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The Influence of Ergonomic Devices on Mechanical Load during Patient Handling Activities in Nursing Homes

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Objectives: Mechanical load during patient handling activities is an important risk factor for low back pain among nursing personnel. The aims of this study were to describe required and actual use of ergonomic devices during patient handling activities and to assess the influence of these ergonomic devices on mechanical load during patient handling activities.

Methods: For each patient, based on national guidelines, it was recorded which specific ergonomic devices were required during distinct patient handling activities, defined by transferring a patient, providing personal care, repositioning patients in the bed, and putting on and taking off anti-embolism stockings. During real-time observations over ∼60 h among 186 nurses on 735 separate patient handling activities in 17 nursing homes, it was established whether ergonomic devices were actually used. Mechanical load was assessed through observations of frequency and duration of a flexed or rotated trunk >30° and frequency of pushing, pulling, lifting or carrying requiring forces <100 N, between 100 and 230 N, and >230 N from start to end of each separate patient handling activity. The number of patients and nurses per ward and the ratio of nurses per patient were used as ward characteristics with potential influence on mechanical load. A mixed-effect model for repeated measurements was used to determine the influence of ergonomic devices and ward characteristics on mechanical load.

Results: Use of ergonomic devices was required according to national guidelines in 520 of 735 (71%) separate patient handling activities, and actual use was observed in 357 of 520 (69%) patient handling activities. A favourable ratio of nurses per patient was associated with a decreased duration of time spent in awkward back postures during handling anti-embolism stocking (43%), patient transfers (33%), and personal care of patients (24%) and also frequency of manually lifting patients (33%). Use of lifting devices was associated with a lower frequency of forces exerted (64%), adjustable bed and shower chairs with a shorter duration of awkward back postures (38%), and an anti-embolism stockings slide with a lower frequency of forces exerted (95%).

Conclusions: In wards in nursing homes with a higher number of staff less awkward back postures as well as forceful lifting were observed during patient handling activities. The use of ergonomic devices was high and associated with less forceful movements and awkward back postures. Both aspects will most likely contribute to the prevention of low back pain among nurses.

Keywords: awkward posture; back pain; ergonomic device; force; patient handling; real-time observation

INTRODUCTION

The most common musculoskeletal disorder among nurses is low back pain (Smedley *et al.* 1995; Knibbe

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and Friele, 1996; Lagerstrom *et al.* 1998; Ando *et al.* 2000; Eriksen, 2003; Bejia *et al.* 2005). A significant proportion of back pain episodes can be attributed to patient handling activities (Hignett, 1996; Knibbe and Friele, 1996; Hoogendoorn *et al.* 1999; Ando *et al.* 2000; Warming *et al.* 2008; Karahan *et al.* 2009). Nurses manually lift patients during transfers, adopt awkward postures during patient care, and push or pull during repositioning of patients or manoeuvring equipment. These activities with awkward back postures and high exerted forces have been reported as causes of back complaints (Garg and Owen, 1992; Smedley *et al.* 1995; Warming *et al.* 2008; Da Costa and Vieira, 2010). Smedley *et al.* (1995), for example, found that repositioning patients and transfers of patients from bed to chair were associated with an increased occurrence of low back pain.

Various ergonomic devices have been developed in the past years to reduce mechanical load during patient handling activities in order to prevent the occurrence of back complaints. Several laboratory studies have demonstrated the efficacy of these ergonomic devices during experiments (Garg *et al.* 1991; Zhuang *et al.* 1999; Silvia *et al.* 2002; McGill and Kavcic, 2005). Zhuang *et al.* (1999), for example, showed that different types of lifting devices reduced spinal compression forces by two-thirds. However, intervention studies at the workplace have difficulties showing the effectiveness of ergonomic devices in reducing the occurrence of back complaints (Hignett, 2003). A recent systematic review concluded that there is only moderate evidence for the effectiveness of multicomponent patient handling interventions, including appropriate lift or transfer equipment to reduce mechanical loads (Tullar *et al.*, 2010). At the workplace, the results of the ergonomic interventions will depend not only on the efficacy of the intervention itself but also on the appropriate implementation of this intervention in the actual work situation (Roquelaure, 2008; Koppelaar *et al.*, 2009). It is, therefore, important to study the actual use of lifting aids during patient handling activities and to determine their effect on mechanical load among nurses.

