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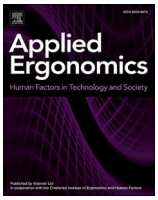

The influence of organizational factors, eldercare worker characteristics and care situation on the use of assistive devices during resident handling in eldercare work

Kristina Karstad [a,*], Charlotte D.N. Rasmussen [a], Charlotte Lund Rasmussen [a], Reiner Rugulies [a,b,c], Karen Søgaard [d,e], Alex Burdorf [f], Andreas Holtermann [a]

[a] National Research Centre for the Working Environment (NRCWE), Lersø Parkallé 105, 2100, Copenhagen Ø, Denmark
[b] Department of Public Health, University of Copenhagen, Øster Farimagsgade 5, 1014, Copenhagen K, Denmark
[c] Department of Psychology, University of Copenhagen, Øster Farimagsgade 2A, 1353, Copenhagen K, Denmark
[d] Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Campusvej 55, 5230, Odense M, Denmark
[e] Department of Clinical Research, University of Southern Denmark, Campusvej 55, 5230, Odense M, Denmark
[f] Department of Public Health, Erasmus University Medical Center, P.O. Box 2040, 3000 CA, Rotterdam, the Netherlands

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ABSTRACT

We evaluated the influence of organization, eldercare worker and care situation on the use of assistive devices during resident handling in eldercare work. We conducted a multi-level study among 20 nursing homes, 126 wards within the nursing homes, 549 eldercare workers within the wards, who performed a total of 1306 care episodes including 3695 resident handlings. The influence of organization (i.e. nursing home and ward), eldercare worker and care situation (i.e. care episode and resident handling) on the use of assistive devices was evaluated using variance components analysis and multivariate generalized linear mixed model. Nursing homes, wards, eldercare workers, care episodes and 'within care episode' all contributed to the total variance in use of assistive devices. Organizational factors and care situation factors were significantly associated with use of assistive devices. All levels of the nursing homes, but in particular care situation, influence the use of assistive devices during resident handling.

1. Introduction

A large percentage of the world's working population experience low back pain (LBP) (Bevan et al., 2009; Vos et al., 2015), which imposes high costs to the individuals afflicted as well as workplaces and society (Bevan, 2015; Mäntyselkä et al., 2002; Saarni et al., 2006; March et al., 2014). High annual prevalence of LBP has especially been reported among eldercare workers (Davis and Kotowski, 2015) leading to increased incidence of sickness absence and early retirement (Andersen et al., 2012; Jensen et al., 2012; Clausen et al., 2014). This is incongruous, when the demographic changes, inducing an aging population, will place additional pressure on the eldercare sector (Hussain et al., 2012), that calls for a healthy and sustainable workforce.

Eldercare workers are exposed to a range of organizational, psychosocial and physical factors associated with LBP (Lagerström et al., 1998; Heneweer et al., 2011; Aagestad et al., 2014; Miranda et al., 2011, 2014; Engkvist et al., 2000; Eriksen, 2004; Holtermann et al., 2013), many of which are related to the task of resident handling (i.e. transferring, repositioning and turning the resident). In order to prevent and reduce LBP among eldercare workers, resident handling has received considerable research attention particularly with the aim of lowering the physical loads from these tasks. Assistive devices have been shown to markedly reduce the physical demands during resident handling (Bohannon, 1999; McGill and Kavcic, 2005; Zhuang et al., 1999; Garg et al., 1991a, 1991b). In the last decade, the developments in technology and a greater focus on the benefits of using assistive devices in eldercare work has led to greater choice and availability of devices in Danish nursing homes. However, assistive devices are only effective in lowering the load, if they are actually used. Despite the availability of assistive devices, studies at nursing homes and hospitals have shown that consistent use of assistive devices has yet to be fully realized (Koppelaar et al., 2011; Noble and Sweeney, 2018; Schoenfisch et al., 2019).

* Corresponding author.
E-mail address: kristinakarstad@gmail.com (K. Karstad).

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In each resident handling situation it is the eldercare workers' decision if assistive devices should be used. However, the eldercare worker is part of a large and complex organization that may present facilitators or barriers for use of assistive devices. Studies have identified a number of such organizational factors (e.g. time constraints, staffing ratio and availability and accessibility of assistive devices) (Koppelaar et al., 2009, 2011, 2013; Noble and Sweeney, 2018; Schoenfisch et al., 2011, 2019). Furthermore, eldercare worker factors (e.g. knowledge/ability, motivation, musculoskeletal complaints) have shown to be associated with the use of assistive devices (Koppelaar et al., 2009, 2011, 2013; Schoenfisch et al., 2011, 2019). The use of assistive devices will also depend on the conditions during the care situation such as type of resident handling, residents' physical and mental characteristics, residents' weight and assistance from colleagues (Noble and Sweeney, 2018; Schoenfisch et al., 2011, 2019; Koppelaar et al., 2009). While it is well documented that the different types of resident handling (i.e. transferring, repositioning and lifting the residents) are a decisive factor for use of assistive devices (Koppelaar et al., 2011; Noble and Sweeney, 2018; Schoenfisch et al., 2019), the underlying reasons have not been investigated. Therefore, the use of assistive devices will depend on factors in three interrelated areas: organization, eldercare worker and care situation.

