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## **An evaluation of the biomechanical risks for a range of methods to raise a patient from supine lying to sitting in a hospital bed.**

Mike Fray <sup>a</sup>, Sue Hignett <sup>a</sup>

<sup>a</sup> *Loughborough Design School, Loughborough University, UK*

Transferring patients has long been identified as a contributory cause of MSD in healthcare processes. One common action that is known to increase the musculoskeletal risk to healthcare workers is raising a person from supine lying to sitting on the side of the bed (Jordan et al., 2011). Best practice guidelines suggest that this activity should be replaced with mechanical devices e.g. profiling bed or hoist/lifter technology (e.g. Smith ed 2011). Practitioner evidence from many locations indicate that many people are being assisted from supine lying to sitting using manual techniques and healthcare workers are being placed at risk. This study reviewed several different methods using single and paired carers and different assistive devices to complete this transfer.

A simulation task was designed as part of a user trial. Patient actors (n=4) were trained to respond as specific client groups who represented 2.5<sup>th</sup>, to 97.5<sup>th</sup> %-ile patients. Healthcare workers (n=9) completed 5 methods for raising a person from supine lying to sitting and 3 methods for lowering a person from sitting to lying with (1 and 2 carers). All conditions (n=11) were repeated to ensure a standard method and movements were recorded (n=5 minimum per participant). Data were collected for the biomechanical evaluation by motion capture (CODAmotion) technology, anthropometer data for body size and a Kistler force plate. Additional force measures for analysis of the loading calculations were recorded using a Mecmesin AFG2500N force gauge using staged re-enactments using repeated measures. All participants and patients completed subjective reviews of the transfers reporting effort, security and safety. The results were combined to calculate the musculoskeletal risks during the various transfers. Differences were identified between the movement, positions and the biomechanical loading characteristics of the fully manual methods, the profiling bed assisted methods and a novel assistive device.

**Practitioner Summary:** The biomechanical risks of patient handling activities are well known. Many studies have quantified the risks for full weight lifting activities, which is widely accepted as hazardous and should be replaced by mechanical methods e.g. hoisting. The detailed biomechanical analysis of other patient handling tasks is not so well reported. This study explores the forces required to assist a range of patients from lying to sitting on the side of a bed and vice versa using a series of handling techniques. The results show that simple assistive devices that utilise the body weight of the patient can make a clear difference to the risks of these activities.

**Keywords:** Biomechanics, Forces, Patient handling, Patient transfers, Healthcare ergonomics

### **1. Introduction**

Patient moving and handling is an essential and necessary part of healthcare in hospitals and community settings and extends more widely to supporting people in their own homes in the social care role. The risk management of patient handling tasks is dynamic and a range of techniques, assistive devices and mechanical options are used to promote mobility, complete safe patient movement alongside the facilitation of activities of daily living. The development of safe patient handling (SPH) has focussed on both the reduction of risks to the carers and the improvement in the quality of care for the patient by maintaining dignity, comfort and reduction of possible hazards (Fray and Hignett, 2015). The very nature of healthcare and the nursing of patients (rather than lifting/handling innate objects) mean that manual handling is not confined to lifting and mobilising patients. Risks can arise due to the numerous (and seemingly small) tasks associated with patients activities of daily living (Kay et al., 2012) that include feeding, toileting, dressing, washing etc.

Many published papers have reported through systematic review that technique training or introduction of (any) equipment alone is ineffective in reducing injury rate (Hignett 2003, Martimo et al 2008, Roffey et al 2010,). What appears to be successful is a combination of multiple approaches involving implementation of moving and handling equipment (to reduce biomechanical loads and reduce overall exposure), administrative/ logistical support and interdisciplinary education/ behavioural change (Black et al 2011, Koppelaar et al 2011, Lim et al 2011, Burdorf et al 2013). The management of musculoskeletal risks and the reduction of injuries for care workers still require focus due to have highlighted the growing issue of protecting healthcare workers from back injury especially in the light of the obesity epidemic and the aging of the nursing population (Keuhn 2013).

