lundgren, 2008). The recent studies point out individual differences and high complexity of Tarsal movements which can be summarized into pronation and supination movements. Pronation occurs in the midstance which helps to increases the available motion of the forefoot, shock absorption and adaptation to ground. Towards the end of stance, foot supination increases and leads to decrease available motion of the forefoot resulting in stability to the front (Barwick, 2012). Unnatural biomechanics of foot reduces the foot ability to do normal performance (Massie, 1999). Pronated foot is on the most common reasons of people's referring to orthopedics and clinics as seen in a wide range of deformities such as reduction of internal longitudinal arch height, heel external rotation and anterior foot abduction (Murley, 2009). It is generally believed that pronated foot acts as a facilitator in bringing about overtraining damages and pathologic conditions such as plantar fasciitis, Achilles tendon shortening, stress fracture, shin splint and pain in heel, knee and back (Burns, 2005). Heel internal rotation concomitant with medial longitudinal arch height is called supinated foot contributing to a wide range of lower extremity deformities such as forefoot adduction , finger forking, genu varum and other symptoms (Manoli, 2005). It was structurally determined that for people with this deformity. During walking, time and area of contact with ground become less and they have weak shock absorption due to locking of midtarsal joints (Williams, 2004). Review of kinematic studies comparing individuals' movement performance on normal and pronated foot in walking. Shows that in individuals with pronated foot, due to the situation of heel external rotation and internal longitudinal arch collapse, subtalar joint stays in pronation position in the ending of stance, therefore, foot bone stability reduces and foot confronts lack of force to progress in Toe-off (Hunt & Razaghi, 2004). On the other hand, elongation of heel eversion (Dorsey 2001; Razaghi, 2004) and increase of internal rotation of tibias in loading response (Dorsey, 2001) can disturb the main performance of muscular-skeletal structure of foot as a force absorbent. Foot deformities create some changes in the movement of lower extremities and in some cases increase the damage risk. The relationship between foot deformities and damage risk increase of lower extremities can originate from abnormal activity of muscles. For example, people with flat foot are dependent on extra muscular support in walking (Hunt, 2004; Murley, 2004). In electromyography, Murley et al in 2004 showed that pronated group act higher percentage of maximal EMG amplitude for tibialis anterior in contact and for tibialis posterior in midstance than normal group. In addition, for peroneus longus, it was specified that this group has lower activity of EMG in stance.

While in some studies there is no report of such difference (Keenan, 1991). Therefore, it is necessary to do researches about the physiological response and selected muscle activity of lower extremities to different postures of foot in walking which result in elucidation of incidence mechanism and prevention from damages. Regarding the anatomical structure and position of foot and reduction of foot performance in abnormal structure and limitations of previous researches in investigating muscles, it is of great importance to understand the muscle activity during walking on supinated and pronated foot compared with normal foot. Therefore this study aims to compare the activity of selected muscles of lower extremities during walking among young women on supinated, pronated, and normal foot.

Material & methods

Participants
This is a semi-experimental research included in comparative researches. Of girl students 18-25 years old, 45 were placed in three 15-member groups of normal, pronated and supinated foot. The people having orthopedic symptoms, skeletal-muscular injuries, chronic joint pain and any neurovascular and cardiac discover were excluded from the research. No subject had no experience of using medical shoes and used no walking aid. Before the experiment, all subjects filled consent form to participate in the study. The research was issued by Ethics Committee of Hamadan Medical Science University and the consent forms were confirmed by the committee.

Foot measurement
To determine the exact structure of foot, X-ray was used in full profile and semi profile of foot in bearing weight under knee specialist. The final confirmation of foot structure was carried out with X-ray under orthopedic physician and Foot Posture Index (FPI). In the method of foot structure determination and abnormality severity of FPI, the subjects stood in a position where feet are parallel and open to shoulder width. The subjects were asked to divide their weight on the feet equally. Then, the researcher observes six indexes of interest from back view, as following: talar head palpation, supra and infra malleolar curvature, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch, and abduction/ adduction of the forefoot on the rearfoot. After completion of assessing every six indexes and labeling them, the scores were added together. The score summed is placed at -12 (over supination) and 12 (over pronation) by experimenter. Those, whose FPI is at 1 to 7, are in normal foot group, those whose score is +8 to +10 at pronated foot group and those whose score is at +11 and 12 are at over pronated group. If the index is 0 to -3, or -4 to -12, the subject belongs to supinated foot group or over supinated group, respectively (Redmond 2006). FPI measurements have shown good validity (Evans, 2012).

