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Effectiveness of powered hospital bed movers for reducing physiological strain and back muscle activation

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ABSTRACT

Battery powered bed movers are becoming increasingly common within the hospital setting. The use of powered bed movers is believed to result in reduced physical efforts required by health care workers, which may be associated with a decreased risk of occupation related injuries. However, little work has been conducted assessing how powered bed movers impact on levels of physiological strain and muscle activation for the user. The muscular efforts associated with moving hospital beds using three different methods; powered StaminaLift Bed Mover (PBM1), powered Gzunda Bed Mover (PBM2) and manual pushing were measured on six male subjects. Fourteen muscles were assessed moving a weighted hospital bed along a standardized route in an Australian hospital environment. Trunk inclination and upper spine acceleration were also quantified. Powered bed movers exhibited significantly lower muscle activation levels than manual pushing for the majority of muscles. When using the PBM1, users adopted a more upright posture which was maintained while performing different tasks (e.g. turning a corner, entering a lift), while trunk inclination varied considerably for manual pushing and the PBM2. The reduction in lower back muscular activation levels may result in lower incidence of lower back injury.

1. Introduction

1.1. Background

Work related injuries are a major cause of preventable pain and disability that impacts on a significant portion of the general population (Bureau of Labor Statistics, 2010). Most occupational physical injuries can be prevented by identifying and removing causes, or by reducing people's exposure, such as replacing manual force exertion with mechanical force (Haviland et al., 2010). Research indicates that making changes to workplace design is an effective way to prevent manual handling injury (Snook and Ciriello, 1991; Waters et al., 1993).

Within the hospital environment there has been a long established association between the manual handling of patients and resulting occupational injuries (Burdorf and Sorock, 1997; Hoogendoorn et al., 1999). Health care workers experience one of the highest incidence rates of work-related musculoskeletal disorders with 293 per 10,000 workers recorded in the United States of America in 2006 (Bureau of Labor Statistics, 2006). In particular, lower back pain among health care workers has been identified as a significant issue with an increased risk of injury compared to other professions (Colombini et al., 1999; Jang et al., 2007; Smedley et al., 2005; Waters et al., 2007). Ando et al. (2000) conducted a questionnaire on 314 full time nurses and found that over half experienced some degree of back pain in the previous month. Retsas and Pinikahana (2000) reviewed manual handling injuries in an Australian hospital and identified that75.9% of injuries reported were back injuries. Due to an ageing workforce the costs associated with low back pain are increasing per incidence in different workforces (Wasiak et al., 2006).

Health care workers have rated moving hospital beds as one of the top physical tasks for complaints of musculoskeletal pains (Ando et al., 2000). Traditionally hospital beds have been manually pushed by experienced ward staff and nurses. However, in recent years battery powered bed movers have become increasingly common. This is likely due to the evolving occupational health and safety requirements of hospitals. The aim of the powered bed movers is to facilitate the safe movement of beds and patients by health care workers. Hospitals have purchased powered bed movers with the aim to reduce overall workload for staff and simplify the task of moving beds or patients between wards, departments, or to and from theatre. This allows staff to direct more focus on the needs of the patient. Additionally, only one person is

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required to safely transport a hospital bed when a powered bed mover is used while procedures recommend that two nurses are present for manually transporting a hospital bed.

While extensive research has been conducted on the impact of manual lifting and carrying tasks (Retsas and Pinikahana, 2000; Snook and Ciriello, 1991; Waters et al., 1993), including modelling the impact of body positioning and posture (Wagner et al., 2010; Waters and Garg, 2010), less work has assessed the effect of different loads for pushing and pulling tasks (Hoozemans et al., 2002), in particular studies assessing the movement of hospital beds. One of the earliest studies on pushing and pulling tasks was completed by Snook and Ciriello (1991) who conducted multiple manual handling experiments to develop maximum acceptable weights and forces for pushing and pulling tasks. Ciriello et al. (2001) later established maximum dynamic pushing forces for high and low coefficient of friction floors based on psycho-physiology; although of particular interest for bed pushing in a clinical environment, their study did not represent the complexity of floors in hospitals. In addition to the cited psycho-physiologic studies, Knapik and Marras (2009) established maximum pushing and pulling forces based on biomechanical calculations of lumbar spine loading. Significant research on pushing and pulling has been through the development of standards ISO 11228 Part 2 (International Standards Organization, 2005) and EN 1005-3 (European Committee for Standardization, 2009). Schaub et al. (2007) assessed the muscular capabilities and workload of flight attendants for pushing and pulling aircraft trolleys. Force limits were developed for the target population using international and national German standards (e.g. ISO 11228-2, EN 1005-3). However, their recommendations are limited to the subject population and work environment assessed in the study. Similar limitations are reported by Hoozemans et al. (2004), who applied a biomechanical model to investigate shoulder and lower back forces when pushing and pulling. They concluded that cart weight and handle height substantially affected the mechanical load at the lower back and shoulder and recommended that low cart weights are maintained and designed so that it is possible to push or pull at shoulder height.

