Quantitative Measurement of Stressful Trunk Postures in Nursing Professions

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Introduction: The evaluation of stress to the spinal column in the provision of care has mostly concentrated on the handling of loads. However, awkward body postures alone, without load transfer, can also be stressful for the spinal column. Therefore in this study all the body postures and movements of nurses were quantitatively measured within a working shift.

Methods: The body postures were recorded with the CUELA measurement system (computer-assisted recording and long-term analysis of musculoskeletal loads), coupled to the individual, and this detected all movements of the trunk and the legs. These measurements were supported by video recordings, so that exact allocation of the measured data to the tasks performed was possible. In all, 24 shift measurements were carried out in 8 wards. Extent, frequency and duration of trunk postures were measured in three planes and assessed on the basis of several standards (DIN EN 1005-1, DIN EN 1005-4, ISO 11226).

Results: A mean of 1131 (±377) trunk inclinations of >20° were performed in each shift. This corresponds to a frequency of 3.5 min⁻¹. A total of 237 of these inclinations lasted for >4 s. A total of 72 (±35) min was spent bending forward with an inclination of >20°. However, the mean time spent in transferring patients (counting only the lifting process) and heavy materials was only 2 min per shift. Postures with trunk inclination of >60° were adopted for a mean of 175 (±133) times. The main tasks responsible for this were ‘bed making’ (21%), ‘basic care’ (16%) and ‘clearing up/cleaning’ (16%).

Conclusions: It could be shown that many stressful trunk postures are assumed in nursing work during a shift. Future preventive measures should therefore consider not only load handling but also tasks with awkward postures.

Keywords: field study; musculoskeletal disorders; nurses; trunk posture analysis

INTRODUCTION

Professional nurses have an elevated risk of developing musculoskeletal diseases, in particular in the back (Ando et al., 2000; Hofmann et al., 2002; Menzel, 2004). Transfer of patients often involves moving heavy loads and previous studies have shown that this is one of the main factors in the development of back problems (Marras et al., 1999; Engkvist et al., 2000; Byrns et al., 2004). In addition, static postures, frequent bending and torsion of the trunk have been recognized as possible risk factors (Estryn-Behar et al., 1990; Engels et al., 1996; Knibbe and Friele, 1996; NIOSH, 1997). Intervention studies to reduce stress have mostly focused on learning patient-transfer techniques and the use of aids. On the other hand, several literature reviews have shown that interventions predominantly based on technique training for patient transfer did not provide long-term reduction in the back problems suffered by professional nurses (Lagerström et al., 1998; Hignett, 2003; Nelson and Baptiste, 2004). This indicates that a multifactorial approach is required.

The daily duties of nurses include a variety of different tasks—only one of which is patient transfer. According to the observational study of Harber et al.
(1987), nurses spend much of their working time with tasks which are not in the vicinity of the patient. Engels et al. (1994a) quantified the proportion of these tasks as 60%. They also measured that hospital nurses spend 20% of their working time and elderly care nurses 25% of their working time in awkward postures as defined by the OVAKO Working Posture Analysis System (Karhu et al. 1977). In an additional study, Engels et al. (1996) showed that nurses regard not only patient transfer but also work in awkward postures and frequent bending, as being stressful. Wilke et al. (1999) performed intradisc pressure measurements and showed that the compression force acting on vertebral disc L4/L5 is partially dependent on the trunk posture. The pressure is particularly low when the subject is standing upright and increases when the subject bends forward. Yip (2004) has described frequent bending of the trunk during work as an independent predictor for the incidence of back problems. The high proportion of static trunk postures, as in basic care provision, also represents an important factor when the overall postural exposure is to be considered (Lee and Chiou, 1995; Knibbe and Friele, 1996; Jansen et al., 2001).

