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Reliability of assessing trunk motor control using position and force tracking and stabilization tasks

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ABSTRACT

System-based methods have been applied to assess trunk motor control in people with and without back pain, although the reliability of these methods has yet to be established. Therefore, the goal of this study was to quantify within- and between-day reliability using systems-based methods involving position and force tracking and stabilization tasks. Ten healthy subjects performed six tasks, involving tracking and stabilizing of trunk angular position in the sagittal plane, and trunk flexion and extension force. Tracking tasks involved following a one-dimensional, time-varying input signal displayed on a screen by changing trunk position (position tracking) or trunk force (force tracking). Stabilization tasks involved maintaining a constant trunk position (position stabilization) or constant trunk force (force stabilization) while a sagittal plane disturbance input was applied to the pelvis using a robotic platform. Time and frequency domain assessments of error (root mean square and H_2 norm, respectively) were computed for each task on two separate days. Intra-class correlation coefficients (ICC) for error and coefficients of multiple correlations (CMC) for frequency response curves were used to quantify reliability of each task. Reliability for all tasks was excellent (between-day ICC $\geq$ 0.8 and CMC $>$ 0.75, within-day CMC $>$ 0.85). Therefore, position and force control tasks used to assess trunk motor control can be deemed reliable.

1. Introduction.

Impairments in trunk motor control have been associated with back pain. Studies have shown that individuals with back pain have poorer trunk proprioception (Brumagne et al., 2000, 2004; Newcomer et al., 2000), delayed trunk muscle reflex response (Radebold et al., 2000, 2001; Reeves et al., 2005; Cholewicki et al., 2005), more trunk kinematic variability (Vogt et al., 2001), and poorer postural control (Radebold et al., 2001; Luoto et al., 1998) than healthy individuals. Despite growing evidence demonstrating motor control deficits with back pain, our understanding of how these impairments lead to or result from back pain is still underdeveloped. This lack of understanding is in part due to the complexity of the motor control system, and how parts of the system contribute to its overall behavior.

To resolve the complexity in motor control, some researchers have applied system-based methods to study human movement, including trunk motor control (Franklin, 2006; Moorhouse and Granata, 2007; Franklin et al., 2008; Reeves et al., 2009; Hodges et al., 2009; Zeinali-Davarani et al., 2008; Peterka, 2002; Maurer et al., 2005; Goodworth and Peterka, 2009; Bazrgari et al., 2011). Typically in these studies, input disturbances are applied to the trunk/pelvis and the ability of the motor control system to reject these disturbances is assessed. For more details on system-based methods readers are referred to Jagacinski and Flach (2003). However, for system-based methods to be useful, they must be demonstrated to be reliable. To our knowledge, there is only one study assessing the reliability of system-based methods using position disturbances applied directly to the trunk during a force control task (Hendershot et al., 2012). The within-day reliability (ICCs

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0.48–0.95) was consistently better than between-day reliability (0.19–0.72) for predicting system properties (i.e., trunk mass and stiffness, reflex gains and delays).

The goal of this study was to assess the within- and between-day reliability of a set of motor control tasks involving trunk angular position and force tracking, and trunk angular position and force stabilization. Throughout the paper, *angular position* will be referred to as *position* for concise presentation.

Table 1
Characteristics of the subjects (standard deviations in parenthesis).

Subject characteristics	Females	Males
Height [m]	1.66 (0.08)	1.78 (0.09)
Weight [kg]	60.7 (10.7)	80.5 (4.4)
Age [yrs]	29.7 (12.7)	35.5 (16.3)
N	6	4

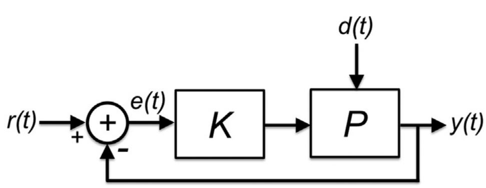

Fig. 1. Components of the trunk motor control system.

2. Methods

2.1. Subjects

Ten healthy subjects were recruited for the study (Table 1). Subjects were in good general health with no history of back pain lasting longer than 3 days or any neurological condition that could affect motor control. Subjects were instructed to wear their corrective lens if their eyesight was impaired. Michigan State University's Biomedical and Health Institutional Review Board approved the research protocol and all subjects signed an informed consent form prior to testing. Subjects were tested on 2 days, separated by a minimum of 24 h.

