The Ergonomic Report

An Analysis of Physical Work of Care Aides

Ergonomic Research Team

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E1 Introduction

Early in the project, ergonomists Judy Village, Tony Leyland, and Carol Uy conducted tours and informal interviews at several Intermediate Care facilities (non-study facilities) to gain an understanding of issues relating to physical work, work organization, staffing, resident needs, care aide concerns, health and safety incidents, and administrator concerns. During these visits, each ergonomist was paired with a care aide and permitted to observe them during work activities, ask questions, and record observations. These informal interviews and task analyses were recorded and later discussed by the ergonomics group. The main findings from the on-site research, which helped to focus the next phase of methods development, were that:

- physical demands on care aides can vary tremendously, even when working with the same residents;
- it is impossible to define a "typical" workload or shift;
- resident handling is relatively minimal and thus may not account for many injuries; and
- injuries are multi-factorial, and contributing factors may include facility design, equipment availability, number of tasks performed (resident-care and non-resident-care), and the individual worker's technique and posture.

The ergonomists observed that workload variation occurred between resident assignments (number of residents and their functional capabilities), between two care aides with the same resident assignment, and even with the same care aide and resident assignment on different days. The non-cyclical nature of the job, which results in workloads that vary across and between shifts, raised a challenge in determining and describing the physical work of care aides. Another challenge lay in determining a "typical" workload due to the many variations from numerous demands. Care aides and management were reluctant to describe anything as typical.

Another observation that guided methods development was the relationship between resident acuity (dependence) and the physical demands of the job. Although many determinants may affect this relationship, the ergonomists assumed that caring for more severely dependent and ill residents results in more physically demanding work for care aides. For example, residents who cannot walk, toilet, dress, and feed themselves independently require more attention, which increases physical workload and produces an increased risk of musculoskeletal injury (MSI) for the worker.

Resident handling and incidences of physical aggression were described by the workers and managers as the most common cause of acute back strain. Yet preliminary observations of care aides revealed very few tasks that appeared to involve the high peak spinal loading that can result in acute back strain. As well, reports of physical aggression were said to be relatively rare. However, the ergonomists did observe that care aides were at risk of injury due to repeated and sustained bending and twisting of the spine, such as assisting a resident to dress, eat, toilet, walk, and bathe, and in non-resident care activities such as bed-making.

An extensive review of the ergonomics literature for methods and techniques of measuring physical workload revealed that the majority of methods involved short-cycle work. It was determined that a variety of ergonomic methods would be employed including: collection of information directly from records; measurement of physical layouts within each facility; interviews with care aides; specific questions within the telephone survey; direct observation and documentation of task performance and frequency of performance; and direct measurement of several determinants of acute and cumulative physical demands. The proposed methods were then evaluated in a three-day pilot test conducted at a non-study Intermediate Care facility. Based on results of the pilot study, the ergonomic methods were modified and detailed research protocols were drafted.

E2 Ergonomic hypothesis and objectives

An ergonomic hypothesis was developed stating that facilities with higher injury rates would have workers who experienced one or more of the following:

- more time in bent and twisted postures (increased spinal loading);
- more lifting, transferring, and assisting of residents;
- more instances of physical aggression; and/or
- more instances of unexpected physical loading (e.g., resident falling).

It was hypothesized that increased spinal loading among workers in facilities with higher injury rates could be due to many possible determinants. The ergonomics group suggested that each of the following factors could have some relationship to physical workload and spinal loading, and would thus need to be measured:

- staffing levels, as measured by resident-to-worker ratios and staffing at heavy times of day;
- acuity or dependence of residents (the number and distribution of residents who require a high level of care);
- layout of facility (e.g., hallway length/width, room dimensions);
- equipment availability (bathing equipment, mechanical lifting equipment, electric beds, etc.);
- number of resident lifting, transferring, and repositioning tasks performed per care aide per day;
- frequency and organization of bathing residents; and
- frequency of bed-making.

The objectives of the ergonomic analysis of physical work of care aides were to:

- determine if there are differences in the physical work load of care aides in high injury-rate facilities compared with low injury-rate facilities; and
- determine the physical work variables related to increased risk of injury, MSI, and musculoskeletal pain.

Physical workload would be determined from the following measures:

- cumulative spinal compression (lower back);
- peak spinal compression (lower back);
- peak neck and shoulder muscle activity;
- total number of transfers, repositions, baths given, and beds made;
- facility design (age of building, length and width of hallways, dimensions of resident rooms and bathrooms);
- ratings of perceived exertion; and
- dependency of residents.

E3 Literature review

Peak spinal loading has been identified as a risk factor for low back disorder by several large epidemiological studies (Marras et al., 1993; Punnett et al., 1991). Each of these studies of the risk factors for MSI of the low back used sophisticated data collection and analysis techniques.

The peak risk factors included torso angle of more than 20 degrees, torso velocities, spinal compression, and lumbar moment of force. These studies were conducted using jobs in repetitive work environments that involved relatively short duration work cycles. Punnett et al. (1991) utilized video methods to show that the relative risk of back injury is related to both the amount of trunk bend and the percentage of the work cycle in which the trunk was bent. Although monitoring of posture exposure over several hours of work is technically feasible by video, the methods are very tedious, time consuming, and expensive.

Cumulative spinal loading has also been identified as a risk factor for low back disorder. Kumar (1990) used a structured questionnaire / interview in a retrospective study of 161 Alberta institutional care aides (14 males, 147 females). Those with back pain (6 males, 95 females) were compared to those without back pain (8 males, 52 females). Spinal loading estimates were obtained by using recall, line drawings, and/or a manikin model to obtain estimates of working postures; these postures were then analyzed using a two-dimensional biomechanical model. Cumulative compressive and shear loads were then calculated based on estimates of task duration and frequency. The groups with pain had significantly greater average estimates of cumulative spinal compression (males = 15.6 MN.s, females = 14.5 MN.s) than the no-pain groups (males = 6.6 MN.s, females = 9.3 MNs). Even though the recall approach has the potential to affect the magnitude of the cumulative compression estimates, this is one of the first studies that clearly identified this risk factor in an occupational setting.

Norman et al. (1998) was one of the first large-scale case-control epidemiological studies to look at psycho-social, biomechanical, and demographic risk factors for the reporting of low back pain, including peak and cumulative exposure variables. The study was conducted in an Ontario automotive assembly facility. Independent risk factors identified for the reporting of low back pain were: 1) peak shear force on the lumbar spine; 2) cumulative compression integrated over the duration of the shift; 3) usual (not peak) force on the hands; 4) workers' perceptions of high physical demands, 5) poor workplace social environments; 6) low job control; 7) high (not low) co-worker support; 8) high (not low) job satisfaction; and 9) better education relative to those who performed similar jobs. The odds ratios for the combination of risk factors were 15:1 for low back pain. Extensive biomechanical measurements were made on more than 250 workers over a two-year period with observations ranging from two to eight hours during normal work (104 cases and 130 controls) and representing more than 1,175 assembly and maintenance tasks. All workers were videotaped, and a trained observer identified all occurrences of "substantial" spinal load by estimating the instants of high spinal moments resulting from forward inclined trunk postures and/or high forces on the hands. These postures were then analyzed in a computerized biomechanical model to determine peak spinal loads. The cumulative spinal load for each job was calculated by totalling the cumulative spinal loads estimated for all of the tasks performed for that job. A cumulative load for each task was calculated based on the peak load for the task and the duration of exposure.

Norman et al. (1998) found strong correlations within peak spinal loading variables and within cumulative loading variables, but poor correlation between the two. This indicates that peak and cumulative loading are measuring different aspects of risk for these jobs. The final multi-variate logistic regression model of the biomechanical variables contained four risk factors related to the reporting of low back pain: 1) peak lumbar shear force; 2) peak torso flexion velocity; 3) cumulative lumbar moment over the entire shift; and 4) time averaged usual hand force. For workers exposed to all four risk factors, the odds ratio was more than 6.0. They also reported that very little predictive power was lost by substituting cumulative spinal compression for cumulative integrated lumbar moment in the regression model.