In the Netherlands, national guidelines in healthcare prescribe the use of different ergonomic devices during specific patient handling activities. For example, a lifting device is required during transfers of patients who need assistance in movements. These guidelines facilitate structured patient handling programmes in healthcare organizations with the overall aim to reduce mechanical load at work. Although these guidelines are not legally binding, they form an essential part of the self-regulatory mechanism within the healthcare sector in order to reduce strenuous working conditions. Since compliance to these guidelines is not expected to be perfect, this development offers interesting opportunities to study differences in mechanical load during patient handling in nursing homes according to required use, actual use, and non-use of available ergonomic devices. Therefore, the aim of this study was to describe the required and actual use of ergonomic devices during patient handling activities and to assess the influence of these devices on mechanical load during patient handling activities.

METHODS

Study population

The present cross-sectional study took place in 17 nursing homes with a structured patient handling programme. This programme centered around of the presence at each ward of an ergocoach. This is a person trained and specialized in ergonomic principles who is responsible for supporting the process of working according to ergonomic principles in his ward. Their activities include being available for questions from colleagues, identifying problems, contributing to workplace improvements, and training personnel. In total, 37 nursing homes were approached with written information about the study purpose with a supportive letter of the national organization in the healthcare sector responsible for training and support of ergocoaches. A subsequent visit was paid to each organization in order to explain aims and time constrains of the study in more detail. Eventually, 17 nursing homes (response 46%) decided to participate. Primary reasons for non-participation were lack of time, merger of the facility, and construction work in the facility.

In the Netherlands, there are two types of nursing homes. Firstly, the home which is destined for long-term care for elderly who are not able to live entirely independent ($n = 10$). The home for elderly provides general support for uncomplicated nursing care for physical, psychogeriatric, or psychosocial problems as a result of old age. Secondly, the home that is intended for people who need specific nursing care, residential care, or revalidation as a result of disease, disorder, or old age but no longer need specialized medical care in a hospital ($n = 7$).

The data collection was carried out between 2007 and 2009. Individual nurses ($n = 186$) were observed while performing patient handling activities. At the organizational level, ward characteristics policies

were collected by means of a self-administered questionnaire filled out by the team leader of the ward (response 67 of 69). The number of nurses, the number of patients, and the ratio of (full-time equivalent) nurses per patient at ward level were regarded as potential determinants of mechanical load. A ratio above the median value of 0.6 was interpreted as a favourable ratio of nurses per patient. Individual characteristics of nurses, such as age, gender, work experience, and presence of back complaints and any musculoskeletal complaints were collected by interview.

Informed consent was obtained verbally from all nursing homes and nurses prior to the study in accordance with the requirements for non-identifiable data collection in the Dutch Code of Conduct for Observational Research (www.federa.org).

Observations at the workplace

Real-time observations at the workplace were conducted to evaluate the actual use of ergonomic devices during patient handling activities and to assess the influence of ergonomic devices on mechanical load during these activities. Four patient handling activities were defined: (i) transferring a patient, for example from bed to chair, (ii) personal care, like washing and dressing a patient, (iii) repositioning patients in the bed, like turning a patient and moving the patient up in bed, and (iv) putting on and taking off anti-embolism stockings.

The procedure of the workplace survey started with a separate introduction at each ward to seek permission of team leaders and nurses involved. Researchers visited each ward during the periods with most patient handling activities, primarily the first 2 h of the morning shift between 07.00 and 09.00 h and the first hour after lunch between 12.00 and 13.00 h. Observations took place only during patient handling activities. Within each ward, all nurses present were selected for participation and informed that data collection was completely anonymous. All nurses who were invited to contribute to the study gave the required verbal informed consent. Observations would start with the first nurse handling a particular patient and end after all nursing activities with that patient were finished. Subsequently, the same nurse was followed to a second patient when patient handling activities were expected to occur or otherwise, a second nurse was observed during handling of another patient. In total, 186 nurses performed 735 separate patient handling activities. About 56% of the nurses were observed once during a specific patient handling activity, and 44% of the nurses were observed repeatedly during specific patient handling activities within the same patients and with different patients.