Instrument
Superficial electromyography of muscles was made with a 16-channel device. One foot in each subject was analyzed. EMG signals were Collected from tibialis anterior, peroneus longus, medial gastrocnemius, biceps femoris Using a 16-channel system of MYON (model: MYON m320) in sampling frequency 1200 Hz. Dipole electrodes (Electrode type: H124SG-Covidien) containing glue and conducting jelly were used. The electrode size was (24 mm), and internal distance of electrodes (20 mm). Skin preparation (hair shaving, skin rob with alcoholic cotton) were based on SENIAM protocol (Hermens, 2005). To determine the contact time of heel and midstance, six cameras (Vicon T40-S) were used at 120 HZ. Markers were placed at the following places: 1th metatarsal head (left, right), 5th metatarsal head (left, right), heel (left, right) and Head of foot thumb (left, right). To analyze electromyography data during walking, the contact time of heel and ground and midstance had to be determined, with camera vertically. The least amount of camera data in the heel of right foot during walking was considered to be contact time of heel with ground and midstance when the left foot finger marker took off the ground and the person stood on the right foot. The subjects were allowed to walk on a 10-m path for two minutes in their selected speed before the test. To prevent the speed effects on EMG parameters, the speed was controlled with a chronometer. In each path, the data were collected for 10 s. To minimize the percentage of error, raw data were passed from by-pass filter (10-450) (Carlo, 2010).

In electromyographical signal processing, to provide the comparison between different muscles and different subjects, MVIC was carried out with Perotto protocol. In this research, the normalization reference of electrical activity is MVIC, considered for 5 seconds for muscles (Perotto, 1994).

Data Analyses
Mean and SD of data were used for descriptive statics. To determine normality of variable distribution, Kolmogorov–Smirnov and One-Way ANOVA to compare groups in the information related to independent variables were used at significance level of 0.05. Tukey’s Post Hoc test was used to determine significant differences between muscles.

Results

The subjects’ characteristics are shown in Table1. The participants did not have any difference in age, height, weight and Body index in different groups. The difference was about foot structure, based on the place of subjects in groups of study. Tables 2 and 3 show the mean and SD of muscle activity in the muscle of study in participants in heal contact with ground and midstance phase. The muscle activity in contact with ground was significantly greater in pronated foot group than that in normal foot ($P=0.003$) and supinated foot group ($P=0.002$).

Table 1. Subjects' characteristics on the study

Variable	Pronate	Normal	Variable
2.8±22.2	3.7±23.2	1.9±22.1	Age(years)
4.1±167.6	5.2±165.6	6.2±169.3	Height
5.2±65.4	4.9±68.4	5.1±67.4	Weight
1.6±20.5	1.9±21.8	1.5±20.2	BMI
1.4±-2.3	1.1±+9.6	1.7±+4.1	FPI*

The sign (*) shows the difference between pronated, supinated and normal foot groups.

Table 2. Mean and SD of muscle activity involved in different postures in contact stage of heel and ground during walking (%EMG_{MVIC}).

F	P	Supinate	Pronate	Normal	Muscles
08.77	0.001	6.29 ±10.62†	6.94 ±18.65*†	3.35 ±10.89*	Tibialis Anterior
39.04	0.000	4.78 ±13.00†¤	1.75 ±3.82†	1.49 ±5.20¤	Peroneus longus
11.31	0.000	1.73 ±4.71†	1.75 ±6.51*†	0.79 ±3.99*	Medial Gastrocnemius
01.95	0.155	2.20 ±7.44	3.53 ±9.24	1.80 ±7.84	Biceps Femoris

* Significance level for normal and pronated foot group, ¤ Significance level for normal and supinated foot group, † Significance level for pronated and supinated group

Table 3. Mean and SD of muscle activity involved in different postures in contact stage of heel and ground during walking (%EMG_{MVIC}).

F	P	Supinate	Pronate	Normal	Muscles
2.29	0.11	3.18 ±6.05	3.81 ±6.34	1.13 ±4.12	Tibialis Anterior
187.98	0.00	2.43 ±15.54¤	1.43 ±3.24†	1.37 ±5.12¤	Peroneus longus
11.365	0.00	1.61 ±7.33†	3.61 ±11.93†*	2.72 ±8.34*	Medial Gastrocnemius
1.25	0.30	0.96 ±5.82	1.45 ±6.55	2.30 ±5.64	Biceps Femoris

* Significance level for normal and pronated foot group, ¤ Significance level for normal and supinated foot group, † Significance level for pronated and supinated group

The muscle activity for peroneus longus in contact of heel with ground in supinated foot group was greater than that in normal (P=0.000) and pronated group (P=0.00). For medial gastrocnemius, there was significant difference in heel contact with ground between normal and pronated groups (P=0.000) and midstance (P=0.003). There was a significant difference in external oblique muscle in midstance phase between normal and pronated groups (P=0.030). No significant difference was observed for muscle activity in gluteus medius, external oblique and erector spinae.

