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The amount of postural change experienced by adolescent computer users developing seated –related upper quadrant musculoskeletal pain

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Background: Improved techniques of measuring sitting posture have not led to a more comprehensive understanding of poor posture, nor its association with pain. There is also an evidence gap regarding critical thresholds of sitting postural change over time related to pain production. This paper describes postural angle changes over a 12-month period, and describes the process of placing defensible cut-points in the angle change data, to better understand associations between posture change over time, and onset of upper quadrant musculoskeletal pain (UQMP).

Methods: This paper reports on data captured at baseline and 12-month follow-up, in adolescents in school using computers. Four sitting postural angles, head flexion (HF), neck flexion (NF), craniocervical angle (CCA) and trunk flexion (TF), and self-reported seated UQMP in the previous month were captured at each time-point. Research questions were: 1) What is the magnitude and direction of change in each postural angle over 12 months? 2) What are best cut-points in the continuous posture change distribution to most sensitively test the association between posture change and UQMP? 3) Is gender-specific cut-points required? The 12-month posture angle change data was divided into quintiles (0–20th%; 21-40th%, 41-60th%, 61-80th%, >80th%), and the odds of UQMP occurring in each posture change quintile were calculated using logistic regression models.

Results: Two hundred and eleven students participated at baseline, of which 153 were followed-up at one year. Both males and females with postural change into extension (which represents lesser flexion range) were more at risk for the development of UQMP, than any other group. The best cut-point for HF was 40th% ($\leq -3.9°$), NF was 20th% ($\leq -2.9°$) and TF was 40th% ($\leq -1.1°$). For CCA however, change at or beyond 40th % for extension or beyond 60% for flexion was associated with UQMP.

Conclusions: Identification of critical postural angle change cut-points assists in considering the pain-producing mechanisms for adolescents using desk top computers.

1. Introduction

Measurement of spinal posture has improved significantly in the past three decades. Initially, due to limited technical capacity, posture was commonly measured in one plane only, as arrangements of body segments, such as around a plumb-line, by tracing spinal positions from a flexible ruler, by photographs or visual observation (Singla and Vegar, 2014). Now, with technology advancements, it is common to use three-dimensional (3D) posture analysis, by photographically capturing and analyzing multiple sequences of multiple anatomical points per second (Brink et al., 2011; Capodaglio et al., 2012; Rosário, 2014).

Since the 1900's, associations between good or poor posture and health status have been postulated. 'Good' posture was generally defined as body segments that were closely aligned with midline, and a common assumption that good posture was not associated with pain (Claus et al., 2009; Brink and Louw, 2013a; Grandjean and Hunting, 1977; Griegel-Morris et al., 1992). However, improved ways of capturing the position and arrangement of anatomical spinal points have not led to improved understanding, or definition,

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of good and poor posture for epidemiological analysis, particularly in relation to pain. The assumption that 'poor' posture is associated with pain persists, even though the definition of 'poor spinal posture', and how this relates to pain, remains unclear (O'Sullivan et al., 2013; Richards et al., 2016).

Over the last twenty years, sitting postures have been increasingly investigated because of an increasing global trend of sedentariness (Lindsay et al., 2016; Ng and Popkin, 2012; Hey et al., 2016). Work-related sitting (computer use) and generally more seated leisure activities (television viewing, gaming etc.) have led to more time spent in sitting by people of all ages (Clemes et al., 2014; Cliff et al., 2016). Although there is an increasing body of literature that reports that prolonged sitting is associated with spinal musculoskeletal pain (Ariens et al., 2001; Hallman et al., 2015; Brink and Louw, 2013a), there is also convincing evidence that counters such relationships (Briggs et al., 2009; Aminian et al., 2015; Cliff et al., 2016; De Rezende et al., 2014).

There is agreement in the literature that multiple factors are associated with seated-related musculoskeletal or spinal pain, for instance age (Sedrez et al., 2015), gender (Straker et al., 2011), duration of sitting (Brink and Louw, 2013a), psychosocial factors (Darlow, 2016), and posture (Brink et al., 2015). Moreover; many factors can influence the way a person sits e.g. gender (Straker et al., 2011), ergonomics (Straker et al., 2008; Van Niekerk et al., 2013), lifestyle (Sedrez et al., 2015) and muscle activity (Claus et al., 2009; Schinkel-Ivy et al., 2013). Research has classified sitting postures related to musculoskeletal or spinal pain in various ways e.g. individual angles (Brink et al., 2015; Straker et al., 2011), movement patterns (Dankaerts et al., 2006) or clusters of posture presentations (Astfalck et al., 2013; Richards et al., 2016). Whilst these attempts to define sitting postures associated with pain assist in understanding how postures become habitual over a person's lifetime, they still have not led to a better understanding of directionality or causality, for instance whether "poor" sitting posture leads to pain, or whether pain influences sitting posture (Hill, 1965).