There are only a few field studies in the literature in which spinal stress during nursing work has been investigated by recording body postures. The most frequent methodological approach has been to use specially trained observers, who accompany the volunteers under practical conditions and evaluate their postures at fixed time intervals (Engels et al., 1994b; Hignett, 1996). Another method is to take a video recording of the volunteers and to evaluate their postures on the monitor after the recording has been completed (Lee and Chiou, 1995). However, detailed and continuous recording of postures necessitates the use of sensors. A wide variety of measurement systems have been used, ranging from single attached sensors to complex sensor systems.

Observational studies do not allow continuous measurement of posture and the observer’s subjective evaluation can also lead to imprecision. The mobile measurement systems described in the literature may guarantee continuity, but either only record single body angles (Jansen et al., 2001) or restrict the volunteer’s freedom of movement, for example because external system components are attached to the volunteer by a cable and must be carried along all the time (Morlock et al., 2000).

A new attached measurement system has now been developed which records the volunteer’s pattern of movement under realistic working conditions and minimized interference. Therefore, it has been possible for the first time in nursing professions to measure the volunteers’ postures and activities under practical conditions in an objective, continuous and detailed manner. The present article portrays the measurement system, the measurement results from eight wards and the new aspects of stress exposure which have been found.

**METHODS**

**Measurement system**

Body posture was measured with the personally attached CUELA system (computer-assisted recording and long-term analysis of musculoskeletal loads), as developed in the BG-Institute for Occupational Safety and Health (BGIA, 1998; Ellegast and Kupfer, 2000). Figure 1 shows the measurement system in use. Trunk and leg postures are measured with several sensors. The sensors attached to the joints and trunk provide the necessary information on position and angles (Table 1), thus permitting the kinematic reconstruction of the volunteers’ movements. Parallel to this, the floor reaction forces are measured by special pressure-sensitive insoles in order to differentiate between walking, sitting and squatting more precisely. The sensors’ sample rate is 50 Hz, so that even dynamic movements can be realistically mapped.

The movements of the trunk are recorded in three planes with the help of the corresponding sensors, attached to the thoracic and lumbar spine. The first plane includes movement in the sagittal direction, that is the forward inclination of the trunk. The

Fig. 1. The CUELA measurement system in use.
The sagittal inclination of the thoracic and lumbar spine was formed by the angle between the gravitational axis and the corresponding trunk axis (Fig. 2). To determine the mean trunk inclination, a secant was calculated between the two measuring points in the thoracic and lumbar spines. The angle between the gravitational axis and this secant then gave the mean trunk inclination. The second plane includes lateral movement away from the medial axis, known as the lateral inclination. The mean lateral inclination was calculated analogously to the sagittal trunk inclination. The rotation of the trunk between the thoracic and lumbar spines is known as torsion and corresponds to the third plane of movement. During torsion, the thoracic spine is rotated to a greater extent than the lumbar spine. The torsion angle is derived from the difference between these two measurement points. Leg movements are recorded by measuring the angular positions of the hip and knee joints in the sagittal direction. The system components are attached with the help of a belt system. This fulfilled the following requirements for use under practical conditions:

- The sensor units may not slip.
- It must be possible to adjust the measurement system individually for each volunteer.
- If at all possible, it may not interfere with the volunteer’s activities. It should be so comfortable to wear that it causes no additional stress.
- It should be possible for the volunteer to fasten the system rapidly onto the necessary working clothing.

At the start of each measurement, the volunteer must assume a standardized upright posture. All the body angles to be measured are then set at zero, so that an individual neutral posture is defined for each volunteer. At the end of each measurement, this standardized posture is adopted again. Comparison with the starting position then assures that the sensors have not been displaced during the measurement.

