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Electromyography Activity of Selected Leg-dominant Lower Limb Muscles during Stance Phase of Running on Treadmill and Overground

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Abstract:

The aim of present study was to compare electromyography activity of selected leg-dominant lower limb muscles during stance phase of running on treadmill and overground. Fourteen male students ran at 3.3 m/s in both treadmill and overground conditions. Electromyography activity of some selected lower limb muscle was recorded during initial 50% and terminal 50% of stance phase. Paired t-test was employed for data analyses. The results showed a significant difference in total activity of selected lower limb muscles between treadmill and overground running conditions ($P<0.05$). Rectus femoris, vastus medialis, vastus lateralis, and biceps femoris activation during overground running were found significantly higher than running on the treadmill in initial 50% stance phase ($P<0.05$). No significant electromyography change was observed for selected muscles during terminal 50% of stance phase in both treadmill and overground conditions ($P>0.05$). It was concluded that treadmills running condition may be possibly useful in designing specific training programs that are aimed to control or reduce lower extremity muscles activity. According to the results of this study, treadmills running condition caused lower muscle activity consequently, may increase biomechanical efficiency or used in clinical setting.

***Keywords*:** Electromyography, lower limb muscles, running, sport surfaces, treadmill.

INTRODUCTION

Overground and treadmill running are two popular modes that used in scientific investigations, physical therapy practice and physical training raises issues on differences in running patterns on a treadmill and on overground surfaces (1,13,12,23). Previous studies have been shown that different biomechanical changes are created in the user, while running on different surfaces (9,15,14,24,21,19) .The running's surface has been defined as the fundamental aspects in designing the exercises that should be considered (9,24). Despite pattern similarity on treadmill and overground running, several studies have been shown the major differences between running on treadmill compared to overground (5,2). Numerous studies have been reported that there are biomechanical and physiological differences, such as metabolic energy consumption during treadmill and overground running or walking (6,17,26,16,20). For example, Nigg et al (1995) reported that most of the lower extremity kinematic variables were substantial differed depending on the individual subject's running style, running speed in treadmill and overground conditions (16). Nonetheless, Watt et al (2010) showed kinematic and kinetic patterns of walking are similar in older adults while walking on treadmill and overground situations. Conversely, while walking on the treadmill step length and stride time was shorter and joints torques was reduced compared to overground condition (26). According to the results of these sample studies, it seems that different surfaces have different effects on biomechanics of the human locomotion.

Runners usually adapt themselves in biomechanical features such as their landing style while running on different surfaces (24, 8). This adaptability may associate with neuromuscular adaptation while running on different surfaces (24). However, still this is debated that what neuromuscular changes will created in result of biomechanics alterations on the treadmill (25). Hong et al. (2012) and Baur et al. (2007) reported that the maximum plantar pressure is reduced while running on the treadmill in comparison to other surfaces (5, 4). Though, if we accept the biomechanical differences between treadmill and overground running conditions, then we should expect changes in muscles activation. Subsequently, these changes may help to design of some specific exercise protocols with the aim of reducing the muscles activity for injured individuals (14) or increasing the level of muscles activity for increasing the exercise intensity. Although considerable studies have been devoted to kinematic and kinetic variables of the treadmill and overground running, rather less attention has been paid to muscle activations. One of the few studies carried out by Wang et al. (2014) suggests that the activity of lower limb muscles has a significant reduction while treadmill running in comparison to other surfaces (8).

In contrast, some studies have indicated that there are no differences in muscles activity between treadmill and over-ground walking (19, 2, 7). For example, Di Nardo et al (2014) evaluated the activity of lower limbs muscles while treadmill walking vs overground walking condition. They found no significant difference in the tibialis anterior muscle activity between the two conditions, but activity of gastrocnemius muscle was increased on the treadmill in footflat phase (7).

Nevertheless, the different subjects, different research methods, evaluating the different muscles in the body and substantial differences in the objectives of the researches could create these contradictory results. Furthermore, the results of related studies of the walking cannot be extended to other activities such as running. Therefore, this study aimed to compare electromyography activity of selected leg-dominant lower limb muscles during stance phase of treadmill and overground running conditions.

MATERIAL & METHOD

Subjects: A total of 14 male students (age: 22.5±5.5, weight: 6.7±66.6 kg, height: 177±7 cm, dominant leg: right) were selected to participated in this study. Subjects were free of any cardiovascular pathology, neurological disorders, lower extremity injuries, and foot or ankle surgeries. Also, all subjects had normal foot posture with no foot deformities. Participants were active recreational runners engaging in training at least three times per week whilst completing a minimum of 25km per week and had previous experience of treadmill running (22). Bu Ali Sina University Graduate Studies and Research Council (The code of approval: 1184255, Date: 2015), in agreement with the Declaration of Helsinki, approved all the procedures before the beginning of the investigation. Subjects enrolled in this study after they agreed to contribute, all procedures were explained, and informed written consent was obtained.

