Estimation of Low Back Loading in Bedside Care: The Importance of Bed Positioning to Patient Handling Task

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Introduction

There is particular concern for caregiving performed outside of the institutional setting. In the home environment, caregivers reported considerably higher numbers of lost work days due to injuries compared to nursing home or hospital based caregivers. There is an expected annual growth in home care services of 6.1 percent from 2010 to 2029 due to lower costs of home healthcare settings rather than the higher costs of inpatient facilities. However, there doesn't appear to be any change in the common practice of home care workers performing patient lifting activities alone, either as a professional or informal family caregiver. This underscores the need to choose the best practices for the individual in addition to the best equipment available. However, little detailed knowledge exists concerning the bed as a risk for increases in low back pain.

Objective

This study reviews and investigates the issues surrounding spinal loading during patient handling, with a specific focus on the bed height and the bedside practices of caregivers.

Methods

Review of scientific papers published until 2014.

- Definition of area of interest, aim of the review, inclusion criteria of papers and search strings following systematic reviews methodology (inclusion criteria: observational, quasi-experimental, or experimental studies, in English, patient handling tasks involving a bed)
- Search through electronic databases (MEDLINE (via PubMed), Scopus, Science Direct, and CINAHL) using search strings, and further hand-search through references obtained.

Results

Seventeen articles that carried significant findings and had several characteristics comparable to the proposed study are presented in this review.