Discussion

This study aims to compare muscle activities in walking among young women on supinated, pronated and normal foot. The results showed that the muscle activity of tibialis anterior in heel contact in pronated foot group was significantly greater than normal group but no significant difference in midstance phase in three groups.

In heel contact with ground, tibialis anterior muscle has greater activity to control plantar flection and reduce collision speed of forefoot with ground. These findings are consistent with those of Murley et al in 2009. The results of this research for muscle activity of peroneus longus showed that in the pronated foot group, it was significantly less than that in normal and supinated foot group in the contact of heel with ground and midstance during walking. These findings show that the muscle of peroneus longus in the pronated foot group had less activity in contact of heel and midstance than normal and supinated foot group. These performance differences between feet are likely to show less activity of peroneus longus muscle in the pronated foot to make a compensatory mechanism to prevent from greater pressure on internal arch (Murley, 2009).

Also, the greater activity of peroneus longus muscle in supinated foot group than pronated foot group occurs in reaction to supination in subtalar joint in this group. For biceps femoris muscle, there was no significant difference among three groups. These show that the muscle activity of biceps femoris is not influenced by foot structure in contact of heel and ground and midstance. As change in the structure of foot back didn't make any change in the activity of this muscle it seems unlikely that this muscle play important roles in invertor or evertor of foot in pronated and supinated foot groups compared with normal foot groups.

The increase of muscle activity of medial gastrocnemius during walking has been reported as a compensatory mechanism related to mechanical disturbances of joint (Ringleb, 2007). Medial gastrocnemius leads to plantar flexor and invertor momentum of ankle and prevents from extra pronation of ankle as a dynamic fixer (Simon 1987). When the subtalar joint have over evertion, the performance of medial gastrocnemius increases (Wang, 2011). The strength point of this research is to investigate the selected muscles of lower extremities in normal, pronated and supinated.

It was known that structure change of foot can make a change in the activity of lower extremities. The limitation of this study was that invertor activity of tibialis posterior was not determined due to the needle electromyography record. The results of this research can help the rehabilitation experts to design exercise programs for people having abnormal structure.

Conclusion

As pronation and supination bring about changes in lower extremities and pelvic-back area, they make change in performance of some selected muscles in pronated and supinated foot group compared with normal foot group. The performance of muscles is under the foot structure. This difference in muscle activity can act as a neuromuscular compensatory mechanism to reduce the overweight internal longitudinal arch in pronated foot individuals.

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USPOREDBA ODABRANIH MIŠIĆNIH AKTIVNOSTI DONJIH EKSTREMITETA U HODANJU MLADIH ŽENA UZ STOPALO U SUPINACIJI, PRONACIJI I NORMALNO

Sažetak

Promjena anatomske strukture stopala smanjuje sposobnost stopala za normalnu izvedbu. Ova studija ima za cilj usporediti odabrane mišiće donjih ekstremiteta tijekom hodanja za pojedince na hod sa supinacijom, pronacijom i normalno. Ukupno 45 studentice su izabrani kroz indeks držanja stopala i rendgenom kod liječnika specijaliste u tri strukturne grupe koje se sastoji od normalnog stopala, u pronaciji i supinaciji. Elektromiografijom su registrirane aktivnosti mišića tibialis prednji, peroneus longus, medijalni gastrocnemius i biceps femoris u tri skupine, a hodanje u određenom putu uz odabranu brzinu hoda. Svaki napor istovremeno je registriran Elektromiografski i us pomoć kamere. Jednosmjerna ANOVA test je korišten za usporedbu skupina na razini od 0.05. Aktivnost mišića tibialis prednji, medijalni gastrocnemius je bila veća u skupini sa pronacijom stopala, nego u skupinama sa supinacijom i normalnoj skupini. Mišićna aktivnost peroneus longusa bila je veća u skupini sa supinacijom stopala nego u druge dvije skupine. Nema značajne razlike kod mišićne aktivnosti biceps femorisa. Što se tiče nalaza ovog istraživanja, mišićna promjene nastupa u skupinama sa pronacijom i supinacijom stopala i izraženije je nego u normalnom stopalu.

***Ključne riječi**: mišićna aktivnost, hodanje normalno stopalo, pronacija, supinacija*

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Correspondence to:
Hamideh Khodaveisi
Department of Sport Biomechanics
School of Physical Education and Sport Sciences
Kharazmi University
Tehran, Iran
Email: khodaveisi_hamideh@yahoo.com