The effect of different postures on anatomical structures can be tested theoretically in cadaver studies, or in mathematical models. However, in pragmatic studies using in-vivo studies, externally-measured posture using skin markers over anatomical points is used as a proxy for the behavior of underlying spinal segments. This approach to measurement is underpinned by the notion that epidemiologically, whilst posture is not the most proximal exposure for pain in a causal pathway, it is the most easily measured (Rothman, 1986). Causes of musculoskeletal or spinal pain may result from "biomechanical compromise" to spinal structures such as facet joints, ligaments, joint capsules, intervertebral discs, muscles (imbalance, motor control) or nerves. Modern imaging techniques such as low does X-ray (Van Niekerk et al., 2008), and other non-invasive techniques (Aroeira et al., 2016; Capodaglio et al., 2012) are currently unable to provide information on spinal structure performance during daily activities. Without knowing what is happening in the underlying structures when the spine is in different postural positions, it is not possible to identify what the causal agents of pain are. Thus, any discussion regarding the relationship of posture and pain should acknowledge that posture is a proxy measure for underlying spinal structures, and that using posture as a measure of spinal structure performance may introduce erroneous assumptions of risk, or causality.

What is lacking in the current evidence base is an understanding of how sitting posture changes over time (months or years), and whether postural changes are associated with pain production in previously asymptomatic people. This question is particularly relevant for adolescents who are developing adult postural behaviours (Cliff et al., 2016). Spinal structures grow significantly during adolescence, where peak growth velocity for sitting height has been reported for boys at age 14 years and for girls at age 12 years (Busscher et al., 2011). It seems important to acknowledge therefore, that postural perturbations, over and above the influence of growth changes as body systems mature, might be overwhelming to the immature neuromusculoskeletal system and make these adolescents more vulnerable to injury to spinal structures (Hasler, 2013; Busscher et al., 2011; Wang et al., 2015). Hasler (2013) postulates that the ongoing biomechanical changes to spinal structures that occur during puberty are underpinned by bony (vertebral) growth spurts. Any accompanying change in, or adaptation of, muscle strength, muscle length and proprioception lags behind bony development, and thus can place significant biomechanical stresses on spinal bony and soft tissue structures (Adirim and Cheng, 2003). This hypothesis is underpinned by a common occurrence where adolescents, exposed to high level sport activities, or to poor physical situations (such as poorly designed and sized furniture), appear to be more susceptible to injury and pain, possibly due to mechanical disadvantage within peak spinal growth periods (Hasler, 2013). Accordingly, the relationship between the biomechanics of certain activities (ROM, movement patterns, peak loads) and the adolescents' genetic factors (spinal anatomy, bone density, muscle power, proprioception) will determine the biologic response in terms of spinal growth modulation and the development of pain (Hasler, 2013).

Also missing in the literature is a protocol for determining a threshold of how much postural change in spinal segments is related to pain production. Spinal postural change is measured in degrees of movement, a continuous measure. It is common in epidemiological statistical practices to divide continuous data into binary form, by placing a cut point appropriately in data distributions (Altman et al., 1994). Whilst assigning the median value is the most commonly used approach, it is not certain that this is the correct approach when considering posture change (Altman and Royston, 2006). For instance, postural change can occur in two directions in any plane, and there is no clarity about whether large or small change could be related to pain production.

This paper reports on analysis of a subset of data from a longitudinal study of adolescents who were asymptomatic at baseline. The aims of the longitudinal study were to determine how:

- sitting posture, measured as individual angles i.e. *head flexion* (HF), *neck flexion* (NF), *cranio-cervical angle* (CCA) and *trunk flexion* (TF), changed over a 12-month period (in magnitude and direction of change), for adolescents who were asymptomatic at study commencement; and
- change in postural angles, anthropometric measures and psychosocial measures were related to the development of upper quadrant musculoskeletal pain (UQMP).

This current paper aims to explain the methodological processes applied to determine cut points in continuous postural angle change data over time to understand associations between postural change and UQMP.

2. Methods

2.1. Ethics

The Human Research Ethics Committee from the Stellenbosch University approved the study (N08/08/209). Permission for including eligible students and conducting this study during school hours were provided by the Western Cape Education Department. All participating students and parents provided written informed consent.

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