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Effects of work experience on work methods during dynamic pushing and pulling

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ABSTRACT

Pushing and pulling are potential risk factors for work-related low back disorders (WRLBDs). While several studies have evaluated differences in work methods related to work experience, such evidence for dynamic pushing and pulling is limited. Eight novices and eight experienced workers completed dynamic push/pull tasks using a cart weighted to 250% of individual body mass in two different configurations (preferred vs. elbow handle heights). Multiple measures [hand forces, torso kinematics and kinetics, and required coefficient of friction (RCOF)] were obtained to assess WRLBD and slip risks. Experienced workers generated higher medio-lateral hand forces, during both pulls and pushes, though with a more substantial difference during pushes (~74%), and which involved the use of hand force components other than to move the cart in an anterior-posterior direction. Experienced workers also had lower peak torso kinematics in flexion/extension and lateral bending, and lower torso flexion/extension kinetics. The latter is suggestive of a lower risk for WRLBDs, though levels of exposures to WRLBD risk were low to moderate in both groups and were often relatively small and inconsistent across the task configurations. Group-level differences in RCOF were quite small, indicating a comparable slip risk between the two groups. Thus, it was considered inconclusive whether the work methods used by experienced workers during dynamic pushing and pulling are advantageous regarding WRLBD and slip risks.
Relevance to industry: Distinct movement strategies (work methods) were used by novices vs. experienced workers during dynamic cart pushing/pulling tasks. Regarding WRLBD risks, however, the benefits of the motor control strategies adopted by experienced workers for such tasks were inconsistent and task specific.

1. Introduction

Work-related low back disorders (WRLBDs) continue to be important occupational problems, and which accounted for ~13% of all nonfatal occupational injuries requiring days away from work in the U.S. in 2010 (BLS, 2011). Manual material handling (MMH) in particular has been noted as an important risk factor (Kuiper et al., 1999). MMH tasks include lifting, lowering, pushing, pulling, and carrying. Of these, pushing and pulling has received relatively less attention (i.e., vs. lifting/lower), in relation to WRLBDs. Indeed, it is difficult to conclude that a clear causal pathway exists between pushing/pulling and WRLBDs, particularly given the relatively moderate levels of exposures involved as assessed by biomechanical measures (Roffey et al., 2010). Biomechanical exposures are probably main contributors to injury risk (Marras, 2000), though the specific pathways leading to WRLBDs are likely complex. Epidemiological evidence does indicate a potential association between pushing/pulling and WRLBDs (Hoozemans et al., 1998), and musculoskeletal control has been noted as an important aspect related to low-back injury risk (Preuss and Fung, 2005).

Work experience is of particular interest here, and which is often considered to lead to motor control strategies or work methods that are pre-programmed. However, the purposes of the strategies/methods used by experienced workers are currently unclear, particularly in terms of WRLBDs. Furthermore, mixed results have been reported regarding the specific differences in work methods related to experience in the context of lifting/lowering (for review, see Lee and Nussbaum, 2012). In brief, some studies have reported lifting techniques among experienced

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Table 1
Participant information (means (SD)), and results of *t*-tests comparing the novice and experienced groups.

	Age (yrs)	Experience (yrs)	Stature (m)	Body mass (kg)	Lumbar isokinetic strength (Nm)	
					Flexion	Extension
Novice	20.6 (1.1)	0.0 (0.0)	1.77 (0.08)	81.2 (12.1)	238.3 (92.5)	317.3 (65.0)
Experienced	20.9 (1.4)	2.7 (1.0)	1.78 (0.09)	79.8 (10.1)	231.3 (42.2)	312.3 (39.1)
Test result	$t = -0.41$	–	$t = -0.33$	$t = 0.26$	$t = 0.14$	$t = 0.26$
	$p = 0.69$	–	$p = 0.75$	$p = 0.80$	$p = 0.89$	$p = 0.80$

workers that appear protective (Authier et al., 1996; Gagnon, 1997; Keir and MacDonell, 2004; Marras et al., 2006), whereas others demonstrated that such benefits may be inconsistent or task specific (Granata et al., 1999; Lee and Nussbaum, 2012; Plamondon et al., 2010). Effects of experience have been also reported for a variety of other occupational tasks (Gregory et al., 2006, 2009; Madeleine et al., 2003; Madeleine et al., 2008; Pal et al., 2010). Some of these showed that work experience does not contribute consistently to reduced WRLBD risks (Gregory et al., 2006, 2009). Thus, the association between work experience and WRLBDs is likely to differ substantially between specific tasks or contexts.