It is clear that care staff are exposed to load throughout many aspects of their work that includes moving equipment, pushing, pulling, bending and stooping all of which can result in awkward postures; patient moving and handling is just one facet (Hodder et al 2010,). Although use of hoists and other lifting devices certainly have been shown to impart a lower frequency of forces exerted, it is the cumulative effect of many physical patient handling activities over time that has most detrimental effect (Koppelaar et al 2011, Knibbe & Knibbe 2012, Jager et al 2013, Freitag et al., 2012). One of the situations that impose such postural risks to carers is care of a person in bed. Many carers would choose to assist a person in bed with what is perceived to be minimal assistance. The level of risk for small movements when assisting people in bed depend on many physical factors including: the anthropometry of the care staff, the height of the bed, the physical shape and size of the person being assisted and most importantly the patient's ability to assist (ArjoHuntleigh, 2010).

This particular study investigates the regularly performed task of raising a person from lying in a bed to a sitting position on the side of a bed. This task is usually completed in preparation for a subsequent task e.g. dressing, washing or further mobility activities such as standing or the use of an active hoist. A small number of studies have tried to quantify the forces, motions and the biomechanical risks associated with these type of activities (Skotte and Fallentin, 2008, Theilmeier et al., 2010, Jager et al., 2012, Jordan et al., 2010) though the use of assistive devices was not included in these investigations. Several best practice guidelines (Smith ed. 2011, DIAG, 2011, etc.) suggest mechanical and physical assistive methods to reduce the risks and these techniques will be incorporated in this evaluation. The focus of this study is to quantify the forces required to raise a person from lying to sitting on the side of a bed and vice versa.

## **2. Method**

The project team explored the published information regarding current best practice to assist people with limited movement for the transfers that raised someone from a bed and lowered them back from sitting to lying (Smith ed. 2011, DIAG, 2011, etc.). This gave the background information to develop a realistic scenario to explore the different activities and created the transfer task. The scenario was to transfer a patient with limited trunk abilities and reduced mobility from supine lying in a bed to sitting on the side of the bed and vice versa. There was agreement in the best practice guide that the most hazardous technique would be a manual scoop method to lift and rotate the patient from supine to sitting in one movement.

Including the wide range of techniques and the different patient numbers meant the number of transfers to be completed by each participant was high. The order of presentation was structured to allow an even number of each type of condition to be recorded. The safety and well-being of the carers was a concern and all activities were observed, regular breaks were enforced and the ability to not complete tasks was repeatedly voiced during the data collection days.

The trial was held in a laboratory location and each participant completed the same series of preparations. During the welcome, the participant was required to complete a health declaration, safety information was discussed before the anthropometric data was measured. As an introduction to the physical trial each participant was requested to show the technique that was most widely used/recommended in their normal working environment to raise a patient with the described mobility (Arjo-Huntleigh ab 2011). All participants described the same method for a manually assisted lying to sitting movement. This roll and sit method was incorporated into the conditions for the trial (Conditions 2 and 4).

### **2.1 Conditions**

Data was collected for the following 5 techniques and scenarios. Data were collected for all 5 techniques to raise the patient using the participant as a single care worker. Data were collected for lowering the patient

for the 3 methods on to a flat bed. As a comparison a number of activities were also completed using two carers, the participant taking the more hazardous tasks related to assisting the trunk was data was the focus of this action. The two carer techniques did not include the use of the novel device as the size and movement did not allow for two person use.

1. Scoop Transfer on a Flat Bed - This transfer is completely manual. The participant moves the patient in a single move from supine to sitting on the side of the bed. The participant's hands were placed under trunk and under legs to enable to task to be completed.
2. Roll and Sit Up on a Flat Bed - This transfer is completely manual but the process is broken into stages. The participant lifts the patient's legs into crook lying, roll the person into side lying, drop the legs over the bed edge and raise the trunk to sitting.
3. Novel Device from a Flat Bed - This transfer is assisted by the use of the novel device. The participant was trained in the use of the device. The device is placed parallel to the edge of the bed with a small amount under the patient's trunk. The participant will follow the guidance below (2.1.1).
4. Roll and Sit Up on a 30 degree Raised Bed - This transfer is completely manual but the process is broken into stages. The carer will lift the legs into crook lying, roll the person into side lying, drop the legs over the bed edge and raise the trunk to sitting
5. Novel Device from a 30 degree Raised bed - This transfer is assisted by the use of the novel device. The participant will follow the guidance below (2.1.1)

For the novel device the participants and patient actors followed the following protocols. All participants were trained in the use of the device before data collection

#### *2.1.1 For Lying to Sitting*

1. Carer to select bed height as suitable for themselves
2. Patient supine in controlled position in bed. Bed and frame to be marked for patient sizes
3. Patient's hip joint to be marked for convenience and alignment.
4. Carer will raise the patient's legs into crook lying before inserting device or for manual transfers
5. Patient to be rolled into crook side lying
6. Insert device into position parallel to edge of bed.
  - a. Insert part of device under the patient's shoulder
  - b. Align with hip position
  - c. Reach to device handle and use two hands to raise up into sitting
7. End position is to be suitable to use a transferring hoist.

