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Review

Methods for assessment of trunk stabilization, a systematic review

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ABSTRACT

Trunk stabilization is achieved differently in patients with low back pain compared to healthy controls. Many methods exist to assess trunk stabilization but not all measure the contributions of intrinsic stiffness and reflexes simultaneously. This may pose a threat to the quality/validity of the study and might lead to misinterpretation of the results. The aim of this study was to provide a critical review of previously published methods for studying trunk stabilization in relation to low back pain (LBP). We primarily aimed to assess their construct validity to which end we defined a theoretical framework operationalized in a set of methodological criteria which would allow to identify the contributions of intrinsic stiffness and reflexes simultaneously. In addition, the clinimetric properties of the methods were evaluated. A total of 133 articles were included from which four main categories of methods were defined; upper limb (un)loading, moving platform, unloading and loading. Fifty of the 133 selected articles complied with all the criteria of the theoretical framework, but only four articles provided information about reliability and/or measurement error of methods to assess trunk stabilization with test–retest reliability ranging from poor (ICC 0) to moderate (ICC 0.72). When aiming to assess trunk stabilization with system identification, we propose a perturbation method where the trunk is studied in isolation, the perturbation is unpredictable, force controlled, directly applied to the upper body, completely known and results in small fluctuations around the working point.

Contents

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1. Introduction

Trunk stabilization can be defined as maintaining control over trunk posture and movement, in spite of the disturbing effects of gravity and external and internal perturbations. Trunk stabilization is dependent on the passive (osteoligamentous), active (muscular) and neural sub-systems that contribute mechanically and in terms of acquiring and processing information to guide mechanical responses (Cholewicki and McGill, 1996). Stabilization of the trunk is required to control trunk movement during daily activities like standing, sitting, walking (MacKinnon and Winter, 1993; van der Burg et al., 2005), and can be limiting in performing precise arm and hand functions (Kaminski et al., 1995; Pigeon et al., 2000). Importantly, it has been hypothesized that inadequate trunk stabilization could contribute to low-back pain (LBP) through high tissue strains and/or impingements (Panjabi, 1992a,b).

Trunk stabilization is achieved differently in patients with low back pain (LBP) compared to healthy controls. These differences in trunk control have been interpreted as cause of the persistence of LBP (Hodges et al., 2009; MacDonald et al., 2010), and were even shown to be prospectively associated to LBP incidence (Cholewicki et al., 2005). Specifically, several studies have indicated longer reflex delays after an external mechanical perturbation of trunk posture in LBP patients than in controls (Magnusson et al., 1996; Radebold et al., 2000, 2001; Reeves et al., 2005). In apparent contrast, higher trunk stiffness, i.e. a higher mechanical resistance to such perturbations has also been reported (Hodges et al., 2009; van Dieën et al., 2003a). The latter is probably explained by findings of increased co-contraction of trunk musculature in patients compared to controls (van Dieën et al., 2003b). This has been interpreted as an adaptive response to enhance control over trunk movement and therewith prevent pain (Lund et al., 1991; van Dieën et al., 2003a). In fact, increased trunk stiffness through co-contraction could explain the longer delays found. With increased stiffness, the same mechanical disturbance will cause a smaller and slower deviation of trunk posture. Consequently, the disturbance would be perceived later and cause a slower and smaller increase in excitatory drive of the trunk musculature, resulting in an apparent increase in reflex delays. So paradoxically, the finding of an increased delay could actually reflect a functional, adaptive response to enhance trunk stability.

The above indicates that the contributions of intrinsic stiffness and reflexes to trunk stabilization need to be assessed simultaneously. This is possible using system identification techniques, which apply some form of external (often mechanical) perturbation and measure responses such as the trunk kinematics and trunk muscle EMG, from which properties of the stabilizing system, such as the intrinsic stiffness and reflex delays are estimated (Schouten et al., 2008; van der Helm et al., 2002). Many different methods using such an approach have been reported (Goodworth and Peterka, 2009; van der Helm et al., 2002; van Drunen et al., 2013). However, not all methods appear equally suitable. For example, not all take into account the intrinsic and reflexive contributions simultaneously. Furthermore, setups in some studies allow movement corrections in multiple joints (e.g. ankle, knee and hip), due to which experimental effects or between-group differences cannot be ascribed solely to the trunk.

To support interpretation of previous literature and to optimize methods for studying trunk stabilization in relation to LBP, we aimed to provide a critical review of previously published methods. We primarily aimed to assess their construct validity, to which end we defined a theoretical framework operationalized in a set of methodological criteria. This theoretical framework comprised the two criteria as introduced above as well as the criteria based on the requirement to allow for linear system identification, since a wide range of well-established techniques is available for this. The criteria are further detailed in the methods section. In addition, the clinimetric properties of the methods were evaluated, to assess their potential value in a clinical setting.

2. Methods

2.1. Theoretical framework

To evaluate the methods found in the literature, a theoretical framework was defined. In the introduction, two major criteria were already introduced: (1) the necessity of being able to simultaneously assess intrinsic and reflexive contributions to trunk stabilization and (2) the necessity to study the trunk in isolation.

To be able to assess the intrinsic and reflexive contributions to trunk control simultaneously through linear identification techniques, the method has to meet the following criteria:

Unpredictable	Disturbances must be unpredictable, since the presence of feed forward control to an expected perturbation renders it impossible to quantify reflexive and intrinsic components. System identification techniques assume a closed loop between the output forces and movements and the control input, e.g. the movement occurring upon perturbation of a static posture is assumed to be the basis for reflex inputs. When voluntary movements through feed forward control occur, this obviously would lead to a misinterpretation. To prevent feed forward control, an unpredictable perturbation should be used
Known Disturbance	To allow for system identification, the disturbance should be known (in terms of amplitude and timing). It is important to note that the disturbance is defined as the external input, which should be distinguished from the contact force between a device applying a perturbation and the subject, as this results from an interaction between device and subject
Perturbation Type	To permit the use of linear identification techniques, the disturbance should result in small fluctuations around a fixed working point, i.e. it should not entail large force differences and should not result

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