Procedures: Surface electromyography (sEMG) signals were collected using a 16-channel electromyography system (Biomonitor ME6000 T16, Mega Electronics Ltd., Kuopio, Finland) at 2000Hz sampling rate and a signal-to-noise ratio of over 110 db. Before placement of the electrodes (disposable electrodes of Ag/AgCl with the conductive gel), subjects' skin was prepared with shaving hair in the site and the skin was cleaned with alcohol wipe to reduce the electrical resistance of the skin (24).

The electrodes were placed on the vastus medialis (VM), rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), gastrocnemius lateralis (GL) and tibialis anterior (TA) muscles of the dominant leg of the participants according to the SENIAM recommendations (10). A ground electrode was placed on the tibial tuberosity. The electrodes placed in the interface between the nerve center of the muscle and distal tendon. Center to center spacing of the electrodes was 20 mm (24) (Figure 1). The reason for choosing these muscles is because of their important roles in running and also, the availability of them in surface electromyography. Subjects' dominant legs were determined by using three tests of hitting the ball, stepping up, and restoring the balance, at the beginning of their entrance to the laboratory. Foot that was used commonly (for at least 2 out of 3 tests) was identified as the dominant leg (18).

Figure 1. Electrode placement on: (a) vastus medialis, (b) rectus femoris, (c) vastus lateralis, (d) biceps femoris, (e) tibialis anterior, (f) gastrocnemius lateralis (3).

Subsequently, Maximum Voluntary Isometric Contraction (MVIC) was done to normalize the muscles activities data. Each subject asked to sit on a chair and put his knee at a flexion angle of 90 degrees, then his leg was fixed and he was asked to make every effort to do the knee extension to 5 seconds due to collect data of quadriceps MVIC. The subject was lie prone on a bed and his knee was bent to 70 degrees for hamstring; then he was asked to make every effort to do the knee extension to 5 seconds. The subject sat on the chair and he was asked to his knees and put soles of his feet against the wall for gastrocnemius (so that the angle of the foot and leg to be 90 degrees), he was asked to make every effort to do the plantar extension to 5 seconds. The subject was asked to do ankle dorsiflexion motion for 5 second in stand-up mode for tibialis anterior. The made resistance was applied by the tester in all movements. MVIC test was done twice for each muscle and the subject was given one minute rest between each test.

Two foot switches (Motion Lab Systems, Inc., USA) were attached under the most posterior part of the heel and on the first joint of foot-toe under the shoes in order to identify the key points of the running stance phase. In the present study, stance phase was introduced as the time of external area of the posterior part of the heel crash to the ground until the separation of the first joint of the foot-toe bottom from the ground.

In the treadmill running condition, participants were given a 6-minute habitation period to run on the treadmill at a speed of 3 meters per second for warm-up and to become familiarized with treadmill running (1, 24). Then, they ran on the treadmill at a speed of 3.3 m/s for 2 min for data collection. Five successful steps of the dominant foot stance phase during the last minute were selected for data analysis. In the overground condition, subjects ran at 3.3±5% m/s across a 25 meter long laboratory floor while running speed was monitored by two sets of infrared photocells. As the other condition, five successful steps of the dominant foot stance phase selected for analysis. On each running condition, participants completed five successful trials. Both treadmill and overground running were measured based on the method of Wang and Colleagues (24). All tests was done by using same running shoes were made by Asics company, in order to eliminate the interaction effect of the surface with the shoes.

All electromyography raw were processed using Megawin software. The raw EMG signals were rectified and bandpass filtered filter with bandwidth ranging from 20 Hz to 500 Hz. The linear envelope was then treated using the RMS to obtain the EMG amplitude. Then, the average EMG amplitude of each muscle was calculated. The average EMG amplitude of the muscle activation was normalized by dividing by the MVIC of each muscle while running in two phases of primary 50% and final 50% of the stance phase.

Statistical analyses: The Shapiro–Wilk statistic for each condition was used to demonstrate normal distribution. Paired t-tests were utilized with an adjusted *a* level of $p \leq 0.01$ based on the number of comparisons made for each muscle at the first 50% and the final 50% of running stance phase. All statistical procedures were conducted by SPSS 18.0 (SPSS, Inc., Chicago, IL, USA).

DISCUSSION & CONCLUSION

Comparing the muscles activity amount at the first 50% of the stance phase: At the first half of the stance phase of running, the muscle activation of rectus femoris, vastus lateralis, vastus medialis and biceps femoris significantly decreased in treadmill condition compared to overground running (Table 1). For tibialis anterior and gastrocnemius lateralis, treadmill condition exhibited lower muscle activation, but there was no significant.

Table 1. Mean and SD of normalized electromyography activity from selected leg-dominant lower limb muscles at the first 50% of stance phase of running on treadmill and overground.

