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Ergonomic identification and biomechanical evaluation of workers' strategies and their validation in a training situation: Summary of research

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Abstract

Our goal was to evidence the role of workers in the search for safer manual handling strategies. Different strategies used by expert and novice workers, such as footwork (positioning/displacement), box manoeuvres (handgrips and load tilting) and posture were ergonomically identified. They were biomechanically evaluated to shed light on their potential for safe handling by reducing back loadings, back asymmetries and mechanical work requirements. The experts' strategies were validated in a training situation and evaluated by two independent studies among novice workers. The first, a control study, showed that free practice did not lead to safer handling practices. The second, a training situation based on observing contrasted performances of experts and novices for footwork, box manoeuvres and back posture, when combined with practice and the search for optimal solutions, prompted the novices to adopt new ways of manoeuvring boxes and positioning themselves that appear safer for back efforts, asymmetries, and mechanical work. These elements should be included in educational programs for safe handling.

Relevance

The observation of contrasted strategies of expert and novice workers using an ergonomic approach, supplemented by biomechanical evaluations of these strategies, is a key factor in designing training programs for safe handling.

Keywords: Training; Handling strategies; Safety; Expert and novice workers; Biomechanics

1. Introduction

Training in safe handling techniques is recommended as a way to reduce risk factors in the working environment. However, training programs have not so far led to substantial reductions in musculoskeletal problems, especially back injuries, perhaps owing to inadequate training methods (St-Vincent et al., 1989) and their inadaptability to a variety of tasks, workplaces and workers (Sedgwick and Gormley, 1998). A broad consensus of opinions favours the promotion of sound mechanical principles; however, they do not appear to be easily applicable to the range and complexity of manual handling situations. Integrating theory with practice and evidence-based practice have been identified as potential influences on the effectiveness of manual handling education (Gray and White, 2004).

Two potential solutions could be to design more valid biomechanical experiments for handling tasks and to develop training programs based on expert workers' knowledge of their jobs. Biomechanical analyses have several drawbacks as to the validity of experimental tasks. In fact, to improve data reliability, researchers often control workers' performance in a way that may alter its validity—e.g., restrictions of feet displacements on small force plates, use of handles on experimental

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boxes (when field studies have shown they are seldom utilized) or limiting analyses to lifting in a single plane (sagittal). Training methods may also be called into question, especially teaching techniques that focus on specific instructions such as leg lift (squat) rather than back lift (stoop), weight distribution on both legs (Nygård et al., 1998), straighter trunk postures (Nussbaum and Torres, 2001) or use of a back lordosis (Schenk et al., 1996). Even if these elements are acquired, their long-term effect in reducing back injuries may be limited. An investigation into the performances of workers themselves is one way to remedy these shortcomings, the assumption being that expert workers are best qualified to provide key elements for safer handling strategies.

This study has three specific objectives: To ergonomically identify the different strategies used by expert and novice workers (Section 2); to biomechanically evaluate these strategies for their safety potential (Section 3), and to validate experts' strategies in a training situation by determining whether novices could learn them and thus improve safety conditions (Section 4).

2. Identification of workers' strategies using an ergonomic approach

Little literature is available on the characteristics of expert and novice workers in industry. The quantity of manual handling tasks and the complexity of environmental conditions make identifying their strategies a challenge. It was hypothesized that comparing experts with novices would help identify some fundamental elements for safe manual handling practices, which could further be evaluated for safety by biomechanical methods. Experts were therefore compared with novices in varied handling conditions (weights, positions in height and depth, loading/unloading carts), using an ergonomic approach (Authier et al., 1995, 1996).

The workers studied were six experts with a transportation firm and five novices hired as part-time workers in different handling jobs. Questionnaires administered to fellow workers and managers first identified a pool of workers as those having the best handling skills. Only workers with at least 10 years' experience (average: 20 years) who were free from back and shoulder musculoskeletal problems were retained. Accident data analyses interestingly revealed a lower annual rate of handling accidents among these experts (0.13 accident per worker per year vs. 0.83 for the entire firm). The novices had to have at least three months' handling experience (average: 0.7 month). The groups were differentiated as to age (average: 40 years for experts and 23 for novices), but were similar in terms of body mass, height and maximal trunk strength (Gagnon et al., 1996).

Each group presented important ergonomic differences, especially as concerned load manoeuvres (tilts, handgrips) and footwork (feet orientation and steps) (Authier et al., 1995, 1996). Interestingly, these elements do not appear to have been biomechanically studied. The experts used the following strategies: they favoured diagonal handgrips with one or both hands on the box corner(s), in conjunction with box tilting; at take-off, they orientated the pelvis, supporting foot and the load towards the deposit area; they moved taking several short steps, with the load tilted and remaining tilted at deposit; and they avoided large knee flexion at take-off and deposit. In contrast, the novices used diagonal handgrips less often but more often positioned one hand on the face of the box; they seldom tilted the box; they more frequently faced the take-off area rather than the deposit and often took few but large steps; and, they also flexed their knees more.

These were the most common characteristics observed. However, both groups also used a wide range of handgrips and load tilts, reflecting the initial height of load and its weight (Authier et al., 1995). These observations confirm that one single technique cannot provide an optimal response for a variety of situations. Instead, workers have to constantly adapt to varying situations.

It is unlikely that strategy differences can be explained by height, weight or muscular strength, since these factors were similar for both groups. While other characteristics such as age may have influenced the results, it is difficult to predict how they could influence handling strategy choices. Strategy differences should mainly be explained by experience. The lower accident rate among experts reported earlier might also be an indication that they adopted safer handling practices. Experts' strategies thus appeared to present a potential for safety that merited further analyses. The next objective was to evaluate the experts' and novices' strategies for their safety content using biomechanical methods.

3. Biomechanical evaluation of workers strategies

Since footwork and box manoeuvres were the two main differential elements characterizing experts' and novices' strategies, the challenge was to evaluate their safety aspects. Evaluating safety is a complex procedure: low back problems are multi-factorial and there is lack of consensus about their mechanical causes. However, overexertion, repeated loadings and trunk torsion support the role that mechanical malfunction plays in back problems (Hsiang et al., 1997). Thus, the safety criteria most often used in biomechanics include low back loadings and stresses in the soft tissues, asymmetry of back posture and mechanical work or energy requirements. Our analyses partly referred to these criteria.

Low back (L5/S1) loadings were evaluated using net moments, either with a 2D or a 3D model for estimating