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Lower extremity muscle activation during over ground versus treadmill running

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Abstract

Introduction: Treadmills employ a movable belt that creates a backward force not normally present during running. Discrepancies exist in the literature regarding differences in joint kinematics, kinetics and muscle activation during overground running (O) and treadmill running (T). The authors sought to identify lower extremity muscle activation differences between O and T in heel-strike runners while running at their preferred speed. The backward motion of the treadmill was hypothesized to decrease hamstring activation, which would in turn require a new forward propulsion mechanism to exist.

Methods: Ten recreational runners volunteered for the study. Active surface electrodes (were placed on the following muscles of the right lower extremity: Rectus femoris, Semitendinosus, Biceps femoris, Tibialis anterior, Soleus, Gastrocnemius, Gluteus maximus and Gluteus medius. Participants then underwent a five-minute jogging warm-up on a treadmill at their own preferred pace. Maximum voluntary isometric contractions (MVICs) were performed for each of the eight muscles in order to normalized the measurements. Muscle activation data were collected and analyzed for O and T with participants running at their preferred pace. Paired t-tests were performed to determine differences in muscle activation between O and T running for each of the eight muscles. The level of significance was set at 5%.

Results and discussion: No significant differences were observed between O and T running for each of the eight muscles tested. Individual muscle activity was similar between O and T with the soleus exhibiting the highest activity and the rectus femoris demonstrating the lowest for both scenarios. Support for the hypothesis was not observed, as the average muscle activation patterns between the two running conditions were similar for each of the eight lower extremity muscles. These results are different from previous studies and may be due to the participants running at a self-selected speed or inability to analysis each phase of gait individually.

Conclusion: Based solely on the average muscle activation of eight lower extremity muscles, the treadmill is an acceptable alternative to overground running in recreational runners.

Keywords: muscle activation, treadmill, overground running, lower extremity, kinematic variables, gastrocnemius

Introduction

Treadmill running is frequently sought as an equivalent mechanism to study running form and provide environment-controlled arenas for rehabilitation and training. Furthermore, treadmills may be a safer option compared to overground running (O) as it pertains to developing tibial stress fractures.[1] There continues to be conflicts within the research if O and treadmill running (T) are similar enough to be freely exchanged.

Several kinematic and kinetic studies have investigated the difference between O and T with varied results.[2–5] Several possibilities for these mixed observations have been presented including lack of familiarity with the treadmill and differences in the mechanical properties of the two running surfaces.[4] The kinematics of running between O and T tend to be similar or only slightly different. Fellin, Manal and Davis[6] reported similar kinematic curves of the hip, knee and rearfoot in all three planes between O and T in twenty healthy, recreational runners. Similarly, Sinclair et al.[7] found significant differences in only nine of 54 kinematic variables studied when comparing O and T of 12 active, healthy runners. Most of the differences were observed in the sagittal plane of the hip and ankle.[7]

Unlike the kinematics of running, kinetic variables tend to vary between O and T.[5] Willy and associates[8] found greater ankle concentric power and an increase of force on the Achilles tendon when running on a treadmill, but no significant differences were observed at the Patellofemoral joint. Similarly, Riley et al.[5] found several significant kinetic differences between O and T. They noted a significant difference in peak anterior and medial ground reactive forces as well differences in knee and ankle joint moments.[5]

We believe the moving belt of the treadmill may have possible adaptations to neuromuscular system and differences in muscle activity. Treadmill runners consistently have reduced vertical oscillations in their center of mass and a reduced forefoot loading, which suggest that all or part of the triceps surae is less active. This was supported by Bauret et al.[9] who observed a decrease in soleus muscle activation during push-off phase of T. The same study reported increased activity in the soleus and peroneuslongus muscles during the weight acceptance phase during T, suggesting T requires more stability than O.[9]

Despite studies demonstrating different muscle activity in multiple muscle groups for purposes of push off and stability these studies did not allow their subjects to run at their preferred speed. Allowing the participants to jog at their preferred speed may reduce some of the unfamiliarity factor that can occur with the use of a treadmill. Therefore, the objective of this study is to assess differences in lower extremity muscle activation between O and Tat a self-selected speed. The backward motion of the treadmill was hypothesized to decrease hamstring activation, which in turn would require a different forward propulsion mechanism.

Methods

Participants

Ten recreational runners (6 male, 4 female, age: 24.0±2.71, weight: 72.3±13.4kg, height: 1.72±0.12m) volunteered for the study. Participants did not have a history of an orthopedic injury over the past 12 months and ran at least three times a week for at least six months. Runners ran with a rearfoot strike pattern which was determine by mutual agreement between a Certified Athletic Trainer and a Sports Physical Therapist who each had over ten years of clinical experience working with runners. Participants gave written informed consented which was approved by the Institutional Review Board before they were allowed to partake in the study.