Although many barriers for the use of assistive devices during resident handling have been identified, most have been identified through process evaluations in intervention studies (Koppelaar et al., 2009, 2011) or through self-reports by employees (Noble and Sweeney, 2018; Schoenfisch et al., 2019). Accordingly, barriers for the use of assistive devices are often reported by the eldercare worker (individual level) who perceive the barriers and not from the level (e.g. nursing home, ward, or care episode level) where it actually occurs. In addition, almost all studies have presented qualitative descriptions of barriers without any quantification of their importance. In order to gain more knowledge applicable for developing future interventions to increase the use of assistive devices, there is a need for multi-level studies investigating the independent influence of organization (i.e. nursing home and ward), eldercare worker and care situation (i.e. care episode and resident handling) on the actual use of assistive devices.

The aim of this study is to evaluate the influence of organization, eldercare worker and care situation on the use of assistive devices during resident handling in eldercare work by a) investigating to what degree the use of assistive devices is attributed to the levels: nursing home, ward, eldercare worker, and care episode, and b) determine which specific factors at each level are associated with the use of assistive devices during resident handling.

2. Material and methods

2.1. Design

For evaluating the influence of organization, eldercare worker and care situation on the use of assistive devices during resident handling in eldercare, we used baseline data from the Danish Observational Study of Eldercare work and musculoskeletal disorderS (DOSES) (Karstad et al., 2018a). The DOSES cohort is a comprehensive multi-level dataset, based on information of 553 eldercare workers from 126 wards at 20 nursing homes in Denmark. The study protocol has been described in detail elsewhere (Karstad et al., 2018a). DOSES has been approved by the Danish Data Protection Agency and the Ethics Committee for the regional capital of Denmark (H-4-2013-028).

2.2. Study population

In total, 83 nursing homes located in the Copenhagen area were invited to participate in DOSES, of which, 20 nursing homes (18 municipal and 2 private nursing homes) including 126 wards agreed to participate. Each of the 20 nursing homes had one upper-manager who participated in DOSES (three upper-managers were administrating two nursing homes). Furthermore, 42 team managers, who administered the 126 wards located at the 20 nursing homes, also participated in DOSES. A short screening questionnaire, including a question on whether the eldercare workers would like to participate in DOSES, was administered to 941 eligible eldercare workers working permanently at the 20 nursing homes. Those who wished to participate were invited to a health check session including baseline questionnaire, accelerometer measurement and health and physical capacity measurement. In total, 553 eldercare workers filled in the baseline questionnaire and were included in the DOSES cohort.

In order to maintain as much data as possible and restricting possible selection bias, the only criterion for the eldercare workers to be included in the present study analysis was participation in one of the 1306 observed care episodes, including one or more resident handlings, performed at the 126 wards within the 20 nursing homes. In total, 549 eldercare workers were observed during a minimum of one care episode at baseline and included in the analyses. Thus, the final study population for the present study consisted of 20 nursing homes, 126 wards within the nursing homes, 549 eldercare workers within the wards who performed a total of 1306 care episodes including 3695 resident handlings (see Fig. 1).

2.3. Data collection

Baseline measurements for each of the 20 nursing homes took place over a continuous period of one to two weeks (depending on the size of the nursing home). We started baseline data collection on the first nursing home in September 2013 and finalized the data collection on the last nursing home in December 2014. We structured data according to the level (i.e. nursing home, ward, eldercare worker, care episode and resident handling level) in which data was collected and could be classified according to their hierarchical levels. Linkages of data between the different levels were accomplished by identification numbers for nursing home, ward, eldercare worker and care episode, which was registered for each respective resident handling.

2.3.1. Organizational factors

The nursing home manager and team managers of every nursing home answered a web-based questionnaire about formal and informal organizational structures at the nursing home and wards. At nursing home level, we used size of nursing home (total number of wards) filled in by the upper-manager as possible determinant for use of assistive devices. At ward level, we used the information filled in by the team-manager for each ward on staffing ratio (total number residents divided by eldercare workers working in a shift), size of ward (total number of residents), assigned ergonomic advisor and team-manager's present. Furthermore, we conducted a workplace walkthrough at every nursing home and ward (Koppelaar et al., 2013; Karstad et al., 2018a). We collected information on location (if the assistive devices were located at the room of the resident, in the hallways, at depot, at remote depot, not presence at all) and accessibility of assistive devices (how often the assistive devices were not in the correct space) for each ward. During meetings with upper-and team-managers, we collected information regarding the type (somatic, dementia, rehabilitation or independent living) of each ward.

