Safety analysis of patient transfers and handling tasks

ER Vieira and S Kumar

doi:10.1136/qshc.2006.022178

Updated information and services can be found at:
http://qshc.bmj.com/cgi/content/full/18/5/380

These include:

References
This article cites 23 articles, 2 of which can be accessed free at:
http://qshc.bmj.com/cgi/content/full/18/5/380#BIBL

Rapid responses
You can respond to this article at:
http://qshc.bmj.com/cgi/eletter-submit/18/5/380

Email alerting service
Receive free email alerts when new articles cite this article - sign up in the box at the top right corner of the article

Notes

To order reprints of this article go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to Quality and Safety in Health Care go to:
http://journals.bmj.com/subscriptions/
Safety analysis of patient transfers and handling tasks

ER Vieira,1,2 S Kumar3

ABSTRACT

Background: Low-back disorders are related to biomechanical demands, and nurses are among the professionals with the highest rates. Quantification of risk factors is important for safety assessment and reduction of low-back disorders.

Objective: This study aimed to quantify physical demands of frequent nursing tasks and provide evidence-based recommendations to increase low-back safety.

Methods: Thirty-six volunteer female nurses participated in a cross-sectional study of nine nursing tasks. Lumbar range of motion (ROM) and motion during nursing tasks were measured. Compression and shear forces at L5/S1, ligament strain and percentage of population without sufficient torso strength to perform 14 phases of nine nursing tasks were estimated.

Results: Peak flexions during trolley-to-bed, bed-to-chair and chair-to-bed transfers reached the maximum flexion ROM of the nurses. Average lumbar flexion during trolley-to-bed transfers was >50% of flexion ROM, being higher than during all other tasks. Mean (SD) compression at L5/S1 (4754 N (437 N)) and population without sufficient torso strength (37% (9%)) were highest during the pushing phase of bed-to-trolley transfers. Shear force (487 N (40 N)) and ligament strain (14% (5%)) were highest during the pulling phase of trolley-to-bed transfers.

Conclusions: Nursing tasks impose high biomechanical demands on the lumbar spine. Excessive lumbar flexion and forces are critical aspects of manual transfers requiring most of the nurses’ capabilities. Evidence-based recommendations to improve low-back safety in common nursing tasks were provided. Fitness to work, job modifications and training programs can now be designed and assessed based on the results.

Work-related low-back disorders (WLBDs) are the prevalent and most costly work-related musculoskeletal disorder, and they are associated with the work physical demands.2,3 Nurses are among the professionals with the highest rates of WLBD.4–6 A generally accepted approach to reduce the risk of WLBD is to identify unsafe tasks, determine the critical factors in the tasks and modify those critical factors to improve low-back safety. Thus, it is important to quantify physical demands to identify the risk factors and to design evidence-based interventions to control WLBD in nursing jobs.

Manual patient transfers were previously reported by nurses as the most stressful transfer method and these tasks were previously reported as the main cause of WLBD among nurses.7,8 The greater the manual handling of patients, the higher the prevalence of WLBD.9 In a previous study, we reviewed the injury records for the previous 5 years in the same hospital where the current study was done.7 Approximately 70% of the WLBD in nurses happened while transferring or handling patients. WLBD occurred most often in orthopaedic nurses (32%) and intensive care nurses (17%). The orthopaedic and intensive care nurses completed a questionnaire survey. Indeed, the tasks considered most physically demanding were patient transfers by orthopaedic nurses, and turning and repositioning in bed by intensive care nurses.3

Considering the results of our previous study, the objectives of the study presented in this article were to quantify physical demands of manual patient transfers by orthopaedic nurses, quantify physical demands of manual patient turning and repositioning in bed by intensive care nurses, identify specific risks involved in different phases of these tasks and offer evidence-based recommendations to increase low-back safety during these common nursing tasks.

METHODS

Participants

Twenty-one orthopaedic nurses and 15 intensive care nurses not having WLBD participated in the study (>70% of the nurses working full time). The mean (SD) ages for the orthopaedic and intensive care nurses were, respectively, 35 (7) and 34 (9) years; weight was 74 (8) and 68 (6) kg, and height was 168 (5) and 167 (7) cm. The same nurses played patients’ role during the recorded transfers. This study was approved by the University and Hospital Research Ethics Committee.