The observations with a hand-held computer and structured software (Noldus, 1991) were performed by two researchers, both educated and experienced in observing human movements. The researchers rated the use of ergonomic devices and different characteristics of mechanical load during patient handling activities according to a strict protocol. The whole procedure was pretested among 31 nurses in two nursing homes that were not included in this study. The inter-rater agreement for non-neutral trunk posture was high (Pearson correlation $r = 0.72$) and moderate for pushing and pulling ($r = 0.36$) and lifting ($r = 0.26$). After this pilot, reasons for disagreement were discussed and the observation protocol was tightened.

Use of ergonomic devices

The national guidelines prescribe the type of ergonomic device to be used during different patient handling activities: lifting devices for transferring a patient, an electric adjustable bed and an adjustable shower chair during personal care, such as washing and dressing, an electric adjustable bed and a slide sheet for repositioning a patient in bed, and a compression stocking slide for putting on and taking off anti-embolism stockings (Knibbe *et al.*, 2007). These guidelines combine the level of functional mobility of the patients with specific activities during handling patients. In general, ergonomic devices are required for patients who are able to assist and contribute actively but unable to perform the activity on their own, and patients who are passive with no or very little contribution to the required movements. A stocking slide should always be used for putting on and taking off anti-embolism stockings of a patient (Knibbe and Friele, 1999).

The required use of ergonomic devices was retrieved from the personal care file of each patient. In absence of this information, nurses were asked to provide additional information. Before the observations at the workplace, the researcher collected information on the required use of ergonomic devices. Subsequently, during the observations of patient handling activities, the actual use of these ergonomic devices was registered.

Quantitative assessment of mechanical load

The real-time observations registered four measures of mechanical load: duration of trunk flexion or rotation $>30°$ (% work time with non-neutral

trunk posture) and frequency of pushing, pulling, lifting, or carrying requiring forces <100 N, between 100 and 230 N, and >230 N.

An awkward back posture was defined by at least 30° of flexion or rotation of the trunk, based on an extensive survey showing that postural patterns between nurses and other occupations differed most strongly above this value (Jansen *et al.*, 2001) and on the definition of awkward back postures agreed upon in the national guidelines (Knibbe *et al.*, 2007).

For each patient handling activity that required a forceful movement, studies were identified that presented actual measurements of the forces applied during corresponding patient handling situations from volunteer participants or healthcare workers, primarily in a laboratory set-up (Garg *et al.*, 1991; Garg and Owen, 1992; Bohannon, 1999; Zhuang *et al.*, 1999; McGill and Kavcic, 2005; Knibbe and Knibbe, 2006). Acknowledging substantial differences in measurements of sustained forces during patient handling, this information guided the assessments of the authors to classify each activity within the categories <100 N, 100–230 N, and >230 N. For example, the forces exerted for turning a patient in bed was set between 100 and 230 N without a sliding sheet (Zhuang *et al.*, 1999) and <100 N with the appropriate use of a sliding sheet (McGill and Kavcic, 2005). Incorrect use of ergonomic devices and resistance of patients resulted in higher assessment of exerted forces. The lower limit of <100 N reflects current guidelines for manual handling (Mital *et al.*, 1997) and the upper limit was adopted from the well-established National Institute of Occupational Safety and Health (NIOSH) equation for lifting of loads (NIOSH, 1991).

Data analysis

Since mechanical load may vary at different levels within nursing homes, a nested analysis of variance was used to calculate the proportion of variance due to nursing homes, wards within the nursing homes, individual nurses within the wards, and patient handling activities observed nurses.

