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Original article

What is slumped sitting? A kinematic and electromyographical evaluation

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ABSTRACT

Slumped sitting is a commonly used reference posture when comparing effects of upright sitting in both clinical and non-clinical populations alike. The exact nature of slumped sitting has not been clearly defined, including regional differences within the posture, and how the passive nature of slumped sitting compares to an active-flexion posture. Kinematic and electromyographical (EMG) data were collected from 12 males during three repeats of slumped sitting and seated maximum forward flexion. Spine angles were defined in four regions (three thoracic and lumbar) as well as for the pelvis, and EMG was collected from eight muscles bilaterally. Kinematic data were expressed as a range of motion (in degrees), and as a percent of full forward flexion while seated (%SIT-FF) and standing (%STAND-FF). EMG data were normalized to a percent maximum contraction (%MVC). Results showed that slumped sitting is characterized by 10° posterior pelvis rotation, near end-range flexion of the mid- (90%SIT-FF) and lower- (81% SIT-FF) thoracic regions, and mid-range flexion of the upper-thoracic (51%SIT-FF) and lumbar (43%SIT-FF) regions. Comparison of slumped by %STAND-FF showed the upper- and mid-thoracic regions to have high variability and large values (over 100%STAND-FF). Muscle activation showed a significant 3%MVC reduction in the lower-thoracic erector spinae muscle when moving from upright to slumped sitting. These data highlight the postural differences occurring within different spine regions, and interpretations that could be drawn, depending on which normalization (sit or stand) method is used.

1. Introduction

The biomechanics of sitting has been a topic of interest for over a century with important concepts such as spine angles and electromyography (EMG) commonly reported (Harrison et al., 1999). One notable sitting posture identified is slumped sitting, which to this point has been generally defined as pelvic posterior rotation along with a relaxed (into flexion) thoracolumbar/trunk (O'Sullivan et al., 2002, 2006b). Slumped sitting is a common upright-comparative posture used in various research topics ranging from clinical back pain populations (Dankaerts et al., 2006a, 2006b; O'Sullivan et al., 2006c; Astfalck et al., 2010), to healthy pain-free groups (Claus et al., 2009a, 2009b; Caneiro et al., 2010), to broader topics such as implications on chest wall shape and lung capacity (Lin et al., 2006; Lee et al., 2010), and sports such as kayaking (López-Miñarro et al., 2010). Regardless of how often slumped sitting is used, it remains unclear as to what the defining characteristics are from both movement and muscle activation perspectives.

Classic work by Floyd and Silver (1951a) found lower thoracic and lumbar erector spinae (ES) muscles to decrease in full-flexion during upright standing and found similar responses during sitting in a follow-up report, suggesting the transfer of load onto the passive tissues (Floyd and Silver, 1951b). Additionally, Floyd and Silver (1955) found greater activation in lumbar ES muscles during upright sitting compared to both upright standing and slumped sitting; and Floyd and Silver (1952) showed reduction in ES activity during slumped sitting similar to upright standing flexion. More recently, Callaghan and Dunk (2002) found frequent reduction in thoracic ES activity when moving from upright to slumped sitting yet showed few cases of lumbar ES reduction. O'Sullivan et al. (2002, 2006b) reported significant decreases in thoracic ES, internal oblique (IO), and multifidus during slumped versus upright sitting; however, in the case of O'Sullivan et al. (2006b) the multifidus change depended on the upright posture. Different results by O'Sullivan et al. (2006a) found decreases in multifidus and IO, yet variable results within thoracic ES. Only slumped angles were reported in O'Sullivan et al. (2006a) in terms of pelvic rotation, lumbar, and a single thoracic angle, which may not allow for

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differentiation of movement within and between the thoracic spine. Claus et al. (2009a, 2009b) analyzed kinematics and EMG (respectively) of four different sitting postures (three upright and slumped). The main foci were to assess different upright postures with slumped sitting used as comparison. Regardless, these authors reported slumped showed significantly greater kyphosis in the lower-thoracic and lumbar region (Claus et al., 2009a), and EMG during slumped was lower than at least one upright posture (Claus et al., 2009b). Each of the aforementioned studies have analyzed slumped compared to upright sitting; however, it remains unclear how slumped differs within itself across different regions of the spine. Furthermore, slumped has been identified as a passive posture (O'Sullivan et al., 2002) resulting in lumbar flexion (Claus et al., 2009a); however, slumped sitting is often normalized to a percentage of maximum standing flexion (Callaghan and McGill, 2001; Callaghan and Dunk, 2002), and has yet to be compared to maximum flexion in sitting, which could be considered an active posture also resulting in lumbar flexion.

Therefore, the purpose of this study was to quantify slumped sitting in terms of kinematic and EMG measures. Specifically, range of motion (ROM) angles from four spinal regions plus the pelvis were reported and also expressed as a percentage of maximum forward flexion in both standing (%STAND-FF) and sitting (%SIT-FF). Each expression of slumped sitting (ROM, %SIT-FF, %STAND-FF) was compared within itself and between seated maximum flexion. Furthermore, EMG patterns from eight bilateral muscles were evaluated at peak angles achieved during slumped, maximum flexion, and upright sitting.