Laboratory investigations and practical measurements were performed to validate the repeatability and long-term stability of the system; only very slight deviations were found (BGIA, 1998). Comparative measurements with a commercial optical motion capture system were performed to evaluate whether attachment of the sensors to the working clothes could give rise to imprecision in the measurement of the body angles (VICON, Oxford, UK). A mean deviation of <4% was found for the trunk angle in the sagittal plane and for the hip and knee joint angles. Much larger deviations were found in the comparison of the torsion and lateral flexion angles of the trunk. One reason for this may be the calculation of the angles from the absolute marker coordinates of the VICON system. Morlock et al. (2000) found similar deviations in the validation of their measurement system with the VICON system.

All the necessary system components are attached to the volunteer, so that no connection to external components is required and the volunteer can move freely throughout the field of work. The measurements are accompanied by a video recording, allowing subsequent precise allocation of the measurement data to each task. Specially developed software allows the clear representation of all measured values with the help of an animated computer figure.

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### Table 1. Joints and body regions covered by the CUELA system, their degrees of freedom and applied sensors

<table>
<thead>
<tr>
<th>Joint/body region</th>
<th>Degree of freedom</th>
<th>Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic spine</td>
<td>Sagittal and lateral inclination at the level of Th1</td>
<td>Inclinometers and gyroscopes</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>Sagittal and lateral inclination at the level of L5</td>
<td>Inclinometers and gyroscopes</td>
</tr>
<tr>
<td>Thoracic and lumbar spine</td>
<td>Torsion between thoracic and lumbar spine</td>
<td>Digital angle sensor</td>
</tr>
<tr>
<td>Hip joints</td>
<td>Flexion/extension</td>
<td>Potentiometers</td>
</tr>
<tr>
<td>Knee joints</td>
<td>Flexion/extension</td>
<td>Potentiometers</td>
</tr>
</tbody>
</table>
(Fig. 3). The measured values are also portrayed in an angle–time diagram. Synchronization of the video film and the measurement data makes it possible to show the corresponding real-life situation at any time point of measurement. For this purpose, the volunteer had to make standardized movements at the start of each measurement; this fixed characteristic synchronization points. These can be exploited later for the synchronization of video and measurement data. If the camera had to be switched off during the measurements, for example at the wish of the patient, transfer tasks were recorded manually.

Ergonomic evaluation

We propose different angle classes for the ergonomic evaluation of the movement of the trunk in three planes. These are based on different standards and the different angle classes of the movements of the trunk in the literature (Drury, 1987; DIN, 2000; ISO, 2000; BGIA, 2004; DIN, 2005). The underlying idea in these classifications is that joint position should be regarded as most favorable when it is near the neutral position. The closer a joint angle is to the extreme value in the corresponding range of motion, the higher is the resulting risk of injury. As Standardization EN 1005-4 (DIN, 2005) applies to working with machines, the angle classes suggested there for the lateral inclination and torsion were adapted to the dynamics of realistic nursing work (Table 2).

The standard rates lateral inclination and torsional movements in the angle range between 10° and 20° as critical. However, these can even occur during rapid walking and are therefore assigned in the present study to the acceptable range of everyday stress.

As part of the classification and assessment of working postures, the following criteria were examined to evaluate the risk of injury to the locomotor system in the back:

Deviation of the joint angle from the neutral position. Classification of the ergonomic joint angle ranges has been undertaken by the European Committee for Standardization in DIN EN 1005-4 (2005) and by the International Organization for Standardization in ISO 11226 (2000). The present study therefore investigates which movements of the trunk within the individual angle classes are made and how often per working shift. A movement is then defined as first exceeding and then passing under the lower limit in the corresponding angle class. Figure 4 shows intervals of movements of different intensity, using sagittal inclination as an example. The illustrated time interval of 24 s contains four intervals >20° and three intervals >60°.

Static postures. According to standard DIN EN 1005-1 (2000), postures are designated as static postures if they are held for longer than 4 s, at a constant or slightly changing force. Therefore, all trunk movements outside the neutral range are examined to establish whether they last for longer than 4 s. The frequency is then determined.

Fig. 3. User interface of the software to evaluate measured data, with animated computer figure and synchronized video sequence.

