Changes of Lumbar Muscle Flexion Relaxation Phenomenon When Standing on Unilaterally Elevated Ground

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Occupational tasks performed on uneven ground surfaces are common in agriculture and construction industries. The influence of unilaterally elevated ground surface on lumbar muscle flexion relaxation phenomenon (FRP) during trunk flexion and extension motion has been investigated in the current study. Ten subjects performed trunk flexion and extension motion on flat ground and two unilaterally elevated ground conditions while lumbar muscle EMG and trunk kinematics data were recorded. Results of this study demonstrated clear difference in bilateral lumbar muscle FRP under elevated ground conditions. The current finding can be used to better understand uneven ground surfaces as a risk factor for the development of low back pain.

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INTRODUCTION

Low back disorder (LBD) is one of the most common occupational problems in industry (Manchikanti 2000). Previous research reported that nearly 40% of the LBDs are work related and some labor intensive jobs have even higher incident rate (Punnett et al., 2005). Roughly 10-20% of all the US workers' working productivity was affected by LBDs to a certain degree each year (Silje et al., 2012).

Previous studies have identified uneven ground surface as a risk factor that may increase the risk of LBDs. Although flat ground working conditions are very common in indoor occupational environments, many tasks performed in outdoor environment involve working on uneven ground surfaces, such as the fishing industry (Ning et al., 2010) and construction industry (Simeonov et al., 2003). Past studies have showed that uneven ground conditions could increase the possibility of falling (Simeonov et al., 2003), increase both spinal compression force and shear force while perform weight lifting tasks (Shin et al., 2004) and decrease body stability (Lin et al., 2012). However, the effect of uneven ground surface on lumbar active (i.e. muscles) and passive (e.g. ligaments, discs) tissue interaction during trunk bending motion (e.g. lifting tasks) has never been investigated.

Low back muscle flexion relaxation phenomenon (FRP) is an effective method to explore the interplay between lumbar active muscle and passive tissues. FRP normally occurs at close to trunk full flexion posture where lumbar passive tissue quickly becomes the dominant weight bearer and back extensor muscle activity suddenly ceases (Kippers et al., 1984). Previously several researchers have used FRP to investigate the low back muscle activation mechanism on flat ground (Ning et al., 2011). However, no previous study has investigated the effect of uneven ground surface on FRP. Based on the existing literature and research reports, it is highly possible that uneven surface with vertical height difference could influence the FRP as well as change the load distribution between the active and passive components of lumbar spine. The purpose of this study was to quantify the effect of the unilaterally elevated uneven ground surface on the low back muscle activation pattern when performing trunk bending motion.

METHOD

Subjects

Ten healthy subjects, without self-reported low back pain participated in this study. The experiment protocol was reviewed and approved by the local institutional review board. All subjects provided written informed consent before participation.

Experiment design

In the current study, a single independent variable: HEIGHT was tested. HEIGHT was defined as the vertical height difference between left and right foot (Figure 1). Three levels were tested: 0 cm (flat ground condition), 16.5 cm (6.5 inches) and 25.4 cm (10 inches). Based on the results of our pilot study, having left or right foot standing on the elevated location resulted in similar activation pattern in the low back musculature. Therefore, during the data collection, right foot was always elevated.

There were two categories of dependent variables in the current study: trunk inclination angle (referred as trunk angle later) and lumbar flexion angle (referred as lumbar angle later). Trunk angle describes the magnitude of trunk flexion with near 0^o at upright posture; lumbar angle represents the natural curvature of lumbar spine with -15^o to -30^o at upright posture which represents its natural lordosis. The four dependent variables were: 1. left erector spinae (LES) EMG-Off trunk angle; 2. LES EMG-Off lumbar angle; 3. right erector spinae (RES) EMG-Off trunk angle and 4. RES EMG-Off lumbar angle. The EMG-Off point (namely the initiation of FRP) was defined as the point during trunk flexion where EMG activity ceases (Figure 1). The decision algorithm for lumbar muscle FRP was described in detail previously (Ning et al., 2011).

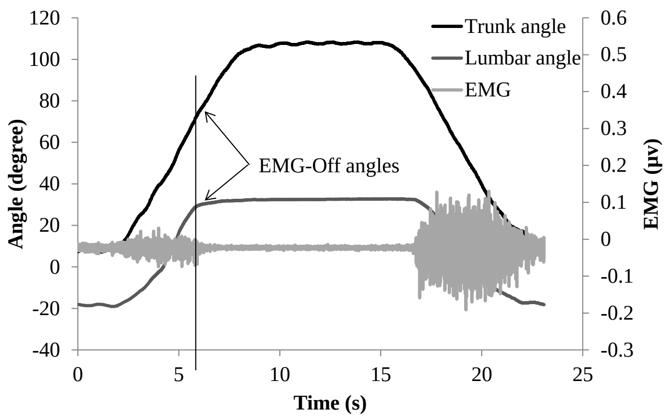

Figure 1: The identification of EMG-Off point and the corresponding lumbar flexion angle and trunk inclination angle.