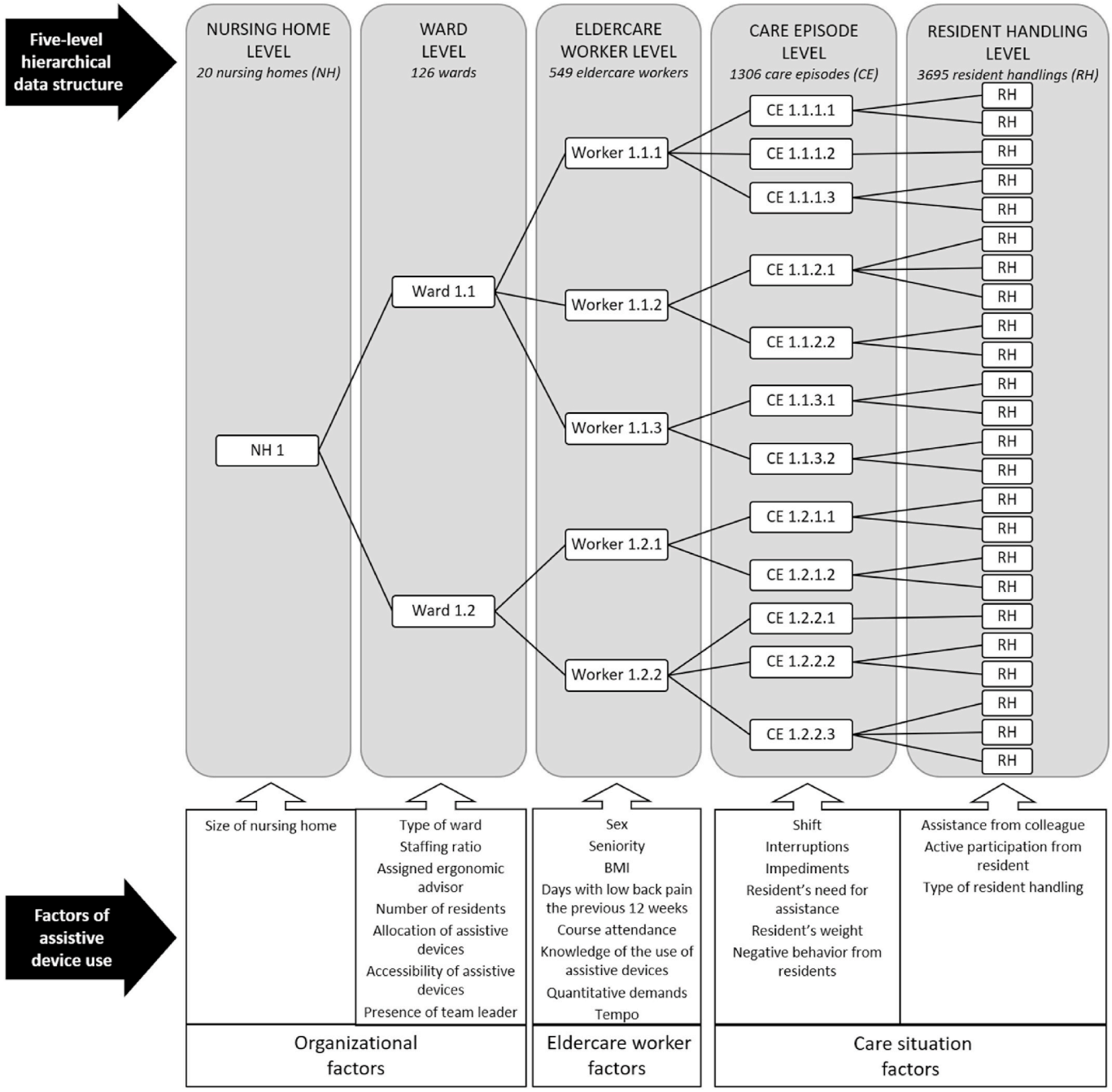

Fig. 1. Scheme of the five-level hierarchical data structure of the present study and the investigated specific factors and the level at which they are measured. For each resident handling it is observed whether an assistive device is used or not used (outcome). Observations of resident handlings (RH) (level 1) are clustered within care episodes (CE) (level 2), care episodes are clustered within eldercare workers (level 3), eldercare workers are clustered within wards (level 4) and wards are clustered within nursing homes (NH) (level 5).

2.3.2. *Eldercare worker factors*

Information on eldercare worker factors was collected through a computer-based structured questionnaire provided to the eldercare workers at their workplace. We used information on sex, job seniority, days with low back pain the previous 12 weeks (slightly modified version of Nordic Musculoskeletal Questionnaire) (Kuorinka et al., 1987), course attendance within resident handling technique within the last 2 years (two response categories: yes and no) and knowledge of the use of assistive devices (five response categories reduced to two: Very high/high and partly/poor/very poor) in this study. Furthermore, we included two self-reported psychosocial demands 1) quantitative demands (Pejtersen et al., 2010) and 2) work pace (Pejtersen et al., 2010). Both were measured by two questions from the Copenhagen Psychosocial Questionnaire (Pejtersen et al., 2010) with five response categories.

The response categories were for each question recoded into the values of 1–5. A sum score of the two questions resulted in a sum score from 2 to 10. At the health check session height and weight were measured by research personnel to calculate the body mass index (BMI).

2.3.3. Care situation factors

We mainly used direct workplace observations to collect information on specific care episodes and the resident handlings occurring in each care episode. A care episode is defined as the timeslot from the moment the eldercare worker establishes contact with the resident until the eldercare worker leaves the resident again. During one care episode, one or more caring activities could occur including several resident handlings. In DOSES, more than 4700 direct observations of care episodes were conducted at baseline containing all caring activities performed by the eldercare workers during morning and evening shifts on all participating nursing homes and wards. The observations of the care episodes were conducted by trained observers following a strict protocol (Karstad et al., 2018b). The observations were performed using tablets with the software Noldus Observer XT pocket observer (Noldus, Wageningen, The Netherlands). The inter-rater reliability of the observations was shown to be good (Karstad et al., 2018b).

In total, 3695 resident handlings were observed within 1306 care episodes. At care episode level, we used information on shift (day or evening shift), number of interruptions of the care performed (e.g. interruptions from colleagues or other residents, alarms on phone), number of impediments (e.g. broken assistive device, assistive device not in place) and number of negative behaviors from the resident towards the eldercare worker as possible determinant for assistive device use. Furthermore, we used information from standardized lists, provided by the team managers at baseline, on the residents' bodyweight and need for physical assistance (four categories: light (without or only little help), moderate (resident is the active part and can carry his/hers own weight), comprehensive (resident can partly carry his/hers own weight and can only partly participate) or complete (resident cannot carry his/hers own weight and cannot participate in activity). At resident handling level, we observed whether colleagues assisted with resident handling, whether the resident helped substantially in performing the resident handling (estimated by the observer as at least 25% reduction in physical load for the eldercare worker) (Karstad et al., 2018b) and type of resident handling (transferring, repositioning or turning the resident).

