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ABSTRACT

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Prolonged stooping has been known as one of key contributing factors to the development and occurrence of low back injuries or disorders. Specifically, workers at construction sites and agricultural fields are often required to maintain a deep upper body forward flexion posture to conduct work at or below knee height, and it has been associated with their high prevalence of low back disorders. To better understand the cause-effect relationship between prolonged stooping and low back disorders, this project examined how the activity of low back muscles and movement patterns change during a course of a simulated crop harvesting task in a laboratory. More specifically, this project was aimed to understand how a stooped work task that resembled crop harvesting work can increase the risk of work-related low back disorders by analyzing various biomechanical signs of muscle fatigue and joint instability in a human subject experimental study.

Study results found low but consistent use of low back muscles during a stooped work task and the development of muscle fatigue after the stooped work task. The continuous use of low back muscles during prolonged stooping caused the muscle fatigue and could be one of key risk factors for low back disorders of workers who frequently conduct stooped work tasks.

Previously, prolonged stooping has been considered as a static work posture. Low back muscles were thought to be fully flexed and relaxed (flexion-relaxation), and researchers did not pay attention to the changes in the muscles. The results of this study, however, suggest the importance of biomechanical evaluation of muscle activities to properly assess the risks of prolonged stooped work tasks.

Findings of this study can be used to develop a method and a device that can assess the level of risks of prolonged stooped posture by using wearable muscle activity monitoring sensors. Future research will focus on the development of a wearable monitoring device and assessment method for preventing work-related low back disorders from prolonged stooped work tasks.

SECTION 1

Significant Findings

- Different from common expectations and hypotheses that have been employed in previous research, low back extensor muscles were not in relaxation status during prolonged stooped work. Results of this study indicate that stooped work tasks such as crop harvesting, gardening, and roofing require low but continuous activation of the low back muscles to conduct manual works at or near the ground level.

- The continuous low-level exertions of the low back muscles can lead to the development of muscle fatigue during a stooped work task, and it may degrade the joint stability of the lumbar spine. Repetitive exposures to prolonged stooping without sufficient rest breaks can damage the stability of the lumbar spine and contribute to the development of work-related injuries or disorders.

- In this study, the amount of muscle fatigue development and other physiologic changes were compared between two micro-break schedules ('30-sec stooping + 6-sec rest' vs. '60-sec stooping + 12-sec rest') during repetitive stooped work. Results found that the two micro-break schedules caused similar muscle fatigue and other biomechanical changes. It suggests that biomechanical risks associated with prolonged stooped work was not sensitive to the changes in micro-break schedules, if the overall work duration is consistent.

Translation of Findings

- Findings of this study indicate that the low back muscles may lose their capacity and ability generate required forces after prolonged stooping. To avoid work-related low back disorders after stooping, it is recommended to avoid heavy exertions such as lifting, pushing or pulling immediately after a prolonged and/or repetitive stooped tasks.

- Results of this study suggest the possibility of the development of a wearable health monitoring system that can continuously track the changes of the level of risks for low back during stooped work tasks by tracking and analyzing the development of muscle fatigue using the electric signals (electromyography) from the low back muscles.

- In addition, study design and experimental methods of this study can be used in future research to further investigate the effects of different work-rest schedules and determine proper work-rest schedules that can minimize or avoid the development of cumulative damages and risks to the low back.

Outcomes/Impact

- This study produced potentially valuable empirical data that show the importance of proper assessment of muscle fatigue development in the risk assessment of prolonged stooping. Previous research has focused on the changes in the passive spinal tissues such as ligaments as the muscles were thought to be in a relaxation status (flexion-relaxation phenomenon). However, in this study, it was found that the low back muscles were actively working during work-related stooped tasks. Findings of this study will promote and guide future research to pay additional attention to the muscle biomechanics and physiological responses when assessing risks associated with prolonged and/or repetitive stooped postures at workplaces.

SECTION 2

Scientific Report

1. Background

Low back disorder (LBD) is one of the most common disorders that has caused substantial economic burden on society. One of major physical risk factors that have been related to the occurrence of low back pain or disorders is frequent exposures to static upper body deep flexion postures or prolonged stooping (Bernard, 1997; Shin et al., 2009).

Occupational tasks that require workers to work at or below knee height for extended periods of time (e.g. landscaping and horticultural services, roofing work and concrete work) have reported relatively high incidence rates of LBDs compared to industry averages (BLS, 2008), and construction and farm workers have ranked the prolonged stooping posture as one of the most problematic work postures for work-related LBDs (Goldsheyder et al., 2002; Rogers and Granata, 2006). Although the mechanism of injury is still under investigation, it is commonly accepted that frequent exposure to prolonged stooping is one of the major risk factors for LBDs (Fathallah et al., 2008).