Apparatus

Electromyography (EMG) data were recorded using bi-polar surface EMG electrodes (Model Bagnoli, Delsys Boston MA, USA) placed over bilateral L3 paraspinals; electrodes were placed 4 cm away from the center line of spinal column. Trunk kinematics was recorded using magnetic field-based motion tracking system (Model Motion Star, Ascension Burlington VT, USA). Three motion sensors were place over the skin of the C7, T12 and S1 vertebra level respectively. Two wood steps were used to elevate subjects' right foot, and the height of the structure was 16.5 and 25.4 cm respectively (Figure 2).

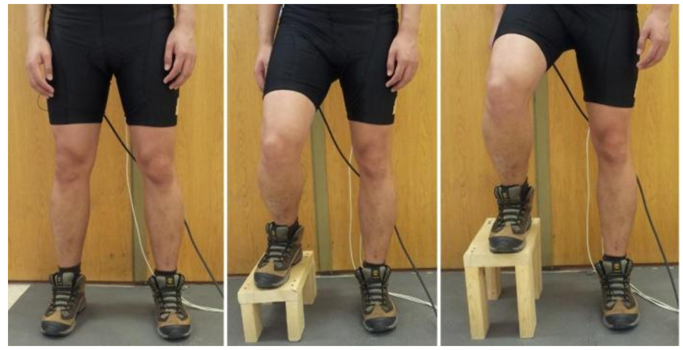

Figure 2. Frontal view of the foot posture (left panel: flat ground; middle panel: 16.5cm; right panel: 25.4cm).

Experiment protocol

Upon arrival, the experiment procedure was explained to the subjects and signed consent documents were obtained. Next, a training section was provided in order to have subjects warm up trunk muscles and learn the experiment protocol. After that, three motion sensors and two surface electrodes were secured to the designated sites. A level ground condition was established as the control condition and the two unilateral elevated ground conditions were enabled by having subjects stand their right foot on the previously described wooden steps. In each condition subjects performed 5 repetitions of slow trunk flexion and extension motion. The pace of the motion was set as: 7 seconds to bend from upright posture to full flexion posture, remain in full flexion posture for 6 seconds then use 7 seconds to return to upright posture. A metronome was used to control the rhythm. During all trials subjects were required to keep their motion in the sagittal plane and avoid abrupt movement. Ample rest was given to subjects between trials in order to avoid the effect of muscle fatigue and lumbar passive tissue elongation.

Data processing

The sampling rate for the EMG data was set at 1024 Hz. Signals were band-pass filtered in software (Matlab, Natick, MA, USA) with a high-pass frequency of 10 Hz and a low-pass frequency of 500 Hz. A notch filter of 60 Hz and its aliases were also used in the data processing procedure. Trunk kinematics data was collected with sampling frequency of 102.4 Hz and synchronized with EMG data in the software.

Statistical analysis

Analysis of variance (ANOVA) was performed to investigate the effect of independent variable (HEIGHT) on each of the four dependent variables. The criteria p-value was 0.05 for all statistical analyses.

Tukey-Kramer *post-hoc* analysis was performed to further reveal the difference among the three HEIGHT levels.

RESULTS

Results of this study showed that both LES EMG-Off lumbar and trunk angles were significantly reduced by the increase in HEIGHT (Figure 3, 4), but the RES EMG-Off angles were not significantly affected. The difference between LES and RES EMG-Off trunk and lumbar angles significantly increased with the increase of HEIGHT level (Figure 5, 6).

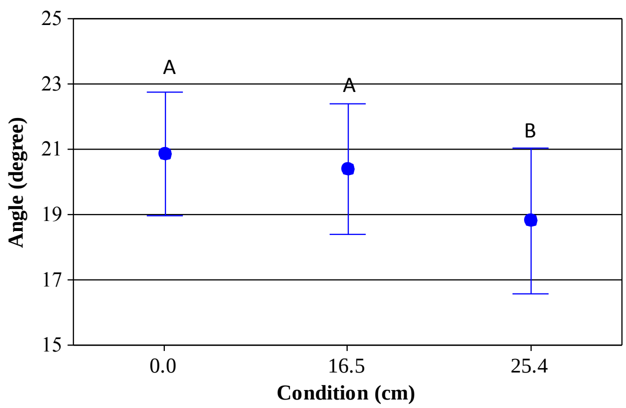

Figure 3. Lumbar EMG-Off angle for the left erector spinae. Different letters indicate angles that are statistically different from one another. Bars indicate the corresponding 95% CI.

