FREQUENCY AND EXTENT OF SPONTANEOUS MOTION TO RELIEF TISSUE LOADS IN NORMAL INDIVIDUALS SEATED IN A WHEELCHAIR

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INTRODUCTION

Pressure sores (PS) are common and potentially severe complication in wheelchair-bounded individuals. Between 25 and 80% of spinal cord injury (SCI) patients suffer PS and 7-8% of death cases among these patients are associated with PS [1]. Healthcare costs of treating PS are vast, in the order of billions of dollars [2]. The dominant clinical approach for minimizing PS is to relief continuous soft tissue pressures under bony prominences by training patients to change their posture frequently. It became generally accepted that paraplegics should lift their buttocks off the wheelchair's seat occasionally using their arms, to relief buttock tissue pressures [3] but the optimal timing for performing these maneuvers is controversial. The most recent published recommendation for management of quadriplegic patients, by the Agency for Health Care Policy and Research (AHCPR) of the US Department of Health, is to relief pressures off their buttocks at least every hour. Paraplegics, who are able to use their arms for the pressure relief maneuvers, are advised to perform lift-offs every 15 minutes [2]. Unfortunately, there is very little basic research to support the timing for pressure relief maneuvers in these recommendations. It is well established that immobilization is the most influencing risk factor for PS onset and consequent chain of complications, such as in the recent death of movie star Christopher Reeve. However, it is unclear how much mobilization during sitting is enough to protect the buttocks from PS. Such basic information can be obtained from studying the spontaneous kinematic behavior of normal individuals during prolonged wheelchair-sitting. The objective of this study was therefore to measure the frequency and extent of motion among healthy young subjects seated in a wheelchair, in order to provide normative data that can be compared with the above medical recommendations.

METHOD

Ten healthy volunteers (5 males and 5 females; age 28±3 years; weight 65±9 kg; height 174±9 cm) were asked to sit comfortably, in a standard wheelchair, in a neutral position (trunk leaning on the backrest and feet on the footrests). Markers for video motion analysis (Fig. 1) were adhered to the shoulders and trunk on the greater humeral tuberosities, supra-sternal notch, xiphoid and umbilicus. A goniometer was attached between the trunk and thigh to measure back inclination in the sagittal plane (Fig. 1). Pre-calibrated pressure sensors (Flexiforce, Tekscan Co., capacity: 63 KPa) were positioned under the ischia (3 for each ischium) to detect body-weight shifting between the left and right ischia. Subjects were monitored while they were watching a movie for 90 minutes (data acquired on the mid 70 minutes). Goniometer and pressure signals were sampled simultaneously and continuously at a frequency of 1 Hz using a 16-Channel A/D board (National Instruments Co.). Motion and pressure data were processed off-line as follows.

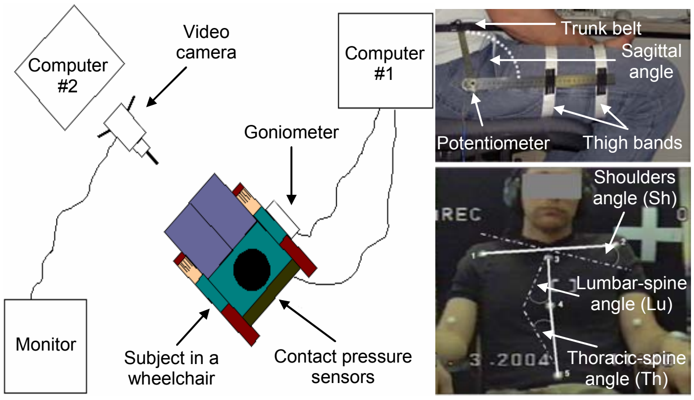

Figure 1. The experimental apparatus. Subjects sat in a wheelchair and watched a movie (on screen of "computer #2"). Interfacial pressure and trunk-thigh angle measurements were acquired using pressure sensors and a goniometer (upper right frame), respectively (using "computer #1"). Video motion analysis was applied in the frontal plane (lower right frame), to measure the motion of the shoulders (Sh), thoracic spine (Th) and lumbar spine (Lu) segments (on "monitor").

For movements in the sagittal plane, a change of 5º or over in the trunk-thigh angle reading of the goniometer was considered as a postural change event. The 5º threshold was selected to filter postural sways of the trunk, which are typically less than 2º during standing [4].

A logarithm of the ratio between left and right interfacial pressures was calculated as function of time. For tendency to the right side of the body, which results in less pressure under the left ischium and increased pressure under the right ischium, a negative value of the log ratio is obtained. For tendency to the left, a positive log ratio is obtained. For movements in the frontal plane, trunk frontal movements greater or equal 5º (equivalent to |log ratio of ischial pressures| ≥ 3) were considered as postural changes (again, to filter trunk postural sways during sitting [4]). A time-dependent stick-diagram was produced for each subject to describe his motion in the frontal plane (Fig. 2). Consistently with the location of motion markers (Fig. 1), we analyzed the motion of the thoracic spine, the lumbar spine and the shoulders. For each frontal postural change event, we measured the segmental angle as function of time during the maneuver, separately for the thoracic spine, lumbar spine and shoulders. We then calculated the difference between the initial and maximal segment angles for each motion event, and for each anatomical segment (means and standard deviations). Angles of sagittal trunk maneuvers were similarly calculated. Unpaired, 2-tail *t*-tests ($p<0.05$) were used to identify statistically significant differences in frequency of postural change maneuvers and in angles of maneuvers between (i) sagittal and frontal motions (ii) left and right trunk tilts, and (iii) females and males.