Fairly recent efforts in the investigation of injury mechanism and the development of prevention strategies, researchers have assessed the risk of injury associated with stooping by quantitatively evaluating the development of micro-tissue damage in the supporting passive tissues of the lumbar spine (Solomonow et al., 2003a), increases in the range of lumbar flexion in upper body full flexion trials (McGill and Brown, 1992; Rogers and Granata, 2006; Shin et al., 2009), delayed occurrence of flexion–relaxation in upper body flexion movements (Solomonow et al., 2003b; Shin et al., 2009), changes in the perturbation response behaviors of paraspinal muscles (Rogers and Granata, 2006; Bazrgari et al., 2011), and increased myoelectric (EMG) activity of lumbar erector spinae muscles (Shin and Mirka, 2007) after prolonged or repeated exposures to stooped postures. These physiologic or behavioral responses of the lumbar spine have been recognized as indicators of mechanical instability of the lumbar spine, and researchers have suggested an association between stooping and the occurrence of spinal laxity and instability as an injury mechanism (Adams and Dolan, 1996; Solomonow, 2006; Shin et al., 2009).

While previous research has consistently shown evidence that suggests the association between stooped postures and LBDs, there is a need for further research with more work-related postures or loading conditions of prolonged stooping. Previously, changes in the lumbar spine musculature of human subjects associated with prolonged stooping have been quantified under controlled and restricted postural conditions. These include requiring participates to maintain an upper body forward flexion posture at the end of the voluntary flexion range or a passively hung (relaxed) upper body posture for up to 20 consecutive minutes in sitting or in quiet standing, with the pelvis and lower extremities restrained to a fixture to isolate the sagittal plane motion of the upper body to those anatomical structures superior to the pelvis (McGill and Brown, 1992; Rogers and Granata, 2006; Shin and Mirka, 2007). No study has yet experimentally confirmed the occurrence of the above-mentioned biomechanical responses of the lumbar spine of human subjects in more work-related and unrestricted prolonged stooped posture conditions.

Although the restricted and somewhat extreme loading conditions (e.g. static full flexion for 20 consecutive minutes) could improve study sensitivity, the lack of empirical data that show the occurrence of similar biomechanical responses of the low back in unrestricted loading conditions could limit the utility of existing knowledge on the injury mechanism. To address this limitation, the current study was aimed to quantitatively assess the effects of prolonged stooping on viscoelastic responses of the low back with more work-related and unrestricted stooped work posture and loading conditions.

Two different stooping scenarios were tested for each subject with different micro-break schedules to cover wider scope of work-related stooping conditions. The two micro-break schedules were specifically chosen not only to represent realistic break schedules but also to compare efficiency of different micro-break schedules in mitigating cumulative effects of prolonged stooped postures while maintaining overall task duration.

2. Specific Aims

The main objective of this research is to quantify the effects of static flexion on spinal stability. Stooped work tasks of two different loading patterns (work-rest schedules) were tested in a laboratory with minimal postural constraints, and the measures of spinal laxity, fatigue development in the low back extensor muscles and the impairment in spinal stability were obtained before, during and after a period of a stooped work task. The successful completion of the work experimentally validates the quantitative relationship between static flexion and the impairment in spinal stability (static flexion → spinal laxity & muscle fatigue → impairment in spinal stability), and provides valuable empirical data to be used to develop a mathematical risk assessment model and an intervention strategy in future research.

This work is an initial step towards the long term goal of the development of efficient injury prevention strategies using a reliable and valid risk assessment method to reduce the risk of low back disorders associated with static deep trunk flexion at workplaces.

Specific aims to achieve the main objective were as follows:

#1: To identify the occurrence of muscle fatigue development during static flexion by quantitatively evaluating myoelectric signals of the low back muscles before, during and after a stooped work task.

#2: To determine the effects of micro-break schedule of stooped work task on the risk of low back disorders by comparing indicators of muscle fatigue and spinal laxity between two different work-rest schedules (shorter and more frequent micro-breaks vs. longer and less frequent micro-breaks).

#3: To explore various biomechanical responses of the low back in more realistic and work-related loading and posture conditions of static flexion.

