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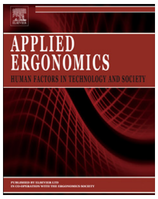

Thoracic and lumbar posture behaviour in sitting tasks and standing: Progressing the biomechanics from observations to measurements

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ABSTRACT

Few studies quantify spinal posture behaviour at both the thoracolumbar and lumbar spinal regions. This study compared spontaneous spinal posture in 50 asymptomatic participants (21 males) during three conditions: 10-min computer task in sitting (participants naïve to the measure), during their perceived 'correct' sitting posture, and standing. Three-dimensional optical tracking quantified surface spinal angles at the thoracolumbar and lumbar regions, and spinal orientation with respect to the vertical. Despite popular belief that lordotic lumbar angles are 'correct' for sitting, this was rarely adopted for 10-min sitting. In 10-min sitting, spinal angles flexed 24(7–9)deg at lumbar and 12(6–8)deg at thoracolumbar regions relative to standing ($P < 0.001$). When participants 'corrected' their sitting posture, their thoracolumbar angle −2(7)deg was similar to the angle in standing −1(6)deg ($P = 1.00$). Males were flexed at the lumbar angle relative to females for 10-min sitting, 'correct' sitting and standing, but showed no difference at the thoracolumbar region.

1. Introduction

It is important to quantify spinal posture behaviour because spinal posture influences and is influenced by many biomechanical, motor control and performance variables. Studies that have compared sitting and standing, or slumped and upright sitting demonstrate that lumbar spinal posture influences intervertebral shear (Hedman and Fernie, 1997), lumbar muscle activity (Claus et al., 2009; Floyd and Silver, 1955), coordination required to control the spine (Urquhart et al., 2005), respiratory efficiency (Lee et al., 2010; Lin et al., 2006), pelvic-floor muscle activity (Sapsford et al., 2006), cervical muscle activity (Falla et al., 2007) and cognitive attention (Lajoie et al., 1993).

Public health advice has conveyed the message that sitting is worse for spine health than standing (McGill, 2014; Pynt et al., 2008), and that good sitting posture should aim to achieve a lordotic lumbar spinal curve similar to standing (Andersson et al., 1975; Castanharo et al., 2014; Pope et al., 2002), but for some people, prolonged standing provokes more pain than sitting (Gallagher et al., 2014). It has also been proposed that sitting should involve frequent postural adjustment (McGill, 2014; Pope et al., 2002). The messages seem clear, and are consistent with community perceptions about good sitting posture (O'Sullivan et al., 2013a), but are they correct? Evaluation of the literature on sitting posture reveals important gaps in the scientific methodology that has underpinned these messages.

Flexed lumbar postures were thought to damage the spine more than upright postures. Since the 1950s it was proposed that lumbar flexion in sitting raised compressive load relative to standing, and thus damaged the intervertebral discs (Castanharo et al., 2014; Keegan, 1953) However, detailed review of intradiscal pressure studies (Claus et al., 2008a; Dreischarf et al., 2010) and measures with spinal internal fixators (Rohlmann et al., 2001) show that intradiscal pressure in slumped sitting is often comparable to that in standing. Epidemiology studies provided conflicting evidence regarding whether sitting with a flexed spine was worse for spinal health and back pain than standing (Battie et al., 1995; Kelsey and Hardy, 1975; Sparrey et al., 2014). However, not all individuals sit

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in a similar manner, and this is likely to contribute variability in the data. Unfortunately epidemiology studies have not quantified spinal posture behaviour of research participants. A clinical trial with a cross-over design showed that intervention to improve workplace sitting posture could reduce the incidence of low back pain (Pillastrini et al., 2010), although spinal behaviour was not quantified. More recently, postural interventions that were informed by the individual patient's pain provocative positions, were observed to reduce discomfort relative to a control condition (O'Sullivan et al., 2013b), or disability and pain relative to a control group (Sheeran et al., 2013). These studies have not quantified postural behaviour over sustained periods, although spinal position (Nairn et al., 2013), and movement behaviour (Dunk and Callaghan, 2010) vary over time. If detailed and standardised measures of spinal posture could be applied in studies of posture behaviour, the potential to compare and combine data from multiple studies (i.e. metanalysis) would be greatly improved. Such standardisation and metanalysis would provide foundation for conclusive determination of relationships between posture and spinal pain.

Although it is easy to qualitatively observe the postures that people adopt during functional tasks such as using a computer, there are limited data available to quantify spinal posture behaviour. Existing studies have methodological limitations in three main areas: i) instantaneous measures such as radiography, photography or an electromechanical device (Celenay et al., 2015; Makhsous et al., 2003; Straker et al., 2007) provide a basis to describe posture, but cannot be considered a functional measurement; ii) participant's awareness that spinal posture is the being measured risks biasing their postural behaviour; iii) normalisation of posture data to range of motion of individual participants (Dunk and Callaghan, 2005, 2010) is vulnerable to error associated with measuring the range of motion and inter-subject variability, thus confounding comparison of results between subjects or between studies.