2.3.4. Use of assistive devices (outcome)

For each of the 3695 resident handlings observed, it was registered if any kind of assistive device (e.g. transfer belt, sliding sheet, draw sheet, electric turning sheet, floor hoist, ceiling hoist) was used or not. The use of assistive devices was dichotomized – whether or not an assistive device of any type had been used.

2.4. Data analysis

We used variance components analysis (VCA) to calculate the proportion of variance in use of assistive devices during resident handling attributed to the levels: nursing homes, wards within the nursing homes, eldercare workers within the wards, care episodes within the eldercare workers, and within care episodes (i.e. resident handling). Nursing home, ward, eldercare worker and care episodes were entered into the model as hierarchical random-effects. Fig. 1 and Table 1 illustrate and describe the five levels in the VCA.

The proportion of variance is presented as "percent of variability" and is calculated separately for each level. Percent of variability is calculated from the Covariance Parameter Estimate (CPE) and the constant 3.29 [35]:

$$\text{percent of variability} = \text{ICC}^{*}100 = \frac{CPE}{CPE + 3.29}{*}100$$

As the specific type of resident handling is likely to be of importance for the use of assistive devices, VCAs were performed stratified on repositioning and turning of the resident (not possible to stratify into transfers as there were too few events without use of an assistive device) (see results in appendix A). Due to a smaller sample size in the stratified VCA, they were performed with a four-level structure. Nursing home, ward and eldercare worker were entered into the model as hierarchical random-effects.

To identify factors associated with the use of assistive devices during resident handling within each level of the nursing homes, we used the following two-step procedure. First, univariate analyses were conducted with each potential determinant added individually as a fixed-effect to the developed VCA model (i.e. retaining nursing home, ward, eldercare worker and care episode as hierarchical random-effects). All variables with a p-value less than 0.10 were selected for further investigation. Second, we constructed a multivariate model by forward selection starting with the variables with the lowest p-value. Variables with a p-value less than 0.10 and resulting in the lowest -2loglikelihood were retained in the final model. The extent of missing data differed across measurement level. To keep most data in the analysis we chose to analyze the different factors potentially associated with the use of assistive devices in different datasets with different sample sizes. Organizational factors were analyzed in a dataset including data from nursing home and ward level (N = 2713), eldercare worker factors in a dataset including only data from eldercare worker level (N = 1751) and care situation factors in a dataset including data from care episode and resident handling level (N = 3227). As no eldercare worker factors retained in the multivariate model, the sample size for this analysis could be performed at the level of nursing home and ward (i.e. N = 2713).

We conducted two sensitivity analyses. First, to examine whether a non-perfect hierarchical structure (i.e. out of the 549 eldercare workers performing resident handling in our study, 37 provided care to residents in two wards) would influence the results of the main VCA analysis, we included only those eldercare workers performing residential care in only one ward in the analysis. Second, to test the robustness of the five level effects structure in the univariate and multivariate generalized linear mixed model, we performed the analysis only including four levels (i.e. nursing home, ward and eldercare worker entered into the model as hierarchical random-effects) to the models.

For descriptive statistics, SPSS (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) was used. All other analyses were conducted using the procedure PROC GLIMMIX in SAS version 9.4 software (SAS Institute, Cary, NC, USA).

3. Results

Table 1 presents the characteristics of the included nursing homes, wards, eldercare workers, care episodes and resident handlings in our study. The nursing homes differed with respect to number of wards, number of residents and permanently employed eldercare workers. The wards within the participating nursing homes also differed with respect to number of residents. The wards and shift (i.e. day and evening shift) differed with regard to staffing ratio. Out of the total of 3695 resident handlings, 46% were performed with the use of an assistive device, 44% with assistance of a colleague and 30% with the resident taking an active part in the resident handling.

Table 1
Description of the five hierarchical levels in the variance components analysis (VCA) and characteristics of nursing homes, wards, eldercare workers, care episodes and resident handlings. [SD=Standard Deviation; IQR= Interquartile range].

Nursing homes	**N = 20**
Number of wards, median (IQR)	5.5 (4.0–8.8)
Number of residents, median (IQR)	84 (51.5–96.5)
Number of permanently employed eldercare workers, median (IQR)	63 (45.0–96.0)
Wards	**N = 126**
- ***Wards within the nursing homes***	***Mean = 6.3, Median = 5.5, Min. = 3, Max. = 15***
Number of residents, median (IQR)	11 (9.0–14.0)
Staffing ratio - day (residents per worker), median (IQR)	3.3 (3.0–3.8)
Staffing ratio - evening (residents per worker), median (IQR)	7.3 (6.0–9.1)
Eldercare workers	**N = 549**
- ***Eldercare workers within the wards***	***Mean = 4.7, Median = 4.0, Min. = 1, Max. = 10***
Age (years), mean (SD)	45.6 (10.9)
Sex (females), percent (n)	94.4 (387)
Job seniority (years), median (IQR)	14.0 (7.0–24.3)
Care episodes	**N = 1306**
- ***Care episodes within the eldercare workers***	***Mean = 6.7, Median = 5.0, Min. = 1, Max. = 38***
Duration (minutes), median (IQR)	18.0 (9.5–31.5)
Shift (day), percent (n)	94.4 (387)
Resident handlings	**N = 3695**
- ***Resident handlings within care episodes***	***Mean = 2.8, Median = 2.0, Min. = 1, Max. = 20***
Use of assistive devices, percent (n)	45.8 (1691)
Assistance from colleague, percent (n)	44.3 (1638)
Active participation from resident, percent (n)	29.5 (1091)

We found relatively large differences between the three types of resident handling (i.e. transferring, repositioning and turning the resident) (Table 2). Use of assistive devices was 78%, 38% and 24% in transferring, repositioning and turning the resident, respectively. In transfer situations when the resident did not actively participate, only 2% of the transfers were performed without assistive devices. In comparison, in repositioning and turning without active participation of the resident, 32% and 52% of the handlings, respectively, were performed without assistive devices. When an assistive device was not used, the eldercare workers were more likely to use colleague assistance during turning compared to transferring and repositioning the resident.

