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# Project Report

# Operator Strain Study

Prepared for

## StaminaLift


Prepared by

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September 2010


Government of South Australia | The University of Adelaide Australia | UniSA | novitatech

MDPP is a collaborative research and development program funded by the South Australian Government through the Premier's Science and Research Fund

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# 1. Introduction

## 1.1. Background

Traditionally hospital beds have been moved throughout hospital environments through manual pushing by orderly staff. More recently, electronic bed movers have become increasingly common due to occupational health and safety requirements of hospitals. However, little research has been completed comparing the more traditional method of manual pushing to the newly designed electronic bed movers. It remains unclear which muscles are put under strain during manual pushing compared to using an electronic bed mover. Reductions in the activation levels of different muscles may reduce workplace injuries associated with moving hospital beds.

## 1.2. StaminaLift

StaminaLift is a South Australian company that produces a hospital bed mover. The company claims that the StaminaLift Bed Mover (SBM) prevents work related injuries by reducing the effort required to move hospital beds. The SBM is powered by two variable drive DC electric motors and is operated with a joystick control. A patented locking-jaw lifts and grips the bed chassis, eliminating the need for manual attachment and providing positive braking for safe operation in all situations. The SBM works well in tight spaces and is highly manoeuvrable with the capacity to lift 250 kg and push 500 kg.

## 1.3. Previous work

Blewett et al. (2006) examined the use of the SBM in both private and public hospital settings. They compared the forces used to initiate and maintain movement for two of the most common hospital beds in use, a relatively easy-to-move barouche and a relatively difficult-to-move ICU bed. Each bed was made up and had a 100kg patient on board. They examined the beds over different floor surfaces using a Salter Electronic force gauge, measuring operation forces. These values were compared to the recommended forces for pushing tasks by Liberty Mutual (Liberty Mutual, 1994). The Liberty Mutual values assume an acceptable task will accommodate 75% of females. The assumptions made in determining these values included the hand height of approximately 0.9 metre to initiate the force and a rate of application every 30 minutes. The sustained forces were based on initiating the task every 30 minutes and pushing the bed for 15 metres. The study assumed that the forces required to initiate and sustain the movement of beds over 250 metres, a typical journey in both hospitals in the study, were excessive and would be expected to predispose to body stressing injuries. This assumption was not further justified. Forces on vinyl floor were found to be 150-180N and 450-1200N on carpet. The force required to initiate the SBM, as measured against the joystick, was found to be less than 20 N. A significant difference in the forces required in manual versus assisted bed movement was found. The study further pointed out that reports from hospitals that use the SBM indicated that there had been no injuries in those institutions that could be attributed to bed or trolley movement with assistance from the SBM since the introduction of the units. Hence a sizeable reduction in manual handling injuries and associated costs in those organisations was concluded.

## 1.4. Study Aims

The primary aim of this study was to compare the muscular effort required to move a hospital bed using three different methods; SBM, Electrodrive Gzunda Bed Mover model G2 (GBM), and manual pushing. The study quantified muscular effort using standard surface EMG (sEMG) methodologies. The study also aimed to identify the effects particular movements (e.g. turning a corner, entering the lift) had on muscular activation levels. Lastly, the study aimed to compare cervico-thoracic acceleration and inclination while pushing the hospital bed using the three different methods.

# 2. Method

This study was undertaken at the Flinders Medical Centre which allowed the study to be conducted within a realistic hospital ward environment.

## 2.1. Subjects

Six male subjects (age 22-48) were recruited from the participating research institutes (3 from UniSA, 3 from Flinders University). Table 1 describes the subject characteristics including the anthropometric measurements taken for the study.

Table 1: Mean and standard deviation for the subject's age, height, weight and anthropometric measurements.

| Subjects | Age (yrs) | Height (cm) | Weight (kg) | Arm length (cm) | Trochanterion height (cm) |
|---|---|---|---|---|---|
| 6 | 29.5 ± 9.3 | 177.8 ± 3.7 | 80.9 ± 7.9 | 76.5 ± 2.4 | 91.3 ± 2.4 |

## 2.2. 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). Trials were measured in the morning (27x) and early evening (27x). Subjects 1-3 were always measured in the evening and subjects 4-6 always measured in the morning. In summary, the aim was to complete 54 trials (6 subjects x 3 cases x 3 repetitions). In total 51 trials were completed. One subject was not able to perform the Gzunda trials due to a back injury.

The subjects were required to undergo a separate training session for each of the bed movers in order to familiarise themselves with each system. The training and data collection sessions for each system took place as outlined in Table 2. The times shown were selected to avoid peak traffic times for bed movement in the hospital. This would help reduce uncontrollable variables that may impact on the trials and require retrials to be run.

Table 2: Test sequence for case studies.

| Study/type | Subjects/Daytime | Date and Time |
|---|---|---|
| CS1: Manual pushing | S1-S3, evening | Thursday 12th August, 5-8pm |
| CS1: Manual pushing + StaminaLift training | S4-S6, morning | Friday 13th August, 6-9am |
| CS2: StaminaLift | S1-S3, evening | Wed 18th August, 5-8pm |
| CS2: StaminaLift + Gzunda Training | S4-S6, morning | Thur 19th August, 6-9am |
| CS3: Gzunda | S1-S3, evening | Tue 24th August, 5-7pm |
| CS3: Gzunda | S4-S6, morning | Wed 25th August, 6-8am |

## 2.3. Session structure

Prior to commencing data collection each subject was required to read the information sheet and sign the consent form. The anthropometric measurements were then taken. The next step was to attach the self-adhesive dual electrodes to the subjects for sEMG as well as double-sided self-adhesive tape for attaching wireless sensors (sEMG, accelerometer and inclinometer). The Noraxon TeleMyo DTS wireless system was used for this study.