Nursing tasks

Nine tasks were evaluated: patient transfers from trolley to bed (T-B), bed to trolley (B-T), bed to chair (B-C), chair to bed (C-B), chair to wheelchair (C-W), wheelchair to chair (W-C), turning patients towards (T-T) the nurse side of the bed, turning patients away (T-A) from the nurse side of the bed and repositioning patients in bed (R-P) towards the headboard. Detailed description of the tasks is provided online. The orthopaedic nurses performed T-B, B-T, B-C, C-B, C-W and W-C, and the intensive care nurses performed T-T, T-A and U-B once.

Lumbar motion

Three maximum flexions, extensions, lateral flexions and rotations were performed to measure the lumbar range of motion (ROM) on the frontal and transversal planes using electrogoniometers (elgons) (Biometrics, Gwent, UK) and perpendicular marker photogrammetry.10 The elgons were...
placed in attachment ducts and were attached to the skin over the spinal processes of T12 and L5 using double-adhesive tape. The nurses were videotaped from the sagittal plane, and frames were extracted to represent the neutral, fully flexed and fully extended postures. The difference between the neutral and the fully flexed postures defined the flexion ROM and the difference between the neutral and fully extended postures defined the extension ROM. The lumbar motions in the sagittal, frontal and transversal planes during the nine tasks were recorded using elgons using the same procedures.

**Lumbar compression and shear forces, ligament strain and population without sufficient torso strength to perform the tasks**

The tasks were video-recorded from the sagittal plane at 30 Hz using a Canon mini DV media digital camera (Canon, Lake Success, NY, USA) and synchronised with the elgons’ by an LED and an electric pulse. Round, highly reflective surface markers were placed on the ankle, knee, shoulder, elbow and wrist regions to facilitate the identification of joint position. The videos and elgons’ data were used to measure the postures and to determine beginning, end and duration of the tasks and their different phases. Joint angles were measured on video frames using the Angles software version 1.2 (University of Alberta, Edmonton, Canada).

We used the 3D Static Strength Prediction Program (3D SSPP V.4.3, University of Michigan, Ann Arbor, Michigan, USA, 2000) to estimate instantaneous compressive and shear forces on the lumbar spine (L5/S1). Cumulative compression and shear forces during the tasks were calculated by multiplying the load of the different tasks and phases by their duration. The joint angles, height, weight, age, sex, vector directions and external forces were used as inputs. The B-C, C-B, C-W and W-C transfers were not analysed with the biomechanical model because they were asymmetrical with movements in multiple planes. Future studies could perform laboratory simulations to evaluate these tasks in an environment that would allow for the use of multiple cameras.

**Data analysis**

The lumbar motion during the tasks was normalised by the lumbar ROM. Peak and average lumbar motion, estimated instantaneous and cumulative L5/S1 compression and shear forces, ligament strain and percentage of the population without sufficient torso strength were entered in a spreadsheet. Statistical analysis was performed using SPSS statistical package SPSS 11.0, Chicago, IL, USA). Descriptive analysis was performed, and the physical demands (job motion and spinal load on the different tasks and phases, and ligament strain and percentage of the population not capable) were compared using two-way ANOVA. Bonferroni post hoc tests adjusted for multiple comparisons were done for specific comparisons when ANOVA showed significant differences among groups. The significance level was set to 0.05.

**RESULTS**

**Lumbar motion**

The mean (SD) lumbar ROM was 53° (8°) of flexion, 15° (9°) of extension, 24° (6°) of lateral flexion and 18° (12°) of rotation. Figure 1 presents the normalised peak lumbar motion during the tasks. Flexion was higher than the other movements (mean difference >15%, p<0.001). Peak flexions were <50% of ROM only during U-B. For the other movements, only peak right rotations during T-B and B-T were >50% of ROM. Little extension was performed during the tasks. Peak flexions during the orthopaedic nurse transfers were higher than during the intensive care nurse tasks (mean difference >21%, p<0.006).

