Changes in Perceived Comfort, Strength and Electromyographic Response in Lower Back, Hip and Leg Muscles during 8-Hour Prolonged Sitting

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Abstract— **Many occupations require workers to sit for an extended period of time. This study investigated the changes in perceived comfort, strength and electromyographic (EMG) activity of 14 lower back, hip and leg muscles during prolonged sitting. Twenty-five subjects (13 males) sat of a chair for eight hours. Subjects could move freely on the chair and engage in sedentary activities such as reading. At baseline and every one-hour interval (h0 – h8), subject's perceived comfort at the back, hips and legs, together with the maximum isometric back extension torque and the EMG pattern of 14 muscles were assessed. The root mean squared magnitude and the median frequency of the power spectrum of the EMG signals were calculated. As sitting time increased, subjects showed increased level of discomfort for the lower back (P = 0.002), hip (P < 0.001) and leg (P < 0.001) muscles. At the hip, males indicated more discomfort than females over time (sex × time interaction: P = 0.049). Back extension torque declined with increasing sitting time (P = 0.044). The average torque during the second half (h5 – h8) of the sitting period decreased by 9.3% (P = 0.007) compared with the first half (h0 - h4). Overall, no consistent change in EMG pattern was observed. For most muscle groups, there was no effect of time or sex on EMG magnitude or median frequency. In conclusion, prolonged 8-hour sitting lead to slightly increased discomfort and reduced strength. Muscular fatigue resulting from quiet sitting may be too subtle to be detected by surface EMG.**

Keywords— **fatigue, EMG, isometric, spine, torque.**

I. INTRODUCTION

Many occupations such as office workers and professional drivers require sitting for an extended period of time on a daily basis. Prolonged sitting alone, and/or in combination with whole body vibration and awkward postures, has been named as a risk factor for various medical conditions including low back pain [1,2], herniated disc [3] and sciatica [1]. The economic burden of low back pain is very large in many countries, with the total cost estimated to be US$84.1 to US$624.6 billion between the years of 1995 to 2004 in the United States alone [4]. These data suggest that occupational illness resulting from prolonged sitting not only negatively influences the quality of life of workers but is also costly to the society.

Prolonged sitting will lead to static loading on soft tissues and cause discomfort [2], which may be related to impaired work performance and/or medical conditions. Thus, evaluating and monitoring muscular fatigue and discomfort can be useful for maintaining good health and reducing the financial and time cost for treatment and recovery. Surface electromyography (EMG) has been used extensively to provide an objective measurement of muscular fatigue. Fatigue is generally associated with decreased median or mean power frequency [5,6] and increased amplitude [6,7] of the EMG signals. However, many studies induced muscular fatigue using high intensity exercise in a relatively short duration, for example, sustained submaximal isometric contraction until voluntary exhaustion. This type of fatigue protocol does not reflect the fatigue condition resulting from prolonged quiet sitting as in sedentary occupations. Studies examining the effect of sitting on back muscles and joint biomechanics often use a shorter than actual workday duration, for example, two hours [8,9]. Using a longer duration that approximates an actual workday would provide more insight into the possible influence that prolonged sitting may cause. The purpose of the present study was therefore to investigate changes in perceived comfort, strength and EMG activity of the lower back, hip and leg muscles during eight hours of prolonged sitting. A secondary aim was to explore whether prolonged sitting influenced males and females differently.

II. METHODS

A. Subjects

Table 1 Physical characteristics of 25 subjects

	All	Males	Females
n	25	13	12
Age (yr)	24.2 (3.4)	25.2 (3.8)	23.0 (2.5)
Height (m)	1.67 (0.08)	1.73 (0.06)	1.61 (0.05)*
Mass (kg)	63.4 (10.9)	71.6 (8.6)	54.6 (3.6)*
BMI ($kg \cdot m^{-2}$)	22.6 (2.2)	24.0 (1.9)	21.1 (1.3)*

*Values are expressed as mean (SD); BMI = body mass index; *significant difference between males and females (P < 0.001).*

Twenty-five healthy subjects were recruited (Table 1). Informed consent was obtained prior to experimental procedures which were approved by relevant Institutional Review Boards. Individuals who had been diagnosed with deep vein

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thrombosis, convulsion or epilepsy, or those with acute or chronic pain, surgery or serious injury histories in the neck, back, hips or knees were excluded. Females who were or might be pregnant or breastfeeding were also excluded.