Next, the maximum voluntary contraction (MVC) of the selected muscles was recorded using standardised tests. All tests were demonstrated and practiced prior to data collection. The MVC measurements were later used to determine the percent maximum voluntary contraction (%MVC). The MVC for the selected (outlined in section 2.3.1.3) muscles were recorded prior to each data collection session.

The patient was then required to move a bed with a 80kg payload (representing a patient) from one ward to another along a standardised route (outlined in section 2.3.2) in Flinders Medical Centre. Three trials were then completed by each subject using the relevant method (e.g. manual pushing) for that session.

These steps will now be outlined in more detail.

### 2.3.1. Noraxon measurements

#### 2.3.1.1. EMG site selection

The following muscle activities on the left and right side of the body were measured for all trials, transmitted wireless to a NORAXON DTS EMG system within 10m range and recorded digitally:

- M. trapezius (upper back/neck)
- M. latissimus dorsi (upper back)
- M. erector spinae (ES) (lower back)
- M. obliquus externus (abdomen)
- M. obliquus internus (abdomen)
- M. biceps femoris (upper leg)
- M. gastrocnemius medialis (lower leg)

Figure 1 illustrates the seven different muscles that were measured on the left and right side of the body along with the two additional measurements explained in the following section.

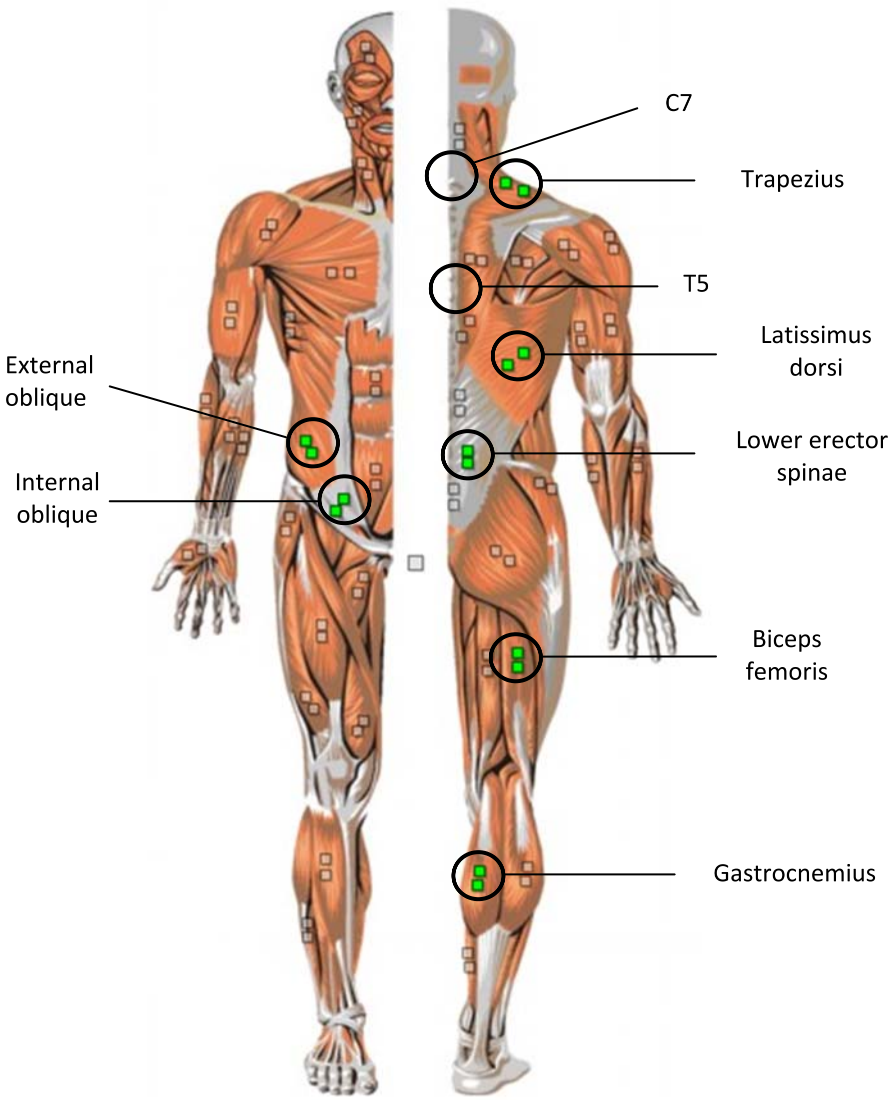


Figure 1: The measurement sites of the seven muscles, C7 (acceleration) and T5 (inclination) for this study.

Figure 2 provides an example of some electrodes and wireless EMG transmitters placed on the body. It also shows the accelerometer placed at C7 and the inclinometer placed at T5.