2.2. Data collection

Fig. 1 depicts the components for a generic trunk motor control system. The plant, denoted by *P*, is a function of the plant parameters, which characterizes physical aspects of the subject (e.g., anthropometrics, trunk stiffness, trunk damping, etc.), whereas, the collection of control processes, denoted by *K*, is a function of controller parameters which represents the control logic for ensuring stable trunk behavior. The reference input and the disturbance input signals are denoted by $r(t)$ and $d(t)$, respectively; while the output signal of the system is $y(t)$. The error signal $e(t)$ represents the difference between the reference input and the output signals of the system (i.e., $e(t)=r(t)-y(t)$). For tracking tasks, the control objective is an output $y(t)$ that follows a time-varying reference input $r(t)$ such that $y(t)\rightarrow r(t)$ so that $e(t)\rightarrow 0$. For stabilization tasks, the control objective is an output $y(t)$ that rejects disturbances $d(t)$ and follows a constant reference input $r(t)=c$ such that $y(t)\rightarrow c$ so that $e(t)\rightarrow 0$. In both cases, the objective of the control system in Fig. 1 is to minimize error $e(t)$ for either a time-varying reference $r(t)$ or disturbance $d(t)$ input.

The trunk motor control system was assessed using one-dimensional position tracking and stabilization, and force tracking and stabilization tasks in the sagittal plane. Trunk position tracking and stabilization were performed using an experimental set-up that included a robotic platform (Mikrolar Rotopod R-3000, Hampton, NH) to apply disturbances to the pelvis, string potentiometers (Celesco

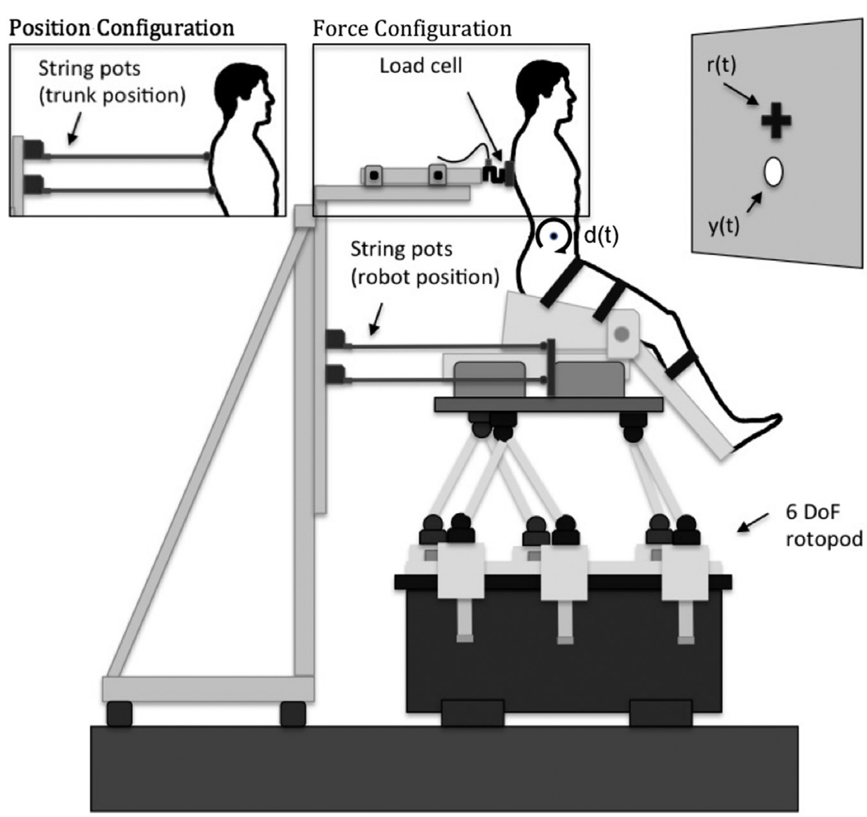

Fig. 2. Experimental set-up for trunk force tracking and stabilization tasks. Subjects were strapped to the robot seat such that the hip and knee angle were approximately 120°. This posture was chosen to allow subjects to maintain natural lordosis in the lumbar spine. Subjects were encouraged to maintain an upright posture and to avoid "slouching" during the trials. Subjects performed all tasks with their arms crossed in front of their body. Visual feedback for tracking tasks was provided from a monitor placed 1 m in front of the subject with the center of the monitor at eye height. For tracking tasks, the reference input signal $r(t)$ varied within a range equal to 60% of the full screen height, centered around the middle screen. This visual resolution was consistent for stabilization tasks and between days.