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Oblique abdominal muscle activity in response to external perturbations when pushing a cart

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ABSTRACT

Cyclic activation of the external and internal oblique muscles contributes to twisting moments during normal gait. During pushing while walking, it is not well understood how these muscles respond to presence of predictable (cyclic push-off forces) and unpredictable (external) perturbations that occur in pushing tasks. We hypothesized that the predictable perturbations due to the cyclic push-off forces would be associated with cyclic muscle activity, while external perturbations would be counteracted by cocontraction of the oblique abdominal muscles. Eight healthy male subjects pushed at two target forces and two handle heights in a static condition and while walking without and with external perturbations. For all pushing tasks, the median, the static (10th percentile) and the peak levels (90th percentile) of the electromyographic amplitudes were determined. Linear models with oblique abdominal EMGs and trunk angles as input were fit to the twisting moments, to estimate trunk stiffness. There was no significant difference between the static EMG levels in pushing while walking compared to the peak levels in pushing while standing. When pushing while walking, the additional dynamic activity was associated with the twisting moments, which were actively modulated by the pairs of oblique muscles as in normal gait. The median and static levels of trunk muscle activity and estimated trunk stiffness were significantly higher when perturbations occurred than without perturbations. The increase baseline of muscle activity indicated cocontraction of the antagonistic muscle pairs. Furthermore, this cocontraction resulted in an increased trunk stiffness around the longitudinal axis.

1. Introduction

Pushing and pulling are common manual materials handling activities and have replaced lifting and carrying in many workplaces to prevent the development of low-back pain (LBP) (Schibye et al., 1997). However, pushing and pulling activities can also contribute to the risk of LBP (Damkot et al., 1984; Harber et al., 1987; Hoozemans, 2001; Plouvier et al., 2008). The load at the low-back is determined by the external forces at the hands in combination with the posture and movements of the upper body (Hoozemans et al., 1998). Compared to pulling, low-back moments around the transverse plane are lower during pushing, because of opposite moment directions produced by hand forces and gravitational loading (de Looze et al., 2000; Laursen and Schibye, 2002; Hoozemans et al., 2004; Boocock et al., 2006; Lett and McGill, 2006). Because of these low moments during pushing, trunk stiffness will be relatively low, which may put the spine at risk of mechanical injury (Cholewicki and McGill, 1996), especially given that unpredictable perturbations

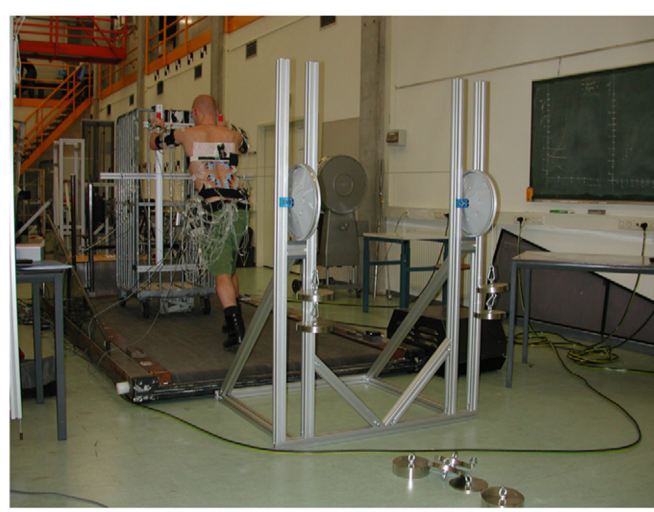

Fig. 1. The experimental setup of the four-wheeled cart on the treadmill and the ropes of the pulley system behind the subject used to manipulate target forces.

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frequently occur during pushing due to irregularities of the floor or due to poorly functioning wheels and given the high inertia of objects that are transported (Cholewicki and McGill, 1996; Schibye et al., 1997; Chaffin et al., 1999).

When pushing while walking both the push-off forces created to walk as well as hand forces due to irregularities in rolling resistance may perturb the trunk around its longitudinal (twisting) axis. In normal gait, angular momentum of upper and lower body vary in counterphase (Bruijn et al., 2008). This implies that trunk muscles create a twisting moment that is opposite to the moment resulting from the push-off forces. External oblique (EO) and internal oblique (IO) muscles are the main contributors to twisting moments (Dumas et al., 1991; Ng et al., 2001; Kumar et al., 2003) and these muscles are cyclically active during normal gait (Callaghan et al., 1999).

In contrast to the predictable cyclic push-off forces, forces at the hands may vary unpredictably because of irregularities in rolling resistance as mentioned above. When experiencing unpredictable hand loads during lifting, subjects responded by stiffening the trunk by cocontraction (van Dieën and de Looze, 1999; van Dieën et al., 2003). Therefore, the objective of the present study was to investigate how trunk motion and EO and IO muscle activity are controlled in relation to the time-varying twisting moments that occur during pushing a cart in situations without and with perturbations. We hypothesized that in pushing while walking EO and IO would be cyclically active. In addition, we hypothesized that unpredictable perturbations applied to the cart would cause increased cocontraction of EO and IO muscles and thus increased tonic muscle activity, to stiffen the trunk around its longitudinal axis.