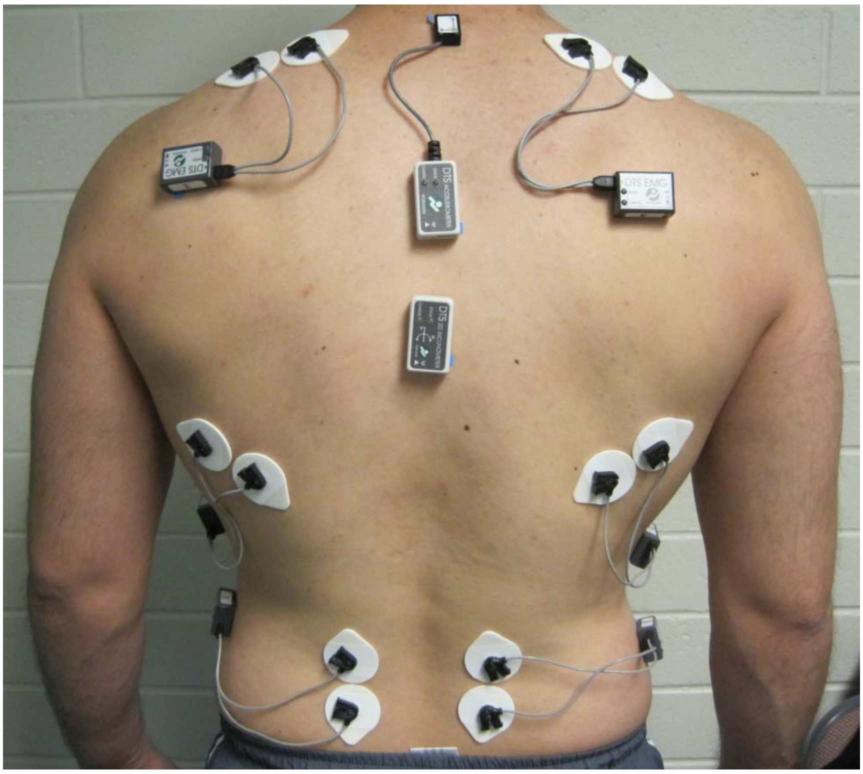

Figure 2: One of the subjects with the electrodes, wireless EMG transmitters, accelerometer and inclinometer placed on the back.

#### 2.3.1.2. Additional Measurements

In addition to acquiring sEMG measurements, the study also used one accelerometer at the cervical spine (C7) to measure spinal acceleration in x/y/z-directions and one inclinometer at the thoracic spine (T5) to measure trunk inclination in two directions. This data was also transmitted wireless, time synchronized with the sEMG data and recorded onto the NORAXON DTS EMG system.

Observations relating to the performed task, outstanding environmental events or important activity by the subjects were minuted by an observer. As part of this process the observer minuted different events that took place including the following:

- Start
- Walking along a hallway
- Turning a corner
- Stopping before the lift
- Entering/exiting the lift
- Finish

The full list and definitions of each interval is outlined in Appendix 1.

#### 2.3.1.3. MVC trials

Standardised tests were completed to obtain the MVC values for each muscle measured in the study. Three trials were completed for each MVC test in order to provide multiple opportunities for the subject to record a maximum voluntary contraction. An example of the tests used is shown in Figure 3. This test measured the MVCs for the right internal and external oblique. The subject was required to lie on their left side and then push their right hip up as hard as possible. The researcher applied resistance in the hip region to prevent the subject from raising their hips too high. The subject completed this isometric contraction for a period of five seconds. Each exercise was repeated three times with a break of 10 seconds.

Figure 3: MVC test for the right oblique muscles.

### 2.3.2. Study route for trials

The study was conducted within a realistic hospital ward environment at Flinders Medical Centre. The hospital bed was moved between wards along a standard route with four 20 kg weight discs placed on the bed to represent an 80kg person (Figure 4).

Figure 4: One of the subjects using the StaminaLift during a trial. The four 20 kg weight discs are placed evenly along the bed.

The route incorporated two different hospital floors with the subject required to use a lift to move between floors. The route covered both carpeted and vinyl floor coverings and replicated the typical distance and number of turns required during an average bed transport at the hospital. Figure 5-9 illustrate the standard route used for this study.

Figure 5: The start point is 25 metres from this junction along this corridor on Level 6.


Figure 6: There is a 90°right angle turn to approach D Block lifts and then another 90°right angle turn to enter the lifts to descend to Level 2.


Figure 7: There is a 30° ‘S’ turn after exiting the lifts on Level 2 which enters into a corridor.

Figure 8: There is another straight section of corridor of 35 metres length.


Figure 9: The bed is then turned around and the bed is taken along the same route back to the start position.

## 2.4. Data checks

All MVC trials were continuously monitored during the trials and immediately checked after the trials were completed. These checks aimed to ensure that the values were realistic and the difference between the right and the left side of the body were credible. Trials were repeated for any data that were determined to be invalid.

The three bed moving trials were continuously monitored by running the Noraxon software on the laptop. This was highly beneficial as it allowed the researchers to immediately identify any issues with the data recording (e.g. electrodes not working correctly).

## 2.5. Data storage

All experimental data were transferred to the ErgoLab workstation at UniSA, Mawson Institute. Recordings were then deleted from the laptop used during the study. After processing of the experimental data, all raw data (recordings) and processed data were securely archived on the ErgoLab data drive. This information can only be accessed by ErgoLab staff.

## 2.6. Data analysis

### 2.6.1. Treatment of EMG data

All steps in the treatment of EMG data were completed in the Noraxon software, MyoResearch XP Master Edition 1.07.52. All EMG data was subject to three main processing steps prior to analysis; filtering, rectification and smoothing. The first step was to run a Bandpass filter. For this study the low frequency was set at 18 Hz, high frequency set at 500 Hz and the window set at 301 points. The data were then rectified to achieve positive amplitude curves. Lastly, the data were smoothed using the root mean square (RMS) algorithm to obtain a moving average value for the signal. The RMS window for this study was set at 50 ms. Both the MVC and bed moving trials are processed in this manner.

### 2.6.2. Normalisation to %MVC

The bed moving trials were then normalised to the MVC trials. The peak values from the MVC trials are not calculated by a single data point but as the highest mean amplitude over the highest signal portion. The time window used to normalise the MVC was 500 ms. The MVC for each muscle was then saved and the bed moving trials were normalised to the MVC values, thus providing %MVC. The %MVC was divided into the 11 intervals and the average values of processed data over reach interval were calculated in MyoResearch.