A recent study by Burdolf and van der Beek (1999) discussed the challenge of choosing appropriate assessment techniques for occupational studies of musculoskeletal disorders. They reported data using an inclinometer attached to the trunk of nurses in a Dutch nursing home. The inclinometer, attached at L2-L3, measured eight hours of continuous angular position of the trunk in the sagittal plane (frequency of 16 Hz) and compared this with office workers. Trunk angle was divided into four classes and duration into five classes. The frequency of trunk motion in each class was compared, as was the percentage of trunk postures in a particular angle for a particular time. The researchers reported that not only were nurses more often found in flexed positions greater than 40º (104 times/hour vs. 48 with office workers) and 60º (46 times vs. 10), but nurses also spent more time in these postures than office workers (5% vs. 2.4% and 1.9% vs. 1.0%). The combination of these two factors would tend to result in higher cumulative spinal loading for the nurses compared to the office workers.

Seidler et al. (2001) used a modification of the Kumar (1990) approach to evaluate cumulative occupational exposure of the lumbar spine to lifting, carrying, and working postures with extreme forward bending. A case-control study was conducted between 229 male patients with symptomatic osteochondrosis or spondylosis of the lumbar spine and 197 control subjects. Data were gathered in structured personal interviews. Instead of using a biomechanical model to evaluate specific working postures, cumulative forces to the spine over the entire working lifetime were calculated using a Mainz Dortmund dose model, based on over-proportional weighting of compression force relative to respective duration of lifting. Self-reported estimates of occupational lifting, flexion, and duration were collected, and a lifetime cumulative dose calculated. Seidler et al. (2001) found that working postures with extreme forward bending for up to 1,500 hours (calculated over all working years) was associated with the diagnosis of osteochondrosis or spondylosis (OR 2) and the odds ratio increased to 4.3 for more than 1,500 hours exposure. Combined exposures to lifting or carrying with working postures with extreme forward bending yielded an odds ratio of 16:1. This is one of the first studies to use a cumulative exposure risk factor as an independent variable. The authors noted that, although a pathogenic concept of chronic increases in inter-vertebral pressure has long been considered an important cause of lumbar spinal disease, it has been difficult to quantify. This quantification is relevant in Germany where compensation systems recognize occupational disorders of the lumbar spine due to lifting, carrying, and bending.

Several authors have recently discussed the array of various techniques for measuring workload exposure in musculoskeletal studies (Burdorf and van der Beek, 1999: Wells et al., 1997; Guangyan and Buckle, 1999; Genaidey et al., 1994; van der Beek and Frings-Fresen, 1998; Wells, et al., 1994). Some authors have broadly classified the various assessment techniques into three categories: subjective judgment by workers, systematic observations, and direct measurements. In the first category, workers respond to questions, usually in self-administered questionnaires, diaries, or interviews. Burdorf and van der Beek (1999) suggest that information collected in this way is subject to systematic bias and lack of precision and that little is known about the factors affecting self reports, such as the relationship with health status. However, Toomingas et al. (1997) found no differential bias in exposure ratings in studies of musculoskeletal disorders where subjects reported both exposure and outcome variables. Wells et al. (1997) stated that with self reports, respondents could identify whether exposure to vibration or lifting stress occurred, but did not tend to give reliable information on either the nature or magnitude of the exposure. The advantages of questionnaire data are the efficient, low resource usage and potentially large sample size.

Various researchers have developed postural recording and assessment tools (e.g., OWAS, RULA) to facilitate the systematic observation approach. These tools are designed to use either direct observation or video recordings as a sampling measure. They are best suited for short- cycle time, cyclical jobs; otherwise, the methods are very time consuming and labour intensive.

Direct measurement, the third assessment category, is generally preferred. It tends to yield specific information regarding the components of a physical load. Equipment costs, set-up time (e.g., calibrations), and analysis time all tend to increase the costs of this approach, and so Burdorf and van der Beek (1999) argue that information of this nature must be integrated with other measures. The trade-off between various approaches is the amount of precision and accuracy in exposure level, duration, and frequency. Burdurf and van der Beek (1999) compared observational measurement (more than two hours) with direct measurement (more than eight hours) for the same day with nurses and office workers. While there were large standard deviations with both measurement techniques, indicating substantial variation in trunk flexion within and between workers, the correlation between the two methods was extremely low or absent. The authors conclude there is a current trend toward quantification of risk factors through direct measures. They also identify the most challenging problem as the optimal utilization of available resources in relation to study design, the risk factors of interest, and the sources of variation in exposure to these risk factors within and between workers.

Wells and Norman et al. (1994 and 1997) have demonstrated an EMG-based, biomechanical approach that allows several external exposure parameters, such as posture, force, and movement, to be combined with the anthropometrics of workers into a single estimate of compressive force at the lumbosacral joint. The resulting force, measured in newtons, is considered a proxy for internal exposure to forces acting on a specific part of the spine. Norman et al. (1998) demonstrated that several parameters of cumulative loading and peak loading were significantly associated with workers who had low back pain. Spinal compression was chosen as the common metric (or consistent measure) for investigating exposure of different jobs since it has biomechanical justification. Spinal compression encompasses many of the risk factors found in other studies such as non-neutral trunk postures and lifting (Wells et al., 1997); in general, spinal compression is strongly related to the trunk moment of force. Marras et al. (1993) found the trunk moment of force to be strongly related to low back disorders. Wells et al. (1997) identified that although injury reports cannot be directly related to spinal motion unit failure, a high loading of the spine is almost impossible to separate from high loads on other spinal tissues such as muscle and ligament.

Mientjes et al. (1999) recently compared the EMG-based method used by Wells and Norman to videotaped recordings and three-dimensional biomechanical modelling. The authors concluded that EMG normalized to spinal compression per unit of EMG was accurate for assessing exposure to risk of low back injury, especially in prolonged tasks and those free of dominant axial twisting moments. The technique was successful in estimating the probability at a selected spinal compression force in most situations, with EMG averaging 14% higher. The authors concluded that this technique is acceptable for field use because in the field, pure axial twisting is uncommon. The technique is also attractive for field use because workers can perform their jobs, without restriction, in their normal work environment. It also eliminates the need to videotape a worker, which facilitates analysis time and greatly reduces cost.

E3.1 Measuring resident dependency

The ergonomists determined that residents' health and their dependency on care aides for activities of daily living (ADL) dictated a major component of the physical load experienced by workers. A survey of facilities led to the conclusion that ratings of functional independence were not standardized. Some nursing homes utilized specialized occupational or physical therapists to assist with this task and others did not. A review of the literature on standardized tools, informal telephone interviews with leaders in the physical and occupational therapy field, and a closer investigation of existing tools led us to conclude that the Functional Independence Measure – the FIM™ instrument – would be most appropriate (Guide, 1997).[1]

The FIM™ instrument is a one-page assessment tool that considers independence in activities such as self care, sphincter control, mobility, locomotion, communication, and social cognition; it requires approximately 15 minutes of on-site assessment time per resident by a familiar caregiver. The tool's reliability has been demonstrated (Ottenbacher et al., 1996; Pollack et al., 1996). One ergonomist received training on the use of the FIM™ instrument.

E4 Methods

As mentioned previously, pilot tests to help formulate the ergonomic analysis methods were conducted at a separate Intermediate Care Facility (i.e., not one of the eight in the final study) in June 2001. Results of within-subject and between-subject data were analyzed and presented to the research group. The preliminary results and research group feedback allowed the final evaluation protocol and sampling strategy for the ergonomic assessment component to be established.

It was previously determined that a "typical" unit was difficult to identify. In an effort to ensure a reasonable comparison of workload for the ergonomics analysis, the director of care and an HEU representative at each of the eight facilities was asked to choose the unit considered the

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most “physically demanding.” The ergonomists then asked the director or Hospital Employees’ Union representative to approach care aides in that unit who had a minimum of one-year experience in the facility and had been free of back pain for three months. Care aides who met these criteria were invited to participate in the study, made aware of the procedures via a written consent form, and asked to sign the form prior to the ergonomic assessment.

Between January 17 and February 15, 2002, ergonomic assessments were conducted at all eight facilities. At each facility, four care aides from the chosen unit were instrumented and observed, two the first day and two the second day. A return visit to one facility was necessary to collect data on two other care aides due to technical difficulties on one test day.