A linear mixed-effect model for repeated measurements was used to analyse the effect of ergonomic devices on mechanical load during patient handling activities, adjusted for individual and organizational factors and inter-observer variation. The analyses were performed for each category of patient handling activity separately. The distributions of the measures of mechanical load during each category were evaluated and differed significantly from the normal distribution. Therefore, simple log-transformations were performed which markedly reduced the skewness of the distributions of exposure variables within each patient handling activity. The organizational factors obtained from wards and the observers were included in the mixed-effect model as fixed (categorical) effects. The variances between and within nurses were regarded as random effects. Variance in exposure within a nurse may be due to factors such as patients' characteristics and differences in lifting aids. The variances between and within nurses were pooled across all determinants of exposure and assumed equal across all fixed determinants. This assumption of a compound symmetry covariance structure, resulting in the most restrictive error structure possible, was chosen because of the relatively few measurements available for some determinants, which limited the number of parameters that could be estimated in the model (Burdorf, 2005). For the mixed-effect models, this assumption on error structure was not violated against tests of significance for change in the goodness-of-fit. Given the fact that the potential determinants of mechanical load were interrelated, the first step in the analysis was a separate mixed-effect model for each parameter of mechanical load. The determinant that had the largest reduction in the overall variance was first retained in the second step. Other determinants were subsequently stepwise introduced into the mixed-effect model and evaluated for their improvement in goodness-of-fit. A determinant was included in the final model when introducing a change of at least 10% in other determinants, independent of their level of significance. Given the purpose of the study, the use of an ergonomic device was introduced in the final model by default, independently of its level of statistical significance. The Akaike information criterion (AIC) was used as measure of the overall fit of the model and additional determinants were retained in the mixed-effect model when resulting in a significant improvement in the overall fit. The AIC was used instead of the more conventional two-log likelihood measure since the AIC attempts to find a model that best explains the data with a minimum of parameters. The regression coefficient of each determinant in the mixed model reflects observed differences in mechanical load. Since these regression models are based on log-transformed exposure data, the coefficient must be converted by the natural power before it expresses the reduction in exposure. This was defined as the reduction in exposure factor (REF). All analyses were conducted using the procedure Proc Mixed in SAS version 6.12 software (SAS Institute, Cary, NC, USA).

RESULTS

The study population consisted predominantly of women, ranging in age from 16 to 62 years (Table 1). The average working experience of the nurses was 8 years. Organizations differed considerably with respect to number of wards and number of patients per ward. The ratio of full-time equivalent nurses per patient per ward ranged from 0.1 to 3.3, influenced largely by patients' characteristics.

Table 2 provides information of 735 separate patient handling activities performed by 186 nurses with a total duration of 3399 min. An ergonomic device was required according to the national practical guidelines in 520 of 735 patient handling activities. The actual use of ergonomic devices was 69%, ranging from 14% use of sliding sheets to 85% use of electric adjustable beds for repositioning of patients within bed.

Table 3 shows that the actual use of ergonomic devices decreased awkward back postures as well as forces exerted in all categories of patient handling activities, except for the use of an electric adjustable bed during personal care of a patient and repositioning a patient within the bed. The actual use of lifting devices reduced the frequency of forces >230 N with 86% (from 11.1 to 1.6) and the actual use of a compression stocking slide reduced the frequency of forces between 100 and 230 N with 98% (from 93.2 to 1.8). The mean duration of patient handling activities when using an ergonomic device increased 10%–91%, except for repositioning a patient in bed where the use of a sliding sheet reduced the duration of activity substantially.

Table 1. Organizational and ward characteristics of the nursing homes (n = 17) and individual characteristics of the nurses (n = 186).

Characteristics	Nursing homes
Nursing homes	n = 17
Number of wards per organization, median (range)	4 (1–12)
Workers (full-time equivalent) per organization, median (range)	112 (26–400)
Patients per organization, median (range)	126 (58–320)
Wards within nursing homes	n = 69
Patients per ward, median (range)	30 (10–74)
Nurses (full-time equivalent) per ward, median (range)	14 (4–62)
Ratio full-time equivalent nurse/patient per ward, median (range)	0.6 (0.1–3.3)
Individual characteristics of nurses	n = 186
Age, years, mean (SD)	38 (13)
Gender, female %	96
Working experience (years), median (range)	8 (0–43)
Back complaints in the past 12 months (%)	42
Any musculoskeletal complaints in the past 12 months (%)	60

The largest source of variance in mechanical load was within-nurses, ranging between 21 and 95% (Table 4). The organizations and the wards within the organizations hardly contributed to the total variability in mechanical load.

