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Effectiveness of Powered Hospital Bed Movers for Reducing Physiological Strain and Lower 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; manual pushing, StaminaLift Bed Mover (SBM) and Gzunda Bed Mover (GBM) 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 SBM, 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 GBM. The reduction in lower back muscular activation levels and the load reducing effect of a more upright posture may result in lower incidence of lower back injury.

Keywords. Hospital bed mover, occupational injury, muscle strain

‘Highlights’
We quantify muscular effort required to move hospital beds using powered and manual methods

- Powered bed movers reduce lower back muscle activation levels compared to manual pushing
- Powered bed movers can improve posture while transporting patients

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 to them (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). Healthcare 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; Smedley et al., 2005; Waters et al., 2007; Jang 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 that 75.9% 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 orderly 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 healthcare 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 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 (Waters et al., 1993; Retsas and Pinikahana, 2000; Snook and Ciriello, 1991), 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). One of the earliest studies 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. The majority of research on pushing and pulling has been through the development of standards like ISO 11228 Part 2 (International Standards Organization, 2005) and EN 1005-3 (European Committee for Standardization, 2009). Schaub et al. (2007) completed a significant study assessing the muscle 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). However, their recommendations are limited to the subject population and work environment assessed in the study.

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 (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; SBM (powered) (Figure 1), GBM (powered) (Figure 1) 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 cervico-thoracic inclination and acceleration while pushing the hospital bed using the three different methods.
2. Method

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 Powered Bed Movers

Two powered bed movers were included in the study. The SBM 2100 series (StaminaLift, Adelaide) 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 SBM has the capacity to push 500 kg. The Electrodrive GBM model G2 (Melbourne, Australia) is operated with a ‘twist grip’ throttle and also has the capacity to push 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. The SBM and GBM are able to move a hospital bed up and down ramps, over varied floor coverings (e.g. carpet), into lifts and around tight corners. The ability for both bed movers to push such heavy loads makes it possible to safely move even bariatric patients.

2.2 Subjects

Six male subjects (aged 22-48 years) were recruited from the participating research institutes (3 from University of South Australia, 3 from Flinders University). The median age for the subject was 27 years old. Table 1 describes the subject characteristics including age, height and weight.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>29.5 ± 9.3</td>
<td>177.8 ± 3.7</td>
<td>80.9 ± 7.9</td>
</tr>
</tbody>
</table>
2.3 Test Sequence

To provide proper familiarisation with the task and to avoid cross-talk between the muscle activation patterns for the 3 methods, the study was carried out on 6 different days (2 days per week x 3 weeks). Subjects were split into two groups with three testing sessions conducted for each group (one for each bed moving method). Trials for each bed moving method were held one week apart. Trials were measured early morning and early evening, with subjects 1-3 always measured in the evening and subjects 4-6 always measured in the morning. Data collection was conducted at these times to account for daytime dependent factors and also avoid peak traffic periods in the hospital. This helped to reduce uncontrollable noise that may have impacted on the validity of the data and require the subsequent rerunning of the trials. Subjects were required to undergo separate training sessions for each of the bed moving methods prior to the relevant testing session.

All subjects were provided with extensive training for each bed moving method the week prior to data collection. Conducting the training a week before testing prevented fatigue from impacting on the results.

2.4 Session Protocol

Each subject was fitted with a series of Noraxon self-adhesive Ag/AgCl dual snap electrodes for the purpose of measuring muscle activity, with positional data and acceleration also measured (sEMG, inclinometer and accelerometer). The Noraxon TeleMyo DTS wireless system (Noraxon, Scottsdale AZ) was used for data acquisition purposes. The EMG electrodes were located at seven key anatomical positions including the trapezius, latissimus dorsi, erector spinae (ES), external oblique, internal oblique, biceps femoris and medial gastrocnemius muscles. Both the left and right side of the body were measured.

The study also used one inclinometer at the thoracic spine (T5) to measure trunk inclination in two directions and one accelerometer at the cervical spine (C7) to measure spinal acceleration in x/y/z-directions. Figure 2 illustrates some of the test electrodes fitted to a subject.

![Figure 2: Test subject fitted with test electrodes.](image)
To establish a reference sEMG signal that corresponded to maximum voluntary isometric contraction (MVC), each subject performed a series of standardized tests which were demonstrated and practiced prior to data collection. Three repetitions lasting five seconds were completed for each MVC test in order to provide multiple opportunities for the subject to record a maximum voluntary isometric contraction. Data were checked for outliers/missing values prior to the bed moving trials. The MVC measurements were then used to determine the percent maximum voluntary isometric contraction (%MVC) during the bed moving trials.

Subjects were then required to move a hospital bed with an 80kg payload (four 20kg weights evenly distributed along the length of the bed to represent an average patient) from one ward to another along a standardized route at the Flinders Medical Centre. Eleven time intervals were analyzed (Table 2).

Table 2: Eleven individual time intervals assessed covering a range of different movements and variables.