The average lumbar posture was flexed in the sagittal plane (mean posture 40% of flexion ROM, 95% confidence interval (CI) 37 to 42, mean difference >37%, p<0.001). Average lumbar flexions during T-B were >50% of the ROM. Average postures were close to neutral posture in the frontal (mean posture 0.4%, 95% CI – 0.3 to 2) and transversal planes (mean posture 0.1%, 95% CI – 0.3 to 2). Average flexions during T-B were higher than during W-C (mean difference 19%, p=0.026) and than during the intensive care nurse tasks (T-T, T-A and U-B) (mean difference >22%, p<0.001). Average flexions during B-T, B-C and C-B were higher than during U-B (mean difference >15%, p<0.047).

**Compression and shear forces at L5/S1 during nursing tasks and their phases**

Table 1 presents the lumbar loads during nursing tasks. The average peak compression was 2127 N (95% CI 2087 to 2168). There were differences among the tasks (F = 96, p<0.001) and phases (F = 228, p<0.001). Instantaneous compressions during U-B were the highest (mean difference >298 N, p<0.001). Instantaneous compressions during B-T were higher than during T-B, T-T and T-A (mean difference >450 N, p<0.001). The compressions were the lowest during T-T (mean difference >344 N, p<0.001).

The average peak shear force was 284 N (95% CI 281 to 288). There were significant differences among the tasks (F = 548, p<0.001) and phases (F = 508, p<0.001). Peak shear during B-T, T-T and U-B were higher than during T-B and T-A (mean difference >42 N, p<0.001); during U-B, they also higher than during B-T and T-T (mean difference >27 N, p<0.001).

Figure 2 presents the peak compression and shear forces during the phases of the tasks. Data on cumulative forces during the phases are presented online. Peak compressions during the pushing phase of B-T were the highest (mean difference >705 N, p<0.001). After that, compressions during lifting in U-B were the second highest (mean difference >425 N, p<0.013). In third place were the compressions during pulling in T-B (mean difference >1208 N, p<0.001). Peak shear forces during the phases were highest during the pulling phase of T-B (mean difference >53 N, p<0.028). Followed by the lifting phase of U-B (mean difference >100 N, p<0.001), and they were lowest during the positioning phase of T-B (mean difference >72 N, p<0.001).

**Percentage of estimated ligament strain and percentage of the population without sufficient torso strength to perform the tasks and their phases**

The average ligament strain was 13% (95% CI 12.6 to 13.1). There were differences among the tasks (F = 8, p<0.001) and phases (F = 59, p<0.001). Estimated ligament strains during T-B were the highest (mean difference >1.2%, p<0.017). The average percentage of the population without sufficient torso strength to perform the tasks was 12% (95% CI 11.3 to 12.4). There were differences among the tasks (F = 66, p<0.001) and phases (F = 107, p<0.001). Percentages of the population without sufficient torso strength to perform B-T were higher than to perform B-T (mean difference 3.1%, p<0.026). Percentages during T-B, B-T and U-B were higher than during the turning tasks (T-T and T-A) (mean difference >7.1%, p<0.001).
Figure 3 presents the percentage of ligament strain and percentage of the population without sufficient torso strength to perform the specific phases of the nursing tasks. Predicted ligament strains during the positioning and pulling phases of T-B, pushing phase of B-T and reaching phase of T-T were higher than during the preparation phase of T-B, turning the patient and waiting phases of B-T, pulling towards and holding phases of T-T, organising phase of T-A and both phases of U-B (mean difference \(\Delta \% = 2.7\%, \ p = 0.001\)). The percentages of people without sufficient torso strength were higher for the positioning and pulling phases of T-B, pushing phase of B-T and lifting phase of U-B than for all other phases of all tasks (mean difference \(\Delta \% = 5.6\%, \ p = 0.026\)).

**DISCUSSION**

Peak motions during transfers by orthopaedic nurses were higher than during turning and repositioning tasks by intensive care nurses. Average flexion and ligament strain during T-B were the highest. In addition, the full flexion ROM was used during the transfers exposing the orthopaedic nurses to increased risk of overexertion injuries. Job motion should be within 20% of the ROM and not exceed 50% of the ROM. The National Institute for Occupational Health and Safety suggested even more stringent guidelines with an action limit for joint motion of 10% of the ROM and a maximal permissible limit of 30% of the ROM. During the transfers, peak flexions surpassed the maximum flexions of the orthopaedic nurses in

**Figure 1** Mean and SD (error bars) of peak lumbar motion during the tasks as percentage of the range of motion (percentage of ROM) in the sagittal, frontal and transversal planes (positive deflection = flexion, left lateral flexion and left rotation; negative deflection = extension, right lateral flexion, and right rotation).