RESULTS

Healthy subjects performed 12.5 ± 3.2 and 11.1 ± 5.9 spontaneous movements in the sagittal and frontal planes, respectively, during the 70 minutes timeframe of continuous data acquisition (Table 1). Correspondingly, subjects moved every 6±2 minutes and every 9.1±6.5 minutes in the sagittal and frontal planes, respectively. There was no significant difference between motion frequencies of males and females and between frequencies of sagittal and frontal movements. Interestingly, the number of movements to the right side of the body (females and males pooled) was significantly (3.3-fold) greater (8.5) than the number of movements to the left (2.6) ($p<0.05$), and this was correlated with right being the dominant side in 9 of the 10 subjects. The change of trunk-thigh angle during sagittal postural changes was 10.3±7º. Thoracic spine and lumbar spine motions for frontal postural changes were 14±7º and 15±7º, respectively, and motion of the shoulders was 8º±4º. Male and female motion angles were statically indistinguishable in the frontal plane but in the sagittal plane, males moved to a larger extent (14.6±8º) than females (6.1±1º) ($p<0.05$).

Table 1. Time characteristics of motion of healthy subjects during wheelchair sitting.

# of Subjects	Gender	Number of pressure relief movements				Intervals between movements [minutes]	
		Frontal			Sagittal	Maximal interval	Minimal interval
		Left	Right	Total			
5	Female	4.8±4.6	9±6.1	13.8±5.6	11.4±3.4	24.1±20.6	1±0.01
5	Male	0.4±0.9[a]	8±4.7[a]	8.4±2.9	13.6±2.9	18.4±15.3	1.3±0.3
Pooled for Gender:		2.6±3.9[a]	8.5±5.2[a]	11.1±5.9	12.5±3.2	21.3±17.4	1.2±0.2

[a] Number of movements to the right in the frontal plane was significantly greater than those to the left ($p < 0.05$).

DISCUSSION

This study was aimed at quantifying the frequency and extent of postural change motions in normal individuals during prolonged sitting in a wheelchair, to provide normative data that can be compared with medical recommendations for wheelchair-bounded individuals to prevent PS. A second interesting comparison can be made with kinematics of paraplegics in a wheelchair. Patterson and Fisher found that paraplegics change posture every 29.6 ± 27.5 minutes [5] but in another study, 4 of 7 paraplegics sat for 3-5 hours without pressure relieves [3]. Stockton and Parker reported that ~21% of the paraplegics in their study moved once in an hour or less frequently, and ~55% moved in cycles shorter than once an hour [6], however, more than half of their study population suffered PS. The frequency of postural changes in normals sitting in a wheelchair, reported herein, is generally greater than frequencies of postural changes reported for patients [3,5,6]. Based on our present initial data, ideally, patients should have move once in 6 minutes in the sagittal plane and independently, once in 9 minutes in the frontal plane, to extents of about 15º and 10º, respectively, to prevent PS. One limitation of our experimental design which should be considered while interpreting the results is that we could not identify spontaneous motions which occurred for reasons other than pressure relief (e.g. attributed to emotions or vision). However, considering that motions to relief tissue loads need to be effective in inducing substantial changes in distributions of tissue stresses and strains, our 5º motion threshold might have been successful in suppressing the effects of these other factors. In closure, we found that pressure relief maneuvers in sitting normals are frequent but involve moderate motion. The latter is encouraging in terms of design requirements from an automatic device that produces postural changes during sitting. Unlike present lift-off pressure relief programs, we propose that such device will mimic normal motion during sitting by automatically producing the 10-15º trunk tilts every 6-9 minutes. However, large-scale human studies employing the present methodology are required before final recommendations can be made.

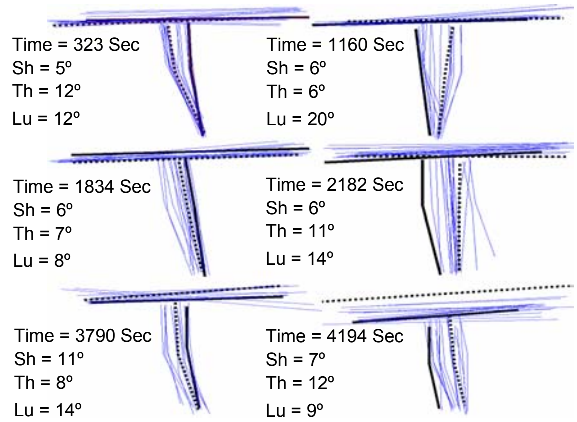

Figure 2. Representative stick diagrams of frontal motion events for the same subject. Sh = shoulders segment angle, Th = thoracic spine segment angle, Lu = lumbar spine segment angle.

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