### 2.6.3. Additional Measurements

The acceleration and inclination measurements did not require processing prior to analysis.

### 2.6.4.Statistical analysis

The primary aim of this study was to identify whether there were significant differences between the three different bed moving methods for each of the muscles measured in the study. This analysis was completed using a one-way ANOVA. The dependent variable was the muscle activity of a particular muscle (e.g. right m. trapezius), inclination or acceleration while the independent variable was the bed moving method (e.g. StaminaLift).The alpha level was set at 0.05.

# 3. Results

## 3.1. Statistical significance

Table 3 summarises the results from the one-way ANOVA test for the 14 sEMG measurements, acceleration and inclination. All measurements had significant differences between the bed moving methods, except for the right trapezius muscle. Seven of the 16 variables showed significant differences between all bed moving methods. Due to data collection issues, acceleration measurements could not be obtained for manual pushing.

Table 3: P-values from the one-way ANOVA analysis. Significant differences are bolded. N/A = not available.

| Measurement | Manual-StaminaLift | Manual-Gzunda | Gzunda-StaminaLift |
|---|---|---|---|
| Trapezius (left) | **0.008** | **< 0.0001** | 0.658 |
| Trapezius (right) | 0.087 | 0.431 | 1.000 |
| Latissimus dorsi (left) | **< 0.0001** | **0.034** | **0.001** |
| Latissimus dorsi (right) | **< 0.0001** | **< 0.0001** | **0.028** |
| Lower ES (left) | **< 0.0001** | **< 0.0001** | **0.023** |
| Lower ES (right) | **< 0.0001** | **< 0.0001** | **0.004** |
| External oblique (left) | **< 0.0001** | **0.002** | **0.016** |
| External oblique (right) | **0.0001** | **< 0.0001** | 0.543 |
| Internal oblique (left) | 0.266 | **0.002** | 0.214 |
| Internal oblique (right) | 0.225 | **< 0.0001** | **0.044** |
| Biceps femoris (left) | **0.011** | **0.040** | **< 0.0001** |
| Biceps femoris (right) | 0.064 | **0.007** | **< 0.0001** |
| Gastrocnemius (left) | 0.893 | 0.118 | **0.005** |
| Gastrocnemius (right) | 1.000 | **< 0.0001** | **< 0.0001** |
| Acceleration (C7) | N/A | N/A | **< 0.0001** |
| Inclination (T5) | **< 0.0001** | **0.014** | **< 0.0001** |

## 3.2. Relative muscular strain

The relative muscular strain (%MVC) measurements are reported in Table 4 which shows the mean and standard deviation across all three trials and all six subjects for each bed moving method. These findings are also illustrated in Figure 10 and 11. In these appendices data from each individual subject are shown. Relative muscular strain, based on the measurement of the electrical activity (MEA) of the recorded muscles, was calculated for the studied time interval only. It cannot be extrapolated over a whole working shift period without considering weighing factors, and is therefore not appropriate for estimating an overall workload dose, which could then be compared with common recommendations for manual materials handling (Ciriello et al., 1990). The results are therefore purely comparative and valid for the limitations of the given study.

Table 4: Mean and standard deviation of %MVC for each of the bed moving methods.

| Measurement | Manual | Gzunda | StaminaLift |
|---|---|---|---|
| Trapezius (left) | 5.2 ± 4.2 | 2.8 ± 1.6 | 3.6 ± 3.1 |
| Trapezius (right) | 4.6 ± 3.4 | 5.8 ± 3.2 | 5.8 ± 2.3 |
| Latissimus dorsi (left) | 11.02 ± 3.3 | 8.6 ± 3.2 | 5.2 ± 2.1 |
| Latissimus dorsi (right) | 16.01 ± 6.3 | 8.3 ± 4.5 | 4.9 ± 2.1 |
| Lower ES (left) | 7.9 ± 1.4 | 6.2 ± 1.4 | 5.2 ± 2.5 |
| Lower ES (right) | 9.8 ± 2.4 | 7.6 ± 1.0 | 6.1 ± 2.6 |
| External oblique (left) | 5.3 ± 2.6 | 4.1 ± 1.7 | 3.1 ± 1.2 |
| External oblique (right) | 4.7 ± 1.5 | 3.2 ± 1.9 | 3.6 ± 1.7 |
| Internal oblique (left) | 6.7 ± 0.8 | 8.1 ± 1.5 | 7.4 ± 3.5 |
| Internal oblique (right) | 7.2 ± 2.1 | 5.5 ± 1.8 | 6.5 ± 2.4 |
| Biceps femoris (left) | 8.3 ± 2.0 | 7.5 ± 1.8 | 5.9 ± 1.6 |
| Biceps femoris (right) | 7.8 ± 1.8 | 6.3 ± 3.0 | 4.9 ± 0.5 |
| Gastrocnemius (left)* | 20.6 ± 10.1 | 24.3 ± 4.1 | 18.8 ± 8.1 |
| Gastrocnemius (right)* | 18.9 ± 4.2 | 18.4 ± 2.0 | 19.2 ± 5.2 |

*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.

