ELECTROMYOGRAPHIC ANALYSIS ON LOWER EXTREMITY MUSCLES DURING OVERGROUND AND TREADMILL RUNNING

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The goal of this study was to compare treadmill running with overground running, so as to investigate if the shoe testing and training on treadmill can reflect the overground performance. Thirteen Chinese male subjects were instructed to run on the four conditions (1.Treadmill, 2.Tartan, 3.Grass, 4.Concrete). Comparisons between running conditions were made for muscle activity. The electromyography (EMG) signals from rectus femoris, tibialis anterior, biceps fermoris and medial gastrocnemius in one stride were evaluated. Results of the root mean square of EMG signal in rectus femoris, biceps femoris and gastrocnemius were found to be significantly different between overground and treadmill running during stance phase and the time point of toe off.

KEY WORDS: EMG, electromyography, muscle activity, shoe testing.

INTRODUCTION: Treadmill has been a common instrument in the research field in which different investigations were evaluated under a speed-controlled running condition. Many running scientific investigations, including running gait pattern at different speeds and sports shoes research, have been performed on a treadmill (Frishberg 1983, Nigg 1995, Wank 1998, Gazendam and Hof 2007, van Ingen Schenau 1980). However, from the biomechanical point of view, whether the data collected on a treadmill can be applied to overground surface is still unknown. Previous studies on different surfaces running have focused primarily on the kinematics analysis and limited information about muscle activity pattern had been presented. With muscle activity parameters taken into account, it can provide more insight into the validity of treadmill running to reflect the situation in overground running.

METHODS: Thirteen male subjects (age = 22.4 ± 3.9 years, body mass = 63.6 ± 9.2 kg, body height = 170.6 ± 6.2 cm) with no known running gait disorders were recruited in the study. They were all heel-toe runners and familiar with treadmill running with shoe size 40 (EURO Standard). A pair of running shoes (TN 600, ASICS, Japan) were provided for them during testing. Each subject was requested to perform running on each of the four situations with a controlled speed of 3.8 ms^{-1} on treadmill (6300HR, SportsArt, US) and the acceptable range was 3.6 ~ 4.0 ms^{-1} on overground surfaces with the use of light gate monitor. Figure 1 showed the experimental set up of the overground on field.

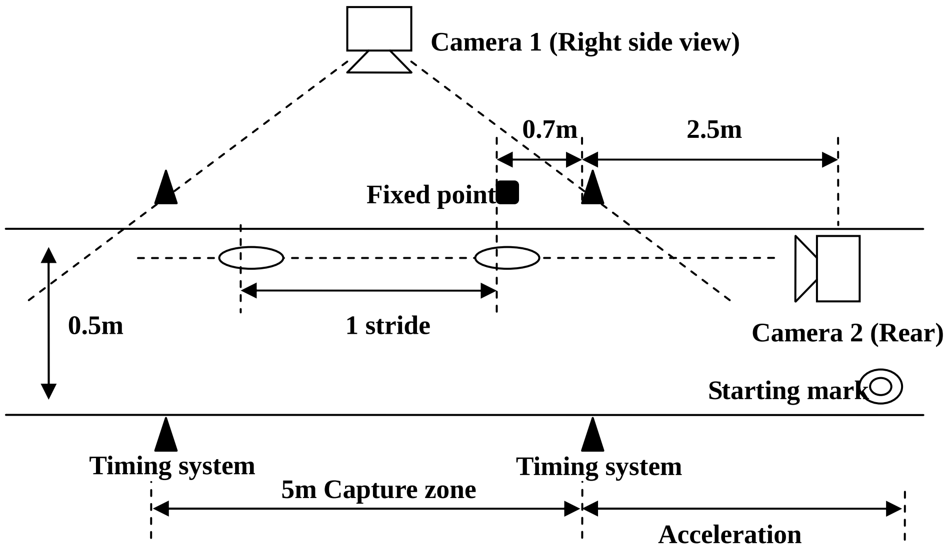

Figure 1: Experimental set up of overground surface on field

Four lower extremity muscles including rectus femoris, tibialis anterior, biceps femoris and gastrocnemius were tested. Each EMG signal was magnitude normalized to maximum magnitude recorded in reference activity. Four controlled reference postures were selected for normalizing each muscle group respectively (Fong, Hong and Li 2008). They were then trimmed into four phases and time normalized to 0-100% stance or swing phase. Band pass filter of 20-500Hz and full wave rectification were applied. An One-way repeated measure ANOVA was used to compare the value of four different running conditions, and followed by Post-hoc Tukey tests.

RESULTS: Significant differences were found on the stance phase and toe off of the stride.

Table 1 Mean and SD of muscle activity parameters (magnitude normalized to reference contraction)

Mean and SD of muscle activity parameters	Treadmill	Tartan	Grass	Concrete	p value	Tukey
Rectus Femoris TO	1.839 (0.540)	14.576 (8.706)	7.003 (5.584)	8.477 (2.990)	< 0.05	(T-Ta)**
Gastrocnemius TO	8.534 (5.950)	39.011 16.098)	19.091 (5.013)	21.200 (0.278)	< 0.05	(T-Ta)**
Rectus Femoris Phase 1	3.673 (2.311)	21.279 (7.611)	15.432 (4.541)	24.729 (13.011)	< 0.01	(T-Ta)*, (T-G)*, (T-C)*, (G-C)**
Biceps Femoris Phase 1	4.776 (2.791	13.310 (7.165)	9.854 (6.210)	12.783 (12.594)	< 0.05	(T-Ta)**, (T-G)**, (T-C)**, (G-C)**

T:Treadmill, Ta:Tartan, G:Grass, C:Concrete

Phase 1:Stance phase, Phase 2:Early swing, Phase 3:Middle swing, Phase 4:Late swing, TO:Toe off

*p < 0.01, **p < 0.05

Throughout stance, EMG in rectus femoris ($P < 0.01$) and biceps femoris ($P < 0.05$) were greater on overground compared with the treadmill. Also, EMG in rectus femoris ($P < 0.05$) and biceps femoris ($P < 0.05$) were greater running on concrete compared with grass. At toe off (TO), the EMG in rectus femoris ($P < 0.05$) and gastrocnemius ($P < 0.05$) were greater running on Tartan compared with treadmill. Significant differences found in mean and SD of muscle activity was showed in Table 1.

