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Lifting strategies of expert and novice workers during a repetitive palletizing task

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ABSTRACT

Thirty manual material handlers (15 experts and 15 novices) were invited to perform series of box transfers under conditions similar to those of large distribution centers. The objective of the present study was to verify whether multiple box transfers leading to fatigue would also lead to differences between expert and novice workers in joint motions and in back loading variables (L5/S1 moments). The task consisted in transferring 24 15-kg boxes from one pallet to another (4 layers of boxes; 6 boxes/layer: 3 in the front row, 3 in the back) at a self-determined pace and then at an imposed pace of 9 lifts/min for a total of 240 lifts. The underlying idea was to set a challenging task that would force the experts to use their skills. Full-body 3D kinematic data were collected as well as external foot forces. A dynamic 3D linked segment model was used to estimate the net moments at L5/S1. The results clearly show that the experts bent their lumbar spine less (10° less) and were closer (4 cm) to the box than novice workers. Knee flexions were similar in both groups except when the box was lifted from ground level (expert ≈ 71°, novice ≈ 48°). The peak resultant moment was not statistically different (expert = 168 Nm, novice = 184 Nm) although experts had lower values on average than novices when lifting heights (and deposit heights) of the boxes increased. Therefore, experts differed from novice workers mostly in the posture-related variables. These differences are especially important to consider when the box is located on the ground, as the back posture and back loading are then at their greatest magnitude and could have a major impact on the distribution of internal forces on the spine.

1. Introduction

Manual material handling (MMH) involves considerable physical work demands and is considered a high-risk task for low back pain (LBP) (Hoogendoorn et al., 1999; Kuiper et al., 1999; Lötters et al., 2003; National Research Council, 2001; da Costa et al., 2010; Nelson and Hughes, 2009). Large spine loading sustained during MMH is a potential cause of low back pain (National Research Council, 2001). The risk increases with the magnitude of the physical exposure in terms of the load moment, trunk motion dynamics and trunk posture (Marras et al., 1993, 1995, 2000). There exists a large variability in low back loading and lifting posture that could be explained by individual differences (between subjects) and by trial-to-trial variations (Granata et al., 1999; van Dieen et al., 2001; Gagnon et al., 2002). Thus, for the same task, spine loading and posture can change markedly between trials and individuals. The study of different groups of workers (experts and novices) could help to reduce this variability and to develop new principles of good manual handling to decrease physical exposure.

Various intervention strategies, such as training employees in safe lifting techniques, are used with the aim of protecting workers from back injuries. Recent reviews have seriously questioned the effectiveness of training programs as a mean of reducing back injuries (Clemes et al., 2010; Demoulin et al., 2012; Haslam et al., 2007; Martimo et al., 2007, 2008; Robson et al., 2012; Verbeek et al., 2011). However, these reviews are based on a small number of studies, and the quality of the training intervention is generally not questioned. Important aspects such as the content of the training course, its duration and its specificity to the work context are worth consideration. Kroemer (1992) asked a simple question about training, namely "What to teach?" This question still needs to be answered. For instance, Demoulin et al. (2012) indicated that training content was not consistent among studies and that the

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training was generally given over a very short time; as a result, the "training" was more like an information session. When training is specific to the task and dispensed over a long time, a decrease in back loading is possible (Schibye et al., 2003), which could lead to fewer back injuries. From our point of view, current knowledge is not sufficient, and it is far from clear whether or not lifting training programs achieve the goal of reducing back injuries by teaching better lifting techniques. Further research is needed to determine the training needs (content) of different subject groups (Demoulin et al., 2012) and the value of training in reducing back injuries.

In the search for the best technique for training workers, different types of studies have been conducted. A first type of study is to instruct participants (generally novice workers) about the technique they should use during MMH, and to measure the effect. These studies have demonstrated the importance of technique in decreasing the horizontal distance between the L5/S1 joint and the load lifted in order to reduce the external back moment (Faber et al., 2009b, 2011; Kingma et al., 2004, 2006, 2010). A second type is to copy the technique used by expert (or experienced) workers. Ergonomic studies (Authier et al., 1995, 1996) have shown that expert workers use techniques—different from those of novices—that could be both safe and advantageous in terms of productivity, but their impact on back loading has not been assessed. Some studies have explored the experts' techniques such as foot movements, knee bending, the width of the base of support, lifting dynamics, and box lifting and tilting strategies (Delisle et al., 1996a,b, 1998, 1999; Gagnon, 2003). These studies have confirmed the value of these techniques in reducing back loading during the handling operation.