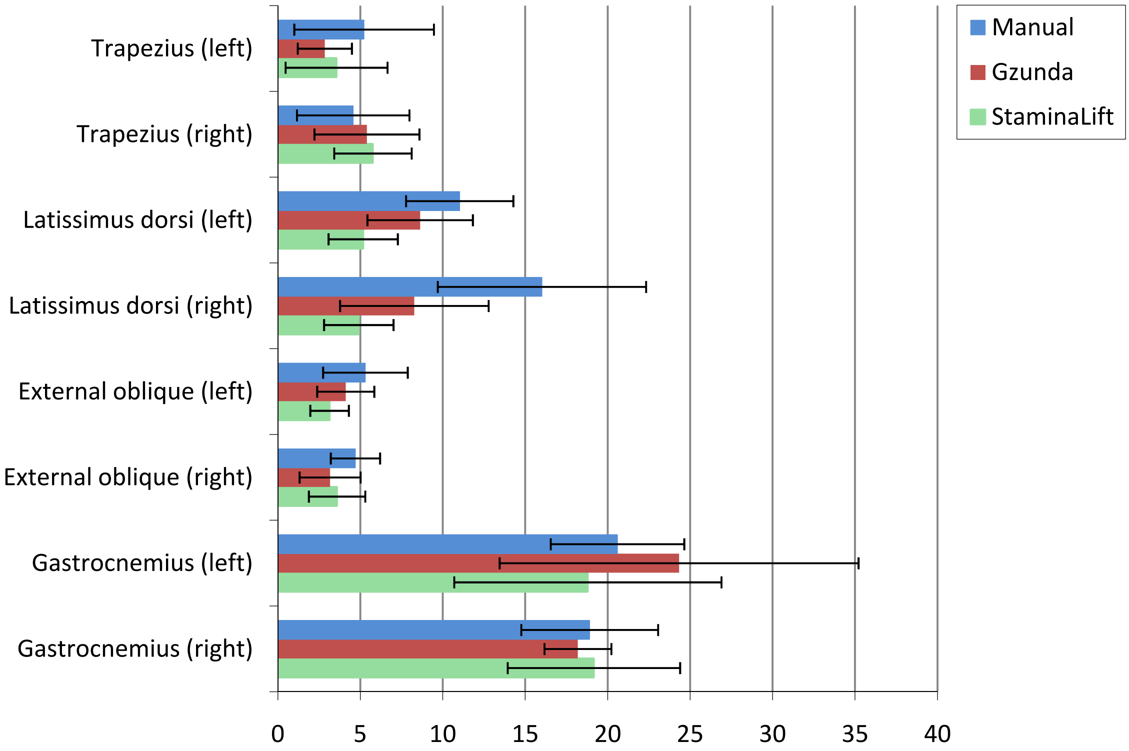


Figure 10: %MVC for the left and right trapezius, latissimus dorsi, external oblique and gastrocnemius. The mean and standard deviation is shown for each measurement.

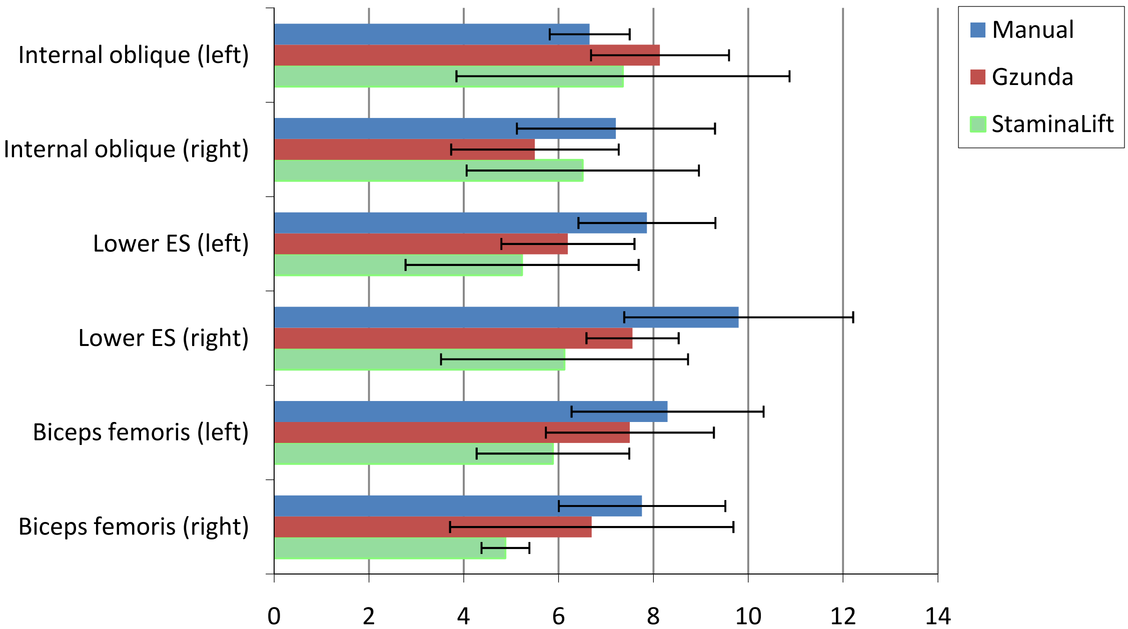


Figure 11: %MVC for the left and right internal oblique, lower ES and biceps femoris. The mean and standard deviation is shown for each measurement

# 4. Discussion

## 4.1. Differences in bed moving methods

Table 3 shows that there are significant differences between the bed moving methods for muscular strain, as well as cervico-thoracic acceleration and inclination. Overall, the SBM reported significantly lower muscle activation levels for 11 of the 14 muscles when compared to manual pushing. The GBM reported significantly lower muscle activation levels for 8 of the 14 muscles when compared to manual pushing. Of the 14 muscles tested, 9 reported significantly lower activation levels for the SBM when compared to the GBM while 4 muscles showed insignificant differences. The right internal oblique had significantly lower activation levels with the GBM.

These findings suggest that the use of an electronic bed mover in a hospital environment results in significantly lower muscle activation levels when compared to manual pushing. When comparing the two electronic bed movers the majority of muscles had lower activation levels for the SBM. This suggests that of the three methods tested, the SBM performed best in reducing the muscular strain placed on the human body when moving beds throughout a hospital environment.