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Straight walk</td>
<td>Start and walk along corridor on level 6 (carpeted floor)</td>
</tr>
<tr>
<td>2</td>
<td>Left corner</td>
<td>90° left turn and stop near lift (carpeted floor)</td>
</tr>
<tr>
<td>3</td>
<td>Enter lift</td>
<td>90° left turn to enter lift (vinyl floor)</td>
</tr>
<tr>
<td>4</td>
<td>Exit lift and ‘S’ turn</td>
<td>90° right turn to exit lift and 30° ‘S’ turn on level 2 (vinyl floor)</td>
</tr>
<tr>
<td>5</td>
<td>Straight walk</td>
<td>Straight walk on corridor (vinyl floor)</td>
</tr>
<tr>
<td>6</td>
<td>3 point turn</td>
<td>180° turn in a 90° corridor (vinyl floor)</td>
</tr>
<tr>
<td>7</td>
<td>Straight walk</td>
<td>Straight walk along corridor (vinyl floor)</td>
</tr>
<tr>
<td>8</td>
<td>‘S’ turn until stop</td>
<td>30° ‘S’ turn and stop near lift (vinyl floor)</td>
</tr>
<tr>
<td>9</td>
<td>Enter lift</td>
<td>90° right turn to enter lift (vinyl floor)</td>
</tr>
<tr>
<td>10</td>
<td>Exit lift and corner</td>
<td>90° right turn to exit lift and 90° right turn on level 6 (vinyl/carpeted floor)</td>
</tr>
<tr>
<td>11</td>
<td>Straight walk</td>
<td>Straight walk on corridor until the end of the route (carpeted floor)</td>
</tr>
</tbody>
</table>

This allowed the impact of the different variables such as a lift, floor coverings and different turns to be assessed. Comparisons could then be made between the different bed moving methods for a number of variables experienced within a hospital environment. Subjects were given an opportunity to practice the route prior to data collection. Three trials were completed by each subject using the relevant method (e.g. manual pushing) for that testing session. An observer continuously monitored each trial to determine if any outstanding environmental events (such as another hospital bed blocking the route) impacted on the data. Data were checked for outliers/missing data prior immediately after each trial to ensure the values were realistic and the difference between the right and left side of the body were credible. If required trials were rerun to ensure quality data was captured.
2.5 Data Processing

Post processing was performed on the data using Noraxon software (MyoResearch XP Master Edition 1.07.52). All raw EMG data were filtered using a Bandpass filter with the low frequency set at 18 Hz, a high frequency of 500 Hz and a window set at 301 points. The data were then rectified to achieve positive amplitude curves and smoothed using the root mean squared algorithm with a window of 50 ms to obtain a moving average. The data acquired from the bed moving trials were then normalized to peak values identified in the MVC tests. Peak values were established by taking the highest mean amplitude over the highest signal portion. The time window used to normalise the MVC was 500 ms. This process provided the %MVC, a valid measure for comparing the three bed moving methods.

Inclination and acceleration did not require processing prior to analysis. Inclination was reported in degrees with zero representing a completely upright posture. Positive values indicated the subject was leaning forward. Acceleration was reported in m/s.

2.6 Statistical Analysis

One-way ANOVA was used to determine whether significant differences existed between bed moving methods. The dependent variable was the muscle activity of a particular muscle (e.g. right internal oblique), inclination or acceleration while the independent variable was the bed moving method (e.g. SBM). The error level was set at 0.05.

3. Results

3.1 Statistical significance

All measurements reported significant differences (p < 0.05) between some bed moving methods with the exception of the right trapezius muscle. Muscle activation levels for the SBM were significantly lower than manual bed pushing for eight muscles (p < 0.0001 to 0.011) while the GBM showed significantly lower muscle activation than manual bed pushing for 11 muscles (p < 0.0001 to 0.04). Seven of the 16 measurements reported significant differences between all three methods.

3.2 Relative muscular strain (%MVC)

Figures 3 and 4 illustrate the relative muscular strain (%MVC) for each bed moving method. The mean and standard deviation of all subjects for each method are shown. The SBM reported the lowest %MVC for over half (8/14) of the muscles. The GBM reported the lowest %MVC for four muscles while manual pushing only reported the lowest %MVC for two muscles, one being the right trapezius which was not significantly different to powered bed movers. Conversely manual pushing produced the highest %MVC values for almost three quarters (10/14) of muscles assessed. When comparing the two powered bed movers, almost three quarters (10/14) of muscles had lower activation levels for the SBM.
Figure 3: %MVC for the left and right trapezius, latissimus dorsi, external oblique and gastrocnemius muscles. The mean and standard deviation is shown for each measurement. *Difficulty in obtaining the maximum values for the gastrocnemius resulted in %MVC values which are arguably higher than expected. However, comparisons between the bed moving methods can still be made as the same protocol was followed between each session.