**Table 1** Lumbar loads during the nursing tasks

<table>
<thead>
<tr>
<th>Variable</th>
<th>Task</th>
<th>Mean</th>
<th>SD</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous compression (N)</td>
<td>T-B</td>
<td>1986</td>
<td>1263</td>
<td>1642</td>
<td>2331</td>
</tr>
<tr>
<td></td>
<td>B-T</td>
<td>2457</td>
<td>1691</td>
<td>1995</td>
<td>2918</td>
</tr>
<tr>
<td></td>
<td>T-T</td>
<td>1641</td>
<td>531</td>
<td>1530</td>
<td>1752</td>
</tr>
<tr>
<td></td>
<td>T-A</td>
<td>2006</td>
<td>586</td>
<td>1884</td>
<td>2129</td>
</tr>
<tr>
<td></td>
<td>U-B</td>
<td>2756</td>
<td>1363</td>
<td>2404</td>
<td>3108</td>
</tr>
<tr>
<td>Instantaneous shear (N)</td>
<td>T-B</td>
<td>271</td>
<td>171</td>
<td>224</td>
<td>317</td>
</tr>
<tr>
<td></td>
<td>B-T</td>
<td>314</td>
<td>55</td>
<td>299</td>
<td>329</td>
</tr>
<tr>
<td></td>
<td>T-T</td>
<td>322</td>
<td>44</td>
<td>313</td>
<td>332</td>
</tr>
<tr>
<td></td>
<td>T-A</td>
<td>186</td>
<td>45</td>
<td>176</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>U-B</td>
<td>350</td>
<td>111</td>
<td>322</td>
<td>379</td>
</tr>
<tr>
<td>Cumulative compression (N)</td>
<td>T-B</td>
<td>14493</td>
<td>10381</td>
<td>11660</td>
<td>17327</td>
</tr>
<tr>
<td></td>
<td>B-T</td>
<td>12577</td>
<td>5857</td>
<td>10979</td>
<td>14176</td>
</tr>
<tr>
<td></td>
<td>T-T</td>
<td>6584</td>
<td>4614</td>
<td>5618</td>
<td>7551</td>
</tr>
<tr>
<td></td>
<td>T-A</td>
<td>7214</td>
<td>4506</td>
<td>6271</td>
<td>8158</td>
</tr>
<tr>
<td></td>
<td>U-B</td>
<td>8273</td>
<td>3957</td>
<td>7251</td>
<td>9296</td>
</tr>
<tr>
<td>Cumulative shear (N)</td>
<td>T-B</td>
<td>1667</td>
<td>767</td>
<td>1458</td>
<td>1876</td>
</tr>
<tr>
<td></td>
<td>B-T</td>
<td>1974</td>
<td>908</td>
<td>1726</td>
<td>2223</td>
</tr>
<tr>
<td></td>
<td>T-T</td>
<td>1315</td>
<td>738</td>
<td>1161</td>
<td>1470</td>
</tr>
<tr>
<td></td>
<td>T-A</td>
<td>699</td>
<td>500</td>
<td>594</td>
<td>804</td>
</tr>
<tr>
<td></td>
<td>U-B</td>
<td>1150</td>
<td>591</td>
<td>998</td>
<td>1303</td>
</tr>
</tbody>
</table>

T-B, transferring from trolley to bed; B-T, transferring from bed to trolley; T-T, turning towards; T-A, turning away; and U-B, repositioning up in bed.
same cases possibly because the external load (patient) forced the low back to flex further than during the active, unloaded ROM tests by stretching the passive structures and viscoelastic tissues of the low back, further increasing the risk of injury. These factors may help to explain the higher rates of WLBD among orthopaedic nurses in relation to intensive care nurses.