## 4.2. Lower erector spinae

Low back pain is a common musculoskeletal disorder. This has a significant impact on work productivity levels with many people forced to take sick and disability leave due to a lower back injury (Landau et al., 1996). This study identified that both electronic bed movers resulted in significantly lower activation levels of the lower ES. Furthermore, the SBM had significantly lower activation levels for the lower ES when compared to the GBM. Figure 12 and 13 illustrate the differences in activation levels of the lower ES for each of the bed moving methods across all eleven intervals. 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, further research is required to determine whether this is the case.

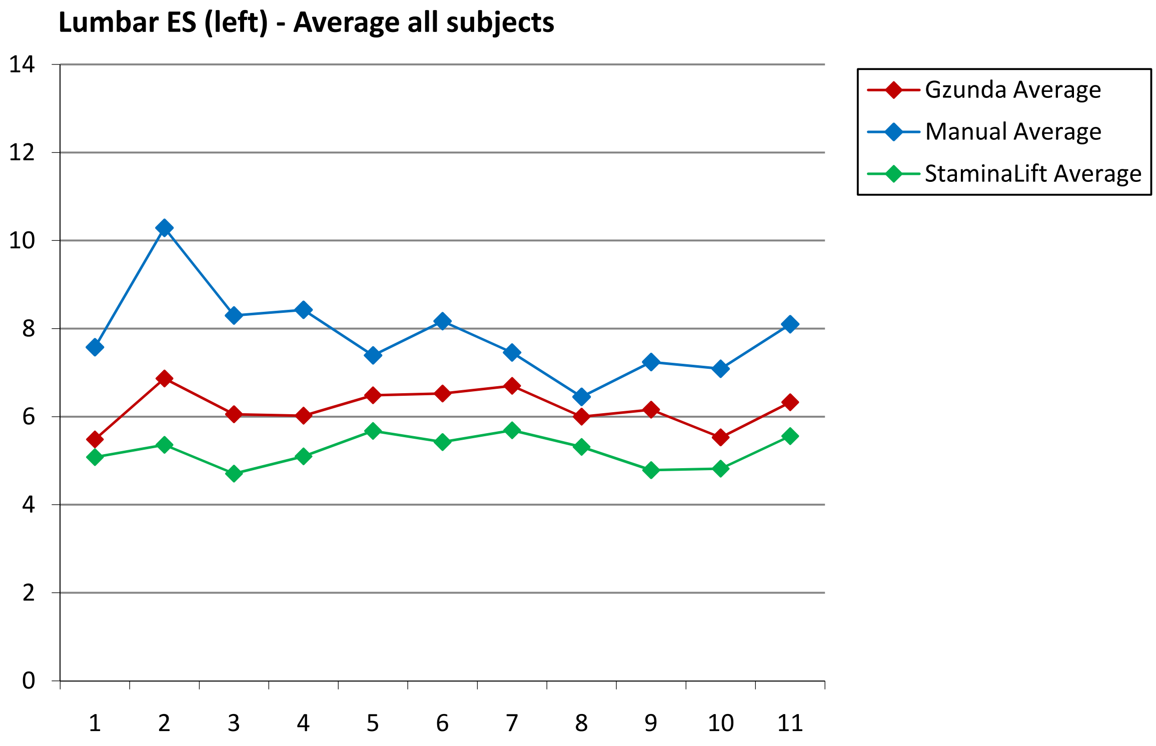


Figure 12: Average values for the left lumbar ES across the three different bed moving methods and eleven intervals.

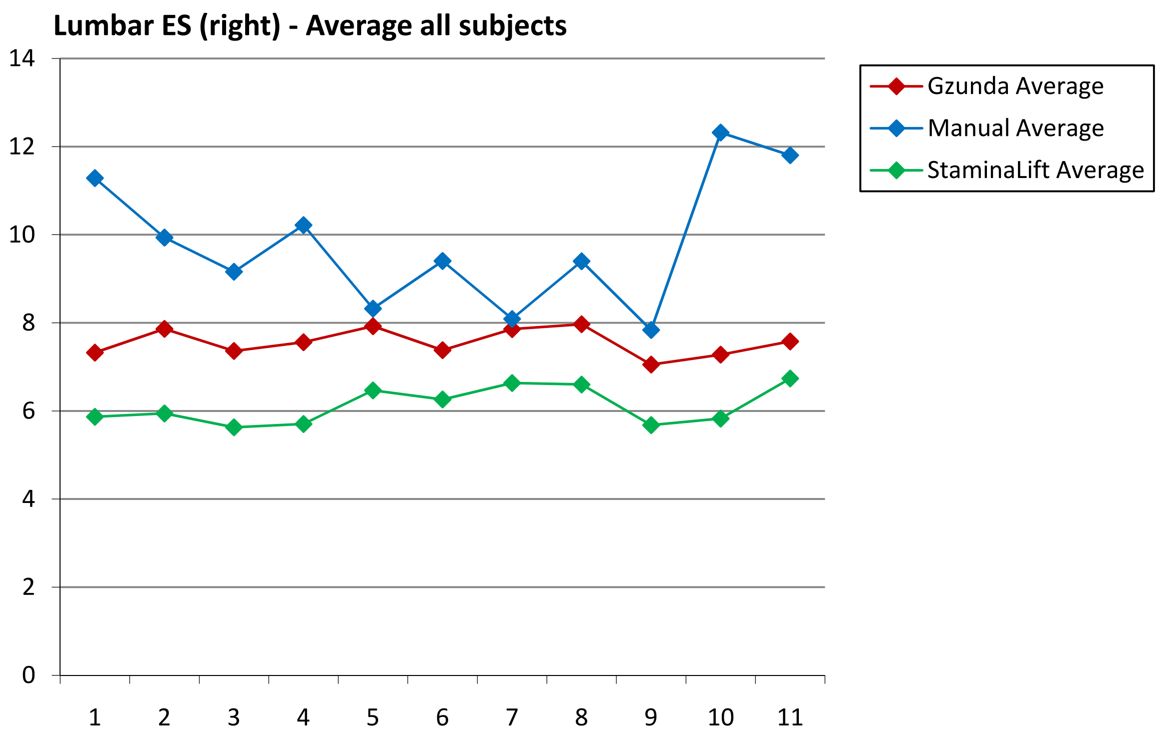


Figure 13: Average values for the right lumbar ES across the three different bed moving methods and eleven intervals.