3.1. Variance in assistive device use at the nursing home, ward, eldercare worker, care episode and within care episode level

All five levels of the nursing homes contributed to the total variability in use of assistive devices during resident handling. The largest source of variance was within care episodes (71%). Nursing homes,

Table 2
Description of the total resident handling tasks (N = 3695) and use of assistive devices stratified on the type of resident handling (i.e. transferring, repositioning and turning the resident).

		WITH USE of assistive devices				WITHOUT USE of assistive devices			
		WITH Active participation from resident		WITHOUT Active participation from resident		WITH Active participation from resident		WITHOUT Active participation from resident	
		WITH Assistance from colleague	WITHOUT Assistance from colleague	WITH Assistance from colleague	WITHOUT Assistance from colleague	WITH Assistance from colleague	WITHOUT Assistance from colleague	WITH Assistance from colleague	WITHOUT Assistance from colleague
		% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
Transfer	1150	0.5 (6)	3.0 (34)	44.7 (514)	30.1 (346)	2.5 (29)	16.8 (193)	1.4 (16)	1.0 (12)
Reposition	1280	0.7 (9)	4.5 (58)	14.7 (188)	18.0 (231)	4.0 (51)	25.8 (330)	13.8 (177)	18.4 (236)
Turning	1265	0.9 (12)	5.2 (66)	11.0 (139)	7.0 (88)	6.9 (87)	17.1 (216)	32.4 (410)	19.5 (247)
Total	3695	0.7 (27)	4.3 (158)	22.8 (841)	18.0 (665)	4.5 (167)	20.0 (739)	16.3 (603)	13.4 (495)

Table 3
Estimated contribution of different sources of variance to the use of assistive devices during resident handling (N=3695) in eldercare work. [CPE = Covariance Parameter Estimate].

Sources of variance	CPE	Standard Error	Percent of variability [a]
Between nursing homes	0.1327	0.0808	3.88
Between wards within nursing homes	0.2905	0.0981	8.11
Between eldercare workers within wards	0.3051	0.0993	8.49
Between care episodes within eldercare workers	0.3262	0.1046	9.02
Within care episodes	–	–	70.50

[a] Calculated from CPE and the constant 3.29 (Twisk, 2006).

Percent of variability $= \frac{CPE}{CPE + 3.29} * 100$.

Table 4
The influence of care situation, eldercare worker and organizational factors on the use of assistive devices in eldercare work. Odds Ratio (OR) and 95% confidence interval (CI) is used as measure of association. OR>1 indicates higher odds for the eldercare worker to use an assistive device.

	Use of assistive devices during resident handling			
	Univariate		Multivariate (N = 2713) [c]	
	OR	95% CI	OR	95% CI
Organizational factors (N=2713) [c]				
Nursing home				
Size of nursing home (number of wards) [a]	1.04	(0.95–1.15)		
Ward				
Type of ward being somatic [b]	0.91	(0.57–1.45)		
Staffing ratio (residents per worker) [a]	0.94***	(0.90–0.98)	0.92**	(0.86–0.99)
Assigned ergonomic advisor [b]	0.88	(0.51–1.50)		
Number of residents [a]	0.95**	(0.91–0.99)	0.94*	(0.88–1.00)
Allocation of assistive devices [a]	1.00	(0.98–1.02)		
High accessibility of assistive devices [b]	1.13	(0.62–2.07)		
Team leader present ≥3 days per week [b]	1.04	(0.58–1.85)		
Eldercare worker factors (N=1751) [c]				
Sex [b] (male)	1.77	(0.83–3.79)		
Seniority [a]	1.00	(1.00–1.00)		
BMI [a]	0.98*	(0.95–1.00)		
Days with low back pain the previous 12 weeks [b]				
- 0 days	REF			
- 1 to 7 days	0.98	(0.65–1.46)		
- 8 to 30 days	1.32	(0.85–2.07)		
- 30 days to every day	0.93	(0.58–1.49)		
Course attendance within the last 2 years [b]	1.03	(0.75–1.43)		
Great knowledge of the use of assistive devices [b]	1.44	(0.80–2.58)		
Quantitative demands [a]	1.00	(0.99–1.00)		
Tempo [a]	1.00	(0.99–1.01)		
Care situation factors (N=3227) [c]				
Care episode				
Shift [b]				
- Evening shift	REF			
- Day shift	1.36***	(1.10–1.68)		
Interruptions [a]	1.15***	(1.05–1.26)	1.22**	(1.03–1.44)
Impediments [a]	1.06	(0.95–1.17)		
Resident's need for assistance [b]				
- Light/moderate need for physical assistance	REF		REF	
- Comprehensive need for physical assistance	2.55†	(1.73–3.75)	1.90**	(1.06–3.42)
- Complete need for physical assistance	4.63†	(3.23–6.62)	4.08†	(2.31–7.19)
Resident's weight [a]	1.01‡	(1.01–1.02)	1.01**	(1.00–1.02)
Negative behavior from resident [a]	1.01	(0.99–1.02)		
Resident handling				
Assistance from colleague [b]	2.16†	(1.78–2.62)		
Active participation from resident [b]	0.08†	(0.06–0.10)	0.10†	(0.07–0.15)
Type of resident handling [b]				
- Turning the resident	REF			
- Reposition the resident	3.32†	(2.53–4.35)	3.08†	(2.29–4.15)
- Transferring the resident	69.53†	(44.45–108.77)	55.38†	(34.60–88.64)