#### *2.1.2 For Sitting to Lying*

1. Carer to select bed height as suitable for themselves
2. Patient sitting in controlled position on the side of bed. Bed and frame to be marked for three patient sizes
3. Patient's hip joint to be marked for convenience and alignment.
4. Insert device into position.
  - a. Place the device as close to the hip as possible.
  - b. Align against flexed hips and flexed knees
  - c. Lower patient in a straight line towards the bed
  - d. Roll in to supine lying and remove the device
5. End position is supine at the end of the roll. There will be no repositioning but observation will note if repositioning is required.

### **3.3 Data Collection**

A comprehensive series of data were recorded during all the transfers. Three repetitions of each activity were included in the trial dataset. Errors or significant differences from the normal movement, body positions or patient movement were not included to give consistency in the analysis.

#### *3.3.1 Anthropometric data.*

A range of measures were collected from each participant and the patient actors to ensure accuracy in the biomechanical calculations. Height was measured with a Harpenden Stadiometer, limb lengths with a Harpenden Anthropometer and the weight with a Kistler Force Plate. This data was used to calibrate the CODAmotion motion capture system.

### **3.3.2 Video Recording.**

All transfers were recorded in high quality video from 3 views, posterior view, lateral view and 45° potero-lateral views were recorded for every activity. Each set of transfers was recorded into a separate file (n=154), with time sequenced footage to allow a task analysis of each activity to be completed and scaled measures to be taken directly from the video footage for biomechanical analysis.

### **3.3.3 Motion capture.**

Data were collected for the biomechanical evaluation by motion capture (CODAmotion) technology. Bony landmarks for each participant were identified to represent the locations of knees, hips, shoulders and elbows. A single cluster formation was used to identify the location and alignment of the lumbar spine. The motion capture data was supplemented by the use of a Kistler 9248A force plate to measure the ground reaction force. Difficulties were experienced with some of the data collection processes for this section and the analysis of this data will be presented in a later paper.

### **3.3.4 Subjective Feedback**

All participants and patients completed subjective reviews of the transfers reporting effort, security and safety. In particular the participants were requested to consider how likely the particular technique was to be used in their regular practice and workplace.

### **3.3.5 Forces to move the patient**

The video footage for each transfer was observed and compared the records from the observed activities. Each transfer was comprised of a series of minor movements to prepare the patient and then to complete the transfer. The analysis of each action allowed the forces applied by the carers to be evaluated and analysed. The point of application and the direction of force application were recorded for each transfer to enable the forces to be measured using the Mecmesin 2500kN Force meter. The line of action and point of application was replicated by the research team to allow the force to complete each action to be recorded. Each force measure was repeated 5 times with a consistency check being employed during data collection to remove outliers. The magnitude was +/- 10% around the mean force was attempted.

All data sets and recordings were supported by observational field notes from the researcher (MF). Due to the volume of data collected in this trial not all information is presented in this paper but will be delivered in alternative publications.

## **3. Results**

### **3.1 Data Collection**

During the trial patient actors (n=4) and carers (n=9) were recruited to complete the trial. The participants completed the trial (3 male 6 female, height 160-199cm). 6 were mostly community based and 3 were mostly hospital focussed. Table 1 below shows the number of participants that completed each task and the number of transfers that were recorded (participants (repetitions)).

Table 1. Data collected for each transfer

Task	Participant:	Small	Medium	Long
<b><u>Raising</u></b>				
1. Scoop Transfer on a Flat Bed		6 (18)	6 (18)	6 (18)
2. Roll and Sit Up on a Flat Bed		6 (18)	6 (18)	6 (18)
3. Novel Device on a Flat bed		6 (18)	6 (18)	6 (18)
4. Roll and Sit Up on a 30° Bed		6 (18)	6 (18)	6 (18)
5. Novel Device on a 30° bed		6 (18)	5 (15)	6 (18)
<b><u>Lowering.</u></b>				
6. Scoop Transfer on a Flat Bed (1)		4(12)	4(12)	1(3)
7. Roll and Sit Up on a Flat Bed (2)		4(12)	4(12)	1(3)
8. Novel Device on a Flat Bed (3)		4(12)	4(12)	1(3)
<b><u>Two Person Raising</u></b>				
9. Scoop Transfer on a Flat Bed (1)		5 (15)	3(9)	4(12)
10. Roll and Sit Up on a Flat Bed (2)		5 (15)	3(9)	4(12)
11. Roll and Sit Up on a 30° Raised Bed (4)		5 (15)	3(9)	4(12)