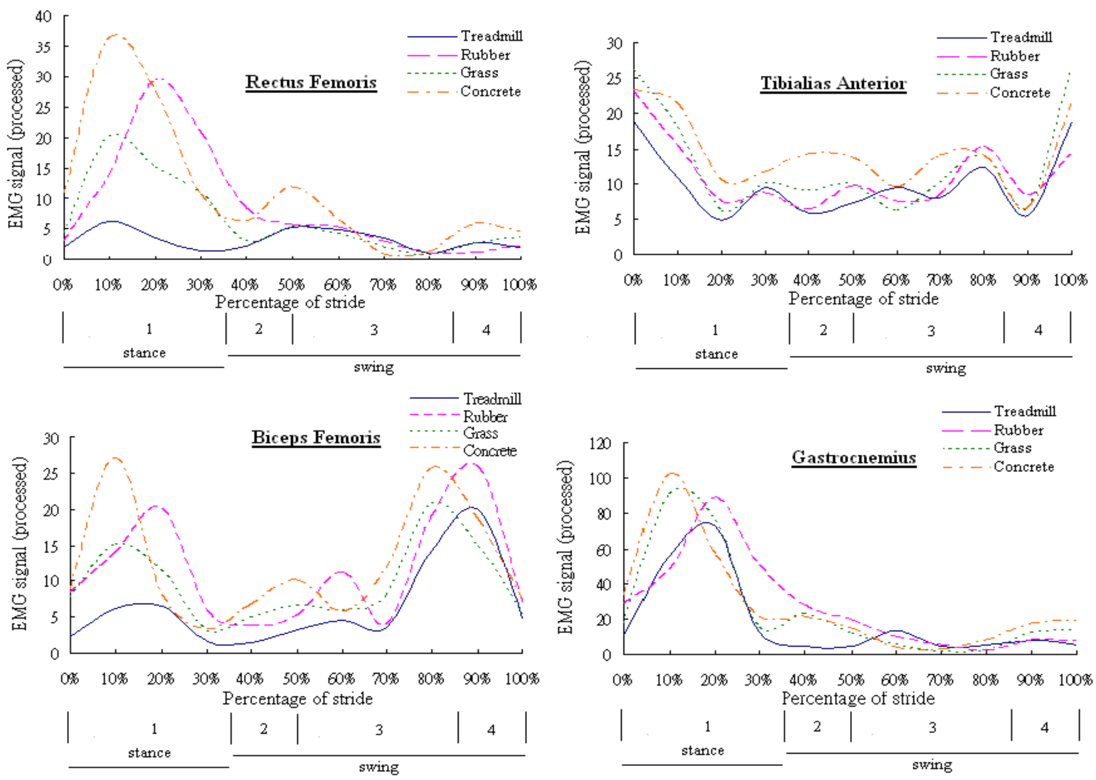

Figure 2: The EMG profile with the normalized average for all subjects

DISCUSSION: At toe off, the muscle activity of rectus femoris and gastrocnemius were lower when running on treadmill compared with tartan surface. In treadmill running, the belt is moving backward continuously, this can be treated as a slightly slippery surface. When we are running on wet or slippery surface, it is easier to slide and more attention is needed. We try to run with smaller steps with higher frequency. The kinematics finding in previous studies (Schache 2001, Wank 1998) reported that the stride length and stride frequency were found to be shorter and higher respectively in treadmill when compared to overground. Therefore, there is not enough time for runner to extend the knee and plantar-flex the ankle. As a result, lower muscle activity of rectus femoris and gastrocnemius were recorded on treadmill. (Fong et al. 2008) showed that when the leg was in fully extended situation, it would be difficult for a recovery action in case of slip. Putting the knee in a slightly flexed position could be a strategy to prepare for correction on slippery surfaces. As the muscle activity rate on treadmill running is lower than that on overground at toe off, it is proposed that the drag force applied by runner at toe off is smaller on treadmill than overground. It is promising to investigate the drag force when running on treadmill and overground comparing with overground.

During stance phase, the muscle activity of rectus femoris and biceps femoris showed lower magnitude on treadmill running as compared with overground running. In treadmill running, there is no need to move the body forward continuously, not much energy is needed to provide forward centre of gravity of the body (CG) movement comparing with overground running during the heel touch down to toe off period. With lower muscle activity rates on treadmill than overground running during stance phase, it is proposed that the foot sole pressure should be different on treadmill and overground running. It is promising to evaluate the sole pressure distribution on treadmill and overground running.

CONCLUSION: The results obtained showed that the muscle activity reacted significant differently between treadmill and overground running. The treadmill running results for any research design should be checked carefully when applying to other overground surfaces. With different muscle activity rates on different running surfaces, it is important to evaluate the training effects as well. Moreover, we proposed that drag force provided by the running shoe sole of treadmill testing shoe may differ from the overground one. The sole pressure distribution may also be different between treadmill and overground surfaces. The drag force and pressure cushioning effects were not reflected truly when treadmill running was used for running shoe testing, sole material selection and sole design.

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