Figure 4: %MVC for the left and right internal oblique, lower ES and biceps femoris muscles. The mean and standard deviation is shown for each measurement.
3.3 Inclination and Acceleration

Inclination was significantly different between the three methods. Figure 5 illustrates inclination across the 11 different intervals (e.g. turning a corner, entering a lift). When subjects used the SBM they maintained a more upright posture with very little variation throughout the 11 intervals (9.7 ± 0.3°). In contrast to this manual pushing (20.4 ± 2.6°) and the GBM (16.9 ± 1.9°) resulted in greater trunk flexion and much more varied values between the different intervals.

![Figure 5](image)

*Figure 5: Inclination for each of the three bed moving methods (manual pushing, SBM, GBM). Zero represents an upright posture.*

Acceleration data for manual pushing was not included in the analysis due to artefacts. The SBM resulted in significantly lower levels of acceleration (0.034 ± 0.11 m/s) than GBM (0.61 ± 0.17 m/s); however, the acceleration for both bed movers was low. As expected, the acceleration levels were varied across the eleven intervals due to the different tasks undertaken throughout the trials.

4. Discussion

4.1 Major findings

The use of a power bed mover in a hospital environment results in significantly lower muscle activation levels when compared to manual pushing. When assessing individual intervals this result becomes more pronounced. For example, turning left caused the activity of the left latissimus dorsi to differ considerably between the three methods. Manual pushing spiked above 20%MVC, the GBM increased to between 10-15%MVC while the SBM remained at about 5%MVC. Similar findings are reflected with the right latissimus dorsi when turning right corners with manual pushing peaking above 25%MVC. These
changes may be due to the three different techniques of controlling movement. In order to
turn a corner, manual pushing was completely reliant on the force produced by the user
while the GBM required some exertion as the ‘twist grip’ throttle did not assist sideways
movement. The SBM uses a joystick control and only required the user to move their
thumb to facilitate a turn which resulted in the lowest %MVC for this type of movement.

Lower back pain is common for musculoskeletal disorders amongst health care workers
and has a significant impact on work productivity levels (Wenig et al., 2009; Freburger et
al., 2009). Both powered bed movers reduced activation levels of the lower ES compared to
manual pushing (Left: 7.9 ± 1.4%MVC, Right: 9.8 ± 2.4%MVC). Furthermore, the SBM
(Left: 5.2 ± 2.5%MVC, Right: 6.1 ± 2.6%MVC) had significantly lower activation levels
for the lower ES when compared to the GBM (Left: 6.2 ± 1.4%MVC, Right: 7.6 ±
1.0%MVC). Lower activation levels of the lower ES may result in reduced incidences of
lower back injury when moving hospital beds in the hospital environment. However,
future research is required to determine whether this is the case.

When using the SBM, the user adopted a more upright posture across all tasks (e.g.
entering a lift, turning a corner). One reason for this may have been due to the increased
effort required by the other two methods for tasks like turning corners. Users of the SBM
are able to manipulate the bed with a simple joystick control while the other two methods
required increased physical exertion. This increase in muscle activation levels likely caused
the increase in forward inclination and the higher variability between the different tasks.
Maintaining a more upright posture can result in a load reducing effect on the body with
spinal bending in the sagittal plane identified as a risk factor for lower back injuries
(Waters et al., 1993; Punnett et al., 1991).

4.2 Limitations and Future Research

The primary limitation with this study was the subject population. Ideally it would have
been beneficial to recruit hospital orderly staff that are experienced with the use of powered
bed movers and are required to move hospital beds as part of their daily work tasks. This
was considered but deemed unfeasible for multiple reasons such as orderly staff already
overworked and health services stretched without the implementation of this study. To
reduce the potential impact of not using orderly staff, all subjects were provided with
extensive training for each bed moving method prior to data collection. Ideally a higher
number of test subjects from both sexes would have been recruited.

It would be highly beneficial to conduct further research into the effects of powered bed
movers. Further research should aim to determine whether there is a relationship between
the use of these devices and an associated reduction in workplace injuries. Hospitals often
designate specific orderly staff to the role of moving beds for a large portion of their
working shift. Calculating the relative muscular strain over an entire working shift would
allow overall workload dose to be measured which could then be compared with
recommendations for manual materials handling (Ciriello et al., 1990; Jung and Jung, 2001).
Other factors that could be considered include quantifying the differences in muscular
strain for abrupt movements (e.g. stopping suddenly to avoid a collision), differences
associated with age and gender, and differences due to the designs of powered bed movers.

5. Conclusion
In the present study, it was identified that powered bed movers produced substantially lower muscle activation levels when compared to manual pushing. Manual pushing was affected more than powered bed movers when increased exertion was required for tasks like turning a corner. Importantly the powered bed movers produced lower muscular strain for the lower back with SBM reporting the lowest activation levels. When using the SBM the user adopts a more upright posture which is maintained despite the different tasks performed (e.g. turning a corner) as the hospital bed is moved throughout the ward. In addition to the load reducing effect of a more upright posture, the reduced muscular effort required in the lumbar region may result in lower incidences of lower back injury when using the StaminaLift as opposed to the two other methods. Further research is required to validate whether this is the case.

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6. References


