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Relationships between each part of the spinal curves and upright posture using Multiple stepwise linear regression analysis

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ABSTRACT

Back pain is a common reason for consultation in primary healthcare clinical practice, and has effects on daily activities and posture. Relationships between the whole spine and upright posture, however, remain unknown. The aim of this study was to identify the relationship between each spinal curve and centre of pressure position as well as velocity for healthy subjects. Twenty-one male subjects performed quiet stance in natural position. Each upright posture was then recorded using an optoelectronics system (Vicon Nexus) synchronized with two force plates. At each moment, polynomial interpolations of markers attached on the spine segment were used to compute cervical lordosis, thoracic kyphosis and lumbar lordosis angle curves. Mean of centre of pressure position and velocity was then computed. Multiple stepwise linear regression analysis showed that the position and velocity of centre of pressure associated with each part of the spinal curves were defined as best predictors of the lumbar lordosis angle ($R^2=0.45$; $p=1.65*10-10$) and the thoracic kyphosis angle ($R^2=0.54$; $p=4.89*10-13$) of healthy subjects in quiet stance. This study showed the relationships between each of cervical, thoracic, lumbar curvatures, and centre of pressure's fluctuation during free quiet standing using non-invasive full spinal curve exploration.

1. Introduction

Back pain has economic importance in occidental countries and affects quality of life (Franke et al., 2014) and daily activities (Brumagne et al., 2008). The prevalence of 632 million people who have displayed back pain attests to this assertion (Licciardone et al., 2013). Among back pain, Thoracic spine pain (TSP) is a common reason for consultation in primary healthcare clinical practice (Briggs et al., 2009; Roussouly et al., 2006). According to Briggs et al. (2009), TSP's are associated with musculoskeletal growth, biomechanical loading, and concurrent musculoskeletal pain. Alternative medicine including osteopathic manual treatment can be individually chosen in order to limit TSP (Barnes et al., 2008). For Licciardone et al. (2013): "Osteopathic manual treatment appears to be an attractive option in patients with severe chronic back pain before proceeding to more invasive and costly treatment". For example, 42.4% of all osteopathic consultations in Quebec concern back pain (Morin and Aubin, 2014). Moreover, spine osteopathic treatment protocols could improve postural stability of patients with back pain as well as that of elderly (Lopez et al., 2011; Noll, 2013). These treatments, however, are based on osteopathic models (Wernham, 1985) that need to be scientifically validated.

Recent studies have shown that back pain has direct influence on postural strategies in different upright postures (Brumagne et al., 2008; Mientjes and Frank, 1999; Moseley and Hodges, 2005). Centre of pressure position and postural sway of patients with low back pain differ with those of healthy people (Mientjes and Frank, 1999). Back pain could alter proprioceptive acuity in different parts of the body (Brumagne et al., 2004). So the central nervous system focuses on other proprioceptive joints and adopts an alternate postural strategy that is probably used to protect the spine (Moseley et al., 2004; Moseley and Hodges, 2005). This alternative postural strategy used by low back pain patients alters their postural balance and limits their ability to respond to external perturbations (Henry et al., 2006). The relationships between the whole spine curvature and postural sway remain however unknown for healthy and back pain population (Brumagne et al., 2008).

Studies focusing on the relationship between the spine curvature and mean position of the centre of pressure often associated force plate measurements with radiography analysis or ESO system (El Fegoun et al., 2005; Gangnet et al., 2003; Glaser et al., 2012; Le Huec et al., 2011b; Roussouly et al., 2006; Schwab et al., 2006; Somoskeöy et al., 2012). The use of radiography analysis has shown potential value in clinical practice and to define the spine

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curvature of healthy subjects. These studies showed that the centre of gravity line of healthy subjects was always in a forward position when compared with the spine in the sagittal plan (Gangnet et al., 2003; Le Huec et al., 2011b; Schwab et al., 2006). The top of the spine and the lumbar sagittal curve present geometric relations with the pelvis orientation during quiet standing (Roussouly et al., 2006; Vaz et al., 2002). The whole spine, however, presented large variability in sagittal profile during upright standing (Gangnet et al., 2003). Moreover, few studies include the cervical and base of the skull in the whole spine (Roussouly et al., 2006). Cervical and base of the skull were defined as important factors in order to avoid diagnostic errors in surgical indications (Le Huec et al., 2011a).

The use of radiography analysis and EOS system contributes to these limitations. Radiography exposure remains limited due to the resolution frame which makes measurement of the whole spine difficult during quiet standing (Roussouly et al., 2006). The different upper limbs positioning used for x-ray or EOS system protocols (with or without external support) in order to estimate the cervical and thoracic locations influence the spine curve in sagittal plane and alter the natural standing balance in upright posture (El Fegoun et al., 2005; Roussouly et al., 2006). Another drawback is that intensified and repeated x-ray exposure of patients with spinal disorders should be avoided in general (Doody et al., 2000; Miglioretti et al., 2013; Ronckers et al., 2010).