At the beginning of the day shift (usually 6:00 a.m. to 7:00 a.m.), care aides were brought to a room where the ergonomic testing equipment was based. Care aides were again briefed about procedures; potential risks and informed consent were confirmed. An area of skin was prepared and cleaned with an alcohol wipe over the trapezius muscles of their shoulder and at L3/L4 over the belly of the erector spinae muscles in their lumbar back. Surface electromyography sensors were taped to the skin at these sites on both sides of the body. The four channels of EMG were collected using a self-contained portable EMG data collection unit (Me3000P Mega Electronics Inc.) that was worn by the care aides in a fanny pack. To facilitate checking signal quality during the calibration trials, the raw EMG signals were collected at 1000 Hz and stored in the unit until transferred to a laptop computer. For the trials collected while performing their normal duties, the raw EMG signals were collected at 1000 Hz, full wave rectified and a 100 ms moving average window was used to calculate one sample every 100 ms (i.e., 10 samples per second).

To calculate the lumbar spine compression using the EMG, it was necessary to calculate a “compression normalization” calibration factor for the lumbar EMG. This was obtained by having each care aide bend to a trunk angle of 60° (with respect to the vertical) with their arms hanging straight down. To ensure adequate muscle activation, the care aide was asked to consciously keep the lumbar spine in lordosis. This was facilitated by having them extend their neck in an effort to “look up.” While holding this posture, a 15-kg weight was placed in the hands of the care aide for five seconds. Three repetitions of this task were performed. The raw EMG signals were then full wave rectified and a 100 ms moving average window was used to create one sample every 100 ms. Each 5-second portion of the EMG-time history when the subject was holding the 15 kg was identified, and the average EMG, in microvolts (μv), for the middle 3 seconds of this period was calculated. The average of these three values was then calculated.

The care aide's height, weight, and gender were then input into a biomechanical model (4DWatbak, University of Waterloo). The model's mannequin was positioned to match the care aide's calibration posture (60° trunk flexion); the 15-kg mass being held in the hands was also entered. The spinal compression, in newtons (N), which the model determined to be acting at L4/L5, was then recorded. An EMG-to-Compression calibration factor (N/μμv) was then obtained by dividing the L4/L5 compression, as calculated by the biomechanical model, by the average EMG produced in the three repetitions of the calibration posture.

Trapezius (shoulder) EMG data were calibrated at the start of the care aide's first rest break in the morning. The worker stood on a platform and restraining straps were placed snugly over their shoulders. The care aide was then asked to raise their shoulders against the resistance of the straps to exert an isometric, maximal voluntary contraction (MVC) of the shoulder muscles. Three maximal contractions were collected in raw EMG. The average of the three peaks was used as the maximum, and subsequent trapezius EMG was scaled as a percentage of MVC.

Care aides were instructed to perform their duties as they normally would while wearing the fanny pack and EMG sensors. An ergonomist followed and observed each care aide for the entire shift, respecting residents' privacy and documenting major tasks performed such as making beds, performing manual lifts and transfers, repositioning residents, using mechanical lifting devices, and bathing residents.

The EMG signals were downloaded to a laptop computer after five segments of the day shift: 1) pre-breakfast (shift start to the beginning of breakfast); 2) breakfast; 3) pre-lunch (post-breakfast to pre-lunch); 4) lunch; and 5) post-lunch. At completion of the day shift, an ergonomist interviewed the care aide, collecting demographic information, history of previous injuries and pain, subjective assessments of workload during the day, and estimates of number of tasks performed. Care aides were asked about problems with the testing equipment and whether the day was "typical" of their workload. The ergonomists also gathered information about facility design and equipment, such as number of lifting devices available. Measurements were taken of hallways and resident bedrooms and bathrooms. Later the same or following day, an ergonomist conducted intensive interviews with one or more care aides to determine a FIM™ instrument score for each resident.

E5 Analysis of EMG data

Cumulative spinal compression: The cumulative spinal compression for each trial, for each care aide, was calculated using software provided with the portable EMG system (ME3000P, Version 1.5, Mega Electronics Ltd., Finland) and the “compression normalization” calibration factor. For each trial, the EMG software calculated the integral (or area under the curve) for the low back channel producing a value in μv*s. Multiplying this value by the calibration factor (N/μv) produced the amount of cumulative compression (N*s) associated with that period of activity.

It is possible for a person to stand and not produce any EMG (e.g., while standing upright). This creates an anomaly because, even when standing, the lumbar spine is compressed by the mass of the upper body, which is more than half a person’s weight. To correct for this anomaly, a standing cumulative compression bias was added to each of the care aide’s compressions. The bias (N*s) was determined by multiplying the lumbar compression (N) while standing upright, as calculated by the biomechanical model, by the length of the care aide’s shift in seconds (minus breaks) and then added onto the cumulative compression calculated from the EMG.

It was also typically impossible to collect EMG for the entire shift (e.g., patient care data could not be collected while the worker was being hooked up to the EMG electrodes and having calibrations performed). The amount of time that EMG was not collected was determined by calculating the difference between the shift length in seconds (minus breaks) and the amount of time EMG data were collected. Since the compression pre-breakfast appeared higher than other portions of the day, the measured average cumulative load pre-breakfast was multiplied by any missing time due to instrumentation and calibration and then added to the pre-breakfast cumulative compression. The average spinal compression for the remainder of the day was multiplied by the missing time over the remainder of the day; this value (N*s) was then added to the value previously calculated for cumulative compression to produce a total shift-long cumulative compression value. Total cumulative compression for a full seven-hour shift was expressed as MegaNewton * seconds (MN*s).

Average compression was determined for each of the five periods in the day by taking the cumulative compression (μv*s) for that time period, multiplying by the calibration factor (N/μv) and adding the appropriate standing bias value (N*s), and dividing by the amount of time that

EMG was collected during that period. Average compression is expressed in newtons (N) for comparison between periods of the day. It was also possible to compare average compressions as a percentage of standing compression. This illustrated how the average compression on the lumbar spine, for each time period, compared to compression during normal upright standing. This was calculated for each subject by dividing their average compression for the time period by their standing compression as calculated using the biomechanical model and multiplying by 100. These values were then compared across time periods. Cumulative compression means, medians, and standard deviations were then calculated for the four subjects for each of the eight facilities and compared with other variables.

Peak spinal compression (lower back) and peak neck/shoulder muscle activity: Peak values for both lumbar (lower back) and trapezius (shoulder) EMG data were determined by exporting the EMG files for each care aide, for each time period. Using an EXCEL spreadsheet, each file was converted into an amplitude probability distribution function (APDF). For the trapezius, APDF values at the 10th, 50th, 90th, 95th and 99th percentiles were recorded for comparison with guidelines suggested by Jonsson (1979). For the lumbar EMG, values were taken at the 95th and 99th percentiles. In addition, for lumbar EMG, the percent of duration of activity that EMG peaks exceeded 3400 N was calculated for each time period in the day. The National Institute for Occupational Safety and Health (NIOSH) in the U.S. considers 3400 N as the cut-off above which spinal compression increases risk of back injury.

For purposes of comparison with other variables in the project, the 99th percentile peaks for both lumbar and trapezius muscles were used. For some care aides, data were sometimes missing for breakfast and lunch periods. However, these data were of shorter duration and generally lower in magnitude, and were therefore eliminated in the analysis and presentation of peak data. The 99th percentile APDF for the remaining three periods of the day was recalculated, and this single value for each subject was used in calculation of average peak.

E6 Results and discussion

E6.1 Demographics of ergonomic subjects

In total, 34 subjects from eight facilities participated in the ergonomics evaluation; the additional two subjects were due to a third day at Sumac Home after some data were missed in the first day of testing. Most subjects worked seven hours after break times were deducted. Hence, approximately 230 hours of EMG data were collected over the duration of the testing. Of the 34 subjects, all were female except for four males. Their average age was 46 years (SD 8.8 years); their average height was 161.8 cm (SD 7.6 cm), and average weight was 66.5 kg (SD 12.15). The subjects were generally experienced care aides, with an average of 12.1 years experience (SD 7.6) and an average of 10.6 years experience at the current facility (SD 6.1).