3. Methodology

3.1. Subjects

Twenty two subjects (12 females and 10 males) who had no chronic or current low back problems participated in the experiment. Prior to participation, each subject provided informed consent on a protocol approved by the institutional review board. Their mean age was 23 yrs (standard deviation, SD: 2 yrs), and mean height and weight were 1.66 m (SD: 0.09 m) and 62.7 kg (SD: 14 kg), respectively.

3.2. Experimental Variables

Various biomechanical measures were quantified before, during and immediately after 7-min work in a stooped posture with periodic micro-breaks to determine the occurrence of stooping-related changes in the lumbar spine musculature. First, the limits of voluntary lumbar flexion and pelvic forward rotation in upper body full flexion trials were obtained before and after the 7-min work, and increments in the peak angles were evaluated as an indicator of viscoelastic and poroelastic changes of passive spinal tissues (Solomonow et al., 2003b; Rogers and Granata, 2006). Second, EMG amplitudes of the lumbar erector spinae muscles and external oblique muscles in weight holding trials were measured before and after the work period, and increments in the amplitudes were interpreted as the compensatory response of the muscles to the reduced moment generating capacity of the passive spinal tissues (Shin and Mirka, 2007; Shin and D'Souza, 2010). Third, the median frequency of the EMG signals from the weight holding trials were compared before and after the work period, and the shift of the median frequency towards lower frequencies was considered as an indication of muscle fatigue development. Finally, the range of lumbar flexion variation (maximum, minimum, mean) and mean amplitudes of the lumbar spine erector spinae muscles were collected at the beginning and periodically during the work period to determine whether the lumbar spine was maintained near full flexion postures and whether the extensor muscles exhibited myoelectric silence (Shin et al., 2009) while maintaining the stooped posture.

The above dependent variables were collected in two work sessions of different schedules for micro-breaks (session 'A' and 'B'). Between the two work sessions, the overall duration of maintaining a stooped posture was kept consistent while the duration and frequency of the micro-breaks varied. Each subject experienced both sessions on the same experiment day. In session 'A', subjects stood up from a stooped posture every 30 s and took a micro-break for 6 s in upright standing before returning to the stooped posture. In session 'B', subjects took a 12-s micro-break every 60 s during the 7-min work period (Fig. 1). For both sessions, the total duration of stooped posture was 6 min, while the total duration of break was slightly longer for session 'A' (66 s). The order of two sessions was randomized and balanced between subjects, and sufficient rest break was provided between the two for each subject.

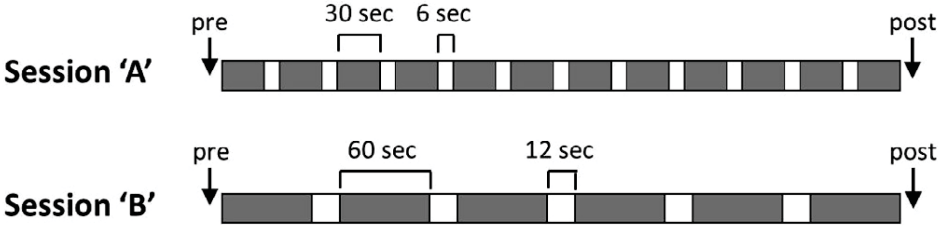

Fig. 1. Two experimental conditions. Gray boxes indicate periods of stooped posture, and white boxes indicate micro-break periods. Arrows show timing of pre- and post-session data collection trials (weight holding + full flexion).

3.3. *Data collection*

Prior to the beginning of each session, the subject conducted a weight holding trial and a full upper body forward flexion trial in series. For the weight holding, the subject held a weighted object, which was equivalent to 40% of the subject's maximum lifting capacity, for 5 s in a forward flexed standing posture with both wrists at the height of knee joints. The subject was asked to keep their legs and arms straight, and minimize the forward rounding of the upper back during the weigh holding. The weight of the hand-held object was determined from a simple static biomechanical model that considered the upper body posture, estimated upper body mass, and posture-specific maximum trunk extension moment that occurred during the maximum voluntary contraction tests.

Immediately after the weight holding trial, the subject returned to an upright standing posture and began a full upper body forward flexion trial towards the voluntary end of upper body flexion. The subject was asked to reach the voluntary limit of flexion in 5 s with both legs kept straight. The speed of flexion was trained prior to the beginning of the experiment and controlled by an auditory feedback (verbal counting of seconds) during data collection. The weight holding and the full flexion trials were conducted again immediately after the 7-min work session.