Table 5 indicates that the actual use of required ergonomic devices was an important determinant of mechanical load in all categories of patient handling activities and the ratio nurses per patient at the ward was an important determinant of mechanical load in the categories transfer of patients and putting on and taking off anti-embolism stockings. The use of ergonomic devices had less mechanical load, especially less frequent exertion of forces, with REFs ranging between 1.6 and 22.0. Converting these REFs into exposure differences, use of lifting devices had a 64% lower frequency of forces exerted, adjustable bed and shower chairs a 38% decrease in duration of awkward back postures, and an anti-embolism stockings slide a 95% lower frequent of forces exerted. The use of ergonomic devices explained up to 60% of the variance within nurses. A favourable ratio of nurses per patient at the ward was associated with less awkward back postures (REFs between 1.3 and 1.7) and lower frequency of forces (REF 1.5). Hence, a higher ratio of nurses per patient was associated with less time spent in awkward back postures during handling anti-embolism stocking (43%), patient transfers (33%), and personal care of patients (24%) and also a lower frequency of manually lifting patients (33%).

Individual characteristics, such as age, gender, work experience, and presence of back complaints and any musculoskeletal complaints, and ward characteristics were not associated with mechanical load during patient handling activities. Adjustment for the observers did not influence these results.

DISCUSSION

The actual use of ergonomic devices during patient handling activities in this study was 69%. A favourable ratio of nurses per patient was associated with a decreased duration of time spent in awkward back postures during handling anti-embolism stocking (43%), patient transfers (33%), and personal care

Table 2. Characteristics of quantitative assessment of mechanical load and ergonomic devices used during patient handling activities.

Category of activity	Devices	H	W	*N*	*n*	Total duration (min)	Necessity of use of a device	Actual use of a device (%)
Transfer activity with patient	Lifting devices	17	68	171	265	812	196	142 (72)
Personal care of patients (A)	Electric adjustable bed	17	58	99	144	1255	120	109 (91)
Personal care of patients (B)	Adjustable shower chair	17	37	59	81	1065	32	16 (50)
Repositioning patients within the bed (C)	Slide sheet	14	51	101	148	170	115	16 (14)
Repositioning patients within the bed (D)	Electric adjustable bed	14	51	101	148	170	115	98 (85)
Putting on and taking off anti-embolism stockings	Elastic compression slide	16	33	40	57	97	57	35 (61)
Total		17	69	186	735	3399	520	357 (69)

H, number of nursing homes; W, number of wards; *N*, number of nurses; *n*, number of observations. A, use of electric adjustable bed; B, use of adjustable shower chair; C, use of slide sheet; D, use of electric adjustable bed.

of patients (24%) and also frequency of manually lifting patients (33%). Use of lifting devices was associated with a lower frequency of forces exerted (64%), adjustable bed and shower chairs with a shorter duration of awkward back postures (38%), and an anti-embolism stockings slide with a lower frequency of forces exerted (95%).

A few limitations of this study must be taken into account when interpreting the results. First of all, selection might have occurred in the participation of nursing homes since it was on voluntary basis and targeting those organizations that employed ergocoaches at their wards. These organizations will have more structured attention for prevention of high mechanical load. The actual use of ergonomic devices in this study may, therefore, be higher than in a random sample of nursing homes. However, information from national surveys in 2008 showed that 85% of the nursing homes have employed ergocoaches at the wards (Knibbe and Knibbe, 2008). This suggests that the results of this study resemble the situation in Dutch nursing homes. Secondly, the assessment of trunk postures through observations may have resulted in some inter- and intra-observer variability, which contributes to the overall variance observed (Takala *et al.*, 2010). However, due to the high number of observations, this will probably have led to a limited influence on estimates of important exposure determinants. Moreover, adjustment for the observers did not influence the estimates of exposure determinants. For the assessment of forces, a crude classification was chosen intentionally, with the advantage of less misclassification. The review of Stock *et al.* (2005) showed that the reproducibility of materials handling was fair to excellent with better results using a crude classification of forces instead of more detailed classification. Thirdly, the definition of the required use of ergonomic devices was based on the level of functional mobility of the patients. The cognitive capabilities of the patients as well as their attitudes or preferences towards ergonomic devices could have influenced the observed actual use of ergonomic devices in this study. Attitude and preferences of patients as well as their specific needs were not determined. Fourthly, in order to evaluate the necessity of ergonomic devices, the patients were categorized into three levels of functional mobility according to national guidelines. This procedure reduced potential bias in the evaluation of the observer, whether the use of a particular device was required or not. The magnitudes of forces applied during each patient handling activity were derived from published studies with actual force measurements and expert assessments by the authors. Within the framework of this large field survey, it was considered not feasible to perform force measurements. The cut-off values of 100 and 230 N reflect the force level considered to be associated with an increased risk for musculoskeletal disorders (Knibbe *et al.*, 2007) and the limit value in the well-known NIOSH equation (NIOSH, 1991). Fifthly, only a part of the observed nurses had repeated measurements. This might have influenced the estimates of the within-nurses variance presented in Table 4. These results should, therefore, be interpreted as indicative values. Finally, no *a priori* sampling scheme was applied to accomplish an optimal randomized distribution over all patient