Of the 34 care aides, 21 had one or more previous time-loss injuries and 13 had none. Injuries were related to the back (12) or shoulder (9). Seven care aides mentioned pain that was ongoing, and another 17 had one or more incidents of pain at some point in the previous year. Twelve care aides stated that they had been injured due to resident behaviour. When asked about workload at the end of the shift, 2 subjects said the workload had been “light,” 17 said “moderate,” and 15 said “heavy.”

E6.2 Results of cumulative spinal compression (lower back)

Means and standard deviations of cumulative spinal compression for each of the eight facilities are shown in Table E1. The overall mean for high injury-rate facilities (HIRFs) is compared with low injury-rate facilities (LIRFs); the non-significant p-value is shown for a 2-tailed t-test (0.2). The second overall mean and p-value shown is with one HIRF removed from the calculations. The injury rate for this facility was on the borderline between LIRF and HIRF. As Table E1 shows, the difference in the means is significant ($p<0.05$) when this borderline facility is removed.

Table E1 – Cumulative spinal compression (lower back) means (MN*s) and standard deviations for eight facilities

High injury-rate facilities (HIRFs)		**Low injury-rate facilities (LIRFs)**		**P Value**
Mean	**(std dev.)**	**Mean**	**(std dev.)**	
22.78	(4.65)	17.78	(5.44)	
18.15	(4.06)	14.17	(2.81)	
16.51	(3.67)	11.69	(1.52)	
13.07	(3.09)*	17.02	(5.27)	
Overall mean: 17.62	**(5.02)**	**Overall mean: 15.39 (4.48)**		**0.2**
Overall mean*: 19.14	**(4.66)**			**0.04**

* This facility was removed for the second calculation of differences between the means.

Figure E1 shows the seven-hour cumulative spinal compression for each subject at all facilities compared with the low back pain reporting index. The low back pain index indicates the percentage of the population who are likely to report back pain at a given level of cumulative compression (based on data collected by Norman et al., 1998). For example, at 0.5 on the low back pain index, 50% of workers would likely report low back pain given a cumulative load of 23 MN*s. For comparison purposes, a person who stands upright for a seven-hour day would have a cumulative compression on their spine of 8.15 MN*s. Standing upright with a 13 degree forward bend for seven hours would yield a compression of 16.7 MN*s. Likewise standing upright with 75 pounds in the hands for seven hours would yield a compression of 16.6 MN*s. Therefore, cumulative spinal compression is based on the combination of bending and load handling over the course of a day.

Figure E1 shows levels of cumulative spinal compression ranging from 10.37 to 28.95 MN*s. Based on the index, the care aides' likelihood of reporting low back pain ranged from 26% to 63%, with a mean of 38%. Note also in Figure E1 the distribution of individual subjects according to their facilities. Although some individual subjects with high compression belonged to low injury-rate facilities (and vice versa), the clear trend is that high spinal compression is associated with high injury-rate facilities.

Figure E1 – Cumulative spinal compression (lower back) for individual subjects compared with low back pain index

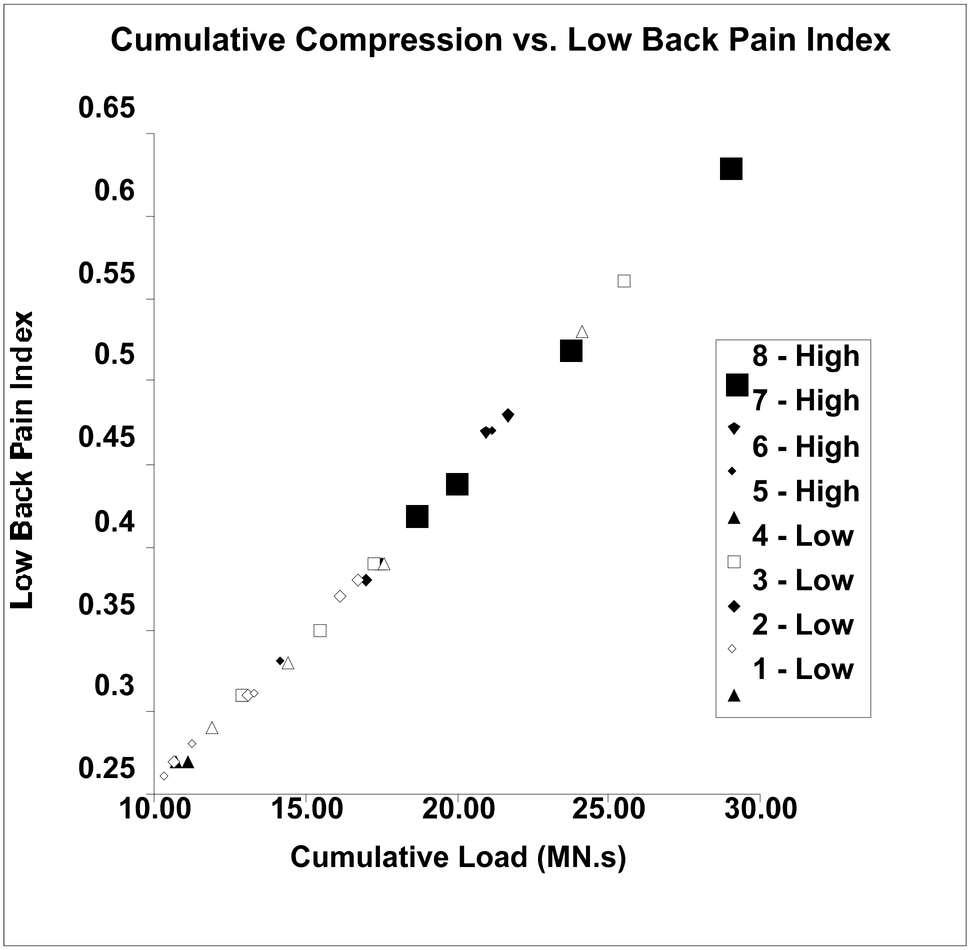


Table E2 shows the means and standard deviations for average spinal compression as a percentage of the subjects' standing compression during the day shift's five time periods. The values thus represent the compression for each period as a percentage above standing compression. Cumulative compression in each time period was converted to average compression by dividing the cumulative value by the total time that EMG was measured. This was done so short periods, such as breakfast and lunch, could be compared with longer periods such as pre-lunch. Average compression for each subject was then divided by the subjects' standing compression, calculated using the Ergowatch biomechanical model for the subjects' mass, height, and gender.

A repeated measures ANOVA compared the five time periods and showed significant results (F (4.76)=11.412, p<0.001). Not surprisingly, Table E2 shows that average compression was highest in the pre-breakfast period when residents were being wakened, dressed, transferred to wheelchairs or walkers, toiletted, and assisted to the dining hall. Pre-lunch had the second highest compression due to bed-making, assisting residents with toiletting and bathing, and sometimes transferring them back to bed for a nap. Further analysis revealed that the mean cumulative compression was different between all pairs of time periods, except between breakfast and post-lunch. In most facilities, post-lunch was a quieter period because many residents were napping, and bed-making and bathing tasks were largely completed.

Table E2 – Average spinal compression represented as percent of standing compression for each time period for eight facilities (combined)

Time period	Mean (%)	Std. dev.	N
Pre-breakfast	221.95	61.82	20
Breakfast	186.63	48.52	20
Pre-lunch	196.34	46.02	20
Lunch	171.51	42.94	20
Post-lunch	181.14	45.68	20

Means and standard deviations for compression at each time period are compared between LIRFs and HIRFs in Table E3 and Figure E2. In all cases, HIRFs had higher average compression for each time period. This was statistically significant (p<0.05) for breakfast, pre-lunch, and post-lunch periods. Pre-breakfast showed less differences in average compression between HIRFs and LIRFs (p=0.11) but the trend was similar. Most care aides considered pre-breakfast to be the "heaviest" period of the day. Data show that this period is indeed heavy even in LIRFs, with less difference in compression than in other periods. Lunch period, although not statistically significant (p=0.059), also showed a similar trend with higher compression in HIRFs.