Table 2. Classification of the trunk postures into angle ranges, adapted from standards DIN EN 1005-4 and ISO 11226

<table>
<thead>
<tr>
<th>Trunk posture</th>
<th>Angle range</th>
<th>Conditionally acceptable</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal inclination</td>
<td>$0^\circ \leq \alpha &lt; 20^\circ$</td>
<td>$20^\circ \leq \alpha &lt; 60^\circ$</td>
<td>$\geq 60^\circ$</td>
</tr>
<tr>
<td>Lateral inclination</td>
<td>$0^\circ \leq \alpha &lt; [20]^\circ$</td>
<td>—</td>
<td>$\geq [20]^\circ$</td>
</tr>
<tr>
<td>Torsion</td>
<td>$0^\circ \leq \alpha &lt; [20]^\circ$</td>
<td>—</td>
<td>$\geq [20]^\circ$</td>
</tr>
</tbody>
</table>

*Original limit value used by the standards is 10°.
Frequency of movement. DIN EN 1005-4 (2005) defines a body movement as being frequent if it is performed twice or more per minute for an extended period. The movement frequency is used as an additional condition for the evaluation of postures which do not correspond to the medically neutral position, but which cannot in principle be regarded as representing a major risk. One example is a sagittal inclination between 20° and 60° (Table 2), which, according to the standard, lies in a conditionally acceptable angle range. This means that this posture is regarded as being acceptable if it is assumed on average less than twice per minute during a working shift. However, it is regarded as being unacceptable if it is assumed two or more times per minute.

To find out which tasks are mainly responsible for stressful postures, synchronized video recordings are used to assign the corresponding task to each sagittal inclination. As there are a lot of different tasks in nursing care, some tasks are subsumed in more general activities, such as 'bed making', 'clearing up/cleaning', 'basic care in bed' or 'patient mobilization'.

In addition, the frequency is determined of all tasks involving load transfer in which high compressive stress on vertebral disc L5/S1 has been demonstrated (Theilmeier et al., 2006). This includes tasks in which objects (sacks of washing, bed bars, instruments etc.) are moved and patients are transferred, such as transfer from the edge of the bed into a wheelchair or lifting up the trunk in bed (Table 3). Following Hartung et al. (1999), an average time of 7.5 s for patient-transfer processes has been assumed in this study. This time corresponds exclusively to the actual lifting process and does not include preparation and secondary steps, which are needed in most patient transfers. The time needed for the transfer of materials, such as sacks of washing or bed bars, is measured individually in the present study and identified by the video recordings. All transfer tasks are added up and the resulting contribution to the time of the total shift is determined. In addition, the times spent in selected postures, in which the volunteer is outside the neutral range and activities, such as sitting, standing, squatting and walking, are added up for the whole shift.

Experimental design

A total of 24 shifts in five different specialties in two hospitals (a general hospital and a cardiology center) were quantitatively studied. These included two surgical wards (SURG), two wards for internal medicine (IM), one ward for geriatric care, two cardiology-monitoring wards and an operating area (OP). These wards were selected on the assumption that the nursing personnel in these wards would be exposed to more physical stress than in the other wards. The two surgical wards largely work on abdominal surgery. They have 27 and 28 beds, of which