During the work period in a stooped posture, the subject was asked to simulate work-related stooped postures by repeating a set of ground touching and walking-in-place motions in a forward flexed posture. Each set consisted of touching the ground four times in 3 s with switching hands and walking four steps in place in 3 s while keeping their hands between the ground and the knee (Fig. 2). No other postural restrictions were imposed. The pace of ground touching and walking was practiced prior to the experiment so a single set (ground touching four times + walking four steps in place) could be finished approximately in 6 s. A short break in upright standing was provided after every five repetitions (30 s) in session 'A' and 10 repetitions (60 s) in session 'B' (Fig. 3). During the experiment, the subject's trunk flexion, lumbar flexion and pelvic rotation angles were quantified by tracking reflective markers in three-dimensional space using the OptiTrack motion capture system (NaturalPoint, Inc., Corvallis, OR, USA). Four reflective markers were attached on the skin of the posterior side of the 11th thoracic vertebra (T11), the 1st and 5th lumbar vertebra (L1, L5) and the 1st sacral vertebra along the vertebral column. Three dimensional coordinates of each marker were tracked at the sampling rate of 100 Hz. Trunk flexion angle was defined by a line that connects T11 and L1 markers, and pelvic forward rotation angle was defined by a line that connects L5 and S1 markers. The difference between the two angles was defined as lumbar flexion angle (Fig. 2). Angles of an upright standing posture were recorded and defined as zero degrees.

Fig. 2. Stooped work posture.

Synchronized with the posture data, EMG signals of lumbar erector spinae muscles and external oblique muscles were collected using Ag–AgCl surface electrodes (Flexcomp, Thought Technology Ltd., Quebec, Canada). EMG data were collected using preamplified sensors with an input impedance of greater than 1012 X, a channel bandwidth of 10–1000 Hz, a common mode rejection ratio of greater than 130 dB, and gain of 500 (MyoScan EMG Sensor, Thought Technology Ltd., Quebec, Canada). Disposable triode surface electrodes were attached to each sensor. The triode electrodes consisted of two bipolar disks (1 cm in diameter) and a reference disk in a triangular shape with an inter-disk distance of 2 cm. Electrodes for the lumbar erector spinae muscles were placed bilaterally on the skin 3.5 cm from the midline at the level of L2 and L4 vertebrae to obtain muscle activities from the upper and lower portions of the lumbar erector spinae muscles. For external oblique muscles, electrodes were placed approximately 10 cm lateral to umbilicus with an orientation of 45° from vertical (Marras and Mirka, 1992). Areas of electrode placement were shaved, abraded and cleansed with isopropyl rubbing alcohol absorbed cotton pads to lower the electrical impedance.

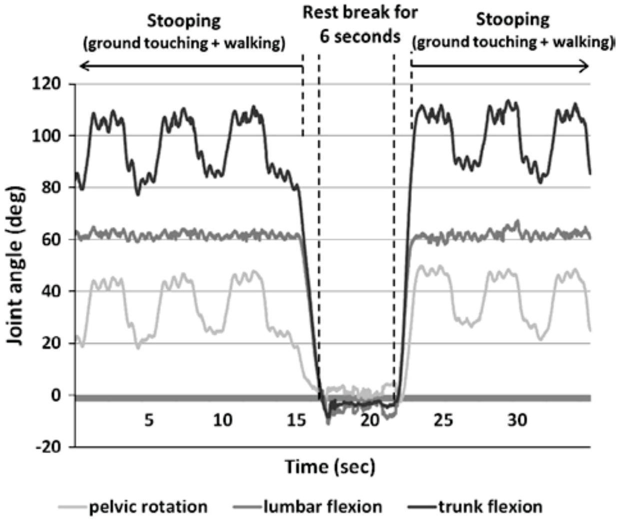

Fig. 3. Sample joint angle data of session ‘A’.

The EMG signals were sampled at 2048 Hz using a 14-bit analog-to-digital encoder (Flexcomp, Thought Technology Ltd., Quebec, Canada), and pre-filtered with a bandpass filter of 10– 500 Hz. Then the time-domain signals were converted to the frequency-domain signals using the fast Fourier transform, and median frequency of each signal was computed.