Table E3 – Mean spinal compression (N) and standard deviations for each time period for low (LIRF) and high (HIRF) injury-rate facilities

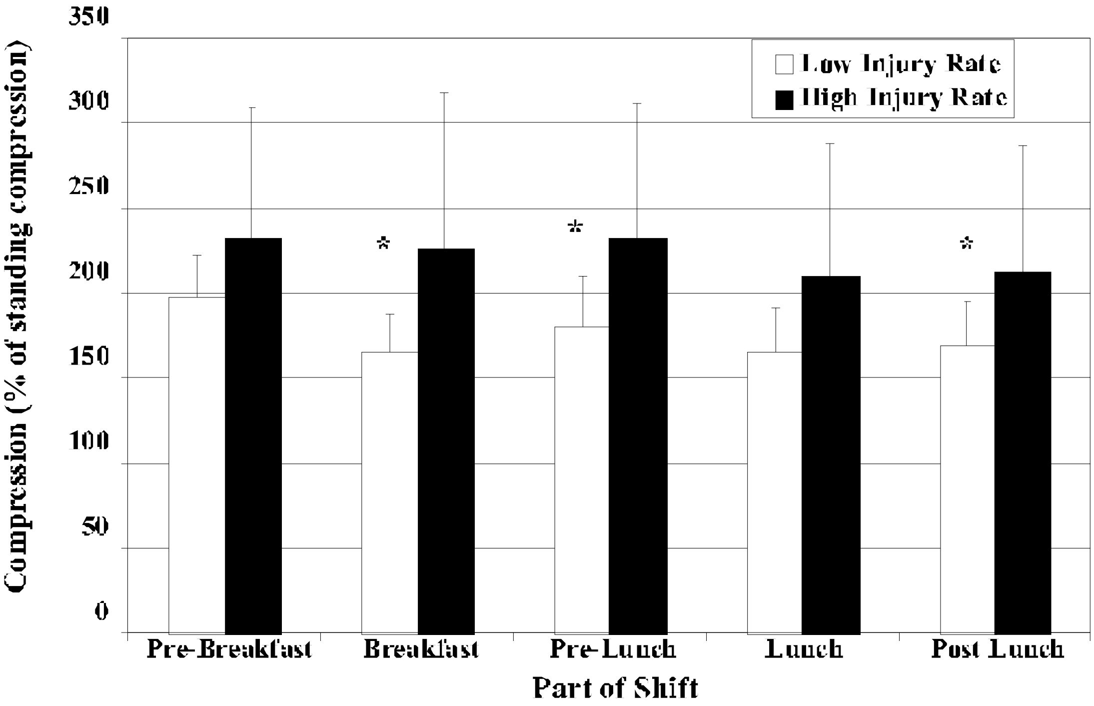
Time period and injury rating	N	Mean	Std. dev.	Signif.
Pre-breakfast LIRF	15	197.58	24.96	0.111
Pre-breakfast HIRF	13	232.07	76.58	
Breakfast LIRF	13	165.88	22.15	0.027*

Table E3 – Mean spinal compression (N) and standard deviations for each time period for low (LIRF) and high (HIRF) injury-rate facilities

Breakfast HIRF	14	226.67	90.89	
Pre-lunch LIRF	15	180.65	29.46	0.024*
Pre-lunch HIRF	16	232.34	79.23	
Lunch LIRF	14	166.03	25.19	0.059
Lunch HIRF	11	210.11	78.31	
Post-lunch LIRF	15	169.61	25.10	0.042*
Post-lunch HIRF	16	212.46	73.92	

*significant at p<0.05

Figure E2. Mean spinal compressions and standard deviations as a percent of standing compression for each period of the day in low (LIRF) and high (HIRF) injury-rate facilities



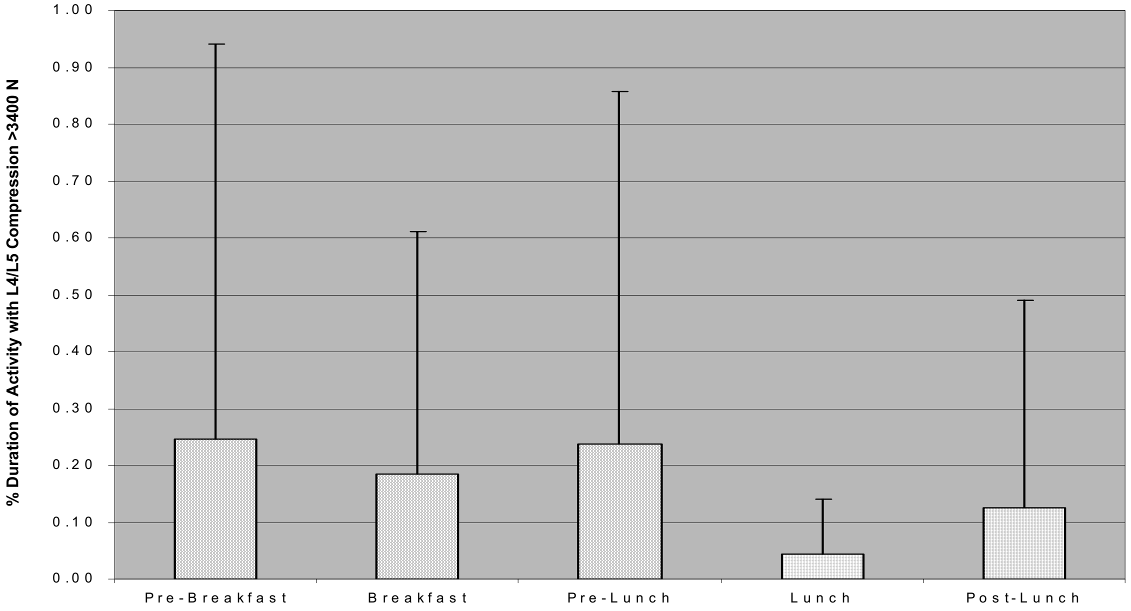
* designates significant differences in compression between LIRFs and HIRFs for this time period

E6.3 Results of peak spinal compression compared with NIOSH Action Limit

Averaged EMG files for each subject, for each time period, were converted into amplitude probability distribution functions (APDF), and peak values were extracted that represent compression values of 3400 N or greater. As mentioned previously, this is the level of compression suggested by the NIOSH Action Limit as the cut-off above which workers are at risk of back injury. EMG values of this magnitude can be caused by high levels of spinal compression, which may be associated with lifting or transferring a resident, reaching across and making a bed, and repositioning a resident in a bed or chair.

Figure E3 shows the percentage of the duration of each time period in which care aides had spinal compression exceeding 3400 N. Despite the large standard deviations in Figure E3, it is once again apparent that peak compressions are occurring mainly during pre-breakfast and pre-lunch periods. For example, the spinal compression exceeds 3400 N for 0.25% of the pre-breakfast period on average. In the 28 trials, the EMG collection during the pre-breakfast period averaged 75 minutes. Thus the average time that 3400 N was exceeded during pre-breakfast was11.25 seconds. Although this may seem to be a very small amount of time, it is important to consider that high spinal compression exertions in most lift and transfer manoeuvres are less than a second in duration.

Figure E3. Percent of duration of each time period that care aides' peak spinal compression exceeds the NIOSH Action Limit (3400 newtons)



E6.4 Results of peak spinal compression (lower back) and peak muscle activity (neck/shoulder) across facilities

To evaluate the differences in peak muscle activity between HIRFs and LIRFs, the 99th percentile amplitude probability distribution function (APDF) was used. Means and standard deviations for both erector spinae (lower back) and trapezius (neck/shoulder) EMG peaks are shown in Table E4. Peak lumbar EMG was converted to normalized compression and is expressed in newtons, while neck/shoulder peaks are expressed as percent of maximum voluntary contraction in microvolts. The 99th percentile APDF was calculated for the entire day by combining data files. Some subjects had missing data for lunch and breakfast (they were on breaks), so these periods were eliminated. Meals generally lasted a short duration – 30 minutes or less – and represented less opportunity for high EMG peaks.

The average peak (99th percentile) neck and shoulder muscle activity at both HIRFs and LIRFs was less than 20% of maximum voluntary contraction. This is well below the 40-60% maximum voluntary contraction recommended by Jonsson (1978) when measured at the 90th percentile. It therefore appears that peak neck and shoulder muscle activity is not problematic.