These three methodological limitations could be managed better. Functional measurement of human behaviour requires repeated measures over a period of time, while performing a task (Dempster, 1955). Single-blinding of participants is difficult to achieve, owing to ethical requirements of informed consent, but keeping participants naïve to the dependent variable of posture would minimise the risk of biasing their behaviour. For data to be compared between participants and between studies, measures of spinal posture could be referenced to geometrical standards, rather than individual participant's range of motion.

Quantitative data for posture during functional tasks would also provide reference values to inform spinal modelling. For example, studies that have modelled neuromuscular control of spinal stability with unstable sitting surfaces represent the upper body as a single segment (Reeves et al., 2009; Tanaka et al., 2010), but the spine can adopt more than one posture in upright sitting. Subtle changes in upright spinal posture affect regional muscle activity (Claus et al., 2009; O'Sullivan et al., 2006) and mechanical variables such as response to whole body vibration (Kitazaki and Griffin, 1998). With the addition of data regarding regional spinal curve, models of unstable sitting could provide new understanding of spinal control systems.

The objective of this study was to identify the features of typical spinal posture during performance of a computer task with a simple ergonomic setup. Although typical spinal posture for computer tasks is commonly observed in daily life, spinal postural behaviour while performing a computer task has not been accurately quantified in a manner that permits comparison between participants. Data from this study are intended to provide normative data for comparison of participant behaviour with manipulation of task variables, psychological variables, or specific cohorts.

To progress from observations to quantitative, comparable measurements of thoracolumbar and lumbar posture in sitting, this study measured regional spinal curves and global spine orientation relative to vertical in three conditions: i) spontaneous sitting posture behaviour, while participants who were naïve to posture measurement completed a 10 min computer task; ii) self ‘correction’ of their posture, as may occur while aware that posture was recorded with an instantaneous measure; and iii) standing.

2. Materials and methods

2.1. Participants

Fifty participants (21 males) completed this repeated measures experiment. The mean (SD) age, height and weight were; males – 22 (4) years, females – 21 (3) years; males – 172 (7) cm, females – 164 (6) cm; and males 66 (12) kg, females – 55 (8) kg, respectively.

All participants were university students or staff, who are expected to be exposed to sitting for a large proportion of the current occupation, although this was not formally assessed. Participants were excluded if they had ever experienced thoracic or lumbar spinal pain that required treatment or rest from normal activities for more than two days, or if they reported a history of any respiratory or neurological condition. An experienced musculoskeletal physiotherapist undertook a physical examination to exclude anyone with abnormal restriction of straight leg raise, spinal mobility or scoliosis that would limit symmetrical performance of sitting postures. Written informed consent was obtained, and all procedures were approved by the Institutional Medical Research Ethics Committee.

2.2. Measurement

Spinal curves were quantified with an optical tracking system (Vicon, USA, reflector position absolute error 0.1 mm) and Nexus software (Vicon, USA). Data were recorded continuously at 30 Hz for the three posture conditions. The boundary between thoracic and lumbar curves was defined at T10, based on literature that described the anatomical transition in facet joint orientation (Singer et al., 1994) and radiographs of normal standing posture (Roussouly et al., 2005). A sagittal angle representing the surface spinal curve at the thoracolumbar region was measured between segments connecting T5-T10 and T10-L3, and the lumbar curve was measured between T10-L3 and L3-S2 (Claus et al., 2008b) (Fig. 1). Positive angles (deg) describe kyphotic surface spinal curves, zero degrees describes a flat surface position, and negative angles describe lordotic surface spinal curves. Global orientation of the spine was measured by the sagittal distance (mm) between the marker at T1 relative to the marker at S2. Anterior sagittal position of T1 relative to S2 was described as a positive T1-S2 alignment.

Fig. 1 illustrates postures associated with different combinations of spinal curves. These can be described as *short lordosis* (negative lumbar angle and flat at the thoracolumbar angle), *flat* (close to zero deg at both regions), *slump* (kyphotic at both regions) or *long lordosis* (negative thoracolumbar and lumbar angles).

2.3. Procedure

Participants wore loose shorts. Their skin was exposed to the level of S3. Males had their upper body exposed. Females wore a bra and a radiography gown to expose reflective markers at the spine. To determine skin positions for reflective markers, participants lay prone with pillows under their abdomen, so that the skin surface was flat from the mid-thorax to sacrum. Manual palpation was used to identify spinous processes, and washable ink was used to mark