Title, First Author, Country, and Year	Article Purpose	Sample Population	Biomechanical measure	Main Findings	Limitations
Effect of individually chosen bed-height adjustments on the low-back stress of nurses, de Looze, Netherlands, 1994	To determine the effects of individually chosen bed-height on the various estimates of mechanical low-back stress	Nurses (14 female; 8 male)	• Light reflective markers placed on the subject's right side at relevant anatomical positions to analyze movement • Direct motion analysis system recorded instantaneous positions of markers • Instantaneous net joint moments and joint reaction forces at the ankle, knee, hip, and finally at L5/S1	• Significant favorable effects of bed- height adjustment were observed for the time integrals of compression and shear force and for peak shear force. • Observed tendency for lower peak compression values with bed-height adjustment was not significant	• Subjects picked their own bed-height • Only one level of adjustment used
Lumbosacral loads in bedmaking, Milburn, Australia, 1997	to determine whether the introduction of larger and heavier beds which were lower to the floor increased the physical stress on employees responsible for room cleaning and bedmaking in the hospitality industry	15 female room attendants	• Hand load measured directly using a 1 kN load cell • Retroreflective markers placed on the wrist, elbow, shoulder, hip, knee, and ankle • A video camera placed ~5 m from the subject with the optical axis lens perpendicular to the plane of the motion sampled at 60 Hz and automatically digitized • LiftTrak was used to compute the dynamic and static L5/S1 compression and static shear force for each test condition.	• Static models severely underestimate the loads on the lumbar spine under inertial lifting conditions • Tasks with the greatest hand loads were not associated with the greatest spinal loads due to differences in the way each task was performed • L5/S1 loads produced during bedmaking may exceed recommended safe lifting limits for certain task height combinations • The use of larger and heavier beds imposes increased loads on the lumbar spine	• The scaled moment arm model led to moment arms that were between 5.0 and 7.5 cm and therefore may have led to an overestimation of L5/S1 compression forces • It is possible that actual compression loads are slightly higher than those predicted by the present model since IAP may not cause a reduction in trunk loading • The hand load required as input into the LiftTrak software for the calculation of L5/S1 compression and shear forces were measured for a single subject and then assumed to represent load acting at the hand for all subjects
Anthropometric variability, equipment usability and musculoskeletal pain in a group of nurses in the Western Cape, Botha, South Africa, 1998	To test the hypothesis that pain and usability problems were related to body dimensions of hospital nurses	100 Full-time nurses	• Linear distances between points on body and standard reference surface measured by anthropometer • Breadth and depth of body segments and distance between reference marks measured by sliding and spreading calipers • Body mass measured by scale • 20cm cubic measuring block was used to determine maximum posterior profusion of sitting person	• 63% of the subjects complained of lumbar backache (82% due to prolonged standing; 75% due to moving patients;71% due to static forward flexion) • All subjects complained of thoracic backache • 82% complained of cervical/shoulder pain (75% due to lifting and moving patients) • 34% of subjects found range of height-adjustable hospital beds sufficient (18% always adjusted for specific task • 39% adjusted bed often • 23% adjusted bed rarely • 34% found beds hard to adjust	• Small variability of factors was not large in relation to measurement errors and confiding factors
Estimation of low back loading on nurses during patient handling tasks: the importance of bedside reaction force measurement, Skotte, Denmark, 2000	To discover if the extent the force extorted on the bedside by the knees or thighs influence the estimation of low back loading	1 Female, nurse	• Experiment videotaped with 50 Hz video system and automatically digitized with a Peak Motus 4.3 system • Analog data from force platform and force transducer on bedside sampled at 1000 Hz	• Horizontal reaction forces normal to the bedside ranged 100N-200N • Reaction forces in other directions were considered too small to be measured • Bedside reaction moment contributed to the total moment	• For some tasks the reaction moment resulted in errors as high as a factor of two • With only one subject statistical significance could not be produced
A posture and load sampling approach to determining low-back-pain risk in occupational settings. Neumann, Canada, 2001	Determine how well an observational work and posture sampling technique was able to identify low-back pain risk factors	Hourly paid workers of an automobile assembly facility	• Biomechanical analysis run to determine the lumbar compression, moment, and joint shears at L4/L5 associated with varied postures and load combinations • Quasi-dynamic , 2D linked segment model with 15 segments • Work sampling data processed summaries posture, external load, and spinal loading exposures • External load summarized as a percentage of time in which forces were greater than 1 kg, posterior shear with flexor moments, and compression levels above NIOSH action	• No significant difference shown between groups for median spinal load, low level compression,, trunk flexor moments, postures near neutral, and the percent of time spent twisted • Posture and load multivariable model significant for % time loaded, wrist or lateral bend • spinal loading multivariate significant for peak moment, average anterior hear, and average posterior shear	
Biomechanical analysis of the effect of changing patient-handling technique, Schibye, Denmark, 2002	to assess the changes in the mechanical load on the low-back when shifting from a self-chosen to a recommended patient-handling technique	9 female health care workers	• Two force platforms to measure the ground reaction forces. • Two force transducers connected by a bar fitted to the bed to measure horizontal reaction force from the bed • 50 Hz video system with five cameras automatically digitized with a Peak Motus 4.3 system (sampling rate 1000 Hz). • A cross-sectional model of the low-back including 14 muscles was used to estimate the compression and shear forces with optimization procedure to minimize the sum of the cubed muscle stresses.	• For 5 of 8 tasks, a significant reduction was observed in spinal loading using recommended technique. • Self-chosen technique found substantial variation in low-back loading	• Peak compression could have occurred outside of the central part included in measurement • Preparatory task (adjusting bed height, positioning patient extremities, placing assistive devices) excluded augmenting task duration and loading peaks