Table E4 shows that the differences between the means in HIRFs compared with LIRFs were not significant at the p=0.05 level. However, the size of the sample was small. Because both groups reached significance at the 0.1 level and showed higher APDFs for HIRFs, it appears that more subjects may have yielded a result of statistical significance. The trend seems to indicate more peak exertions in lower back and shoulder musculature in HIRFs compared with LIRFs.

Table E4. Peak spinal compression (N) and peak muscle activity (neck/shoulder, 99th percentile APDF) for trapezius in LIRFs and HIRFs over all periods of day (excluding breakfast and lunch)

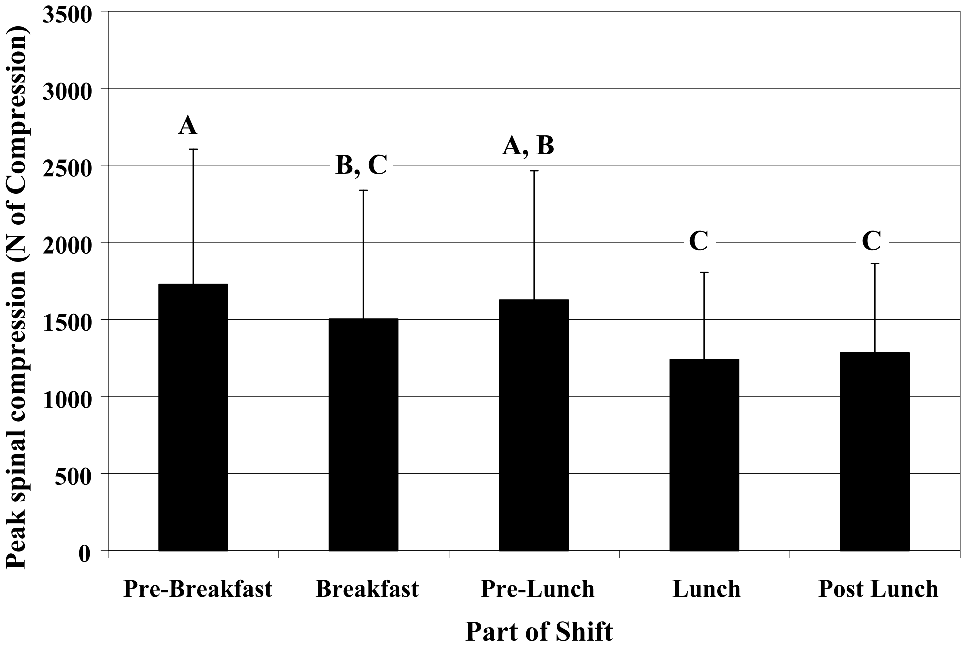
EMG	Injury rating	N	Mean	Std. dev.	Significance (2-tailed)
Erector spinae (N)	LIRF	15	1396.67	657.426	0.121
	HIRF	11	1877.27	869.610	
Trapezius (uV)	LIRF	15	11	4.751	0.075
	HIRF	13	8	13.717	

A comparison was then done of peak spinal compression and peak muscle activity (neck/shoulder) between time periods. The means and standard deviations for each time periods are shown in Table E5 and in Figure E4. There was a statistically significant difference between the five time periods (p=0.013) in peak spinal compression. Further analysis revealed that pre-breakfast and pre-lunch had the highest peaks and were not different from one another (A on Figure E4). Breakfast and pre-lunch were not significantly different from one another (B on Figure E4). In addition, breakfast, lunch, and post-lunch were also not different from one another and were the lower values on Figure E4.

Table E5 – Peak (99th percentile APDF) spinal compression (N) at five time periods

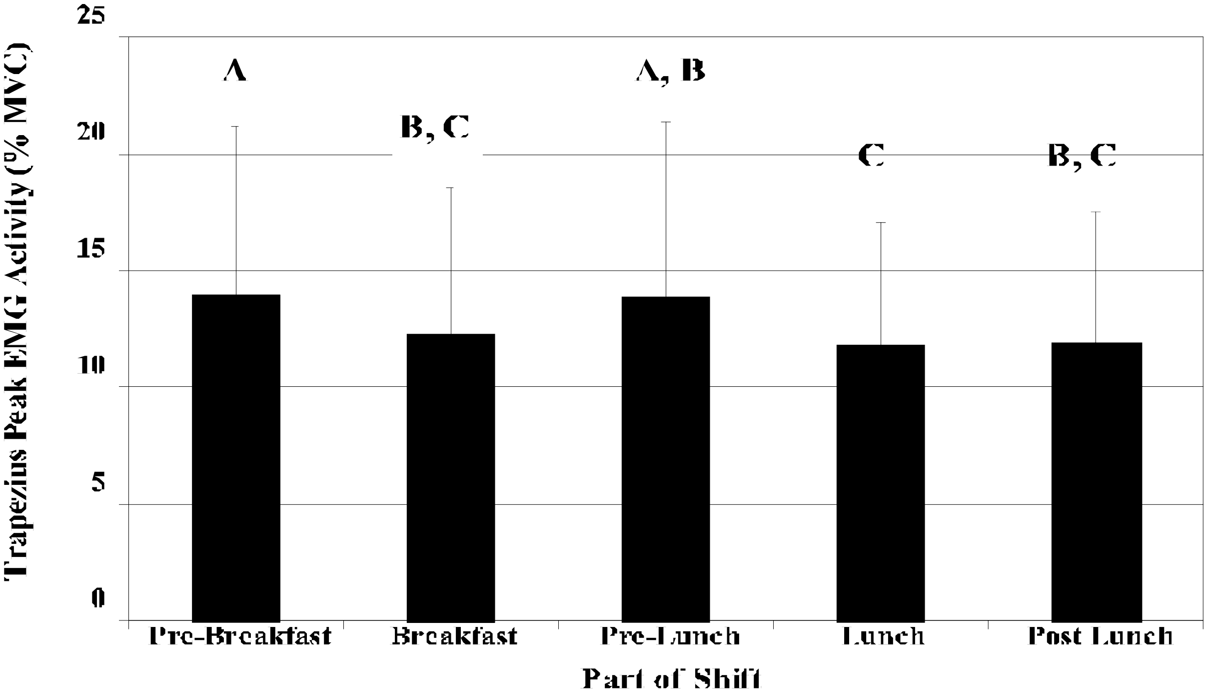
Time period	Mean (N)	Std. dev. (N)
Pre-breakfast	1727.37	877.99
Breakfast	1502.63	835.21
Pre-lunch	1625.79	840.89
Lunch	1238.95	567.44
Post-lunch	1282.11	582.14

Figure E4. Mean peak (99th percentile) spinal compression and standard deviation for five time periods



Mean peak neck/shoulder muscle activity in microvolts (99th percentile) and standard deviations are shown in Table E6 and Figure E5. There was again a significant difference between time periods (p = 0.003). The trends were similar to peak spinal compressions with highest peak activity in the neck and shoulder in pre-breakfast, followed by pre-lunch. These were not significantly different from one another, but pre-breakfast was different from all other time periods. Lowest muscle activity peaks in the neck/shoulder were during lunch; these peaks were not significantly different from breakfast or post-lunch. There were also no significant differences between breakfast and pre-lunch.

Figure E5 Mean peak muscle activity for neck/shoulder (99th percentile APDF, trapezius) and standard deviation for five time periods (microvolts)



The letters at the top of time periods indicate times that are significantly different from each other, $p < 0.05$.

Table E6 – Peak muscle activity for neck/shoulder (99th percentile APDF, trapezius) for five time periods (microvolts)

Time period	Mean (microvolts)	Std. dev. (microvolts)
Pre-breakfast	14.00	7.17
Breakfast	12.32	6.31
Pre-lunch	13.89	7.53
Lunch	11.79	5.29
Post-lunch	11.89	5.56

E6.5 Results of perceived tasks vs. observed tasks

A total of 35 subjects were observed during a full shift. Table E7 shows observed numbers of tasks compared with care aides' perceptions of the number of tasks performed in the shift. The table shows that the range and standard deviations for all tasks are very high. For example, some care aides were observed performing 20 transfers in their shift, while five care aides performed none. Even with the same residents, different care aides performed quite differently in observed tasks. Some care aides were observed to lift, transfer, and reposition residents quite frequently. Other care aides assigned to the same residents spent more time encouraging the resident to be independently mobile; hence, these workers performed very few lifts, transfers, and repositionings. For example, one care aide performed 15 manual lifts and transfers, while three other care aides performed none or one with the same residents.