Table 3. Awkward back postures (percentage of work time) and forces exerted (frequency per hour) among personnel in nursing homes, stratified by patient handling activities.

Category of activity	Device use	*N*	*D*	Non-neutral trunk posture[a] (% of work time)	Forces exerted 100–230 N (frequency/h)	Forces exerted >230 N (frequency/h)
Transfer activity with patient	Not necessary	69	125	9.3	15.8	1.9
	Necessary and not used	54	114	16.7	26.9	11.1
	Necessary and used	142	573	16.5	8.8	1.6
Personal care of patients (A)	Not necessary	24	175	19.7	0.7	0.3
	Necessary and not used	11	84	20.4	0.7	0.7
	Necessary and used	109	996	19.7	5.5	0.5
Personal care of patients (B)	Not necessary	49	680	24.2	0.2	0.2
	Necessary and not used	16	183	28.8	5.2	1.3
	Necessary and used	16	202	28.3	4.2	0.6
Reposition patients within the bed (C)	Not necessary	33	22	19.0	71.9	5.5
	Necessary and not used	99	115	29.5	97.4	9.4
	Necessary and used	16	34	13.5	84.0	3.6
Reposition patients within the bed (D)	Not necessary	33	22	19.0	71.9	5.5
	Necessary and not used	17	28	20.9	87.6	8.5
	Necessary and used	98	120	27.0	96.0	8.0
Putting on and taking off anti-embolism stockings	Necessary and not used	22	29	43.1	93.2	0.0
	Necessary and used	35	68	33.7	1.8	0.0

N, number of measurements; *D*, total duration of patient handling activity (min); A, use of electric adjustable bed; B, use of adjustable shower chair; C, use of slide sheet; D, use of electric adjustable bed.
[a]Non-neutral trunk posture is >30° trunk flexion and/or >30° trunk rotation.

handling activities (Mathiassen *et al.*, 2003). Therefore, it is possible that the mean exposure across different patient handling activities is biased. However, the number of samples seems sufficiently high to provide reliable information to detect differences in the average mechanical load during patient handling activities with and without the use of ergonomic devices.

During the transfer of patients, lifting devices were used in 72% of the situation it was required. The study of Evanoff *et al.* (2003) in the USA showed a compliance of lifting devices in long-term care facilities of ~38%. The good compliance of our study cannot be easily generalized to other countries with different guidelines for use of lifting devices in healthcare. The high compliance to required use must be seen in the light of the considerable attention in the Dutch healthcare for safe patient handling with ergonomic devices and the use of strict guidance for use of specific ergonomic devices in the individual care protocols for patients, as observed in 69% of all separate patient handling activities in this study. These protocols stimulate that the way to assist a patient is no longer largely determined by the individual nurse and is tailored specifically to the patient. In these care protocols for patients, there is a strong focus on lifting aids; thus, it is not remarkable that the use of lifting devices when required during transfers was high. Adjustable shower chairs during personal care were used less often, approximately in 50% of all situations. The lack of manoeuvring space, mentioned as barrier in lifting device use, might also be

Table 4. Estimated contribution of different sources of variance to the total variability in mechanical load due to trunk flexion or rotation and forces exerted.