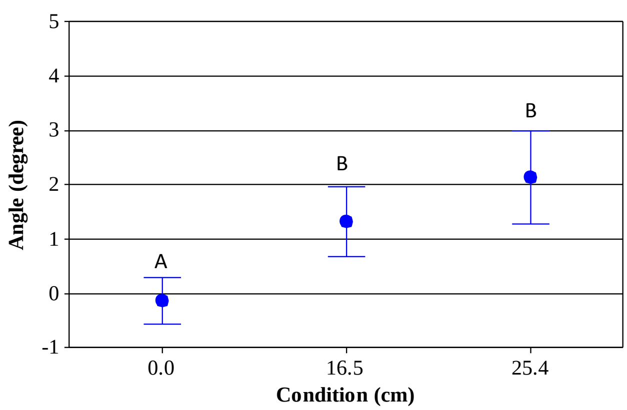

Figure 4. Lumbar EMG-Off angles difference for left and right side of the erector spinae (always right side minus left side). Different letters indicate angles that are statistically different from one another. Bars indicate the corresponding 95% CI.

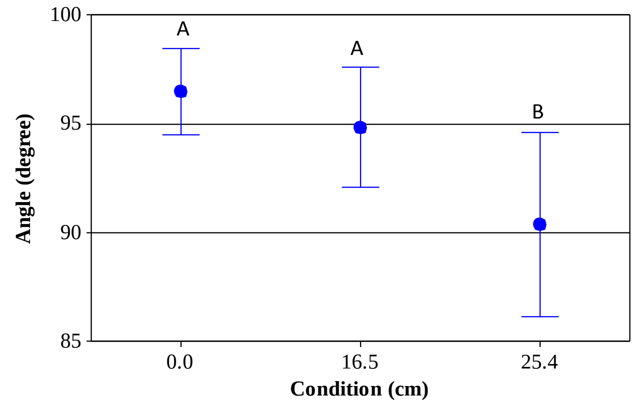

Figure 5. Trunk EMG-Off angle for the left erector spinae. Different letters indicate angles that are statistically different from one another. Bars indicate the corresponding 95% CI.

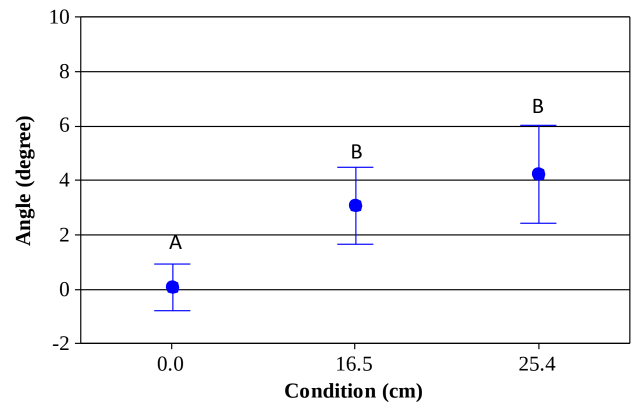

Figure 6. Trunk EMG-Off angles difference for left and right side of the erector spinae (always right side minus left side). Different letters indicate angles that are statistically different from one another. Bars indicate the corresponding 95% CI.

DISCUSSION

Our results showed that in all experimental conditions, both sides of erector spinae muscle demonstrated FRP which concurs with previous findings. However, in the current study the EMG-Off points of left and right erector spinae are different under uneven ground conditions and this difference was enlarged with the increase of height difference between feet. From anatomical point of view, under uneven surface conditions, subjects tended to put more weight on the straight leg (left side in current design) because of the flexion on the right knee. This increase of stress and strain in the lower extremity may eventually increase lumbar passive tissue tension would reduce the activation duration of LES (Shin et al., 2004). As a result, LES EMG-Off happened earlier under uneven surface conditions.

On the other hand, the RES EMG-Off angles were not significantly affected by HEIGHT. Previous study showed that the increase of knee flexion angle could delay the occurrence of FRP (Shin et al., 2004), however in that study the the motion was performed in the sagittally symmetric plane and both knees were flexed to the same degree. In the current study, due to the unbalanced nature of ground surface the body weight distribution among two legs are not balanced, in addition, this distribution could shift during the trunk flexion and extension motion. This confounding factor combined with the effect of knee flexion may result in the unchanged RES EMG-Off point. Further investigation is needed to further explore the effect of body weight between two legs on lumbar muscle FRP.

There are two limitations of this study. First, only male subjects were included in order to eliminate the influence of gender, therefore how female performs in the same experiment design needs further investigation. Secondly, all subjects were college students without real working experiences. Field workers may develop different muscle activation patterns in order to cope with uneven ground surfaces.

CONCLUSION

It is concluded that when subjects perform trunk bending motion on unilaterally elevated ground the lumbar muscles on the same side of the elevated foot (i.e. the right side in the current study) will reach to FRP later than the other side of lumbar muscles. This difference would enlarge with the increase of the differences in foot height. In conclusion, when performing repetitive trunk bending motion with one foot elevated, the elevated side of the lumbar muscles may experience fatigue sooner than the other side.

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