On average, care aides performed between five and six transfers and a similar number of repositionings per shift. Some care aides did no bathing of residents because their facility had designated bath aides. Others gave up to four baths in a shift.

Table E7 – Observed tasks and perceived tasks performed during shift for 35 care aides

Observed task	Average number	Range	Std. dev.	Perceived task
Transfers	5.6	0-20	5.5	12.7
Repositions	5.5	0-16	4.7	6.6
Baths	0.7	1-4	1.0	0.8
Mechanical lift	0.4	0-5	1.0	0.3
Beds made	6.3	0-17	5.1	n/a

In general, the use of mechanical lifting devices was minimal: 26 of the 35 care aides made no use of mechanical lifts on the day of observation. At three facilities, none of the subjects used the mechanical lifts, although they did perform manual transfers. In another facility a care aide was observed using a mechanical lift five times and performing only one manual lift during the shift; at the same facility, other care aides performed the majority of their lifts manually (from 7 to 14 times). In general, it appeared that utilization of mechanical aids was at the discretion of the individual care aide rather than a function of facility policy or resident designations.

Perceived numbers of lifts and transfers did not correlate with observed numbers. Care aides said that, on average, they performed 12.7 lifts and transfers during the shift, yet observations by the ergonomists indicated less than half this number (5.5). The mean number of repositionings, baths, and uses of mechanical aids were close to the observed mean number, but there were no significant correlations between the two. This indicates that care aides' perceptions or memories of tasks do not match what is observed.

E6.6 Correlating ergonomic measures with other study variables

The three major outcomes of the ergonomic analysis – cumulative spinal compression, peak spinal compression, and peak muscle activity (neck/shoulder) – were correlated with variables from the telephone survey and quantitative data collection. Results are shown in Tables E8.1 to E8.5, which group the variables as follows:

- Table E8.1: Injury rates, and self-reported pain, burnout, health, and job satisfaction;
- Table E8.2: Workload and job demands (observed tasks, perceived exertion, resident-to-worker ratio, etc.);
- Table E8.3: Organizational culture (fairness, support, etc.);
- Table E8.4: Safety environment (dementia training, access to mechanical lifts, etc.); and
- Table E8.5: Physical environment (room size, hallway length, etc.).

Table E8.1 **Injury rates and self-reported pain, burnout, health, and job satisfaction**	**Cumulative spinal compression (lower back)**	**Peak spinal compression (lower back)**	**Peak muscle activity (neck/shoulder)**
Time-loss injury rate (study period)	+*	+*	
MSI injury rate	+*	+*	+
Days lost per FTE	+*	+*	
Time-loss days per total claims			+*
Any significant pain	+		
Neck pain in last year		+	
Upper limb pain in last year			+
Health			-*
Burnout (emotional/physical)			+*
Job satisfaction			-*

Explanation of symbols

"+" indicates a positive relationship between two variables with correlations between 0.5 and 0.7 (note that correlations were not rounded up to the highest level, so a 0.49 would not be considered significant).
"+*" indicates a relatively high positive relationship with correlations larger than 0.7.
"-" indicates a negative relationship with the magnitude of correlation between 0.5 and 0.7
"-*" indicates a relatively high negative relationship with correlations larger than 0.7.
A blank space indicates relatively small or no correlation (lower than 0.5).

Injury rates and self-reported pain, burnout, health, and job satisfaction: Table E8.1 shows that both cumulative spinal compression and peak spinal compression are highly correlated with injury rate, MSI injury rate, and days lost per FTE. This suggests that in workplaces where compression to the lumbar spine is high, there are more injuries and more days lost per injury. It is somewhat surprising that compressive load was only moderately related to pain in any body part and was non-significant with low back pain. Pain in the neck was moderately associated with peak spinal compression. The telephone survey used the NIOSH definition of moderate-to-extreme pain recurring at least monthly or lasting longer than seven days (Bernard et al., 1994), a definition that may have been overly exclusive. For example, workers with moderate-to-extreme recurring pain either may no longer be employed at the facility or in fact be off work with an injury; indeed, it would be difficult to perform the job of a care aide with recurrent or extreme pain. Had we used a definition of "any pain in the last year," we may have seen different results with cumulative and peak spinal compressions.

Peak neck/shoulder muscle activity did not correlate highly with injuries and days lost (and only moderately for MSI injury rate). Instead, there were strong correlations with emotional and physical burnout, and strong negative correlations with job satisfaction and self-reported health (measured in the telephone survey). Workers with higher peak muscle activity in their shoulders and neck were more likely to report poor health, low job satisfaction, and high physical and emotional burnout. This is consistent with experiencing emotional and psycho-social stress as shoulder and neck tension. Workers with higher shoulder and neck muscle activity did report moderately more pain in the upper limbs.

Table E8.2 **Workload and job demands**	**Cumulative spinal compression (lower back)**	**Peak spinal compression (lower back)**	**Peak muscle activity (neck/shoulder)**
Cumulative spinal compression		+*	
Tasks observed (total)	+*	+*	+
Transfers (total)	+		
Repositionings (total)	+*	+*	
Exertion	+	+*	+
Resident-dependency-to-worker ratio	+	+*	+
Work pressure	+	+	+*
Workload			+*
Physical demands of job (rating)	+		+
Resident-to-worker ratio	+	+	+

See Table E8.1 for an explanation of symbols

<u>Workload and job demands</u>: Table E8.2 shows correlations between workload/job demands and ergonomic measures. Actual counts of tasks performed correlated well with cumulative and peak spinal compressions, showing strong relationships for total tasks observed and total repositioning, and moderate relationships with total transfers. Peak neck/shoulder muscle activity also correlated moderately with total tasks observed. Therefore, compression in the spine and muscle activity in the back and neck/shoulder are very much a function of how many tasks are performed. Perceived exertion among care aides in the ergonomic study correlated strongly with peak spinal compression and moderately with cumulative spinal compression and peak neck/shoulder muscle activity. Therefore, workers appear to be more sensitive to the peak demands of their jobs: those with higher spinal peaks reported heavier workloads during their shift. This finding underscores the need to measure both peak and cumulative parameters in the workplace.

When perceptions of workload and job demands from the telephone survey are compared with ergonomic measures, the strongest correlations are with peak neck/shoulder muscle activity.

Facilities where workers had higher peak neck/shoulder activity had workers who reported more work pressures and that they were working too hard and had high physical demands. Cumulative spinal compression was moderately related to work pressure and physical demands of the job. Workload pressure was moderately related to peak spinal compression.

Resident-dependency-to-worker ratios (a gauge of resident demands per worker) were strongly correlated with peak spinal compression and moderately correlated with both cumulative spinal compression and peak neck/shoulder muscle activity. The resident-to-worker ratio (number of residents to care aide/LPN) was moderately correlated with all three ergonomic measures; the day-shift staffing ratio was correlated with cumulative spinal compression and peak neck/shoulder muscle activity. It appears that many of these measures overlap and may in fact corroborate one another. Not surprisingly, low staffing levels were related to more loading. This can be explained by more tasks being performed (e.g., transfers, making beds, repositions) and a greater resident demands (based on more residents per care aide/LPN). This also results in significantly higher ratings of perceived workload, work pressure, and physical demands.

The workload and job demand variables all point toward the same general trend. Facilities with less staff have workers who perform more tasks, feel more work pressure, rate higher physical demands, have higher measures of cumulative compression and peak compression in their lower backs, higher peak muscle activity in their neck and shoulder region – and consequently more injuries.

