Assessment of low back muscle fatigue during normal gait

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ABSTRACT

Development of low back muscle fatigue has been evaluated by analyzing electromyography (EMG) measured during isometric back extension exercises which cannot be easily administered in non-laboratory settings. The objective of this study was to explore whether the changes in muscle activation pattern induced by muscle fatigue could be identified during normal walking, which can be easily done in daily life. Nineteen subjects participated in an experiment and conducted normal walking trials on a treadmill with a fatigue generating Biering-Sorensen test in between. Eight EMG sensors were bilaterally attached to back and abdominal muscles. Muscle activation levels and integrated EMG of the walking trials were compared between before and after the fatigue development. In result, it was found that the EMG amplitudes and the integrated EMG of the lumbar erector spinae muscles were increased significantly after the fatigue development. Results of this study suggest that muscle fatigue development could be monitored in a daily activity and it may lead to the development of wearable health monitoring systems with surface EMG sensors.

Keywords: EMG, low back muscle, lumbar spine, muscle fatigue

1. Introduction

Endurance time of skeletal muscles is one of major aspects of human physical capacity. Poor endurance of the low back muscles results in faster and more severe development of muscle fatigue, and it can contribute to the occurrence of low back problems (Biering-Sorensen, 1984; Luoto, S. et al., 1995).

Reliable assessment of muscle fatigue development has been an important topic in previous research that studied injury mechanism and prevention strategies. In order to reliably identify the development of muscle fatigue, several methods have been employed in previous research. They include the tracking of the median frequency of the myoelectric signals of the low back muscles in controlled isometric exertions, reduced strength in maximal voluntary contraction, and increase in the variation of muscle activation level in isometric exertions (Da Silva R. A. et al., 2005; Arnall, F. A. et al., 2002).

Even though these assessment methods have shown sufficient reliability and validity in determining the occurrence of muscle fatigue, they are not suitable as a self-care monitoring method as the existing methods require body restraining fixtures or controlled postures, which cannot be easily repeated in non-laboratory settings.

As a pioneering effort for the development of self-care muscle fatigue monitoring system, the current study explored the possibility of identifying low back muscle fatigue development in common daily activities such as normal walking.

Myoelectric activities (EMG) of low back muscles were recorded while walking and their activation patterns were compared before and after the development of muscle fatigue. Results of this study could be used in future research to develop fatigue monitoring systems including wearable EMG hardware system and data analysis algorithms.

2. Method

Nineteen healthy subjects (10 males and 9 females) ranging from 19 to 24 years old participated in a laboratory experiment (Table 1). Participants consented to a protocol approved by the institutional board before starting the experiment.

Table 1. Subject information (mean and SD).

	#	Age	Weight (kg)	Height (cm)
Male	10	20.7 (1.3)	71.2 (12.3)	176.8 (6.9)
Female	9	21.1 (1.5)	51.6 (4.4)	161.6 (5.9)

Each subject performed a fatigue generating task, and the EMG data of the low back muscles and abdominal muscles were collected during normal walking before and immediately after the fatiguing task.

Fatigue of the low back muscles was generated by the modified Biering-Sorensen test. In comparison with the original Sorensen test, the modified Biering-Sorensen test of the current study employed a prone position on a 45° roman chair to minimize the involvement of hip extensor muscles so the fatigue development could be isolated to low back muscles (Champagne, A. et al., 2008; Kankaanpaa, M. et al., 1998). On the roman chair, the subject was asked to keep the back and hip straight as long as he/she could.

Before and immediately after the modified Sorensen test for fatigue generation, the subject performed normal walking on a treadmill for 2 minutes at a speed of 4 km/h. The subject was asked to walk as normal as possible with no special instruction.

While walking, EMG of the low back and abdominal muscles were collected using 8 surface electrodes (Delsys Bagnoli system, Delsys, U.S.A). The electrodes were attached bilaterally on the erector spinae (ES) muscles at L2 and L4, external oblique (EO) muscles, and rectus abdominals (RA) with double-sided adhesive tapes.

Raw EMG signals were band-pass filtered with a low pass cut-off frequency of 30 Hz and a high pass cut-off frequency of 500 Hz, and notch filtered to remove 60Hz signals. They were then linear enveloped to smooth using a second-order Butterworth filter with a low-pass cut-off frequency of 6 Hz. The linear enveloped EMG data were normalized to the EMG amplitudes from the submaximal voluntary contraction exercises, which included the first 30 seconds of the modified Sorensen test for the low back muscles and a 30 sec plank exertion for the abdominal muscles.

From the normalized EMG data of the continuous walking, data of middle 20 steps were extracted, divided into left strides and right strides and then processed to compute the mean, 10th %-tile, 90th %-ile, and integrated NEMG amplitudes of each stride. The computed values were then compared between the two walking trials (before and after Sorensen test). One way ANOVA was conducted with the significance criterion of $p<0.05$.