Evidence regarding the effects of experience for dynamic pushing/pulling is limited. Chang et al. (2000) reported that experience acquired during five-days of practice in static pulling led to reduced lumbar moments, and Lett and McGill (2006) found that experienced firefighters used lower hand forces and lumbar torques during static pushing/pulling. However, static vs. dynamic pushing/pulling may result in different biomechanical demands and measures. For example, differences in peak or maximum acceptable hand forces between pushing and pulling depend on whether the tasks are static or dynamic (Hoozemans et al., 1998). To the authors' knowledge, no existing study has assessed the effects of experience on torso kinematic/kinetic measures related to WRLBD risks during dynamic pushes/pulls. Although a recent study reported the effects of experience on hand forces during dynamic pushing (Boyer and Lin, 2013), more direct relationships between experience and WRLBDs were not examined. The current study thus determined how work experience affects work methods used during dynamic pushing/pulling, as assessed by multiple biomechanical measures. We hypothesized that experienced workers would exhibit distinct work methods during dynamic pushing/pulling, as has been reported for static tasks (Lett and McGill, 2006). Identifying such differences may help guide future approaches to reduce WRLBD risks, such as a model for training novice workers (Gagnon, 2003; Lett and McGill, 2006).

2. Methods

2.1. Participants

Eight novices and eight experienced workers completed the study, with six males and two females in each group (Table 1). Participants reported no current or prior musculoskeletal disorders and completed informed consent procedures approved by the Virginia Tech IRB. Experienced participants were recruited from among workers currently in jobs requiring "frequent push/pull tasks", which were operationally defined as "involving pushing/pulling conducted 10 h/week on average". All experienced workers reported a minimum of 1.5 years of recent experience in such tasks. Novices were local student volunteers who reported no experience in frequent push/pull tasks, and were selected to achieve age matching (±two years), at the individual level, with the experienced workers.

2.2. Experimental protocols

Isokinetic, concentric lumbar flexor/extensor strength was measured initially to evaluate potential group differences in strength relevant to the experimental task. Maximum voluntary contractions (MVCs) were performed with a commercial dynamometer (Biodex System 3 Pro, Biodex Medical Systems Inc., NY, USA), and using a custom fixture that isolated (immobilized) the pelvis and lower extremities. Strength testing included initial warm-up and rest, and data collection during a minimum of five MVCs, interspersed with 2-min rest breaks to minimize potential fatigue. Concentric efforts were done at 120°/s, with a range of motion from 0° (upright) - 80° (torso flexion). These parameters were selected to obtain high reliability (Keller et al., 2001). Maximum torques were obtained for each participant, across MVCs, after accounting for gravitational effects on body segments and the dynamometer. Additional rest (>30 min) was provided after strength testing.

A cart (width = 76 cm; length = 124 cm including handles) was used for push/pull trials, which had two swiveling solid plastic (nearest the handles) and two non-swiveling pneumatic wheels. The cart was modified to allow for height-adjustable handles (Fig. 1). Pressure in each pneumatic wheel was controlled at ~70 kPa, and the cart mass was set to 250% of individual body mass. This cart mass was selected, in pilot work, to yield peak and mean hand force comparable with an earlier study (Lett and McGill, 2006), and to not exceed maximum acceptable force limits (50% ile) for ~2 m pushes (Snook and Ciriello, 1991). Several practice trials were completed before data collection, during which each participant indicated their "preferred" handle height.

Participants completed trials in four task configurations, involving pushing or pulling the cart with the handle set at their preferred or elbow height. The order of configurations was counterbalanced across participants using 4 x 4 Latin-squares. Following additional practice trials (10 pushes or pulls), participants completed three replications of a push or pull at the set handle height. Before each trial, the solid wheels were aligned parallel to the direction of motion. Similar to earlier work (e.g., Boyer et al., 2012; Park et al., 2012; Queen et al., 2006; Taylor et al., 1999; Wu et al., 2012), preferred work speeds were used, and no specific instructions were provided regarding work methods. Participants began the trials with each foot completely on one of two force platforms (see below), with a self-selected spacing. Participants moved the cart ~2 m (~three steps) in each trial, and actively stopped the cart at the end. Participants wore commercial athletic shoes with soles composed of relatively consistent materials.

2.3. Data collection and processing

Reflective markers were attached over anatomical landmarks as in Dumas et al. (2007) and to the cart, and tracked at 60 Hz with a 7-camera system (Vicon Motion System Inc., CA, USA). To improve accuracy in reconstructing joint centers and segmental kinematics, additional markers were attached over relatively immobile body parts as described earlier (Lee and Nussbaum, 2012). Bilateral