The bandpass filtered EMG data were also full-wave rectified and smoothed using a second-order Butterworth filter with a low-pass cut-off frequency of 3 Hz to obtain the linear envelope EMG (Zhu and Shin, 2012). Linear envelop EMG signals of each muscle were then divided by the maximum amplitude of the muscle that was collected from maximum voluntary contraction (MVC) trials at the beginning of the experiment. The maximum amplitudes of the lumbar erector spinae muscles were collected during an isometric lifting task in standing. The subject pulled a rigid bar upwards, which was positioned at the height of knee joints and linked to a scale, as hard as possible for 5 s while keeping the legs and arms straight. For the collection of the maximum amplitudes of external oblique muscles, the subject sat on a reclined chair with the shoulder and chest restrained by straps, and attempted to move each shoulder towards the knee on the opposite side. Amplitudes of the middle 1 s were averaged to produce the mean MVC EMG of the muscle. MVC trial of each muscle was repeated twice, and a larger value among the two was used for EMG normalization.

3.4. *Data analysis*

Mean normalized EMG (NEMG) and median frequency of EMG of the lumbar erector spinae muscles and external oblique muscles were obtained from each weight holding trial by averaging NEMG signals of the middle 3 s of the 5-s weight holding trial. During the subsequent upper body full flexion trial, peak angles of lumbar flexion and pelvic forward rotation were obtained from the posture data. For the dependent variables that were collected before and after each session, effects of session (A and B) and work period (pre and post) were evaluated by a repeated measures two-factor analysis of variance (ANOVA).

During the work period, the maximum, minimum and mean lumbar flexion angles and mean NEMG of lumbar erector spinae muscles were obtained from a single round of ground touching and walking in place at the beginning and every 2 min of stooped posture to track the changes over the duration of stooped work period. A repeated measures two-factor ANOVA was used to determine the main and interaction effects of session and work duration (2, 4, 6 min of cumulative duration of stooped posture). A statistical package (Minitab V.16; Minitab Inc., State College, PA, USA) was used with a significance criterion of $p < 0.05$ for all comparisons.

4. Results

4.1. Pre- and post-stooped work

Two-factor ANOVA found significant effects of 'work period' on the dependent variables that were collected before and immediately after the work period. However, no significant main or interaction effects of 'session' were found (Table 1). Data of the two sessions were pooled together for subsequent analyses.

For both lumbar erector spinae and external oblique muscles, mean NEMG in weight holding were significantly greater after the 7-min stooped work period. Mean activity of the lumbar erector spinae muscles increased from 25.9% (average over L2 and L4 level muscles) to 35.0% of the MVC amplitudes after stooped work. Similarly, mean activity of the external oblique muscles increased from 8.6% to 12.0% MVC after stooped work, and the increments were statistically significant.

EMG median frequencies were significantly less after the work period, with greater decrements from the L4 level lumbar erector spinae muscles compared to that of the L2 level lumbar erector spinae and the external oblique muscles.

Limits of lumbar flexion and pelvic forward rotation in upper body full forward flexion increased 1.4° and 1.9°, respectively, and the increments were statistically significant.

Table 1. Dependent variables from pre- and post-stooped work weight holding and full flexion trials (LE4: lumbar erector spinae muscles at L4 level, LE2: lumbar erector spinae muscles at L2 level, EO: external oblique muscles).

		Pre	Post	p-Values
NEMG	LE4	0.252	0.341	<0.001
	LE2	0.266	0.359	<0.001
	EO	0.086	0.120	<0.001
Median frequency (Hz)	LE4	106.4	93.3	<0.001
	LE2	96.6	89.8	<0.001
	EO	100.9	93.6	0.002
Limit of joint rotation (°)	Lumbar flexion	59.0°	60.4°	0.033
	Pelvic rotation	58.3°	60.2°	0.025

4.2. During stooped work

ANOVA did not find any significant main or interaction effects of session and work duration on the lumbar flexion angles (maximum, minimum, mean) and the mean NEMG of lumbar erector spinae muscles. Lumbar flexion angle ranged from 53.4° to 61.5°, with an increasing trend over time (Fig. 4). Mean NEMG of the lumbar erector spinae muscles ranged between 10.1% MVC and 16.9% MVC (SD ranged between 8.2% and 16.9%) during the stooped work (Fig. 5).

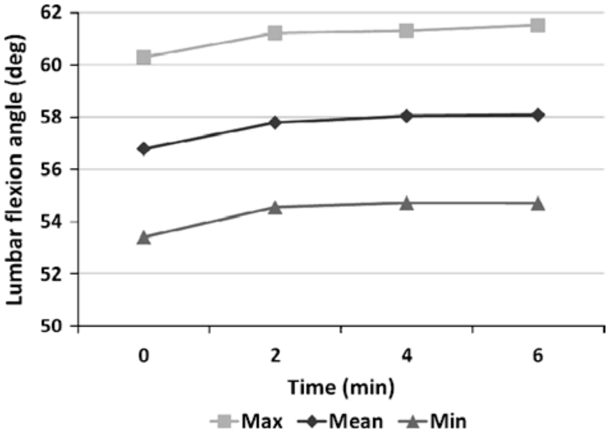

Fig. 4. Maximum, minimum and mean lumbar flexion angles during stooped work.