Muscle	Overground	Treadmill	t-test value	p value	ω^2
Rectus femoris	39.2±17.6	23.9±8.7	4.26	0.001	0.38
Vastus medialis	59.3±32.8	40±17.8	3.26	0.006	0.256
Vastus lateralis	56.1±18.9	35.1±10	6.02	0.001	0.558
Biceps femoris	36±19	22.3±16.9	3.47	0.004	0.284
Tibialis anterior	16±7	9.4±7.2	1.63	0.126	-
Gastrocnemius lateralis	64.7±29.7	52.1±20.3	1.81	0.92	-

Comparing the muscles activity amount at the final 50% of the stance phase**:** As Table 2 shows, there was significant decreased activation for gastrocnemius lateralis, vastus medialis and rectus femoris muscles in treadmill condition at the final 50% of the stance phase. No significant difference was found between treadmill and overground running conditions for other selected muscles activation

Table 2. Mean and SD of normalized electromyography activity from selected leg-dominant lower limb muscles during the final 50% of stance phase of running on treadmill and overground.

Muscle	Overground	Treadmill	t-test value	p value	ω^2
Rectus femoris	18.4±12.7	6.9±4.1	4.061	0.001	0.356
Vastus medialis	26.3±31.3	20.8±10.5	2.954	0.01	0.216
Vastus lateralis	28.7±30	11.2±7.5	2.327	0.037	0.136
Biceps femoris	31.7±17.2	35.8±22	-1.253	0.232	-
Tibialis anterior	8.5±3.6	9.4±4.2	-0.391	0.702	-
Gastrocnemius lateralis	52±20.8	38.8±14.3	4.058	0.001	0.356

The aim of this study was to compare the EMG activity of the selected lower limbs muscles in stance phase of running on the treadmill and overground surfaces. The results of this study showed that there is a significant difference in the activity amount of the lower limbs muscles in the primary 50% of stance phase between two different surfaces. Activities amount of rectus femoris, vastus medialis, vastus lateralis; biceps femoris was significantly higher while running at the overground running condition than while running on the treadmill. The activities amount of gastrocnemius and tibialis anterior increased insignificantly in comparison to running position in gym on the treadmill. Also, there was no significant difference in activity amount of the lower limbs muscles in final 50% of stance phase between both surfaces. While running at the gym, activities of rectus femoris, vastus medialis, and vastus lateralis are significantly higher than while running on the treadmill, but biceps femoris and tibialis anterior activities was increased insignificantly while running on the treadmill in comparison to the overground. The activity amount of the muscles has been different in both surfaces, according to the biomechanical differences of running on the treadmill and over ground and exercising has different effects on the activity amount of the lower limbs muscles. This is because the runners coordinate themselves with kinematic features and the surface hit force while running on different surfaces (24, 8) and this coordination is associated with the neuromuscular changes in running on different surfaces (25). However, still this is debated that what neuromuscular changes will created in result of biomechanical changes on the treadmill (24). Results of Hong et al. (2012) and Baur et al (2007) showed that the maximum pressure of foot and the maximum force of foot plantar are reduced while running on the treadmill in comparison to other surfaces (5, 4).

According to the results of their studies and the observed differences in this study, it can be concluded that while running on the treadmill reduces the ground reaction force and plantar pressure force consequently reduces muscle activity. This issue can be useful in designing the specific exercise program for injured individuals or people who require less activity in their lower limbs. Wang et al (2014), evaluated the activity of lower limbs muscles while running on the treadmill in comparison to other surfaces such as cement and natural grass. They reported that the activity of lower limbs muscles significantly reduced while running on the treadmill in comparison to other surfaces. They concluded that the kinematic adjustment of the lower extremity may explain the electromyography difference when running on different surfaces (24). Lee et al (2008) showed that the tibialis anterior and gastrocnemius activities decrease while walking on the treadmill and as a result the rehabilitation exercises can be done on the treadmill for people with nerve damages (14). Moreover, Hunter et al (2014) evaluated the activity of lower limbs muscles while running on the treadmills with the positive pressure and observed that most muscles showed decreases in activation as more body weight was supported. So these kinds of treadmills may useful intervention for certain running related injuries (12).

However, some studies also have been showed no significant difference (or increase) in the amount of muscle activity between the treadmill in comparison to other surfaces (7, 2, 19, 13). For example, Arsenault et al (1986) showed that the activities amount of soleus, rectus femoris, biceps femoris, vastus medialis and tibialis anterior increased while walking on the treadmill in comparison with walking overground (2). Furthermore, Di Nardo et al (2014) observed no significant difference in the tibialis anterior muscle activity between the treadmill and overground walking conditions, but activity of gastrocnemius was higher on the treadmill condition (7). Kalantari et al (2015) similarly showed that walking at different speeds on the treadmill increased the activation amount of gastrocnemius, biceps femoris, half tendinous, vastus medialis and vastus lateralis and medius gluteus muscles compared to the overground (13). On the one hand, these contradictions indicate the need for further research. On the other hand, there is a difference between walking and running. Due to these reasons, the results of this research can be helpful especially for rehabilitation of injured individuals.

Our findings emphasized the activation of the lower limbs muscles decreased while running on the treadmill during the stance phase among our subjects. It seems that using of the treadmill will be useful for reducing the level of lower limbs muscles activity and designing the specific exercising plans for injured individuals.

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