*P = <0.1; **P = <0.05; ***P = <0.01; ‡P = <0.001; †P = <0.0001.
[a] Continuous variable.
[b] Categorical variable.
[c] Number of cases (sample size) without missing data according to measurement level.

wards within nursing homes, eldercare workers within wards and care episodes within eldercare workers contributed with 4%, 8%, 8% and 9%, respectively (Table 3). Furthermore, we observed differences in the contribution of the different levels to the total variability in use of assistive devices between the two types of resident handling (i.e. repositioning the resident and turning the resident) when stratifying the analysis on type of resident handling (Table A1 in appendix A). When turning the resident, the variability in use of assistive devices was to a larger degree attributed to the level of wards within nursing homes (25% vs. 13%) and eldercare workers within wards (68% vs. 33%), compared to repositioning the resident. Almost nothing (0.4%) of the variability in use of assistive devices when turning the resident was attributed to the level 'within eldercare workers'.

3.2. Determinants of use of assistive devices

The multivariate analyses show that a higher number of residents per staff and higher number of residents within a ward were associated with a statistically significant lower odds (OR 0.92 and OR 0.94, respectively) for using assistive devices during resident handling (Table 4). Regarding care situation factors, more interruptions and a higher weight of the resident were associated with a statistically significant higher odds (OR 1.22 and 1.01, respectively) for using assistive devices during resident handling. Also a higher need for the resident to receive physical assistance (i.e. comprehensive and complete physical assistance compared to light/moderate physical assistance) was statistically significantly associated with higher use of assistive devices during resident handling with ORs of 1.90 and 4.08, respectively. Furthermore, an active participation from the resident was associated with a statistically significant lower odds (OR 0.10) for using assistive devices, and performing a reposition of a resident as well as a transfer of a resident compared to turning of a resident were statistically significantly associated with higher use of assistive devices with ORs of 3.08 and 55.38, respectively. In the multivariate analysis, no eldercare worker factors showed a statistically significant association with use of

assistive devices during resident handling.

3.3. Sensitivity analysis

In general, results of the sensitivity analyses were similar to those of the main analyses when we a) included only those eldercare workers performing residential care in one ward in the analysis (Table B1 in appendix B); or b) included four levels instead of five levels to the univariate and multivariate generalized linear mixed model (Table B2 in appendix B).

4. Discussion

The main findings of our study were that use of assistive devices during resident handling were attributed to all levels of the nursing homes (i.e. nursing home, ward, eldercare worker, care episode and 'within care episode'). However, 'Within care episode' explained most of the variance in use of assistive devices.

Furthermore, we found both organizational factors (i.e. number of residents per staff and number of residents within a ward) and care situation factors (i.e. interruptions, residents' need for assistance, residents' weight, active participation from resident and type of resident handling) were significantly associated with use of assistive devices during resident handling. Eldercare worker factors did not influence the use of assistive devices.

We found considerably differences between the three types of resident handling (i.e. transferring, repositioning and turning the resident) with respect to the use of assistive devices. Assistive devices were used the most during transferring, less during repositioning and least during turning. In situations when the resident did not actively participate almost all transferring were performed with an assistive device. During turning, eldercare workers were more likely to use colleague assistance when an assistive device was not used.

4.1. Variance in assistive device use at the nursing home, ward, eldercare worker, care episode and within care episode level

To our knowledge, our study is the first based on a comprehensive multi-level dataset to investigate to what degree the use of assistive devices during resident handling in eldercare is attributed to the levels: nursing home, ward, eldercare worker, care episode and within care episode, using VCA. The finding that all five levels of the nursing homes contribute to the variability in use of assistive devices during resident handling with 4%, 8%, 8%, 9% and 71%, respectively, has not been reported previously. In multi-level studies by Koppelaar et al. (2011; 2013), both organizational and eldercare worker factors were associated with use of assistive devices. Furthermore, factors on all levels have been reported to influence use of assistive devices in eldercare in previous studies (Noble and Sweeney, 2018; Schoenfisch et al., 2011, 2019; Koppelaar et al., 2009), though no previous study has evaluated to what extent the factors or the levels contributes. The present result lend support to these studies by showing that the several levels of the nursing homes attributes to the use of assistive devices, constituting the complex daily working environment for the eldercare worker and their decision on how to react in each resident handling situation.

In Denmark, nursing homes has a large degree of decision latitude and autonomy, possibly underlying that some of the attributed variance for using assistive devices are found between nursing homes. However, they are also to a high extent under the control of the municipalities and subjects to the same or very similar regulations and guidelines. This might be the reason for the rather low attributed variance from the nursing home level. Furthermore, in the recent years there has been a large national focus on use of assistive devices, "Zero-lifting"-policies and interventions to improve ergonomics at Danish nursing homes. This may also be reflected in the rather low variability in use of assistive devices both between nursing homes and wards, as well as between eldercare workers.