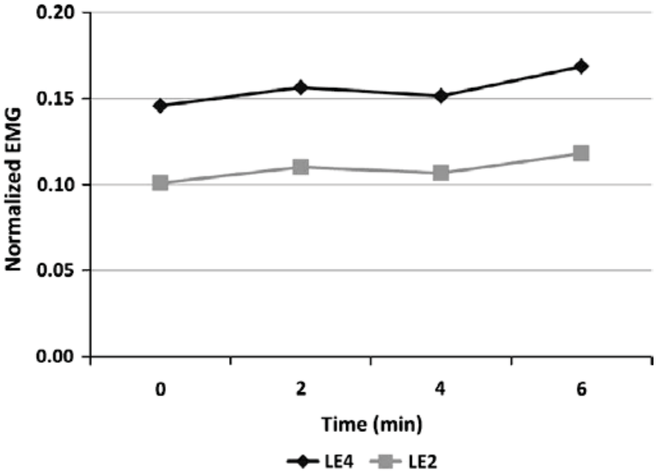

Fig. 5. Mean normalized EMG of the lumbar erector spinae muscles during stooped work (LE4: lumbar erector spinae muscles at L4 level, LE2: lumbar erector spinae muscles at L2 level).

5. Discussion

The main objective of this study was to determine whether prolonged stooped work with no postural restriction would produce viscoelastic responses that are consistent with the findings of previous research that tested more severe loading conditions with postural restrictions. In the current study, the intensity of the two stooped work sessions was determined, based on pilot study results, to produce tolerable pain and discomfort to a healthy young subject so he or she could continue working for at least 20 minutes without the development of significant pain or discomfort on the lower extremities as well as the low back.

Study results showed significant increases in the active limit of lumbar flexion after the stooped work period, and it was consistent with the findings in previous research with postural restriction and severe loading conditions (Solomonow et al., 2003b). The amount of increase in the limit of lumbar flexion of the current study (1.4° in average), however, was smaller than that of previous studies with similar duration of static stooped posture (Shin and Mirka, 2007; Shin et al., 2009), and it might be attributable to the micro-breaks (6 or 12 s) in upright standing that were provided throughout the work period or the nature of unrestricted stooped posture that allowed minor flexion/extension movements of the torso.

One might think that subjects of the current study maintained a stooped posture with less than full flexion of the lumbar spine for most of the work period and it might have led to the less prominent increases in the limit of lumbar flexion as compared to previous research. However, the lumbar flexion angle data that were collected during stooped work indicate that subjects flexed the low back close to their limit of lumbar flexion and maintained the posture within a small range (approximately 90% of the active limit of lumbar flexion). This indicates that the flexion/extension movements of the upper body during the stooped work that resembled occupational tasks (ground touching + walking in place) were made mainly by mild forward and backward rotation of the pelvis, while the lumbar spine was remained fully flexed (Fig. 2).

In addition to the increases in lumbar flexion limits, the limit of pelvic forward rotation was significantly greater after the stooped work period. The greater range of pelvic forward rotation after stooped work could be attributable to an acute improvement of stretch tolerance and/or viscoelastic elongation of the hamstring muscles (Halbertsma et al., 1996; Magnusson, 1998). Previous studies on the effects of prolonged or repetitive stooping have not paid much attention to the pelvis or lower extremities, and it is not known whether the changes in the hamstring extensibility could influence the lumbar spine posture or EMG of low back extensors after prolonged stooping. However, considering the synchronous movements between pelvis and lumbar spine in upper body flexion (Nelson et al., 1995; Granata and Sanford, 2000; Shin et al., 2004), how the acute increase of hamstring extensibility or stretch tolerance after prolonged stooping would influence lumbar spine kinematics and low back muscle activities is interesting. Further research that compares stooped work conditions with and without pelvic rotation would be able to provide some empirical data to explain the potential effects of acute hamstring extensibility associated with prolonged stooping.