B. Experimental Procedures

Data Collection: Each subject performed a standardized warm-up protocol consisting of five minutes of jogging on a treadmill at subject's own pace, followed by five minutes of static stretching exercises for major muscle groups in the neck, back, hips and legs. Subjects were then given time to familiarize with the isometric back extension test on an isokinetic dynamometer (System 3 Pro, Biodex Medical System, NY, USA). During this familiarization period, subjects repeated the back extension exercise three times at sub-maximal (40%, 60% and 80%) effort.

In the experimental protocol, subjects were required to sit on a chair (Fig. 1) for eight hours, a period that approximated one work shift for many occupations. Subjects were not allowed to leave the chair except to use the restroom during the 8-hour sitting period. They could move freely on the chair and engage in sedentary activities such as reading. Drinks and food were provided. Subject's perceived comfort and back extension strength were assessed at baseline (h0) and at every one-hour interval (h1 to h8). For each set of assessment, subjects were asked to indicate their perceived comfort in their lower back, hips and back of their legs in a scale of 1 (very comfortable) to 10 (extremely uncomfortable), respectively. Should a rating of 4 (slightly uncomfortable) or higher was reported, subjects were asked to describe the cause of discomfort (e.g. pain, tingling, numbness, etc.). After the comfort assessment, subjects performed three 3-s maximum isometric back extensions on the isokinetic dynamometer at 90° of hip flexion. The dynamometer crank arm was placed at the upper border of the scapula of the subject. To minimize the influence of fatigue, subjects rested for approximately 60 s between successive trials. The torque torque-time histories were recorded.

Two tethered EMG systems (back: Therapeutic Unlimited 8-channel EMG Model 544; hips and legs: Bortec Biomedical EMG cable telemetry system AMT-8) were used in this study with a total of 14 electrodes placed on the subject's lower back, hips and back of the legs. After standard skin preparations procedures, six electrodes were placed on both sides of the lower back (longisimmus, iliocostalis and multifidus), four for the hips (gluteus maximus upper and lower) and four for the hamstrings (biceps femoris and semitendinosus). Two ground electrodes (one for each EMG system) were also placed on the bony landmarks of the body. The EMG activity of the 14 muscles during back extension on the isokinetic dynamometer was recorded at 2000 Hz onto the laptop computer using the Datapac 2K2 software in synchronization with the torque data. A blanket was placed on the chair to reduce the pressure caused by the electrodes on the legs of the subjects.

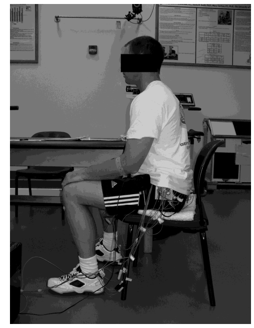

Fig. 1 Subjects sat for an 8-hour period during which they could move freely on the chair and engage in sedentary activities such as reading

Data Processing: For each repetition of back extension, the torque was averaged over a 1-s period during which the torque value remained relatively stable. The maximum torque value out of the three repetitions during each hour was used for subsequent analysis. All torque data were normalized to the value recorded at baseline. The corresponding EMG activity of the 14 muscles during the 1-s stable torque period was further analyzed in MATLAB. Raw EMG data were band-pass filtered (10 – 500 Hz), full-wave rectified and then root mean squared (RMS) over the 1-s window. The median frequency (MF) of the EMG power spectrum during the 1-s period was also calculated.