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lifting upright in bed, perhaps together with raising the head</td>
</tr>
<tr>
<td>2</td>
<td>Raising from lying to sitting on the edge of the bed, or the reverse</td>
</tr>
<tr>
<td>3</td>
<td>From the edge of the bed into a chair, or the reverse, without help from the patient</td>
</tr>
<tr>
<td>4</td>
<td>From sitting to standing, or the reverse</td>
</tr>
<tr>
<td>5</td>
<td>Lifting into or out of the bath</td>
</tr>
<tr>
<td>6</td>
<td>Raising the patient in the bed (possibly two helpers)</td>
</tr>
<tr>
<td>7</td>
<td>Transfer from bed to bed, bed to stretcher etc.</td>
</tr>
<tr>
<td>8</td>
<td>Lifting from floor (two people)</td>
</tr>
<tr>
<td>9</td>
<td>Inserting and removing bedpan</td>
</tr>
<tr>
<td>10</td>
<td>Lifting leg</td>
</tr>
<tr>
<td>11</td>
<td>Carrying patients, possibly with aids</td>
</tr>
<tr>
<td>12</td>
<td>Transfer of materials</td>
</tr>
</tbody>
</table>
four and six, respectively, can be adjusted in height. The morning shift is covered by four or five nursing staff, respectively, three of whom are graduates. In one ward, the age of the patients is mixed; in the other, it is mostly high. The patient mobility is mixed on both wards. The two internal medical wards are a cardiology and nephrology ward and a gastroenterology ward. They have 36 and 35 beds, of which six and five, respectively, can be adjusted in height. The morning shift is covered by six or five nursing staff, respectively, three of whom are graduates. The age of the patients in both wards is mostly high. Patient mobility in one ward is mixed and in the other rather low. The geriatric ward has 50 beds; all bed heights can be adjusted. The morning shift is covered by eight nursing staff, six of whom are graduates. The age of the patients is high and the mobility is rather low. The cardiology-monitoring wards have 16 and 35 beds; all bed heights can be adjusted. The morning shift is covered by three or four nursing staff, all of whom are graduates. Patient age is mostly high. Patient mobility is mixed in one ward and predominantly high in the other. However, these two wards were not full at the time of measurement.

The measurements were always performed during the morning shift, as it was assumed that there would be more physical stress during this shift than in the evening or night shifts. Ryden et al. (1989) confirm this assumption, as they found that working in the day shift is a risk factor for low-back injury. Goncalves et al. (2001) demonstrated that working in the morning shift is a risk factor for developing back symptoms because of the high number of nursing tasks. One nurse per ward (or a relief in the OP) was accompanied by the measurement system for 3 days. The measurements were performed on consecutive days in all specialities, so that the patient fluctuation was kept as low as possible and the team members in the morning shift hardly changed. The volunteers were instructed not to change their order of work during the measurement days and not to perform specific tasks more frequently or not at all because of the measurement.

The volunteers (two male and six female) were aged between 24 and 62 years. They were free of low-back pain during the measurements, so they could perform any required task. Six volunteers were nurses and two were elderly care nurses. One of the volunteers had received several kinesthetic training. All volunteers were engaged in patient care because in Germany no distinction is made between nurses and nurse aides with respect to the tasks of patient care.

Directly after relief of the night shift, the measurement system was attached to each volunteer and the measurement was started. After this, the volunteer could start work and all movements and tasks—except during the breakfast break—were recorded by the measurement system. The measurement was finished as soon as the volunteer had completed caring for his patients. Documentation work toward the end of the shift and the subsequent transfer to the late shift were not included in the measurement, as these tasks are normally performed seated. Therefore, the measurement time was shorter than the normal duration of the morning shift, which in Germany is 7 h in general.

**Statistical calculations**

For any ward, the arithmetic mean and the standard deviation together with the median and 25th and 75th percentiles were calculated for the consecutive shifts measured. Differences between the wards were tested using the Kruskal–Wallis test.

**RESULTS**

The order of work on all three measurement days was routine, with only slight deviations, shown in Fig. 5. The other body angles demonstrated similar homogenous distribution. This applied in all specialities (data not shown). Moreover, the volunteers reported that they required a short period to get used to the system after its attachment. However, after this, the system was pleasant to wear and hardly hindered them in performing their daily work.

The average measurement time per shift was 5 h and 16 min. Within this period, the nurses spent on average 219 min standing, 67 min walking, 24 min sitting and 6 min squatting (data not shown). The volunteers spent on average 72 min bending forward by >20°, including an average of 7 min with an angle of >60° (Table 4). Lateral inclination of >20° was observed for an average of 6 min. Torsional movements of >20° were assumed for an average of 1 min.