Category of activity	Mechanical load	Sources of variance			
		Between organizations, %	Between wards within organizations, %	Between nurses within wards, %	Within nurses, %
Transfer activity with patient	Non-neutral trunk posture	11	5	3	81
	Forces exerted 100–230 N	16	0	0	84
	Forces exerted >230 N	9	1	7	83
Personal care of patients (A)	Non-neutral trunk posture	6	18	32	45
	Forces exerted 100–230 N	2	10	9	79
	Forces exerted >230 N	5	0	0	95
Personal care of patients (B)	Non-neutral trunk posture	9	25	45	21
	Forces exerted 100–230 N	0	0	16	84
	Forces exerted >230 N	0	0	.	0
Repositioning patients within the bed (C)	Non-neutral trunk posture	2	13	9	76
	Forces exerted 100–230 N	0	16	28	57
	Forces exerted >230 N	2	0	12	86
Repositioning patients within the bed (D)	Non-neutral trunk posture	2	13	9	76
	Forces exerted 100–230 N	0	16	28	57
	Forces exerted >230 N	2	0	12	86
Putting on and taking off anti-embolism stockings	Non-neutral trunk posture	0	44	0	56
	Forces exerted 100–230 N	7	25	0	68
	Forces exerted >230 N	0	0	0	0

A, use of electric adjustable bed; B, use of adjustable shower chair; C, use of slide sheet; D, use of electric adjustable bed.

a barrier in shower chair use during personal care (Koppelaar *et al.*, 2009). An electric adjustable bed was used most of the times it was required during personal care as well as during repositioning of patients within the bed. The high compliance might be explained by the presence of electric adjustable beds in most wards. The slide sheet, on the other hand, was used in only 14% of all situations when required for repositioning patients in bed. Organizational and individual factors might have influenced the utilization of the slide sheet, such as lack of time, not enough available, and lack of knowledge (Koppelaar *et al.*, 2009).

This study showed that the mechanical load during patient handling activities when using the required ergonomic devices was almost as low as and sometimes even lower than the mechanical load during patient handling activities without required use of ergonomic devices. The use of lifting devices during transfers reduced the forces exerted by two-thirds. These results corroborate the findings in laboratory studies and workplace surveys (Garg *et al.*, 1991;

Table 5. Determinants of mechanical load during patient handling activities, estimated by linear mixed-effect model for repeated measurements and the explained between- and within-nurses variance by the determinants.

Category of activity	Device necessary and used, REF (CI)	Ratio fte nurse/patient, REF (CI)	Decrease of between-nurses variance, %	Decrease of within-nurses variance, %
Transfer activity with patient				
Non-neutral trunk posture	1.01 (0.8–1.4)	1.49* (1.1–2.0)	18.3	0
Exerted forces 100–230 N	3.13* (2.0–4.8)		33.0	4.8
Exerted forces >230 N	2.76* (2.0–3.8)	1.50* (1.1–2.0)	8.2	28.5
Personal care of patients[a]				
Non-neutral trunk posture	1.61* (1.2–2.2)	1.31 (1.0–1.8)	0	9.6
Exerted forces 100–230 N	1.00 (0.7–1.4)		3.5	0.8
Exerted forces >230 N	1.01 (0.8–1.2)		4.7	0
Reposition patients within the bed (C)				
Non-neutral trunk posture	1.84 (0.9–3.6)		0.1	2.0
Exerted forces 100–230 N	1.92 (0.5–3.2)		0	1.4
Exerted forces >230 N	1.27 (0.6–2.5)		13.8	0
Reposition patients within the bed (D)				
Non-neutral trunk posture	0.95 (0.5–1.9)		0	0
Exerted forces 100–230 N	1.70 (0.7–4.1)		17.1	0
Exerted forces >230 N	1.39 (0.7–2.7)		0	0
Putting on and taking off anti-embolism stockings				
Non-neutral trunk posture	1.16 (0.7–1.9)	1.74* (1.1–2.9)	28.5	0
Exerted forces 100–230 N	21.97* (10.9–44.3)		2.3	59.6

fte, full-time equivalent; 95% CI, confidence interval; C, use of slide sheet; D, use of electric adjustable bed.
[a]Use of electric adjustable bed or adjustable shower chair.
*$P < 0.1$.