A dynamic 3-D biomechanical evaluation of the load on the low back during different patient-handling tasks, Skotte, Denmark, 2002	Investigate the low-back loading during common patient handling tasks	10 Female, health care workers	• Dynamic 3-D biomechanical model of lower body used to calculate net torque at L4/L5 joint • Two force platforms (1 foot placed on each)used to measure ground force reactions • Bedside fitted with two force transducers connected by a bar to measure horizontal reaction force from bed • Experiments videotaped with a 50 Hz video system with 5 camera	• Biomechanically calculated parameters more dependent on task than health care worker • Majority of tasks deemed safe to care out bedsides the high compression tasks that had levels of above 4000N • No correlation found between perceived exertion and EMG measures	• Various techniques that differed from approach used in health care sector were used to carry out tasks • Normalization method doesn't take account effect of EMG-force relationship
Predictors of Shoulder and Back Injuries in Nursing Home Workers: A Prospective Study, Myers, USA, 2002	To determine if physical characteristics and behaviors of nursing home residents are associated with 18-month incidence of shoulder and back injuries in nursing staff who provide direct resident care in a nursing home in Washington State	40 Nursing Assistants in a nursing home in Washington state		• The combined NA injury incidence rate (IR) was 45.8 self-reported back and shoulder injuries per 100 [FTE] workers per year. I • MDS reported resident characteristics failed to predict risk • Exposure to loss of voluntary leg mobility significant to risk (OR 1⁄4 1.11 per person-shifts of exposure, 95% CI [0.97 – 1.27]) • The highest risk on the day shift (OR1⁄41.15, 95% CI [0.95–1.40]).	• MDS information was collected for billing purposes rather than specifically for determining physical load on caregivers. • Misclassification of duties because observations across all shifts indicated that NAs either worked in teams or, during mealtimes, one nursing assistant would take care of all the residents remaining on the unit while the other NAs would feed those who were transferred to the dining rooms.
Comparative Analysis of low-back loading on chiropractors using various workstation table heights and performing various tasks, Lorme, Australia, 2003	To investigate whether chiropractors' workstation table height or the tasks they perform make them susceptible to low-back strain	7 Chiropractors	• 3DSSPP measured the disk compression force and lumbodorsal fascia strain at L5/S1, and estimate loading on extremity joints. • A video camera was used to record the experiment for 3DSSPP analysis • 35-mm camera took still photos of the frontal and sagittal planes while the manipulations were performed • The Lumbar Motion Monitor was used for the dynamic model to measure the maxim sagittal flexion, average rotational velocity, and maximum lateral velocity.	• a significant difference was found for the variables maximum sagittal flexion, disk compression force, and ligament strain as table height was varied. • For the lumbar and thoracic manipulation tasks, the medium table height (655 mm) was found to create the least low- back strain. • For the cervical manipulation task, the high table height (845 mm) was found to be the least straining on the low back. • The low height table (465 mm) was the most straining for all tasks. • Upper extremities were not significantly affected by changes to table height. • There was no significant interaction between table height and task performed.	• Counterbalancing was not used • Study performed on a narrow group of chiropractors
Comparison of cumulative low back loads of caregivers when transferring patients using overhead and floor mechanical lifting devices, Santaguida, Canada, 2005	Describe and quantify the cumulative spinal mechanical loading patterns associated with a bed to chair transfer task using five mechanical lifting devices	5 Female Registered Nurses with experience transferring patients	• OTPT-RAK 3020 motion system collected body position data. • 2 forcepaltes collected ground reaction forces • Exertion rated using Borg scale at completion of every phase of transfer task • State 3-D multisegment model developed for lower body and trunk to estimate mechanical loads to low back • Linked eight-segment model was used to estimate net reaction moments and forces	• Highest perceived exertion for getting sling under patient in bed • Spinal loads or perceived exertion during transport could be attributed to the mechanical kiting device being used	• Have single patient only represented worst-case scenario and reduced variability • Single transfer task and restricted # of devices limits inference to other transfer activities and devices • Heights of bed and chair were fixed limiting anthropometric range of subjects • Laboratory setting limits validity • Subjects leaned against bed
Loading along the lumbar spine as influence by speed, control, load magnitude, and handle height during pushing, Marras, US, 2009	Evaluate the influence of control related variables (type of system, speed, and precision) and other variables (load and handle height) that influence spine loading during pushing	20 inexperienced university students	• EMG- assisted biomechanics model used to assess compression, lateral shear, and A/P shear spine forces at six spine levels of lumbar • Lumbar motion monitor monitored trunk kinematics necessary to estimate vertebral body orientation, trunk muscle length, and trunk muscle velocity. • Magnetic/gravitational sensors placed on torso and arms to track body postures and positions	• Antagonistic coactivation is a primary mechanism of increased spine loading • No difference in spinal loading between floor device and ceiling device	• Straight path of motion masked differences between devices
Effects of training and experience on patient transfer biomechanics, Hodder, Canada, 2010	Analyze trunk kinematics and muscle activity during 3 patient handling tasks selected from a back injury prevention program in novices, before and after training, and trained experienced nurses.	12 untrained individuals and 10 experienced nurses	• Trapezius, external oblique, erector spine, rectus femurs and posterior deltoid monitored bilaterally • Peak EMG was normalized to MVE • A lumbar motion monitor measured angular displacements of the thoracolumbar spine in 3-D	• In all 3 tasks, training to novices resulted in more favorable muscle activities and lumbar motions. • EMG of nurses suggested some learned or protective behaviors.	• Due to being observed, the nurses may have been mindful of their posture than typical • Normalizing muscle activity to their maximal effort may have increased variability due to novice being more familiar with maximal effort than nurses