An average total of 19 load transfers per shift were recorded (Table 5). On average, 11 of these were related to moving patients and 8 to moving materials, such as water crates or sacks of washing. The average period for all transfer processes taken together was 2 min per shift.

Determination of the number of trunk movements outside the neutral range showed that the value of 20° during sagittal movement of the trunk was exceeded an average of 1131 times per shift (Table 6). This gives an average occurrence of 3.5 inclination movements of >20° min⁻¹. The value of 60° was exceeded 175 times per shift, corresponding to a mean occurrence of 0.5 movements min⁻¹. The value of 20° was exceeded an average of 329 times in lateral inclinations and an average of 94 times in torsions.

Combination of the movement planes shows that many of the trunk movements were not performed in a single plane alone. Thus, 19% of all sagittal
inclinations $>20^\circ$ and 29% of all inclinations $>60^\circ$ were combined with torsion and/or lateral inclination. In all, 77% of lateral inclinations $>20^\circ$ were combined with sagittal inclination and/or torsion. About a third of torsions were combined with sagittal or lateral inclination.

Of the 1131 sagittal inclinations per shift $>20^\circ$, an average of 237 lasted for longer than 4 s (Table 6). Inclinations of $60^\circ$ which lasted longer than 4 s were assumed 27 times. Lateral inclinations of $>20^\circ$ were assumed 12 times for $>4$ s. Torsional inclinations of $>20^\circ$ were assumed three times for $>4$ s.

Sagittal inclinations of $>60^\circ$ which lasted longer than 20 s were also predominantly caused by these task groups (for pragmatic reasons, analysis of the tasks was only performed for three randomly selected shifts). The OP was excluded from the overall consideration of the tasks, as the tasks are fundamentally different from those in the nursing wards. On all 3 days of measurement, the OP volunteer performed the so-called relief tasks, essentially acting as support to the OP team. This task consists of providing necessary materials and instruments and in caring for the patient, before, during and after the operation. The duties of the relief include documentation work and clearing up. Allocation of the sagittal trunk movements of $>60^\circ$ to the corresponding tasks showed that the task ‘provide materials’ (with 38%), clearing up/cleaning (with 24%) and ‘move OP sieves’ (with 7%) evoked most of the large trunk inclinations.

**DISCUSSION**

The measured postures were evaluated according to standards DIN EN 1005-4 (2005) and ISO 11226 (2000); this shows that the nurses adopt many postures during a shift that are regarded as critical by the standards. Sagittal trunk inclinations of $>20^\circ$ are only regarded as critical if their average rate of occurrence is more than two times per minute during a shift. This limit was exceeded with an average occurrence of 3.5 inclinations min$^{-1}$ in all wards. The nurses therefore spent a mean of 72 min bending forward by $>20^\circ$, corresponding to 23% of the working time. Sagittal inclinations exceeding an angle of $60^\circ$ were assumed on average 175 times per shift, corresponding to 33 inclinations h$^{-1}$ and 2.2% of the total measurement time.

Table 4. Time spent in different trunk postures—classified by ward

<table>
<thead>
<tr>
<th>Ward</th>
<th>Measurement (#)</th>
<th>Time spent in different trunk postures, M ± SD (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sagittal inclination $&gt;20^\circ$</td>
</tr>
<tr>
<td>SURG1</td>
<td>3</td>
<td>101 ± 13</td>
</tr>
<tr>
<td>SURG2</td>
<td>3</td>
<td>102 ± 34</td>
</tr>
<tr>
<td>IM1</td>
<td>3</td>
<td>41 ± 5</td>
</tr>
<tr>
<td>IM2</td>
<td>3</td>
<td>87 ± 19</td>
</tr>
<tr>
<td>GER</td>
<td>3</td>
<td>113 ± 22</td>
</tr>
<tr>
<td>CM1</td>
<td>3</td>
<td>31 ± 13</td>
</tr>
<tr>
<td>CM2</td>
<td>3</td>
<td>32 ± 10</td>
</tr>
<tr>
<td>OP</td>
<td>3</td>
<td>68 ± 7</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>72 ± 35</td>
</tr>
</tbody>
</table>