3. Results and Discussion

Significant differences were found in the EMG variables of the lumbar erector spinae muscles between the pre-fatigue and the post-fatigue walking trials. Mean, 90th %-ile and integrated EMG values of the L2 and L4 level lumbar erector spinae muscles increased significantly after the fatigue development. No consistent differences in the EMG variables were found from the abdominal muscles (Figures 1 and 2).

This result indicates that, after the Sorensen test, subjects of this study produced more contraction forces using the fatigued lumbar erector spinae muscles during the normal gait. The greater activation level after muscle fatigue has been reported elsewhere and it has been considered as an indicator of muscle fatigue development. However, the uniqueness of the current study was the test of muscle fatigue effects in less-controlled daily activities such as normal walking.

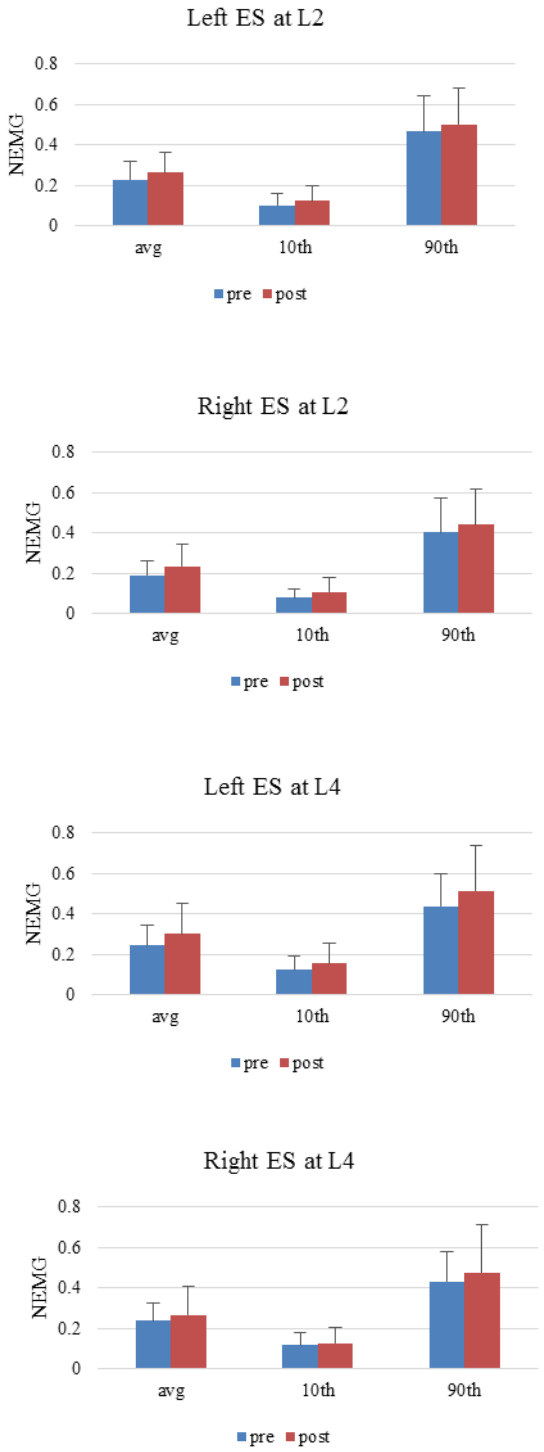

Figure 1. Mean and 10th and 90th percentile of NEMG of L2 and L4 ES muscles before and after the modified Biering-Sorensen test.

In previous research, effects of muscle fatigue were evaluated from isometric exertions that required substantial amount of activation and posture control. Results of the current study suggest that a simple daily activity such as normal speed walking could be used as a testing protocol, if the sensitivity of EMG variables is enhanced through the measurement of 90^{th} %-ile or integrated amplitudes.

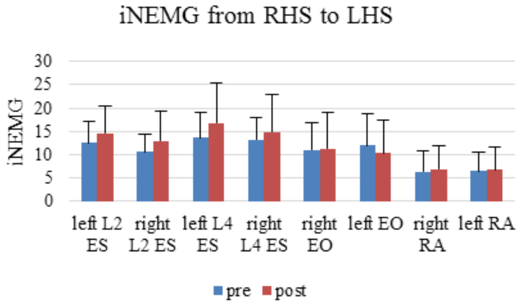

Figure 2. Integrated NEMG of low back and abdominal muscles before and after the modified Biering-Sorensen test.

4. Conclusion

The results of this research suggest that muscle fatigue development can be monitored during normal walking. Compared with previous research where isometric back extension exercises were done in well-furnished laboratory settings, the data collection protocol of the current study could be repeated in non-laboratory setting with minimal postural controls. Results of this study could be used to develop wearable low back health monitoring system in future research.

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