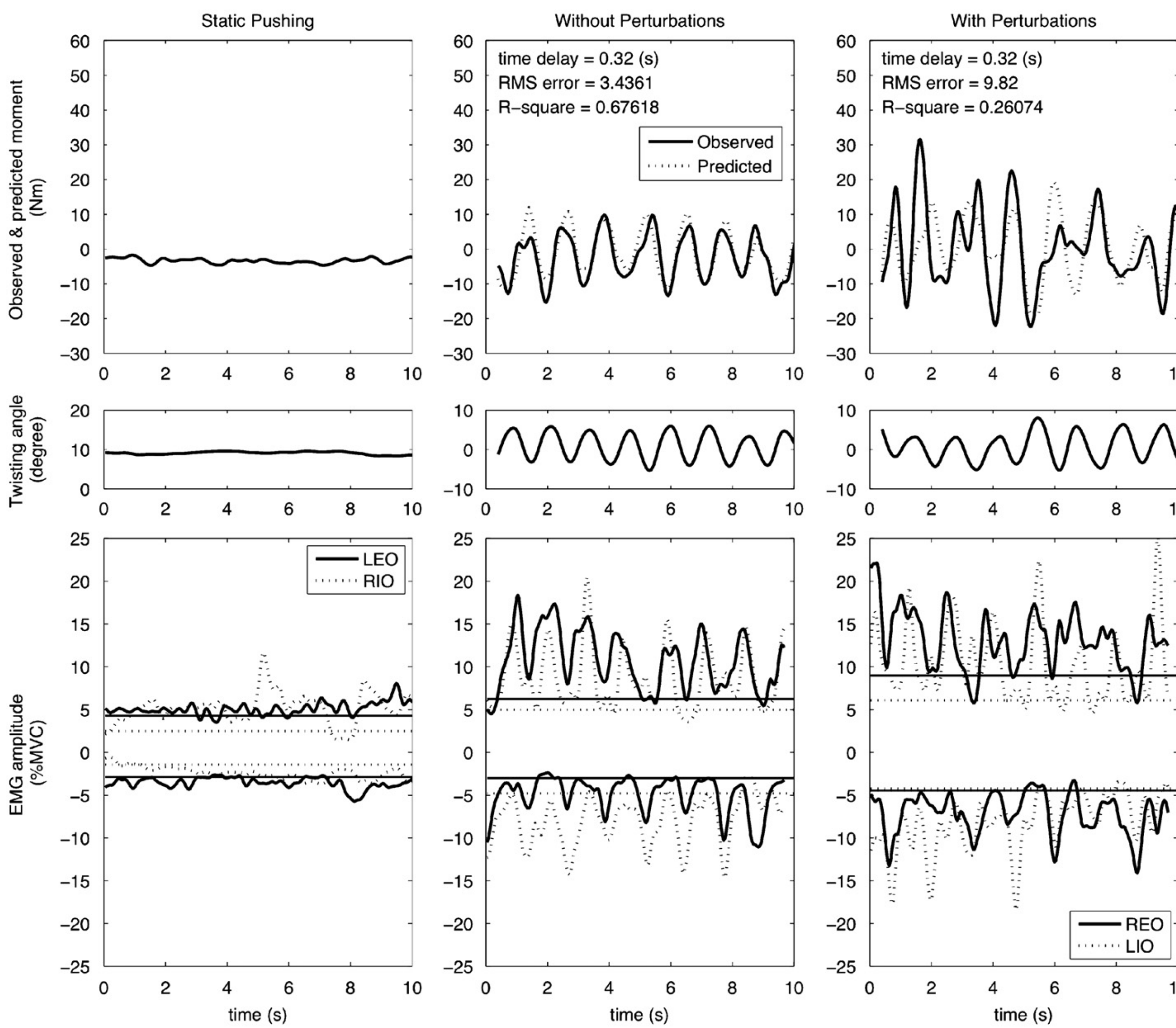

Fig. 2. Typical example of one subject pushing at a target force of 150 N at shoulder height in the pushing while standing condition (a), during pushing while walking without (b) and with (c) perturbations. The upper panels represent the observed time-varying twisting moments and the moments predicted by the linear model. The middle panels represent the twisting angles. The positive parts of the lower panels represent muscle activation as percentage of MVC of the LEO and RIO as synergists and the negative parts represent values of REO and LIO (multiplied by -1). The horizontal lines represent the P10 for each muscle. LEO=left external oblique, REO=right external oblique, LIO=left internal oblique, RIO=right internal oblique.