An increment in the lumbar flexion limits after stooping has been acknowledged as the consequence of viscoelastic and/or poroelastic changes of spinal tissues including posterior ligaments and intervertebral disks (Adams and Dolan, 1996). Reduced resistance to upper body forward flexion due to the viscoelastic changes in the spinal tissues is known to be compensated for by greater activity of extensor muscles, as confirmed in the current study by the significantly greater activity of the lumbar erector spinae muscles in weight holding after the stooped work period. The activity level of the lumbar erector spinae muscles increased approximately 35% (average over the two sessions), and it was comparable to the amount of increases reported in literature with posture restrictions (Shin and Mirka, 2007; Shin et al., 2009).

The increase in the activity of the lumbar erector spinae muscles after stooping could also be partly attributable to local muscle fatigue development. Compared to previous research where the low back extensor muscles were in flexion–relaxation status (1.5–3.1% of MVC EMG) in static full flexion, the lumbar erector spinae muscles in the current study were generating moderate level of active contraction (10.1–16.9% of MVC EMG) during the stooped work period. It could be concluded that the moderate and consistent activation of the lumbar erector spinae muscles, together with the passive stretching of the extensor muscles, contributed to the development of muscle fatigue during the prolonged stooped work, and resulted in the greater activity of the lumbar erector spinae muscles and the shift of EMG median frequency towards lower frequencies.

External oblique muscles also showed greater activity after stooping and it could be seen as a protective response of antagonist muscles to the impairment in spinal stability. Mechanical stability of the lumbar spine, which is known to be provided by stiffness and reaction forces from both passive and active spinal tissues (Panjabi, 2003), might be damaged by decreased joint stiffness due to viscoelastic changes in the passive tissues and reduced force generating capacity of the lumbar extensor muscles. It was believed that the abdominal muscles were required to produce greater co-contraction after stooping in order to compensate for the impairment in spinal stability.

One of the main interests of this study was to see if there is any difference in the viscoelastic responses of the low back between the two stooped work sessions with different micro-break schedules. Importance of short breaks in moderating cumulative viscoelastic changes during prolonged stooping has been consistently reported in literature (Courville et al., 2005; Faucett et al., 2007; Shin and Mirka, 2007), but this study was the first attempt to compare different micro-break schedules in vivo while maintaining the cumulative durations of work and rest consistent between schedules. The current study, however, did not find any significant differences in dependent variables between the two sessions and it might suggest that the physical demands of the two sessions, which were determined in pilot study to cause acceptable and sustainable level of physical discomforts, were not distinctive enough in terms of their influences on the lumbar spine musculature.

It could have been more sensitive if the two tested schedules were more separated in terms of the frequency and duration of micro-break. However, a study with a larger gap in schedule frequency or duration might have been considered as a comparison between prolonged stooping and cyclic flexion, rather than a comparison of different micro-break schedules within prolonged stooped work.

6. Conclusions

In summary, study results indicate that stooped work that resembled job-related work postures and loading conditions could produce comparable viscoelastic responses of the low back to what have been consistently observed in research with more severe loading conditions and posture restrictions. The more pronounced changes in EMG data compared to the amount of changes in lumbar flexion range suggests that the evaluation of EMG data of low back extensor muscles could provide greater sensitivity in quantifying viscoelastic responses of the low back in future research with more realistic loading conditions and prolonged stooped postures. The mild but consistent activation of the lumbar erector spinae muscles observed during stooped work suggests that the low back extensor muscles might not be in flexion–relaxation during work-related stooping activities and it contributed to the development of muscle fatigue as well as viscoelastic changes of the lumbar spine musculature. However, the biomechanical responses of the low back associated with prolonged stooped work were not sensitive to the changes in micro-break schedule.