### 3.2 Patient Actors

The demographics for the sizes of the patient actors were matched against a European data set to represent a cross section of patient anthropometry. During recruitment it was impossible to find an ideal match to 2.5<sup>th</sup>, 50<sup>th</sup> and 97.5<sup>th</sup> %ile participants. The trial was completed using the Small, Medium and Long patient actors in part to reduce the possible musculoskeletal risks to the participants of handling the Large patient. A Large patient was recruited whose anthropometry in terms of size and limb length closely resembled the Long patient but was close to 97.5<sup>th</sup> %ile weight (116.9kg). The force measures were collected from all 4 patient actors. The force analysis was completed by adding the Large patient force to the Long patient dimensions and task analysis. The sizes of the patient actors used in the trial are noted in Table 2.

Table 2. Height and Weight of the Patient Actors

Size	Height (cm)	Weight (kg)
Small	160.6	49.0
Medium	169.8	89.7
Long	182.9	61.3
Large	183.7	116.9

### 3.3 Force data for raising and lowering

The video analysis identified a large range of data was required to fully analyse the techniques (For the raising transfers n=25, for the lowering transfers a further n=9 ). Examples of the forces for some of the tasks are shown to indicate the relevant musculoskeletal risk are shown in tables 3 and 4 for the raising and lowering tasks for single carer actions.

For the raising tasks most of the forces recorded are correlated to the body mass of the patient actors. Some of the recorded forces show unusual data and un-even force depending on the body mechanics and movement of each individual. This is to be expected with real patient loads. It was specifically noted that the smallest of the patient actors sometime showed larger than expected forces. Because some of the activities included two handed force assistance multiple loads were recorded. Further analysis is planned to fully explore the component loading for each of the different multiple loads on the carer.

Table 3. Force measures for raising from supine lying to sitting (N)

	Small	Medium	Long	Large
<b><u>1.Scoop</u></b>				
Under shoulders base of neck over shoulder	205.3	252.3	221.6	271.5
Under shoulder blades	262.0	310.3	275.4	404.7
<b><u>2.Roll and Sit</u></b>				
Side lying to sitting legs on side of bed	188.8	250.0	256.7	290.9
Side lying to sitting legs over side of bed	171.9	238.4	167.0	263.2
<b><u>3.Novel Device Lifting</u></b>				
Sitting up pushing handle	88.8	87.4	121.0	N/A
Sitting up with shoulder hold	63.3	74.2	106.4	173.7
<b><u>4.Roll and Sit for 30 degrees</u></b>				
Lift from 30 legs over side of bed	135.3	151.0	134.0	111.2
Lift from 30 legs on bed	175.6	242.1	182.7	227.5
<b><u>5.Novel Device for 30 degrees</u></b>				
Sitting up with shoulder hold	34.4	55.1	57.6	78.6

Table 4 shows the forces for the lowering tasks. The Scoop lower task included a load for the hand round the trunk and one round the legs to lift them up onto the bed. The novel device which balanced the load of the lower limb with the trunk around a pivot point showed significantly reduced forces for this action.

Table 4. Force measures for lowering from sitting to supine lying

	Small	Medium	Long	Large
<b><u>Scoop lowering</u></b>				
Under legs	122.2	160.8	93.9	157.3
Round trunk	52.1	46.0	58.9	98.1
Combined	174.3	206.8	152.8	249.1
<b><u>Roll and lower</u></b>				
Round trunk	52.1	46.0	58.9	91.8
Roll onto back	57.8	81.6	66.0	50.3
<b><u>Novel Device Lowering</u></b>				
Holding Shoulder Handle	17.0	18.2	41.8	66.4

### **3.4 Subjective responses of the carers and patients**

The participants were shown a series of Likert scales to assess various aspects of the transfers. The scales were designed to show that a higher score was a preferred score, easier, lighter, more comfortable etc. Questions 1 and 2 reviewed the perception of the physical effort to complete the task. For these questions the mean scores across all participants showed that the scoop transfers scored the highest and the two transfers with the novel prototype device scored the easiest.

