Journal of Biomechanics 44 (2011) 1771–1775

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Estimation of centre of gravity movements in sitting posture: application to trunk backward tilt

F. Munoz, P.R. Rougier *

Université de Savoie, Domaine scientifique de Savoie-Technolac, Laboratoire de Physiologie de l'Exercice—EA4338, 73376 Le-Bourget-du-Lac, France

ARTICLE INFO

Article history:
Accepted 6 April 2011

Keywords:
Centre of gravity
Inertia
Sitting posture
Postural control

ABSTRACT

The aim of this study was to highlight, in sitting posture, the value of distinguishing between the movements of the vertical projection of the centre of gravity (CG_v) and its difference from the centre of pressure ($CP-CG_v$). A protocol for healthy, young, trained adults, consisting in tilting their trunk backward or keeping it vertical was used. A frequency analysis shows that statistically significant effects were only seen on $CP-CG_v$ movements: the RMS increased by 37% ($p=0.004$), while the MPF decreased by 5% ($p=0.016$), suggesting an increased muscular activity in these tilting postures. In contrast, no statistically significant effects on CP and CG_v were reported. These data highlight the advantage, in sitting posture, of splitting overall CP displacements into basic components (i.e. CG_v and $CP-CG_v$), each of them having a biomechanical significance.

1. Introduction

Postural tests in sitting position are commonly used to assess the trunk movements of healthy individuals (Bouisset and Duchene, 1994) or of patients with low back pain (Cholewicki et al., 2000; Radebold et al., 2001; Silfies et al., 2003; Reeves et al., 2006; Reeves et al., 2009; van Daele et al., 2009, 2010; van Dieën et al., 2010). Compared to standing posture, these tests can more precisely target the balance control of the trunk by eliminating the regulation of the lower limbs. In most cases, they consist of in measuring the displacement of the resultant CP on a stable or unstable platform while the subjects maintained CG_v within the support surface. This permanent postural regulation by the CP is imposed by the impossibility of maintaining a constant level of postural muscle contraction over time (de Luca et al., 1982). The distance between the CG and the rotation axis causes an inertia for the movements of the CG_v whereas the CP, located in the support surface, has no inertia to counteract for being displaced. These differences in the physical characteristics of the two movements infer horizontal accelerations communicated to the CG and therefore its displacements (Brenière et al., 1987). In addition, previous studies (e.g. Winter et al., 1998; Rougier et al., 2001) in upright standing have stressed the relation between the amplitudes of these $CP-CG_v$ movements and the level of muscular activity at the lower limb level. As a result, maintaining an upright forward tilt increases displacements from $CP-CG_v$ more than CG_v (Rougier et al., 2001). This result demonstrates the importance of taking into account separately these two basic movements during a postural task. Indeed, focusing only on the CP displacements (the controlling variable in the equilibrium maintenance) does not measure its effectiveness on the CG_v movements (the controlled variable according to Massion (1992)).

Three methods have been identified for estimating CG_v displacements (Lafond et al., 2004): (1) kinematic; (2) zero-point-to-zero double integration; (3) CP low-pass filter. The third method, easy to implement with posturographic data, was used in the current study. Although the body motions only mobilise the lowest joints, hence allowing it to be modelled as an inverted pendulum, the moment of inertia is assumed to remain constant all along the trials durations. In this case, the CG_v movements can be considered as low-pass filtered displacements of the CP (Benda et al., 1994).

Moreover, the additional insights provided by these $CP-CG_v$ movements can plainly be relevant for patients with low back pain and scoliosis by expressing the horizontal acceleration communicated to the CG, i.e. the muscular activity level of the system. Although this approach has been used in standing posture for many years (Caron et al., 1997; Corriveau et al., 2000; Rougier et al., 2001; Rougier, 2003; Masani et al., 2007), it remains unexplored to our knowledge in the sitting posture. However, in this posture the amplitude relationship between the CG_v and the CP, through which the CG_v movements can easily be estimated if the position of the arms and head remain fixed regarding the trunk. In the sitting posture, the value of splitting the global CP into two basic components, i.e. CG_v and $CP-CG_v$ displacements, could be highlighted by using a postural task in which the trunk is tilted backwards or not tilted. With this method, only a force

* Corresponding author. Tel.: +33 4 79 75 81 46; fax: +33 4 79 75 81 48.
E-mail address: patrice.rougier@univ-savoie.fr (P.R. Rougier).

0021-9290/$ - see front matter © 2011 Published by Elsevier Ltd.
doi:10.1016/j.jbiomech.2011.04.008