The biomechanical model used assumed that the system was in static equilibrium; for this reason, the lumbar loads during the tasks may be even higher and the percentage of the population capable of performing the tasks may be lower during their dynamic components. Despite this, the compression forces were higher than the National Institute for Occupational Health and Safety action limit (3400 N) during the lifting phase of U-B, pushing phase of B-T and pulling phase of T-B. In a previous study, the peak compression in workers who reported WLBD (3423 N) was higher than in those who did not report it (2753 N, p<0.001). In our study, the peak sear forces during the pulling phase of T-B (mean 487 N (SD 40 N)) and during the lifting phase of U-B (mean 454 N (SD 53 N)) were similar to the values reported for workers with WLBD: 462 N (178 N). These findings help to explain the high rates of WLBD among nurses. The combination of high bending moments, shear and compression forces increases the risk of injury to the lumbar intervertebral disks, back muscles, ligaments and joints.

WLBD and other musculoskeletal disorders are multifactorial in nature. Genetics, morphology, psychosocial and biomechanical factors interact in the causation of these disorders. Thus, it is only feasible to reduce their prevalence as opposed to total eradication as the term prevention may imply. Training in

---

**Figure 2** Mean and SD (error bars) for instantaneous compression and shear forces during the phases of the nursing tasks. T-B, transferring from trolley to bed; B-T, transferring from bed to trolley; T-T, turning towards; T-A, turning away; U-B, repositioning up in bed.

**Figure 3** Mean and SD (error bars) for percentage of ligament strain and percentage of the population without sufficient torso strength to perform phases of the nursing tasks. T-B, transferring from trolley to bed; B-T, transferring from bed to trolley; T-T: turning towards; T-A, turning away; and U-B, repositioning up in bed.
patient handling and transfers alone is not enough to reduce WLBD prevalence.\textsuperscript{2,25} On the other hand, training and education combined with ergonomic interventions, using mechanical lifts, and regular exercise were found to be effective in reducing WLBD rates in nurses.\textsuperscript{6,24–26} The use of mechanical assistive devices reduced the compression forces during bed-to-bed transfers from 2955 to 1189 N.\textsuperscript{27} Despite reducing the peak load, the use of lifting devices may increase the cumulative load because of the longer time to complete patient transfers.\textsuperscript{28} The contribution of different tasks to the average load over a work shift is also important given the cumulative nature of musculoskeletal disorders.

The results of our study support the importance of ergonomic interventions to reduce physical loading but also demonstrates the importance of combined staff training. Training programs could be implemented to emphasise the importance of minimising the time unnecessarily spent in trunk flexion. For example, when turning the patient towards, if not contra-indicated for the patient (eg, hip replacement surgery), the nurse could flex the patient’s contralateral hip and knee, position her hands on the knee and use the femur as a lever to reduce the reach distance and force required. When repositioning the patient up in bed, the nurse could use a slide sheet and lower the headboard to reduce the amount of lifting force required.

Nursing tasks impose significant biomechanical demands on the low-back musculoskeletal system contributing to the high prevalence of WLBD in nurses. The demands of nursing tasks vary depending on the tasks in different hospital departments. Specific tasks should be evaluated because the demands vary even when alternating the direction of the task (eg, B-T vs T-B). Excessive lumbar flexion and forces are critical aspects of the transfers and handling tasks requiring most of the nurses’ capacity. Introducing additional mechanical lifts, minimising the time to complete the transfers, training staff on proper biomechanical techniques to use, promoting safe behaviour at work and reducing the amount of trunk flexion and forces required during the transfers will greatly reduce the physical demands and increase the low-back safety in the nursing tasks analysed. Fitness to work, job modifications and training programs can be designed and assessed based on the results.

Acknowledgements: Funding from the Canitas Health Group, the Alberta Canadian Institutes of Health Research Training Program in Bone and Joint Health and by the Education Ministry of the Brazilian Government (CAPES, proc. 1340-01/8) is gratefully acknowledged. We are also grateful to Dr Helenice JCG Coury (Federal University of Sao Carlos, Brazil) for lending us the electrogoniometer used in the project, and we would like to thank Isac Lima (data analyst and MSc Student) and Susan Armijo Olvo (PhD student) for their help with the statistical analysis of the data.

Funding: Background: Low-back disorders are related to biomechanical demands, and nurses are among the professionals with the highest rates. Quantification of risk factors is important for safety assessment and reduction of low-back disorders.

Competing interests: None.

REFERENCES