Procedure

All testing was performed indoors. Participants began by shaving and cleaning the locations of the designated electrodes locations. Active surface electrodes (rectangular shape 37x26mm) were placed on the following muscles of the right lower extremity: Rectus femoris, Semitendinosus, Biceps femoris, Tibialis anterior, Soleus, Gastrocnemius, Gluteus maximus and Gluteus medius. Participants underwent a five-minute jogging warm-up on a treadmill (Biodex Medical Systems, Shirley, NY, USA) at their own preferred pace. Three five-second maximum voluntary isometric contractions (MVICs) were collected for each muscle and to ensure correct placement of the electrode visual observation of the EMG signals on the computer screen were performed (Table 1). All MVICs were performed according to the testing procedures described by Kendallet al.[10] except for the RF. The MVIC for the RF followed the protocol described by Salzman et al.[11] Following the MVIC, muscle activation data of the same eight muscles were collected and analyzed for O and Twith participants running at their preferred pace. The running condition order was randomized and there was a five-minute break between bouts. The participant was blinded to their running speed when running on the treadmill and data were collected after two minutes of running. The overground running was completed on a 137.8m indoor loop covered by carpet and tile. Data were collected at the end of the participants' fourth lap. Due to the limited capture area for the overground running, ten gait cycles were used for both running conditions. The EMG average value was calculated for each of the running conditions. Delsys Trigno™ Wireless EMG System (Delsys, Inc., Natick, MA, USA) was used to record EMG activation for the MIVCs and the running conditions. The sampling rate was 1000Hz. EMG works® Software (Delsys, Inc., Natick, MA, USA) was used for processing. The EMG data was digitally filtered (10-100Hz), full wave rectified and smooth through a low-pass filter (12Hz, second-order Butterwordth digital filter).

Table 1 Maximum voluntary isometric contractions descriptions

Muscle	Position	Action	Hand placement and resistance
Rectus Femoris	Supine	Flexes hip with knee extended	Anterior surface of the lower leg, proximal to the ankle in the direction of hip extension
Semitendinosus	Prone	Flexes knee with tibia in medial rotation	Posterior surface of the lower leg, proximal to the ankle in the direction of knee flexion
Biceps Femoris	Prone	Flexes knee with tibia in lateral rotation	Posterior surface of lower leg, proximal to the ankle in the direction of knee flexion
Tibialis Anterior	Supine	Dorsiflexes ankle with knee extended	Over dorsal aspect of foot, proximal to the toes in the direction of plantar flexion
Soleus	Prone	Plantarflexes ankle with knee flexed at 90˚	Over plantar surface of foot, proximal to the toes in the direction of dorsiflexion
Gastrocnemius	Prone	Plantarflexes ankle with knee extended	Over plantar surface of foot, proximal to the toes in the direction of dorsiflexion
Gluteus Maximus	Prone	Hip extension with knee flexed at 90˚	Over the posterior thigh, proximal to the knee in the direction of flexion
Gluteus Medius	Side lying	Hip abduction with hip in slight extension and lateral rotation	Over the lateral lower leg, proximal to the ankle in the direction of adduction

Statistical analysis

SPSS Statistics 19 for Windows (SPSS Science, Chicago, IL, USA) was used for statistical analysis. Paired t-tests were performed to determine differences in muscle activation. The level of significance was set at 5%.

Results and discussion

Treadmill running has been accepted as a valid method to study and improve running biomechanics, but it has not been established whether lower extremity muscle activation patterns are altered. This study sought to identify differences in muscle activation between O and T while the participants ran at their self-selected speed. It was hypothesized that a decrease in hamstring activation would occur with T but support for the hypothesis was not observed.

The results of the muscle activation for each muscle and between T and O can be found on (Table 2). No significant differences were observed between T and O for each of the eight muscles tested. Individual muscle activity was similar between T and O with the soleus exhibiting the highest activity and the rectus femoris having the lowest for both scenarios.

Table 2 Mean (SD) of normalized EMG activity during treadmill and overground running

Muscle	Treadmill	Overground	T	P–value
Rectus Femoris	30.0(21.9)	27.7(19.5)	0.579	0.577
Semitendinosus	34.0(23.2)	35.4(16.4)	-0.18	0.861
Biceps Femoris	45.7(33.0)	52.9(39.0)	-0.757	0.469
Tibialis Anterior	36.5(11.9)	32.0(9.00)	0.91	0.386
Soleus	79.0(37.1)	69.8(16.1)	0.998	0.344
Gastrocnemius	37.8(16.6)	41.9(27.6)	-0.819	0.434
Gluteus Maximus	65.6(31.0)	65.0(53.6)	0.045	0.965
Gluteus Medius	44.7(24.7)	46.5(31.1)	-0.573	0.581

The findings of this study are similar to Wank et al.[12] and Baur et al.[9] who observed only small differences in muscle activation of the soleus, gluteus maximus and gastrocnemius muscles and the anteriortibialis muscle, respectively. Contrasting the results of this paper, Wank et al.[12] found significant differences in muscle activation of the rectus femoris with an increase during ground contact and initial swing phases during T. Furthermore, Baur et al.[9] viewed an increase in soleus muscle activation during push-off and a decrease in soleus activity during weight acceptance while O. These variations may be attributed to the participants running at their self -selective speed, thus decreasing the unfamiliarity factor. An alternative explanation for the results was the inability to divide the gait cycle into phases. Unfortunately, the researchers had limited video analysis capability to record the participants during O, which was the major limitation of the study. Last, differences in muscle activation may be associated with the running conditions, since Wank et al.,[12] Baur et al.[9] and the currently study all used different treadmills and overground settings.

In addition to the inability to isolate muscle activation for each phase of running, another limitation of the study was the use of healthy, young and uninjured recreational runners. Therefore the findings of this study should not be generalized to other populations. This study did not analysis the peroneuslongus (PL) muscle. Baur et al.[9] found a delay in the PL activation during O which may highlight the need for increased stability when T. Therefore, future studies should include the PL. Since this study only used a specific population, future studies should investigate the differences in muscle activation patterns in competitive and injured runners during O and T. This may improve running performance and rehabilitation protocols.

Conclusion

Based solely on muscle activation, T can be used as an alternative to O in rearfoot recreational runners if they run at their self-selected speed. Future studies should determine if muscle activation patterns are similar in competitive and injured runners during O and T in order to improve running performance and rehabilitation regiments.

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Conflict of interest

The author declares no conflict of interest.

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