## 4.3. Acceleration and Inclination

Figure 14 illustrates the average acceleration levels across the eleven intervals for the two bed movers. The data for manual pushing was not used as it was incomplete. The SBM resulted in significantly lower levels of acceleration; however, the acceleration for both bed movers was quite low. The acceleration levels are quite varied across the eleven intervals.

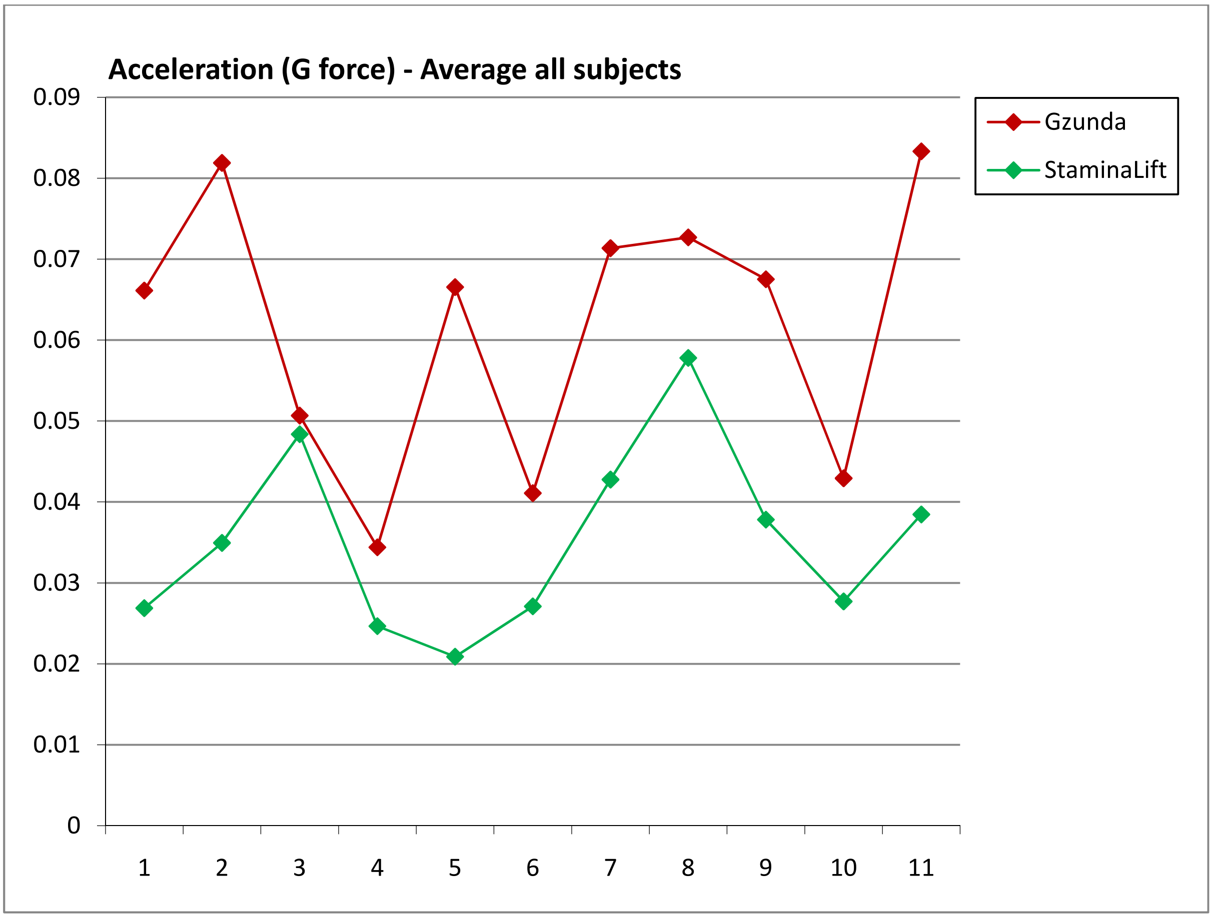


Figure 14: Average acceleration levels for the two bed movers across the eleven intervals. Values are in G force.

Figure 15 illustrates the average inclination across the eleven intervals for all bed moving methods. Significant differences were found between each of the bed moving methods with inclination reported in degrees. Zero represented a completely upright posture with positive values indicating the subject is leaning forward. The most important finding in regards to inclination is that when using the SBM, the posture of the subject was more upright and remained almost constant throughout all 11 intervals. In contrast to this the other two bed moving methods resulted in quite varied values between the different intervals. These results suggest that when using the SBM, the user is able to maintain a more upright posture and can maintain that posture independent of the tasks being performed (e.g. turning a corner) when moving the hospital bed.