The development of three-dimensional non-invasive methods should overcome the problem of assessing the whole spine in standing posture (Blondel et al., 2012; Michoński et al., 2012; Stokes, 1994). With the technological advance, 3D reconstitution of the whole spine has been developed using an optoelectronic system (Blondel et al., 2012; Długosz et al., 2012). Optoelectronics and digital camera protocols do not require any stress for the patient being positioned with arms lying on each side of the body (Blondel et al., 2012; Długosz et al., 2012; Michoński et al., 2012). These non-invasive protocols are still in the under-study phase. Blondel et al. (2012) focused only on three spinal centre joints, (lumbosacral, thoracolumbar and cervico-thoracic joints), in agreement with the anthropomorphic recommendations of Dumas et al. (2007). Długosz et al. (2012) used six reflexive markers and Bezier curve fittings in order to define the whole spine curves. Michoński et al. (2012) used 17 landmarks and automatic recognition surface in order to define the whole back structure. To our knowledge, only Ranavolo et al. (2013) compared optoelectronic 3-D reconstruction of the whole spine with the x-ray method on 10 subjects. Their results showed that the entire spine could be accurately computed using an optoelectronics system and fifth-order polynomial fittings of reflexive markers placed on the cutaneous projection of spinous process of the vertebra. This recent spine modelling (Ranavolo et al., 2013) associated with anthropomorphic data of the trunk (Vette et al., 2011) can be used to improve the analysis of the whole spinal curves during free quiet standing. According to Brumagne et al. (2008), this relationship could help to better understand the postural strategies adopted by back pain patients and their influence on postural instability as well as risks of fall or injuries. It could also help to provide more detailed information about position and movement of each part of the spine, and also help to make assumptions about which parts of the body afferent information can be associated with regarding the change of upright postural strategy.

To our knowledge, there is no study focusing on the relationships between the whole spinal curves and centre of pressure's fluctuations in natural upright posture with arms positioned freely along the subject's body. The aim of this study is to identify the relationship between each angle of the spine curve and centre of pressure's fluctuations on healthy subjects in quiet standing.

2. Methods

This study was performed with 21 healthy male subjects (mean ± standard deviation) age = 25 ± 2 years, weight = 72 ± 11 kg and height = 1.76 ± 0.08 m. All the subjects approved the study protocol and provided an informed consent for their participation. The study was approved by the local ethics committee, and complied with the Helsinki declaration.

Each subject performed four quiet stances in natural position, arms along his body, looking forward, and each foot on one force plate (AMTI, AccuGAIT, 1000 Hz). In total, 84 quiet stances were studied. The subjects stayed in a quiet stance for six seconds according to Blondel et al. (2012) and in agreement with the studies of Nigg et al. (2006) and Emery (2003) (Fig. 1). The subjects had a two-minute break between each quiet stance, during which they were told to walk freely. For each measurement, eight MX cameras with infra-red light recorded 29 passive retro reflective markers attached on the subjects (sampling frequency of 100 Hz). One force plate (AMTI Accugait, sampling frequency of 1000 Hz) recorded the centre of

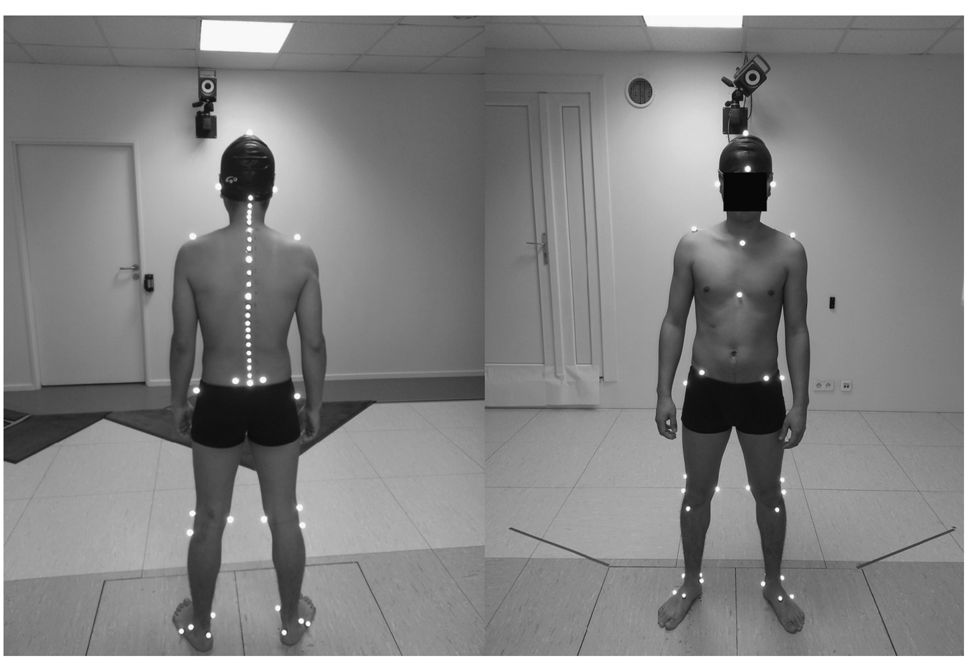

Fig. 1. Subject in quiet stance during the experimentation.