Statistical Analysis: All analyses were performed using the SPSS version 16.0. Dependent variables included the perceived comfort level of the three muscle groups, normalized torque during back extension, and RMS magnitude and MF of the EMG data of 14 muscles. Repeated measures ANOVA (time × sex) was run for each dependent variable. Statistical significance was set at $P < 0.05$. Perceived comfort data are expressed as median and range due to their ordinal nature. All other data are expressed as mean (SD).

III. Results

As sitting time increased, subjects showed increased level of discomfort for the lower back ($P = 0.002$), hip ($P < 0.001$) and leg ($P < 0.001$) muscles (Table 2). Males indicating more discomfort than females over time (time × sex interaction $P = 0.049$, Fig. 2). No main effect of sex was detected in any muscle groups. The causes of discomfort reported by the subjects were mainly related to the electrodes, with a few complaints on numbness and soreness.

There was a significant main effect of time on the normalized back extension torque (P = 0.044). The torque value remained relatively constant from baseline to h4, decreased from h4 to h6 and then slightly increased from h6 to h8 (Fig. 3a). Since post-hoc analyses failed to identify differences among the nine time-intervals, a follow-up paired t-test was used to compare the average torque of the first half (h0 – h4) and the second half (h5 – h8) of the sitting period. The torque decreased by 9.3% (P = 0.007) in the second half of the sitting period (Fig. 3b). No sex-related difference in the normalized torque was detected.

Table 2 Perceived comfort level over eight hours of sitting

Time (hr)	Back*	Hip*	Leg*
0	1 (1-4)	1 (1-4)	1 (1-3)
1	1 (1-4)	2 (1-4)	1 (1-4)
2	1 (1-3)	2 (1-6)	2 (1-5)
3	2 (1-3)	2 (1-6)	2 (1-5)
4	2 (1-3)	2 (1-6)	2 (1-5)
5	2 (1-4)	3 (1-6)	2 (1-5)
6	2 (1-6)	3 (1-6)	3(1-6)
7	2 (1-6)	4 (1-7)	3 (1-7)
8	2 (1-6)	4 (1-7)	3 (1-7)

*Values are expressed as median (range); Comfort level ranged from 1 (very comfortable) to 10 (extremely uncomfortable); *Significant main effect of time detected by ANOVA (P < 0.05).*

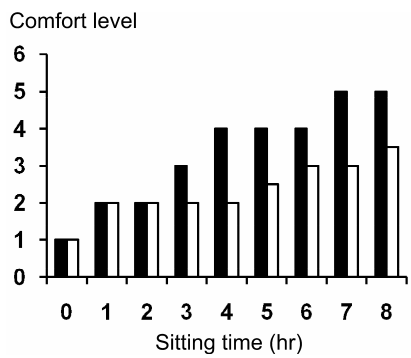

Fig. 2 Median perceived comfort for the hip in males (*closed bar*) and females (*open bar*) over eight hours of prolonged sitting (ANOVA time × sex interaction: P = 0.049)

Overall, no effect of time or sex on EMG magnitude or frequency was found in most muscles with a few exceptions. Significant main effect of time on EMG magnitude was detected only in two leg muscles: left semitendinosus (P < 0.001) and right biceps femoris (P = 0.001), with RMS value decreased over time. Males showed higher RMS magnitude than females in one hip muscle: right gluteus maximum upper (P = 0.024). Significant time by sex interaction was found in one leg muscle: right biceps femoris (P = 0.022), with the EMG magnitude decreasing over time in males but remaining fairly constant in females. The frequency content of the EMG data showed an increase in MF over time in two back and two leg muscles: right multifidus (P = 0.016), right longissimus (P = 0.001), left semitendinosus (P = 0.028) and right semitendinosus (P = 0.006). Males displayed higher MF than females in two back muscles: left and right longissimus (both P = 0.047).