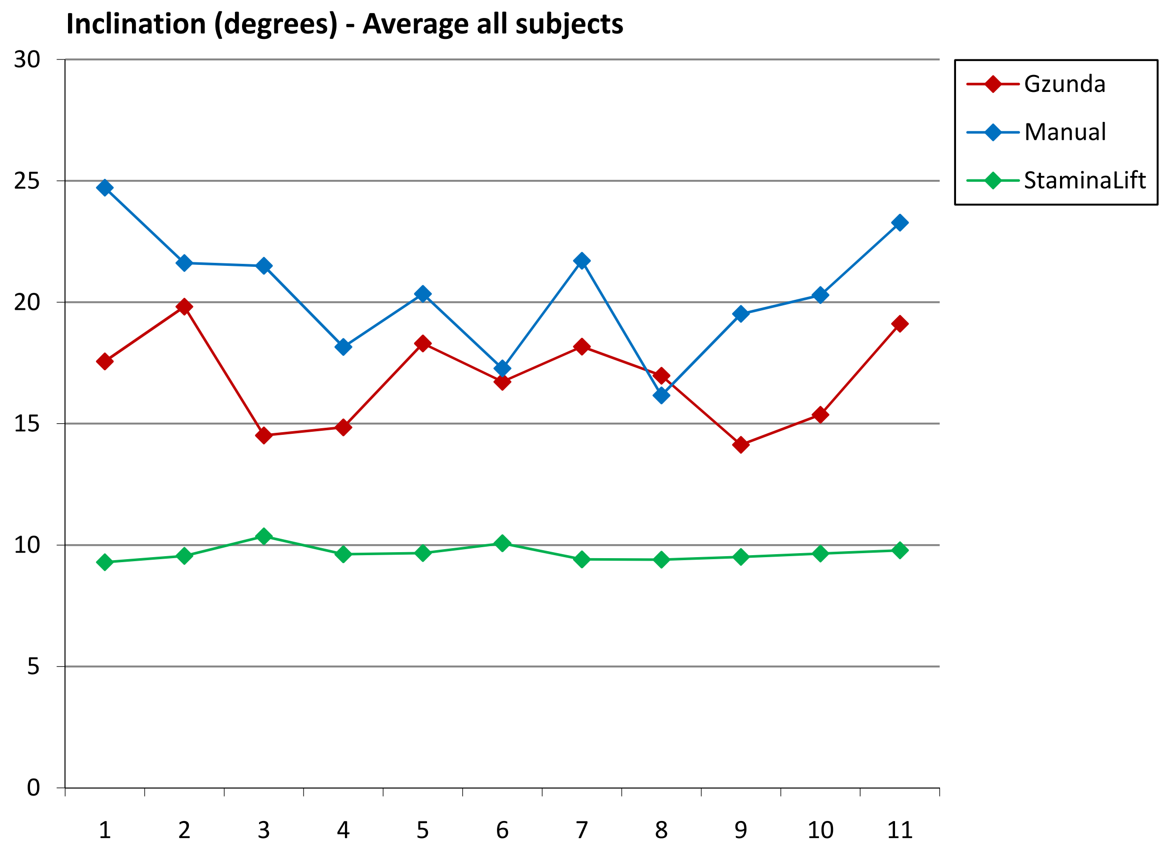


Figure 15: Average values for inclination across the three different bed moving methods and eleven intervals.

## 4.4. Limitations

The only major limitation with this study was the subject population. Ideally it would have been beneficial to recruit hospital orderly staff that are experienced with the electronic 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. It would have been extremely difficult to produce repeatable and valid measurements during normal working practice. The study also aimed to minimise the impact on hospital services and the hospital environment.

The decision to have only males was based on the fact there was a sufficient number of male subjects readily available. A repeatable route and limited subject demographic was vital to the success of establishing significant differences in a small study such as this.

## 4.5. Future Research

It would be highly beneficial to conduct further research into the effects electronic bed movers have on the operator. This research could focus on a number of areas, primarily determining whether electronic bed movers reduce work related injuries associated with moving hospital beds. Future studies should also aim to determine the effect different bed moving methods have on the following factors:

- Overall work strain induced by each method
- Musculoskeletal load due to abrupt movements (e.g. stopping suddenly to avoid a collision)
- Work output levels
- Bed moving costs
- Differences associated with gender and age
- Differences due to design of electronic bed mover
- And operator comfort and satisfaction levels

# 5. Conclusion

The aim of this study was to compare the muscular effort required to move a hospital bed using three different methods; StaminaLift Bed Moving, Gzunda Bed Moving and manual pushing. Results identified that significant differences exist between the three methods across 13 of the 14 muscles assessed in the study. The muscular effort required for StaminaLift Bed Moving was significantly lower than the other two methods for 6 of the muscles, including the right and left lower ES (lower back). When using the StaminaLift 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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# 7. Appendix One: Definitions for the eleven intervals used in the study.

| Number | Name | Definition | Reference |
|---|---|---|---|
| 1 | Straight walk | Start and walk on corridor on level 6 (carpeted floor) | Figure 5 |
| 2 | Corner until stop | 90° turn and stop in front of the lift | Figure 6 |
| 3 | Enter lift | Enter the lift including 90° turn | Figure 6 |
| 4 | Exit lift and ‘S’ turn | Exit the lift 90° and 30° ‘S’ turn on level 2 (vinyl floor) | Figure 7 |
| 5 | Straight walk | Straight walk on corridor | Figure 8 |
| 6 | Turn | Turn of the bed in a 90° corridor | Figure 9 |
| 7 | Straight walk | Straight walk on corridor | Figure 8 |
| 8 | ‘S’ turn until stop | 30° ‘S’ turn and stop in front of the lift | Figure 7 |
| 9 | Enter lift | Enter the lift including 90° turn | Figure 7 |
| 10 | Exit lift and corner | Exit the lift (90°) and the 90° turn on level 6 | Figure 6 |
| 11 | Straight walk | Straight walk on corridor until the end of the route | Figure 5 |