Table 5: Subjective responses of for the 5 raising transfers

Raising Transfers	Biomech. Effort	Comfort	Suitable Position	Individual Acceptance	Organisational Acceptance
Scoop Transfer on a Flat Bed	2.07	2.20	2.20	1.27	2.50
Roll and Sit Up on a Flat Bed	2.94	2.83	2.67	3.50	3.67
Novel Device on a Flat bed	3.67	3.67	3.00	4.06	3.67
Roll and Sit Up on a 30° Bed	3.11	3.06	2.72	3.72	3.78
Novel Device on a 30° bed	4.00	3.76	3.29	3.65	3.41

There was little numerical difference across the range of transfers in terms of the patient position, though the order of satisfaction with the end position did correlate the effort and comfort scores. The data that was collected to explore the acceptance of the transfers on both an individual or organisational level was also close numerically. Further analysis is required to examine the reasons for why this section was not correlated to the others.

#### **4. Discussion**

Studies that attempt to quantify the forces, postures and human movement of patient handling tasks often report the difficulties associated with consistency and the variation of the human form. Variations were noted in the results collected in this trial between different actions and tasks to support the complication with individual differences. The position of the arm around the trunk or the shoulder made a notable difference for the scoop lift in Table 3. The raising and lowering of the legs changed with abdominal volume and the amount of hip flexion. The position of the patient relative to the novel device made large differences to the forces for rolling if too much weight was resting on the device. These differences illuminate some of the complications of patient handling e.g. the use of the profiling bed is seen as a positive benefit in many situations, but the raising of the trunk closes the hip angle and increases some of the activities included here e.g. leg lifting.

These data show the scoop lift that incorporates trunk and legs in a single move required the most force but the roll and sit transfer was similar when the patient's feet remained on the bed and were not lowered off the side of the bed. The measures for the scoop in table 3 represent the force to lift only the trunk and further risk is added with the leg component. There was an identified change between the forces to complete raising transfers from flat lying to the 30° bed in line with what was expected. The use of the novel device to assist the transfers made marked improvements to the forces required to complete both raising and lowering actions. The benefits of the device were relatively more successful for the larger and heavier patients.

Observations of the different types of technique added much to the results of the trial. There were different styles of movement adopted by the individual participants. Participant 3 had a physiotherapy background and chose a strong wide base of movement and swept the patient up through the scoop transfer very well. Participants 5, 6 and 8 all chose to not complete specific moves that they perceived were beyond their ability. The patient actors were a useful addition to this evaluation. They did add human variation to the force calculations but their ability to behave at a standard level of function was perceived by the researchers as being very accurate and repeatable. Consideration of the force collection by the method of repeated measures of re-enacted scenarios could be improved with the use of mechanical force application.

The novel device reduced the forces to complete the transfers markedly and successful use of the device was based on minimal training and supervision. Some factors were noted that could improve the guidance for the use of this type of device. The device was created with two handles but most of the participants preferred the hold at the shoulder which supported the move with less physical force due to the lever advantage. The line of descent when lowering the patient had a tendency to fall across the bed which indicated a secondary movement to lay the patient centrally in the bed. After guidance the carers were able to hold the line of descent and place the patient parallel to the bed edge and roll them centrally without a second movement. Again when rolling the person back into bed after lowering to the bed into side lying the roll back in to bed was made much harder if the legs remained against the device. It was considered that positioning the legs off the device and on the bed would reduce the force for this action further.

#### **5. Summary and further work**

This analysis has showed that in agreement with previous studies, the scoop method for raising someone from lying carries a significant load and should be avoided. It also raises further concerns over the most frequently completed technique of the roll and sit method. The complexity of the human form made the forces different for different body types and shapes. The novel device which used the weight of the lower limb to balance the weight of the trunk markedly reduced the effort for raising and lowering.

This analysis is the first stage in a series of interpretations of this data set. It is planned to consider two specific methods to further illuminate these activities. Firstly to complete a more detailed, higher level biomechanical investigation to include the leverage effects of two handed loading and the postural effects of the carer for the different scenarios. Secondly to consider the cumulative loading on the carers as the use of

assistive devices and changes in the techniques often add a series of smaller minor actions to support the main function of the transfer (Fray and Hignett 2009).

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