Stratifying the VCA on type of resident handling markedly decreased the variation attributed to the care episode. Our results suggest, that both the actual use of assistive devices and the influence from the different levels on the use of assistive devices is highly influenced by the type of resident handling. The actual use of assistive devices was highest (78%) for transfer of the residents compared to repositioning (38%) and turning (24%). Differences in use of assistive devices between type of resident handling has been shown in other studies as well (Koppelaar et al., 2011; Noble and Sweeney, 2018). Furthermore, the variability in the use of assistive devices was to a larger extent attributed to the eldercare worker during turning compared to repositioning. In contrary, for repositioning, the use of assistive devices was to a larger extent attributed to the nursing home level. We acknowledge though, that the stratified VCAs should be interpreted with caution, as the small cluster sizes of eldercare workers in a team makes the results more vulnerable.

4.2. Determinants of use of assistive devices

Several organizational and care situation factors were statistical significantly associated with the use of assistive devices. A higher number of residents per staff, a higher number of residents within a ward and an active participation resulted in less use of assistive devices. Conversely, more interruptions, a higher need of the resident to receive physical assistance, a higher body weight of the resident, and performing a reposition or transfer of a resident compared to turning was positively associated with the use of assistive devices. To our knowledge, investigations on the association between organizational, eldercare worker and care situation factors and actual use of assistive devices using a multilevel approach are limited. However, our findings fit well with those reported by Koppelaar et al. (2011; 2013).

The finding of an association between staffing ratio and total number of residents within a ward with less use of assistive devices may indicate lack of time as it takes longer time to use an assistive device compared to non-use (Omura et al., 2019; Zhuang et al., 2000), or the feeling of lack of time to use assistive devices when being responsible for care to many residents. This finding is in line with previous studies based on interviews and questionnaires among eldercare workers which report lack of time to be a barrier for use of assistive devices (Schoenfisch et al., 2011; Engst et al., 2005).

Active participation from the resident in the specific resident handling situation showed to be associated with lower use of assistive devices. In accordance, higher needs for the residents' to receive physical assistance, noted in standardized lists provided by the team managers, were associated with higher use of assistive devices. This finding is in line with Danish protocols and guidelines focusing on self-management of the resident and using the residents' physical resources, instead of placing them passively in an assistive device (Nyborg, 2015).

The strongest association was found between type of resident handling and use of assistive devices. This is likely explained by the different biomechanical load that the handling tasks places on the eldercare worker, the availability of assistive devices, and the differences in protocols and guidelines. The biomechanical load on the eldercare worker is much higher when transferring than repositioning and turning a resident without use of assistive devices (Skotte et al., 2002) and transfer is therefore seen as the most dangerous task from a safety and health perspective. This is reflected in more focus in recent years on availability of assistive devices (e.g. there are ceiling lifts in every residents room) and protocol and guidelines (e.g. "Zero-lifting"-policies) than for repositioning and turning. In addition, the eldercare workers may be more likely to omit the use of assistive devices in situations where they may find it less needed from a biomechanical and safety perspective (i.e. repositioning and turning compared to transferring or when handling lighter residents), which may also explain our finding of a higher use of assistive devices when handling heavier residents.

We did not find any individual factors statistical significantly associated with the use of assistive devices. This could indicate that providing the appropriate organizational environment is more

important than focusing on the individual when facilitating use of assistive devices. However, previous studies has shown individual factors of importance for use of assistive devices (Koppelaar et al., 2011, 2013). Our results of no important individual factors for use of assistive devices may be influenced by methodological issues (e.g. statistical power) or the availability and choice of investigated factors.

4.3. Strengths and limitations

The innovative design of the data collection in the DOSES project is a major strength as it provides unique opportunities for conducting analyses at different levels of nursing homes with comprehensive data, large sample size and a wide range of measures at each level. Furthermore, information on organizational, eldercare worker and care situation factors was collected on the appropriate level, and not in a questionnaire among eldercare workers. Hence, the data collection ensured independent data in each workplace level.

The actual use of assistive device measured by real-time observations by research personnel limited the risk for reporting bias and reversed causality. However, we acknowledge the limitation of the cross-sectional design precluding inferences about how the specific factors prospectively determine the use of assistive devices.

The findings of our study need to be interpreted within the context of nursing homes in Denmark, characterized by high availability of assistive devices and a well-developed work environment system.

4.4. Practical implications

The overall use of assistive devices among our study participants were 46%. Thus, the use of assistive devices during resident handling in eldercare work still shows great room for improvement in Denmark. However, there were considerably differences in use of assistive devices between type of resident handling (i.e. transferring, repositioning and turning the resident). Though repositioning and turning the resident from a biomechanical perspective is less physically demanding than transferring the resident (when not using an assistive device), in total, they represent approximately 2/3 of all resident handlings, and should therefore not be neglected with respect to the total physical demands on the eldercare workers. We recommend in order to increase the use of assistive devices in eldercare, that other types of resident handling tasks be given the same focus and awareness as transfers.

Many of the care situation factors may not be possible to change. To increase use of assistive devices by eldercare workers, future studies should investigate factors associated with the use of assistive devices in specific resident handling situations, where this study document, that it is only sparsely used.

5. Conclusions

In the present study with almost 3700 direct observed resident handlings, we found that all levels of the nursing homes (i.e. nursing home, ward, eldercare worker, care episode and within care episode) contributed to the variability in the use of assistive devices during resident handling in eldercare work, with the 'within care episodes' explaining the most. Furthermore, we found that specific factors related to organization and care situation were associated with the use of assistive devices. These findings indicate that interventions with the purpose of increasing the use of assistive devices in eldercare should consider to target all levels of the nursing homes.