Ergonomic evaluation of hospital bed design features during patient handling tasks, Mehta, USA, 2011	Evaluate the physical demands resulting from alternative hospital bed design features during two patient handling tasks (transportation and repositioning)	12 Virginia Tech students	• Hand forces to push bed measured with a pair of load cells attached to bed T • Representative posture, mean push force, and net moments at the shoulder and the torso estimated using University of Michigan 3DSSPP T • 3-D coordinate measurement system used to measure horizontal distances between a reference point on the foot-end portion of the bed frame and the participants' knees C	• Steering lock featured showed potential to reduce adjustments required and perceived physical demands during hallway maneuvering • # of adjustments dependent on weight of patient (only heavy patient condition significant) • Cumulative sliding distance increased with bed raising/lowering repetitions • Bed contour feature significantly reduced patient sliding over time • As the # of repetitions increased, patient sliding with the contour feature reached a plateau	• Main effect of patient transportation study influenced by inherent differences between the two beds • Participants were novices • Performed in lab rather than actual healthcare facility • Participants acting as "simulated" patients may not have accurately simulated complete dependency
The effects of caregiver experience on low back loads during floor and overhead lift maneuvering activities, Dutta, Canada, 2011	Investigates the effects of caregiver experience on peak external forces and moments generated at the L5/S1 joint of the low back when maneuvering loaded floor-based and overhead-mounted patient lifting devices	21 Female caregivers between ages 19-60	• 3-D motion capture data processed for activity/condition combination • Net external moments at the L5/S1 calculated about all three axes by summing moments from ground reaction forces and gravity acting on pelvis, thigh, and lower legs	• Floor lift data showed significant effect of experience but not by overhead lift use • Significant differences between more and less experienced caregivers for the turn, push, and leg up activities.	• Findings suggest caregivers learning task in protective ways toward back over time, costing other parts of the body to higher loads • Biomechanical model not detailed enough to observe co-contraction of trunk muscles
A biomechanical assessment of floor and overhead lifts using one or two caregivers for patient transfers, Dutta, Canada, 2011	To compare the loads resulting from a sample of experienced, older caregivers working alone and in pairs using floor and overhead lifts	21 Female caregivers between ages 19-60	• 3-D motion capture data, ground reaction, and anthropometric data combined for biomechanical model • Reaction forces at hands and external moments at L5/S1 were outcome variables (Peak values were used and averaged over three trials)	• Results indicate overhead lift require lower forces to operate than floor lifts during transport phase • Legs Down/Legs Up activities similar between overhead and portable lift • With Pull, Turn, and Push activities the forces and moments associated with the primary and solo conditions were higher with the portable lift in most cases • Caregivers preferred the overhead lift	• Antagonistic muscles contraction not measured, therefore internal spine compression and shear were unable to be estimated • Males not included due to mass restriction of Force Shoes • Scenarios found in normal patient care excluded by clinical design: old equipment, agitated patient, and non level floor surfaces
The effect of working position on trunk posture and exertion for routine nursing tasks: an experimental study, Freitag, Germany, 2013	To examine the influence of the two following factors on the proportion of time that nurses spend in a forward-bending trunk posture: (i) the bed height during basic care activities at the bedside and (ii) the work method during basic care activities in the bathroom.	12 geriatric nurses	• The CUELA measuring system was used to record all trunk inclinations • WIDANN 2.79 synchronized the video recordings • Sensors were placed over the thoracic and lumbar spine • Subjects were video tapped at 50 Hz	• If the bed was raised from knee to thigh level, the proportion of time spent in an upright position increased by 8.2% with no significant effect. • When the bed was raised to hip height, there was a significant increase of 19.8% from thigh height and 28.0% from knee height. • The greater the proportion of time spent in an upright position, the lower the Borg rating (P < 0.001) awarded.	• The participants were not selected at random but as a convenience sample • Most participants were unaccustomed to working with the bed at hip height and were rather reluctant to use a stool in the bathroom at first
Lumbar-Load Analysis of Manual Patient-Handling Activities for Biomechanical Overload Prevention Among Healthcare Workers, Jäger, Germany, 2013	Analyze whether the load on the lumbar spine during specified manual patient-handling activities can be reduced by applying biomechanically improved transfer modes instead of conventional techniques (with and without the use of small aids)	2 Female caregivers with extensive professional experience	• Postural data of nurse gathered via video recording and optoelectronic cameras; patient posture recorded by additional video camera • Position sensor formed by 3 infrared cameras arranged along a defined distance and fixed angle • Forces exerted by nurse recorded by force-sensory bed and chair; with additional force-sensory bars fixed to sides of bed • Force splitting performed when patient was move to/from chair • Force plates in front of bed were used to control the reaction forces • mechanical load on the lumbar spine quantified by a 3-D multi-segmental dynamic simulation tool	• Highest action forces at the hands, loading moment, and reaction forces at the spine generated during moving phase • Most indicators showed lower values using optimized mode and small aids versus conventional methods (8 of 9) • Negligible load reduction found for repositioning patient from head of the bed • Moment values increased with increasing compressive force	• One optoelectronic marker at one hand limited when caregiver held hand under patient • small sample size limited the number of repeated task executions with more/less identical conditions • load on the spine of the caregiver was not considered • limited coordination between the subjects during handling led to competing force exertion

Conclusion

There is indication from these studies that several patient handling tasks including repositioning the patient in bed could potentially produce spinal load at hazardous levels. The advantage of a high bed height on the low back may be to the detriment of other upper body joints. Oppositely, at a lower bed height power is generated by movement of the trunk and lower extremities, which could allow a closer handling of the patient horizontal to the caregiver's shoulder. The span of these studies measured across experience levels, incorporation of mechanical equipment, and patient handling tasks. However, few studies considered variation in bed height and no studies reviewed the back loading imposed in the home care environment.

Next Steps

The second phase of this study will simulate patient handle tasks conducted by experienced nurses in a nursing-home environment. Video recording of these tasks, along with handling force involved will be used to predict the required static strength and spinal load to perform patient handling tasks at varied bed heights using biomechanical modeling on University of Michigan 3D Static Strength Prediction Program (**3DSSPP**) software.

A simple hand dynamometer system was fabricated to estimate the actual pulling and pushing forces in patient handling.

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