Al-Eisawi et al. (1999) found the mean horizontal anterior-posterior hand force of 281N to be highest when force was applied at knuckle level for pushing a cart of 181 kg. Pull forces were moderately higher than push forces. When comparing their results with established psychophysical limits (Snook and Ciriello, 1991) males were comfortably within their maximum acceptable limits, while females were around their maximum acceptable forces when handling the 181 kg cart with 15.24 cm diameter wheels on a carpet tiled floor.

Bennett et al. (2011) assessed muscle activity during pushing and pulling of a 250 kg payload. Of the upper body muscles assessed the erector spinae reported the highest %MVC (13–16%). Lee et al. (2012) also investigated muscle activity levels focussing on trunk rotator muscle activity when turning a loaded cart (200 kg) under different conditions. Results exhibited positive effects of anticipatory muscle activation and planned motion control. They also reported that the electrical activity of rotator muscles were about 15%MVC for an unexpected sharp turn compared to $<5\%$ MVC for straight pushing and gradual turns. This work also established a relationship between exerted hand forces, task demands, trunk posture in the medio-lateral plane and trunk rotator muscle activity.

In addition to muscle activation levels and forces, acceleration and trunk inclination are affected by different manual material handling devices (Lee et al., 2012; Tveit et al., 1994). The design of handle heights substantially affects both muscle activation levels and trunk inclination (Lee et al., 2011b). Trunk inclination and the position of the spine impacts on spinal forces, intradiscal pressure and lever arm lengths (Lee et al., 2012; Tveit et al., 1994).

In the hospital environment, most manual materials handling studies focus on patient transfer, and associated lumbar spine loading; an overview of the related literature can be found in Marras et al. (2009). Kim et al. (2009) investigated hospital bed design features and their effect on physical demands, and concluded that braking and steering assistance features of beds would improve health care worker task demand and associated trunk flexion.

Despite the increase in the use of powered bed movers, little research has been completed to quantitatively evaluate the physiological differences between manually pushing a hospital bed and using the new power augmented alternatives. Blewett et al. (2006) examined the use of a powered bed mover to compare forces used to initiate and maintain movement to manual pushing. Force gauges measured operational forces for two beds and found significant differences in the force required to move the bed manually compared to the powered bed mover. Forces required were 150–200 N on a vinyl floor and 450–1200 N on carpet while the force to initiate the powered bed mover with a joystick control was less than 20 N.

It remains unclear which muscles are put under the greatest strain when manually pushing a hospital bed and how these loads may be altered through the use of a powered bed mover. Understanding how a powered bed mover impacts on the user relative to manual pushing is critical as increased physiological and mechanical strain on the body increases risk of injury (Burdorf and Sorock, 1997).

1.2. Study aims

The primary aim of the study was to compare the muscular efforts required to move a hospital bed using three different methods; powered StaminaLift Bed Mover (PBM1) (Fig. 1a), powered Gzunda Bed Mover (PBM2) (Fig. 1b) and manual pushing. The study also aimed to identify the effects that particular movements (e.g. turning a corner, entering the lift) had on muscle activation levels. Lastly, the study aimed to compare trunk inclination and acceleration while pushing the hospital bed using the three different methods.

2. Material and methods

All procedures conducted in this study complied with ethics approval granted by the Flinders University Ethics Committee (approval number 322/10). The study was undertaken at the Flinders Medical Centre (Adelaide, Australia) enabling the study to be conducted within a realistic and representative hospital ward environment.

2.1. Bed moving methods

Two powered bed movers (PBM1, PBM2) were included in the study. PBM1 was the StaminaLift 2100 series (*StaminaLift, Adelaide*) which is powered by two variable drive DC electric motors and is operated with a joystick control. The joystick control is located in the midline of the bed mover and can be operated at heights of 90–110 cm above floor level by adjusting the main handle. The PBM1 is able to be loaded to 500 kg. The PBM2 was the Electrodrive Gzunda model G2 (*Gzunda, Melbourne*) which is operated with a 'twist grip' throttle and can also be loaded to 500 kg. Twist grip throttles are positioned as left and right handles for the bed mover and are fixed at ~100 cm above floor level. While PBM1 showed a two wheel drive acting at the rear end of the bed due to its compact design, and a single rearward wheel steering concept, PBM2 used a single wheel drive acting at the centre of the bed, with two rearward