ME (P$_{25}$; P$_{75}$) 72 (41; 94) 6 (1; 12) 6 (3; 8) 1 (0; 2)

P value* 0.006 0.006 0.022 0.086

*Kruskal–Wallis test for differences in mean.

CM, cardiology-monitoring ward; GER, geriatric care; M ± SD = mean ± standard deviation; ME = median; P$_{25}$; P$_{75}$ = 25th and 75th percentile.

Fig. 5. Illustration of the percentiles (5, 25, 50, 75 and 95) of the sagittal inclination in the ward CH1.
Morlock et al. (2000) reported that nurses spend 3% of the measurement time with an extreme forward inclination of $>80^\circ$ and that this angle is exceeded on an average of 13.6 times h$^{-1}$. It was also shown that 11.3% of the measurement time is spent with a forward inclination angle of the lumbar spine of $>30^\circ$. These results are only comparable to a limited extent to those of the present study, as Morlock et al. exclusively measured the inclination of the lumbar spine (by using a two-axial goniometer) and not the mean inclination of the whole trunk. Moreover, the mean time of measurement per shift is approximately 3 h. This differs considerably from that in the present study, which was on average 5 h 16 min. Using an electrogoniometer attached to the lumbar spine, Jansen et al. (2001) showed that nurses spend 16% of their working time bending forward by $>20^\circ$. However, in this study too, only the inclination of the lumbar spine and not the mean trunk inclination was measured.

The number of sagittal trunk inclinations was very different in the wards studied. These inclinations were rather rare in the two cardiology-monitoring wards and the internal medicine ward IM1. The cardiology-monitoring wards were not fully occupied and the patients were mostly mobile at the time of measurement. It can therefore be assumed that the number of stressful postures in these two wards would be higher if they were fully occupied. In contrast, ward IM1 was fully occupied at the time of measurement and the volunteer had to care for many bedridden and incapacitated patients. However, the volunteer had received kinesthetic training several times, which had taught him to pay attention to his posture during transfer tasks and other work.

An additional factor for the evaluation of postures is the duration of individual movements outside the neutral range. Standard DIN EN 1005-1 (2002) designates postures as static postures if they are assumed for longer than 4 s. In this study, an average of 237 sagittal trunk inclinations $>20^\circ$ were measured which lasted for longer than 4 s. Permanent inclination of the trunk (without support), as, for example often observed in the basic care of bedridden patients, is strictly speaking not a static posture, as the inclination of the trunk can vary during the task. There is nevertheless often an extended period in which the trunk is not erected into the neutral position (Fig. 4, Interval 3), so that it can be assumed in this case that the risk of injury from muscular exhaustion is comparable. Risk of injury from static postures is thought to be primarily due to the resulting muscular exhaustion. This leads to changes in metabolism, pain perception and kinetic patterns, which can eventually lead to excessive stress on passive structures in the musculoskeletal system. By using heart rate and electromyograph measurements, Hui et al. (2001) showed that the back musculature of nurses is greatly exhausted toward the end of the shift, so that the risk of injury increases during the shift. Harber et al. (1987) and Lee and Chiou (1995) also found that nurses are often exposed to stress from static postures. Knibbe and Friele (1996) showed that static stress is an important factor in the evaluation of the overall stress exposure of nurses and that nurses regard static postures as one of the main stress factors.

