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The effects of a simple intervention on exposures to low back pain risk factors during traditional posterior load carriage

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ABSTRACT

Traditional posterior load carriage (PLC), typically performed without the use of an assistive device, is associated with a high prevalence of low back pain (LBP). However, there are few studies that have evaluated potential interventions to reduce exposures to LBP risk factors. This work examined the effects of a simple, potentially low-cost intervention using an assistive device (i.e., carrying aid) on exposures to factors related to LBP risk during PLC. Torso kinematics and kinetics, slip risk, and ratings of perceived discomfort (RPD) were obtained during simulated PLC on a walkway. Consistent with earlier results, increasing load mass substantially increased torso flexion and lumbosacral flexion moment, as well as RPDs in all anatomical regions evaluated. Using the carrying aid with a higher load placement resulted in substantially lower mean lumbosacral moments when carrying the heaviest load. In contrast, using the carrying aid with a lower load placement resulted in substantially higher torso flexion angles, higher mean lumbosacral moments when carrying heavier loads, and higher peak lumbosacral moments across all load masses. With use of the carrying aid, both higher and lower load placement resulted in significantly lower RPDs in the elbows and hands compared to the control condition. In summary, use of a carrying aid with higher load placement may be beneficial in reducing the risk of LBP during PLC. Future studies are needed, though, to improve the device design and to enhance external validity.

1. Introduction

Traditional posterior load carriage (PLC), which is most often performed without the use of an assistive device (e.g., backpack), has been associated with a high prevalence of musculoskeletal symptoms in several anatomical regions (Muslim and Nussbaum, 2015), including the most common symptom of low back pain (LBP). LBP, in particular, was reported to interfere with daily activities among nearly half of PLC workers surveyed. Substantial societal and personal burdens, including loss of wages and productivity, may later impact workers, as these outcomes have been commonly reported among industrial workers experiencing LBP (Galukande et al., 2006; Lubeck, 2003). Further, LBP has become the leading work-related medical problem worldwide (Kent and Keating, 2005; Loney and Stratford, 1999; Volinn, 1997). Specific task demands, related to the loads being transported, have been shown to influence the risk of LBP during PLC (Muslim and Nussbaum, 2016). For example, increasing load mass or size caused increased torso flexion, lumbosacral (L5/S1) flexion moment, and abdominal muscle activity. The combination of a heavier load mass and a larger load size caused larger increases in paraspinal muscle activity. These changes likely increase mechanical stress and localized muscle fatigue, and in turn can lead to a higher risk of LBP (Chaffin et al., 1999; Chansirinukor et al., 2001; Grimmer et al., 2002; Hodges and Richardson, 1996; Hong and Cheung, 2003; Kennedy et al., 1999; Knapik et al., 1996; Roy et al., 1990). Load mass and size during PLC also affected slip risk, though with a more complex relationship that may be substantially task dependent.

Limited evidence exists regarding efforts to evaluate potential interventions to reduce the risk of LBP related to traditional PLC. Existing studies on PLC tasks have been focused on assessments of physiological cost (Datta and Ramanathan, 1971; Lloyd et al., 2010b) and ratings of perceived discomfort (Lloyd et al., 2010a). Several relevant guidelines have been offered, though, to reduce injuries related to PLC tasks using a backpack. As examples, backpack load is

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suggested to be limited to 10–30% of individual body mass, depending on the limiting criteria and population (Hong and Cheung, 2003; Moore et al., 2007; Sander, 1979; Simpson et al., 2011), lower load placement should be avoided when carrying backpacks heavier than 15% body mass (Singh and Koh, 2009; Stuempfle et al., 2004), and others addressing specific aspects of backpack design (Harman et al., 2000, 2001; Xu et al., 2009). Our recent study also suggested that the use of light and small loads during PLC might be beneficial to reduce exposure to factors related to LBP risks (Muslim and Nussbaum, 2016). However, there may be practical barriers to reducing load mass and size, particularly regarding productivity. Therefore, this study examined a potential control that involves only minimal (or no) loss of productivity, by improving the method of carrying the load.

A distinctive characteristic of traditional PLC is that loads are transported without the use of an assistive device. The loads, which are commonly bagged items, are instead typically held/stabilized with the hands at the upper two corners of the bag, and the loads themselves are typically carried on the posterior trunk area (Muslim and Nussbaum, 2015). Using this method, varied load mass and size were found to cause substantial postural changes (Muslim and Nussbaum, 2016). For example, a more upright posture was adopted when carrying a smaller load, while a more forward leaning posture was adopted when carrying larger loads. This postural difference appeared to be related to different load placements used when carrying varied load sizes. A higher load placement, at the upper back and neck area, could be used when carrying smaller loads, though higher load placement is more difficult when carrying larger loads due to the vertical dimension. As such, redesigning the method to handle loads, by introducing the use of an assistive device, may help by allowing users to hold and support loads in locations that reduce physical demands. In fact, several PLC workers also suggested the use of an assistive device, such as a carrying aid, to improve the task (Muslim and Nussbaum, 2015). The specific purpose of this study was thus to examine the effects of a simple carrying aid during PLC, with different levels of load placement, on exposures to factors related to LBP risk. Risks of LBP were estimated using intermediary measures derived from torso kinematics and kinetics. In addition, perceived discomfort in several anatomical regions. It was hypothesized that the use of a carrying aid with higher load placement would lead to beneficial effects (decreases) in all of these measures.