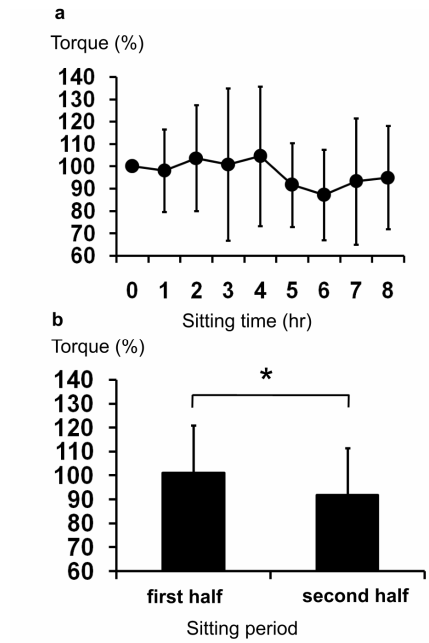

Fig. 3a Normalized back extension torque over eight hours of prolonged sitting (ANOVA main effect of time: P = 0.044). 3b Average back extension toque during the first half (h0 – h4) and the second half (h5 – h8) of the sitting period (paired t-test: P = 0.007); Data are in mean (SD)

IV. Discussion

This study showed that as sitting time increased, subjects reported increased level of discomfort and demonstrated a reduction in back extension strength. However, no consistent change in muscle activity pattern was observed.

The increased level of discomfort in the present study is in agreement with a field study on secretaries which found that subjective discomfort including soreness, heavy legs, stiffness, tiredness, pain and restless increased with working time [10]. Interestingly, males felt more uncomfortable than females in the hip muscles as sitting time increased (Fig. 2). This is in parallel with previous findings that subjective rating during a fatiguing isometric contraction of the back muscles was somewhat higher for men than women, though the difference was not statistically significant [11]. Others also found that after one hour of sitting, the lumber spines of males became stiffer whereas females demonstrated variable responses [8]. The sex-related difference may be related to males having less adipose tissue around the hip than females to provide cushioning.

Subjective ratings of seat discomfort were associated with reported musculoskeletal problems among professional truck drivers [12]. Despite the high concern for back related problems, the level of discomfort at the lower back in the present study was the lowest compared to the hips and the legs. The majority of our subjects did not express higher than 'slightly uncomfortable' rating and that no subject indicated 'very uncomfortable' in any of the three sites. In addition, most discomfort was related to the presence of the electrodes rather than sitting. Thus, the degree of discomfort in an actual working environment may be even less than what has been observed in the present study. On the other hand, subjects stood up and performed back extension exercises every one hour in this study and this may be beneficial since fixed posture is avoided [2].

Back extension strength declined after approximately four hours of sitting, followed by an interesting increase from h6 to h8. The slight increase in torque production towards the end of the 8-hour protocol may be related to increased motivation just prior to the completion of the study. Overall, it is evident that muscle fatigue occurs over eight hours of sitting as reflected by the lower torque production in the second half of the sitting period. The 9.3% decrease in torque is small but reasonable due to the low intensity muscular effort required during sitting.

In general, no consistent change in muscle activity pattern was seen from the EMG data of the 14 lower back, hip and leg muscles. Of the few changes observed prolonged sitting lead to decreased amplitude and increased MF which are surprisingly opposite to the common EMG characteristics of fatigued muscles. A recent study showing that EMG variables assessed in one type of task in a fatiguing test may not be valid for other types of fatiguing tasks [13]. When comparing to muscular fatigue induced by physically exhausting protocols as in many previous studies, the fatigue resulting from prolonged quiet sitting may be too subtle to be accurately detected by surface EMG. Similar to the present study, a previous study also found that torque production and subjective ratings of fatigue showed no correlation with EMG variables during isometric back extension [11]. The lack of consistent sex-related difference in EMG data in the present study is also in agreement with the literature [8].

V. Conclusions

Prolonged 8-hr sitting lead to a slight increase in perceived discomfort and reduction in muscular strength. The fatigue resulting from prolonged quiet sitting, however, may be too subtle to be detected by surface EMG.

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