Investigation of the tasks making a primary contribution to the development of awkward postures is an important factor in the development of preventive concepts. Only once we know which tasks cause stressful postures and, especially, how often these occur during a shift, will it be possible to take specific measures to improve these postures. Hignett (1996)
Table 6. Number of different trunk postures and static postures—classified by ward

<table>
<thead>
<tr>
<th>Ward</th>
<th>Measurement (n)</th>
<th>Number of different trunk postures, M ± SD (n)</th>
<th>Number of different trunk postures ≥ 4 s, M ± SD (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sagittal inclination ≥ 20°</td>
<td>Sagittal inclination ≥ 60°</td>
<td>Lateral inclination ≥ 20°</td>
</tr>
<tr>
<td>SURG1</td>
<td>3</td>
<td>1377 ± 247</td>
<td>311 ± 2</td>
</tr>
<tr>
<td>SURG2</td>
<td>3</td>
<td>1190 ± 228</td>
<td>290 ± 183</td>
</tr>
<tr>
<td>IM1</td>
<td>3</td>
<td>808 ± 129</td>
<td>34 ± 6</td>
</tr>
<tr>
<td>IM2</td>
<td>3</td>
<td>1088 ± 121</td>
<td>172 ± 6</td>
</tr>
<tr>
<td>GER</td>
<td>3</td>
<td>1390 ± 169</td>
<td>202 ± 60</td>
</tr>
<tr>
<td>CM1</td>
<td>3</td>
<td>664 ± 67</td>
<td>40 ± 17</td>
</tr>
<tr>
<td>CM2</td>
<td>3</td>
<td>815 ± 320</td>
<td>34 ± 17</td>
</tr>
<tr>
<td>OP</td>
<td>3</td>
<td>1715 ± 94</td>
<td>313 ± 13</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>1131 ± 377</td>
<td>175 ± 133</td>
</tr>
<tr>
<td>M ± SD</td>
<td>1121 (902; 1427)</td>
<td>169 (38; 304)</td>
<td>374 (220; 438)</td>
</tr>
<tr>
<td>ME(P25;P75)</td>
<td>0.006</td>
<td>0.007</td>
<td>0.021</td>
</tr>
</tbody>
</table>

CM = cardiology-monitoring ward; GER = geriatric care; M ± SD = mean ± standard deviation; ME = median; P25;P75 = 25th and 75th percentile.

*aKruskal–Wallis test for differences in mean.

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Quantitative measurement of stressful trunk postures in nursing professions. 393

Please consult the original document for further details.
With the CUELA system, we analyzed the occurrence of awkward postures assumed by nurses on eight wards. However, the limited number of wards analyzed so far does not allow firm conclusions concerning the postural stress for nursing in general. While for this study wards with a high physical workload for the nurses were chosen, further studies should focus on differences between wards (medical discipline, equipment, training of nurses, work organization etc.) and these might be able to explain differences in the frequency and intensity of awkward postures in nursing.

The floor reaction forces measured were only used in the present study for the automatic recognition of body postures and movement patterns, such as walking. Future studies should also include exact quantification of force effects on the spine to achieve a biomechanical evaluation of the working shifts.

**CONCLUSION**

Professional nurses exhibit a high risk of developing musculoskeletal disorders, particularly in the back. Previous studies have identified patient transfer as one of the main factors responsible for the development of back symptoms. Nevertheless, intervention studies predominantly based on technique training in patient transfer have often been reported to have no effect.

The present study demonstrates that pure transfer processes make up only a very small proportion of the total working shift. Moreover, the study with the CUELA measurement system has shown that nurses adopt many awkward postures throughout the shift—potentially leading to high levels of physical stress and rated as critical according to the standards; this is not only during patient transfer. It was also shown that awkward postures occur particularly frequently in specific procedures, thus presenting a new approach to achieve a reduction in back symptoms. On the basis of the present results, we assume that a reduction in the frequency of awkward postures will reduce the risk of musculoskeletal symptoms.

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