2. Methods

2.1. Participants

Nine healthy male participants from the university and local community completed the study, whose respective mean (SD) age, stature, and body mass were 23.1 (3.0) years, 171.7 (5) cm, and 69.9 (7.2) kg. All participants reported being physically active and having no history of low-back pain or any current medical conditions that might have influenced the results. Males were used to match the typical population doing traditional PLC (Muslim and Nussbaum, 2015), and a relatively young group of participants was included to minimize potential injury risks. Prior to beginning the experiment, all participants completed informed consent procedures approved by the Virginia Tech Institutional Review Board.

2.2. Experimental design and procedures

A repeated measures design was used, in which each participant completed a single experimental session involving PLC simulated in a laboratory environment on a walkway. The session involved all combination of three loads and three PLC methods, as described below. The order of the conditions was counterbalanced across participants (using a 9 × 9 Latin Square). Torso kinematics, kinetics, slip risk, and ratings of perceived discomfort (RPD) were obtained during the session.

The session began with warm-up activities, RPD calibration procedures, and a set of PLC practice trials. Warm up involved light dynamic stretching involving the whole body. To calibrate participants to the RPD scale, each performed a wall-squat task; standing with back against a wall, feet on the floor, and knees bent at 90°. Participants held this posture while intermittently rating their level of perceived discomfort using an existing 10-point scale (Borg, 1982), until they reach RPD = 9. The goal of this activity was to have participants experience nearly the whole range of RPDs (Sood et al., 2007). Practice PLC trials were used to confirm that participants could complete load carriage tasks in all conditions, and to reduce subsequent learning effects within and between trials. Practice trials were also used to identify a starting position on the walkway, to ensure complete foot placement on a force platform during subsequent experimental trials.

Nine load carrying conditions were performed, formed from the factorial combination of three load sizes and three PLC methods. Specific loads were set based on individual body mass (BM), at 20 (20BM), 35 (35BM), and 50% (50BM). Industrial products, including rice, dog food, birdseed, sand, and metal pellets, were used to create the 20BM, 35BM, and 50BM loads, using different bags with respective (unpacked) areas of 30 × 50, 40 × 60, and 55 × 80 cm. Each load was carried using three different PLC methods, including the traditional PLC without the use of an assistive device (B0) and two "intervention" methods using a carrying aid with a higher load placement (B1) and with a lower load placement (B2: Fig. 1). A commercial frame (Deluxe Freighter Aluminum Pack Frame 574-F, StanSport, Los Angeles, CA) was used in this study as a simple carrying aid (Fig. 2), with the waist belt removed to simplify the design. To set the two load placements, the bottom support was moved and pinned into the appropriate location on the frame. The higher placement was set such that the bottom support was roughly at the mid-thorax (T7/T8), and the lower placement such that the support was at roughly waist height (L5). Participants were instructed to hold the top part of the frame to facilitate marker recording for the torso segment (described below). This backpack frame was intended only as a model/prototype of a carrying aid. More specifically, it was expected that subsequent application in the field would be achieved using cheaper materials such as bamboo or wood, but with consideration of the results of design aspects evaluated here.

Each of these nine conditions was replicated three times, in three load carriage trials (yielding a total of 27 trials). These were completed at roughly one carry per minute, and using a self-selected carrying pace over ~5 m on a flat walkway. A helper placed the load on the participant's back or carrying aid at the start and lowered the load at the end of each carry. Rest periods of 5 min, or more as needed, were provided between each condition to minimize residual effects of fatigue or discomfort.

Segmental kinematics data were recorded during PLC trials, using reflective markers attached bilaterally to the feet, shanks, hips, and torso, and based on anatomical landmarks described by Dumas et al. (2007). Marker positions were tracked at 120 Hz using a 6-camera system (Vicon Motion System, Inc., CA, USA). Ground reaction forces and moments were sampled at 960 Hz using two force platforms (OR6, 7-1000, AMTI, Watertown, MA) embedded in the walkway. Marker and force platform data were low-pass-filtered (bi-directional, 2nd order Butterworth) with respective cut-off frequencies of 6 and 12 Hz, and force platform data were subsequently down-sampled to 120 Hz to be consistent with the marker data. After completing the three trials in a given condition,