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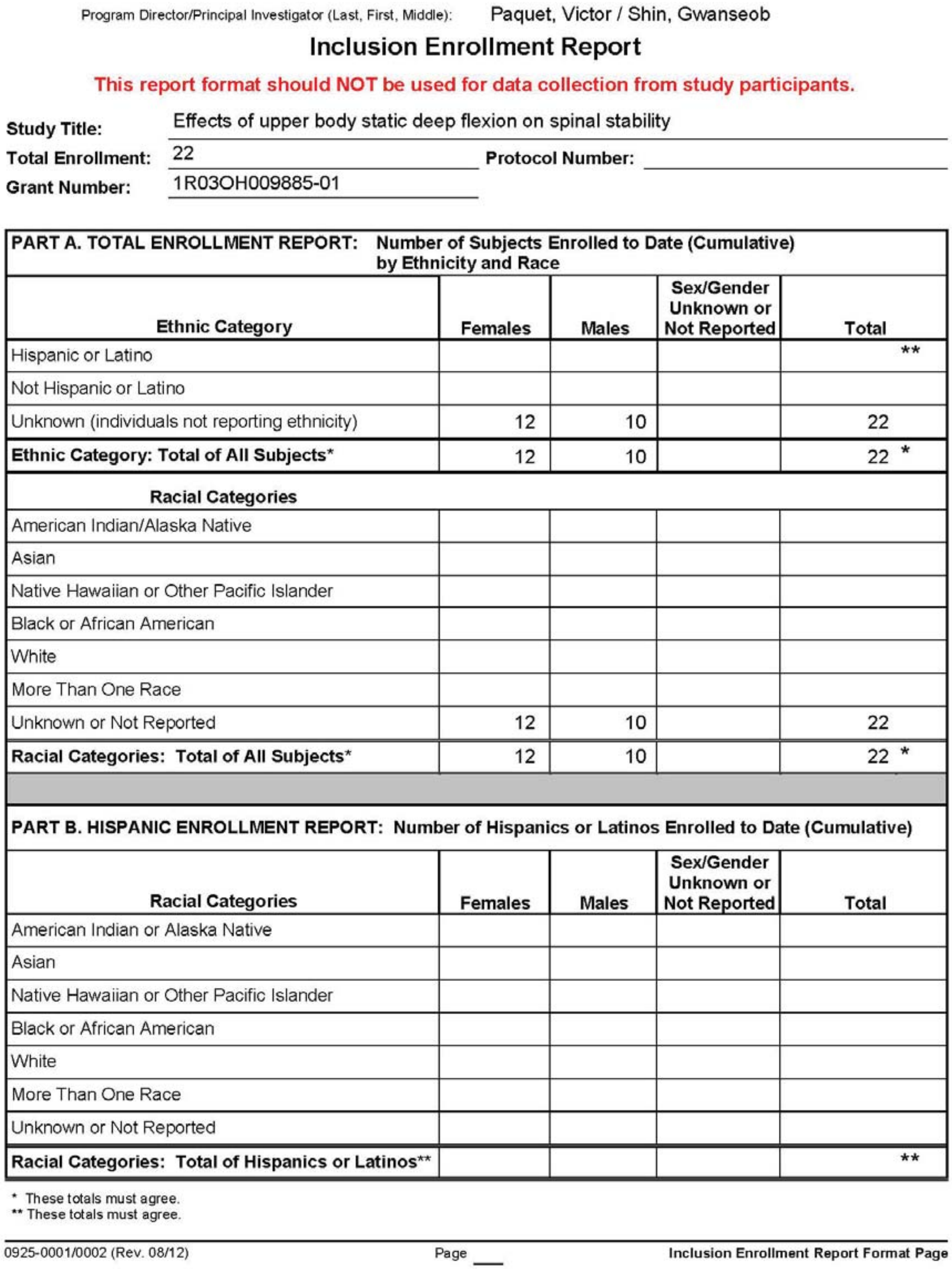

Program Director/Principal Investigator (Last, First, Middle): Paquet, Victor / Shin, Gwanseob

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Effects of upper body static deep flexion on spinal stability

Total Enrollment: 22 **Protocol Number:**

Grant Number: 1R03OH009885-01

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race				
Ethnic Category	**Females**	**Males**	**Sex/Gender Unknown or Not Reported**	**Total**
Hispanic or Latino				**
Not Hispanic or Latino				
Unknown (individuals not reporting ethnicity)	12	10		22
Ethnic Category: Total of All Subjects*	12	10		22 *
Racial Categories				
American Indian/Alaska Native				
Asian				
Native Hawaiian or Other Pacific Islander				
Black or African American				
White				
More Than One Race				
Unknown or Not Reported	12	10		22
Racial Categories: Total of All Subjects*	12	10		22 *

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)				
Racial Categories	**Females**	**Males**	**Sex/Gender Unknown or Not Reported**	**Total**
American Indian or Alaska Native				
Asian				
Native Hawaiian or Other Pacific Islander				
Black or African American				
White				
More Than One Race				
Unknown or Not Reported				
Racial Categories: Total of Hispanics or Latinos**				**

* These totals must agree.
** These totals must agree.

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Publications

1. Xinhui Zhu, Gwanseob Shin: [2013] Kinematics and muscle activities of the lumbar spine during and after working in stooped postures, *Journal of Electromyography and Kinesiology*, 23, 801-806.

   This paper is the direct outcome of this project and contains results and findings related to the original goals and specific aims of the project.