Garg and Owen, 1992; Zhuang *et al.*, 1999; Owen *et al.*, 2002; Marras *et al.*, 2009). Zhuang *et al.* (1999) found that different types of lifting devices reduced spinal loads by two-thirds. In a longitudinal study by Owen *et al.* (2002), the perceived physical exertion among nurses was reduced significantly due to lifting device use. During personal care of patients, the use of an electric adjustable bed or a shower chair reduced the duration of awkward back postures with 36%. Caboor *et al.* (2000) found a significant decrease in awkward back postures during patient handling tasks when using electric adjustable beds. The low number of observations on ergonomic devices used during repositioning patients within their beds made it not possible to properly assess the effects of a slide sheet and an electric adjustable bed separately. This might explain the increase of the duration of awkward back postures when using an electric adjustable bed for repositioning patients. The use of a compression stocking slide during putting on and taking off anti-embolism stockings reduced the forces exerted with 95%. Gelderblom *et al.* (2001) found that the forces exerted required for putting on and taking off anti-embolism stockings were generally between 150 and 200 N. A biomechanical evaluation of putting on and taking off anti-embolism stockings showed that the forces exerted required for putting on and taking off anti-embolism stockings when using an compression stocking slide did not exceed 75 N (Knibbe and Knibbe, 2006).

The use of ergonomic devices explained mainly the reduction in within-nurses variance, indicating that nurses made a choice to sometimes not use the ergonomic device when it was required. Individual as well as organizational factors that vary over time may have played a role. The reduction of between-nurses variance was partly explained by the use of ergonomic devices as well. This indicated that the use of ergonomic devices differs systematically among nurses at the ward. Hence, workplace policies are required that target organizational factors that support appropriate implementation of ergonomic devices (Koppelaar *et al.*, 2011) as well as individual approaches such as training of nurses in use of ergonomic devices (Yassi *et al.*, 2001).

Furthermore, the ratio of nurses per patient at the ward appeared to have an influence on mechanical

load. It has been suggested that there is a link between time pressure (an indicator for insufficient staffing resources) and musculoskeletal disorders (Bongers *et al.*, 1993). Larese and Fiorito (1994), for example, reported that nurses in wards with a low nurse to patient ratio had more musculoskeletal disorders. Our study indicates that a favourable ratio of nurses per patients at the ward will reduce awkward back postures (overall 33%) across most patient handling activities and also will reduce sustained forces during transfer activities. This may reflect the type of organization, the distribution of patients with respect to the functional mobility, but also the ability to share strenuous work activities or more time to adopt appropriate work techniques.

A potential disadvantage of lifting device use was illustrated in our study, namely the duration of transfer activities, which increased with the use of lifting devices (Table 3). Garg *et al.* (1991) found also that lifting devices took significantly more time to make a transfer than manually lifting a patient. Time constraint was mentioned in several studies as a barrier to use lifting devices in healthcare (Koppelaar *et al.*, 2009). Sufficient staffing might give the nurses more time to use lifting devices. However, Pellino *et al.* (2006) found that the total time for transfers reduced from ∼15 min for manual transfers to ∼10 min for transfers with a lifting device. In our study, we were not able to demonstrate the effect of lifting device use on the cumulative time for all involved staff spend on patient handling activities since only one nurse at a time was observed during a transfer activity and effects on activities of their colleagues in the same ward were not ascertained. Another factor that hampers a clear interpretation is that the requirement to use lifting devices during transfer activities coincides with less mobile patients, who may need more time during care procedures.

The important question remains whether the reduction in mechanical load during patient handling activities due to the prescribed use of ergonomic devices will be sufficient enough to prevent the occurrence of low back pain. It has to be considered that the occurrence of low back pain is not always work-related (Lotters *et al.*, 2003). The aetiology of back complaints is multifactorial and epidemiological surveys have identified various individual, psychosocial, and physical risk factors (Burdorf and Sorock, 1997; Hoogendoorn *et al.* 1999; Da Costa and Vieira, 2010). The occurrence of low back pain can, therefore, not entirely be prevented by the use of ergonomic devices. It has been estimated that the elimination of manual patient lifting could theoretically result in a reduction of the occurrence of low back pain by 19–54% (Burdorf and Sorock, 1997). Given the fact that the use of lifting devices in this study was associated with a considerably lower frequency of forceful exertions and duration of awkward back postures, a substantial reduction in the occurrence of low back pain may certainly be expected.

In conclusion, the actual use of ergonomic devices during patient handling activities was high in the nursing homes. The use of these devices during patient handling activities was associated with a reduction in frequency of forces exerted and duration of awkward back postures by 1.49- to 21.97-fold, and thereby, may contribute substantially to a reduction in the occurrence of low back pain.

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