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Postural sway and integration of proprioceptive signals in subjects with LBP

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ABSTRACT

Patients with non-specific low back pain (LBP) may use postural control strategies that differ from healthy subjects. To study these possible differences, we measured the amount and structure of postural sway, and the response to muscle vibration in a working cohort of 215 subjects. Subjects were standing on a force plate in bipedal stance. In the first trial the eyes were open, no perturbation applied. In the following 6 trials, vision was occluded and subjects stood under various conditions of vibration/no vibration of the lumbar spine or m. Triceps Surae (TSM) on firm surface and on foam surface. We performed a factor analysis to reduce the large amount of variables that are available to quantify all effects. Subjects with LBP showed the same amount of sway as subjects without LBP, but the structure of their sway pattern was less regular with higher frequency content. Subjects with LBP also showed a smaller response to TSM vibration, and a slower balance recovery after cessation of vibration when standing on a solid surface. There was a weak but significant association between smaller responses to TSM vibration and an irregular, high frequency sway pattern, independent from LBP. A model for control of postural sway is proposed. This model suggests that subjects with LBP use more co-contraction and less cognitive control, to maintain a standing balance when compared to subjects without LBP. In addition, a

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reduced weighting of proprioceptive signals in subjects with LBP is suggested as an explanation for the findings in this study.

1. Introduction

A greater understanding of possible causes and mechanisms underlying the development and the persistence of low back pain (LBP) is needed for the development of new and better treatment strategies (Costa et al., 2013). Changes in motor control have been established in subjects with LBP, and could be one of the mechanisms that could cause LBP or could result from LBP and then play a role in persistence or recurrence (Hodges & Tucker, 2011).

Postural control, the part of motor control involved in maintaining an upright position (Massion, 1992), is often studied by analyzing postural sway. Postural sway is usually quantified as the movement of the center of pressure (CoP), the point at which the resultant of the exerted forces is applied to the support surface. Recently, two reviews investigating standing postural sway in subjects with LBP were published. The majority of the included studies reported an increased postural sway in LBP, or no effect of LBP on postural sway. In a minority of studies, a decreased sway was found in patients with LBP (Mazaheri, Coenen, Parnianpour, Kiers, & van Dieen, 2013; Ruhe, Fejer, & Walker, 2011a). No systematic differences that could explain these differences were identified (Mazaheri et al., 2013). Only studies that used sway amplitude or velocity related variables were included. Non-linear variables, that give insight into the dynamic structure of the sway pattern, have been used much less frequently in LBP research. This is surprising since CoP regularity has helped understanding the complexity of changes in postural control in many other pathologies. For example, increased regularity of postural sway has been interpreted as evidence of increased cognitive control over posture (Donker, Roerdink, Greven, & Beek, 2007), to compensate for impairments due to e.g., contusion (Cavanaugh et al., 2005), cerebral palsy (Donker, Ledebt, Roerdink, Savelsbergh, & Beek, 2008), Ehlers–Danlos syndrome (Rigoldi et al., 2013) and stroke (Roerdink et al., 2006).

Postural control depends, among other sources of information, on proprioception, which may be impaired in subjects with LBP (Brumagne, Lysens, & Spaepen, 1999; Gill & Callaghan, 1998; O'Sullivan et al., 2003; Willigenburg, Kingma, Hoozemans, & van Dieen, 2013; Yilmaz et al., 2010). The relative weight assigned to proprioceptive signals from a specific body part can be quantified by means of muscle vibration. Muscle vibration is a potent stimulus for muscle spindles (Burke, Hagbarth, Lofstedt, & Wallin, 1976; Roll, Vedel, & Ribot, 1989) and muscle spindles play the major role in the detection of movement (Proske & Gandevia, 2012). Under vibration, the muscle is usually perceived to be longer than it actually is (Cordo, Gurfinkel, Brumagne, & Flores-Vieira, 2005; Goodwin, McCloskey, & Matthews, 1972; Roll & Vedel, 1982), and consequently a corrective movement is made. For example, when Triceps Surae muscles (TSM) are vibrated, a backward shift in CoP occurs. The magnitude of the shift depends on the weight that the central nervous system assigns to these artificially induced signals compared to other sources of information (Brumagne, Cordo, & Verschueren, 2004). This weighting is influenced by the surface a person is standing on (Ivanenko, Talis, & Kazennikov, 1999; Kiers, Brumagne, van Dieën, van, & Vanhees, 2011), but is also changed in subjects with LBP (Brumagne et al., 2004; Brumagne, Janssens, Knapen, Claeys, & Suuden-Johanson, 2008; Claeys, Brumagne, Dankaerts, Kiers, & Janssens, 2011).

Based on the above, we were interested in the relationship of LBP with the structure of the postural sway pattern in standing and the effects of muscle vibration. However, the pattern of CoP movement in quiet standing and in response to muscle vibration can be characterized by a large number of parameters. It is unknown which parameters represent unique properties of the sway pattern and which parameters covary. This makes an a priori choice of parameters not possible, while measuring all possible parameters results in an unacceptable increase in the probability of