Table E8.3 **Organizational culture**	**Cumulative spinal compression (lower back)**	**Peak spinal compression (lower back)**	**Peak muscle activity (neck/shoulder)**
Discretion and choice	-	-	-
Fairness to workers	-	-	
Quality of care	-	-	-*
Favouritism towards residents	+	+	
Adequacy of attention	-*	-	-
Management support	-	-	
Supervisor support	-		
Co-worker support		-	

See Table E8.1 for an explanation of symbols

<u>Organizational culture</u>: Table E8.3 shows interesting correlations between physical workload and organizational culture variables, although few are strongly significant. In general, facilities where workers had higher loads to the lower back (cumulative and peak spinal compressions) had workers who reported less discretion and choice, less fairness, lower quality of care and adequacy of attention for residents, less management support (as well as supervisor and co-worker support), and more management favouritism towards residents. This suggests that perceived unfairness and lack of control over the performance of tasks results in more work for the lower back. Peak neck/shoulder muscle activity was higher in facilities where workers also reported less control over their work and lower quality of care and adequacy of attention for residents. Caution is in order due to the small number of measures performed, yet these findings are consistent with the qualitative results from interviews and focus groups.

Table E8.4 **Safety environment**	**Cumulative spinal compression (lower back)**	**Peak spinal compression (lower back)**	**Peak muscle activity (neck/shoulder)**
Dementia training			-
Worry about work injury			+*
Safety commitment	-		
Accessibility of mechanical lifts			-

See Table E8.1 for an explanation of symbols

<u>Safety environment</u>: Table E8.4 shows that few safety environment variables correlated with physical workload measures. Facilities where workers had higher neck/shoulder muscle activity had less dementia training and less accessibility to mechanical lifts (both moderate relationships); these facilities also had workers who worried more than others about being injured on the job (strong correlation). There was also a moderate relationship between facilities with a strong safety commitment and lower cumulative spinal compression.

Table E8.5 **Physical environment**	**Cumulative spinal compression (lower back)**	**Peak spinal compression (lower back)**	**Peak muscle activity (neck/shoulder)**
Bedroom size	-	-	-
Bathroom size		-	-
Hall length			+
Number of residents per mechanical lift			+

See Table E8.1 for an explanation of symbols

Physical environment: Table E8.5 shows moderate associations between physical environment variables and physical workload, with some interesting trends. Bedroom size was negatively correlated with cumulative spinal compression and both peak measures. Bathroom size was also negatively associated with peak spinal compression and peak activity in neck/shoulder muscles. This is consistent with care aides stating that caring for residents (dressing, transferring, etc.) is more difficult and demanding in smaller bedrooms and bathrooms. Hall length was positively associated with peak neck/shoulder muscle activity. This also makes sense if one considers that peak muscle activity could arise when assisting with walking or pushing a wheelchair down a long corridor. A higher number of residents per mechanical lift was also moderately associated with neck/shoulder muscle activity.

E7. Summary and conclusions

Tissue damage occurs when applied load is greater than tissue tolerance. A load that results in pain (a symptom of injury) may be a one-time event or a peak (e.g., a single heavy lift) or it may be cumulative in nature (e.g., the sum of all repeated bending and lifting). The data in this study allowed for assessments of both peak and cumulative muscle activity and for an exploration of how these loads may be related to injury and workers' perceptions. The design of the study also permitted a detailed examination of factors that contribute to both peak and cumulative muscle loading.

Seven main conclusions were drawn from the study, as follows:

1. A clear relationship existed between greater loading on the low back and neck/shoulder muscles and greater risk of injury. Specifically:

- Workers in facilities with higher injury rates (HIRFs) had significantly higher levels of cumulative compression on the lower back, on average. Other studies demonstrate that such compression levels create a substantial likelihood of low back pain. In this study, the likelihood ranged from 26% to 63% of workers (mean = 38%).
- Workers in HIRFs showed a trend towards larger peak levels of spinal compression and peak muscle activity in the neck/shoulder region. The peak compression estimates in the lower back exceeded the NIOSH Action Limit for disc compression, indicating an increased risk of injury.

- Both cumulative and peak spinal compressions were highly correlated with time-loss injury rate, MSI injury rate, and days lost per FTE.
- Cumulative spinal compression was moderately correlated with significant pain.
- Peak spinal compression was moderately correlated with neck pain during the last year.
- Peak neck/shoulder muscle activity was moderately correlated with upper limb pain over the last year.

2. **Demands upon care aides varied significantly throughout the day shift.** Specifically:
    - Average spinal compressions were greatest before meals (pre-breakfast and pre-lunch), when care aides tend to be more physically involved with residents (i.e., transferring, dressing, toiletting, making beds, and bathing).
    - Average spinal compression during each time period was greater in HIRFs, but the difference was not significant for the pre-breakfast period. This indicates high average compression at both HIRFs and LIRFs during this period.
    - Peak spinal compressions and peak neck/shoulder muscle activity levels were significantly greater before meals (pre-breakfast and pre-lunch).

3. **Care aides with higher peak muscle activity in their shoulders and neck were more likely to report poor health, low job satisfaction, and more physical and emotional burnout.**

4. **Increased workload had a significant negative effect on workers' self-reported health and their perceptions of physical demands and organizational culture.** Specifically:
    - Workload, as measured by staffing levels and resident-dependency-to-worker ratios, was correlated at least moderately with all three ergonomic measures.
    - Workload, as measured by total tasks and total repositionings performed, was significantly correlated with both cumulative and peak spinal compressions and moderately correlated with peak neck/shoulder muscle activity.
    - Perceptions of exertion correlated strongly with peak spinal compression and moderately with cumulative spinal compression and peak neck/shoulder muscle activity.
    - Workers appeared to be more sensitive to the peak demands of their jobs (their perceptions were more strongly correlated with peak spinal compression than cumulative compression). These findings emphasize the need to measure both peak and cumulative loading.

- Workers' perceptions regarding work pressure and high physical demands are related to higher peak neck/shoulder muscle activity and cumulative spinal compression.
- In facilities with higher loads to the lower back, workers reported less discretion and choice, less fairness, lower quality of care and adequacy of attention for residents, less management support (as well as supervisor and co-worker support), and more management favouritism towards residents.

5. **The number of tasks performed by workers and the utilization of mechanical lifts were highly variable among care aides, including workers in the same facility caring for the same residents.** Specifically:
    - On average, care aides performed 5-6 manual lifts/transfers per day and an equal number of repositionings. However, many workers did none and a few did up to 20 lifts.
    - Workers generally perceived themselves to do many more manual lifts than they were observed doing.
    - The minimal and inconsistent use of mechanical lifts indicated a general lack of clear policies and enforcement.

6. **The safety environment showed moderate correlations with workers' physical workload and perceptions of work organization and culture.** Specifically:
    - Facilities where workers had higher neck/shoulder muscle activity had less dementia training, reduced accessibility to mechanical lifts, and more worries than others about getting injured on the job.
    - There was a moderate relationship between facilities with a strong safety commitment and lower cumulative spinal compression.

7. **Facility layout and equipment availability significantly impacts workload.** Specifically:
    - Working in a restricted physical environment (e.g., small bedroom, small bathroom) increased workload, as reflected by cumulative spinal compression and both peak measures. The increased workload was confirmed by care aides' perceptions.
    - Facilities with longer halls were positively associated with peak neck/shoulder muscle activity, as were a greater number of residents per mechanical lift.

This study is among the first of its kind to objectively measure the muscle activity in the lower back and neck/shoulder of care aides for a continuous shift. The findings support the notion that both cumulative spinal compression (due to repeated and prolonged bending throughout a shift) and peak spinal compression and neck/shoulder muscle activity (due to single “heavy” events such as resident repositioning) are key measures of workload and are strongly correlated with injury.

In the study, workers with high cumulative and peak spinal compressions and higher peak neck/shoulder muscle activity worked in situations with lower staffing; they subsequently faced more resident demands and performed more tasks. They also worked in more restricted physical environments with smaller bathrooms and bedrooms, which increased the muscle loading as they performed care. These same workers perceived a higher level of exertion in their shift and reported more work pressure and higher physical demands in their job.

Measured loads on the body were strongly correlated with injury, yet it is important to note that the overall cumulative and peak spinal compressions were high enough, even in low injury-rate facilities, to contribute to low back pain and acute injury. These high loads were especially evident prior to breakfast, when residents have heavy care needs.

The study showed that both cumulative and peak spinal compressions were important determinants of injury, and thus that two different mechanisms of low back injury may be occurring in care aides. The study also showed that, among these care aides, peak muscle tension in the neck/shoulders was correlated with injury and strongly associated with stress, as manifested in reports of poor health, low job satisfaction, and physical and emotional burnout.

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