A third type of studies have been interested in determining the difference between experienced (or expert) and novice workers (Gagnon et al., 1996; Granata et al., 1999; Marras et al., 2006; Plamondon et al., 2010; Lee and Nussbaum, 2012, 2013) with the aim of applying experts' techniques to reduce back loading among novice workers. In one study (Gagnon et al., 1996), the most marked distinction was reduced knee flexion in experts, but the external back moments were not significantly different. Another study (Granata et al., 1999) showed that experienced workers underwent surprisingly greater and more variable lumbar loading (external moments and internal forces) than novice subjects. Conversely, Marras et al. (2006) showed that internal loading was greater for inexperienced subjects than experienced lifters over the course of an 8-hour workday and that biomechanical risk is greatly reduced with experience. Plamondon et al. (2010) found, during a low lifting task from a conveyor to a hand trolley, that although external peak L5/S1 moments were similar, the lifting posture of experts differed from novice workers, with the experts bending their lumbar spine less but bending their knees more. Recently, Lee and Nussbaum. (2012) indicated that experienced workers used lifting/lowering methods with significantly higher peak lumbar extensor accelerations and lumbar moments. Peak flexion/extension angles and velocities were also higher (not significantly) among experienced workers, putting them at higher risk of back disorders. On the other hand, Lee and Nussbaum (2013) in a subsequent paper suggested that the higher torso kinematics and kinetics observed among their experienced workers had the advantage of keeping them in better balance and giving them more torso movement stability compared to the novices.

There is not yet a clear understanding of the advantages/disadvantages of using expert techniques to train workers with the aim of reducing back loading and back injuries. A possible reason why there are such differences between studies could be that the definition of an expert in MMH is not known. How do we classify a worker as an expert? Years of experience is often used to identify people as experts (Farrington-Darby and Wilson, 2006) but is it the only valid criterion? Authier et al. (1993) suggested other criteria such as the recognition of co-workers and few lifetime back injuries. Moreover, what about the selection of novice workers? Their level of skill can vary widely, from "naivette" (one who is completely ignorant about a domain) to "apprentice" (one who is learning about a domain) (Farrington-Darby and Wilson, 2006). As suggested by Lee and Nussbaum (2012), more studies are needed to assess the utility of training based on the techniques of experienced (expert) workers.

The choice of task and its difficulty are also critical since expertise is likely task-specific. Faber et al. (2011) showed that a typical laboratory simulated lifting task as opposed to a more realistic one could give different results. In addition, according to Farrington-Darby and Wilson (2006), tasks that are unfamiliar or so simple that the experts cannot use any of their specific skills or too difficult for novices are potential sources for misleading findings. The degree to which the task is meaningful, challenging and familiar contributes to task realism (Farrington-Darby and Wilson, 2006). The study of Plamondon et al. (2010) presented the results of a specific task that was not very strenuous: transferring boxes from a conveyor to a hand trolley, with frequent rest periods to prevent fatigue. The present study aimed to investigate if a more challenging task of multiple depalletizing–palletizing, bringing fatigue into play, would make experienced workers' strategies differ more clearly from those of novices. In this challenging task, the workers had to continuously transfer 24 15-kg boxes five times from one pallet (depalletizing) to another (palletizing) at two different lifting frequencies: self-paced and imposed pace (9 lifts/min). Only a few studies (Davis et al., 1998; Marras et al., 1997, 1999; Jorgensen et al., 2005) have addressed either the depalletizing or the palletizing task without restricting their workers. The objective of the present study was to verify whether multiple box transfers leading to fatigue would also lead to differences between expert and novice workers in joint motions and back loading variables (L5/S1 moments). A secondary aim was to evaluate the effect of box height and distance on back loading during the repetitive depalletizing-palletizing task. This research is original as both the subjects (experts vs novices) and the repetitive nature of the task have rarely been studied.

2. Method

The study was divided into three experimental sessions. The first was a session during which the subjects were familiarized with the different experimental procedures and some physical capacity parameters (strength and endurance) were measured. The second session specifically studied the continuous transfer of boxes from one pallet to another, which is the subject of the present paper. The third session consisted in studying the effect of expertise during transfer of a box from a conveyor to a hand trolley as published earlier (Plamondon et al., 2010). Most of the sections below, except for the task description, present (with some new elements) the main steps in the method used, which has already been described in detail (Plamondon et al., 2010).

2.1. Subjects

Two groups of male subjects were recruited. The first group consisted of 15 expert workers who met the following three criteria: a minimum of 5 years of experience; a low lifetime incidence of injuries (particularly to the back); and no injury in the year preceding the study. A fourth criterion, in which the expert has to be recommended by either his peers, the union or management (Farrington-Darby and Wilson, 2006), was included but it was not possible to check its application. Ten experts were recruited from