2. Methods

2.1. Participants

Twelve male participants were recruited; all right-hand dominant and asymptomatic of neck, back, and shoulder pain for at least one year prior to collection. The Mean (SEM) for age, height, and weight were 23 (1) years, 1.82 (0.03) m, and 83.35 (4.06) kg, respectively. Prior to data collection, consent forms approved by the institution were signed by all participants.

2.2. Instrumentation

Pairs of disposable surface EMG electrodes (2.5 cm center-to-center spacing; Ambu® Blue Sensor N, Ambu A/S, Denmark) were applied after skin preparation via shave and alcohol swab. Electrodes were placed bilaterally on the following eight muscles: *external oblique (EO)*, *internal oblique (IO)*, *rectus abdominis (RA)*, *latissimus dorsi (LD)*, *upper-thoracic erector spinae (upper-thoracic ES)*, *lower-thoracic erector spinae (lower-thoracic ES)*, *lumbar erector spinae (lumbar ES)*, and *superficial lumbar multifidus (SLM)* (Table 1). Electromyographical signals were differentially amplified (frequency response 10 Hz–1000 Hz, common mode rejection 115 dB at 60 Hz, input impedance 10 GΩ; two of model AMT-8, Bortec, Calgary, Canada), and converted from analog-to-digital at 2400 Hz (Vicon MX motion capture system, Vicon Systems Ltd., Oxford, UK).

Kinematic data were collected at 50 Hz using a seven camera Vicon motion capture system (Vicon Systems, Ltd., Oxford, UK) tracking 63 passive-reflective markers. Twenty-four markers were placed on eight rigid plates (three markers per plate) located along the spine at T_1, T_4, T_5, T_8, T_9, T_{12}, L_1, and the bilateral posterior superior iliac spines (PSISs) (Fig. 1). Remaining markers were placed on the upper legs, pelvis, upper arms, and head.

2.3. Data collection

Following electrode placement EMG calibration measures were collected, consisting of a rest trial (5 min supine on a therapy table, legs extended, arms at sides) followed by determining the maximum voluntary contraction (MVC) for each channel of EMG. The MVC protocol included manually resisted contractions, designed to elicit a maximum for each muscle of interest (similar techniques have been previously reported (McGill, 1991; Drake et al., 2006)). Briefly, the MVC trial for the abdominals (*EO, IO, RA*) was a modified sit-up with resisted trunk flexion, lateral bend, and axial twist. For each *ES* group and *SLM* a modified back extension was performed with the participant prone on the therapy table, trunk suspended over the edge followed by an attempt to extend their trunk to horizontal against manual resistance. The MVC trial for *LD* placed the shoulders in abduction and external rotation so the upper arm was parallel to the ground, elbows bent at 90°, palms forward while seated. Participants then pulled down against manual resistance with the attempted motion being inferior and slightly posterior. Each MVC trial was performed three times with minimum 3 min rest between trials and the maximum value of the three was used for normalization.

Reflective markers were then adhered as outlined above and posture trials were performed. Data were recorded for upright sitting (*upright*) (Fig. 2A), slumped sitting (*slumped*) (Fig. 2B), and maximum forward flexion during both seated (*max-flex*) (Fig. 2C) and standing postures. Instructions for the *slumped* posture were general as participants were instructed to "sit slumped as you normally would", with the only restriction being the head looking forward (Fig. 2B). For the maximum flexion trials in both sitting and standing participants were instructed to flex their spine forward as far as possible, as illustrated in Fig. 2C (sitting). When the participant reached their maximum range, the posture was held for 5 s.

Table 1
Summary of bilateral EMG electrode placement along with references.

Muscle	Placement
External oblique (EO)	15 cm lateral to the umbilicus at an angle of 45[a,b]
Internal oblique (IO)	Below the external oblique electrodes and just superior to the inguinal ligament[a]
Rectus abdominis (RA)	3 cm lateral to the midline of the abdomen, 2 cm above the umbilicus[b,c]
Latissimus dorsi (LD)	Most lateral portion of the muscle at the T_9 level[a,c]
Upper thoracic erector spinae (Upper-thoracic ES)	5 cm lateral from the spinous process at T_4[d,e]
Lower thoracic upper spinae (Lower-thoracic ES)	Location of largest muscle mass, approximately 5 cm from the midline of the spine at the T_9 level[a,c]
Lumbar erector spinae (Lumbar ES)	Location of largest muscle mass, approximately 4 cm from the midline at the L_3 level[a,c]
Superficial lumbar multifidus (SLM)	At L_5, parallel to a line connecting the posterior–superior iliac spine and L_1–L_2 interspinous space[f,g]

[a] McGill (1991).
[b] Mirka & Marras (1993).
[c] Drake et al. (2006).
[d] Burnett et al. (2009).
[e] Caneiro et al. (2010).
[f] O'Sullivan et al. (2006b).
[g] Dankaerts et al. (2006b).