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Data sharing statement

Completely anonymized data can be obtained by contacting the corresponding author.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX A

Table A1
Estimated contribution of different sources of variance to the total variability in use of assistive devices during resident handling in eldercare work. Four level structure with no stratification (N = 3695) and stratified into the resident handling types; turning (N = 1265) and repositioning (N = 1280). [CPE=Covariance Parameter Estimate; S.E. = Standard Error; var. = variability]

Sources of variance	No stratification			Turning			Repositioning		
	CPE	S.E.	Percent of var. [a]	CPE	S.E.	Percent of var. [a]	CPE	S.E.	Percent of var. [a]
Between nursing homes	0.12	0.08	3.55	0.24	0.43	6.68	1.23	0.59	27.16
Between wards within nursing homes	0.27	0.09	7.69	1.11	0.91	25.31	0.48	0.27	12.62
Between eldercare workers within wards	0.46	0.09	12.29	6.86	1.85	67.58	1.63	0.41	33.15
Within eldercare workers	–	–	76.47	–	–	0.43	–	–	27.07

[a] Calculated from CPE and the constant 3.29 (Twisk, 2006). Percent of variability $= \frac{CPE}{CPE + 3.29} * 100$.

References (Appendix A)

Twisk JWR. *Applied Multilevel Analysis: A Practical Guide.* Cambridge: Cambridge Univ. Press, 2006.

APPENDIX B

Table B1
Estimated contribution of different sources of variance to the use of assistive devices during resident handling (N = 3308) in eldercare work. Five level structure including only those eldercare workers performing residential care in one ward (n = 512). [CPE = Covariance Parameter Estimate]

Sources of variance	CPE	Standard Error	Percent of variability [a]
Between nursing homes	0.0903	0.0708	2.67
Between wards within nursing homes	0.2898	0.1038	8.10
Between eldercare workers within wards	0.3416	0.1065	9.41
Between care episodes within eldercare workers	0.2842	0.1080	7.95
Within care episodes	–	–	71.88

[a] Calculated from CPE and the constant 3.29 (Twisk, 2006). Percent of variability $= \frac{CPE}{CPE + 3.29} * 100$.

Table B2
The influence of care situation, eldercare worker and organizational factors on the use of assistive devices in eldercare work. Four level structure (i.e. nursing home, ward and eldercare worker entered into the model as hierarchical random-effects). Odds Ratio (OR) and 95% confidence interval (CI) is used as measure of association. OR>1 indicates higher odds for the eldercare worker to use an assistive device.

	Use of assistive devices during resident handling			
	Univariate		Multivariate (N = 2713) [c]	
	OR	95% CI	OR	95% CI
Organizational factors (N=2713) [c]				
Nursing home				
Size of nursing home (number of wards) [a]	1.04	(0.95–1.14)		
Ward				
Type of ward being somatic [b]	0.91	(0.56–1.46)		
Staffing ratio (residents per worker) [a]	0.94***	(0.90–0.98)	0.92**	(0.86–0.99)
Assigned ergonomic advisor [b]	0.87	(0.52–1.46)		
Number of residents [a]	0.95**	(0.91–0.99)	0.94**	(0.89–1.00)
Allocation of assistive devices [a]	1.00	(0.98–1.02)		
High accessibility of assistive devices [b]	1.10	(0.61–1.98)		
Team leader present ≥3 days per week [b]	1.05	(0.59–1.84)		
Eldercare worker factors (N=1751) [c]				
Sex [b] (male)	1.60	(0.77–3.33)		
Seniority [a]	1.00	(1.00–1.00)		
BMI [a]	0.98*	(0.95–1.00)		
Days with low back pain the previous 12 weeks [b]				
- 0 days	REF			
- 1 to 7 days	0.93	(0.59–1.47)		
- 8 to 30 days	1.32	(0.86–2.02)		
- 30 days to every day	0.95	(0.64–1.40)		
Course attendance within the last 2 years [b]	1.04	(0.77–1.43)		
Great knowledge of the use of assistive devices [b]	1.48	(0.84–2.61)		
Quantitative demands [a]	1.00	(0.99–1.00)		
Tempo [a]	1.00	(0.99–1.01)		
Care situation factors (N=3227) [c]				
Care episode				
Shift [b]				
- Evening shift	REF			
- Day shift	1.35***	(1.10–1.67)		
Interruptions [a]	1.14***	(1.05–1.25)	1.20***	(1.05–1.39)
Impediments [a]	1.05	(0.95–1.15)		
Resident's need for assistance [b]				
- Light/moderate need for physical assistance	REF		REF	
- Comprehensive need for physical assistance	2.28†	(1.59–3.26)	1.69**	(1.01–2.82)
- Complete need for physical assistance	3.96†	(2.86–5.49)	3.24†	(2.31–7.19)
Resident's weight [a]	1.01‡	(1.01–1.02)	1.01**	(1.00–5.26)
Negative behavior from resident [a]	1.01	(0.99–1.02)		
Resident handling				
Assistance from colleague [b]	2.09†	(1.72–2.51)		
Active participation from resident [b]	0.09†	(0.07–0.12)	0.12†	(0.08–0.16)
Type of resident handling [b]				
- Turning the resident	REF			
- Reposition the resident	2.70†	(2.14–3.41)	2.90†	(2.20–3.82)
- Transferring the resident	30.42†	(22.52–41.09)	38.55†	(26.30–56.50)

*P = <0.1; **P = <0.05; ***P = <0.01; ‡P = <0.001; †P = <0.0001.
[a] Continuous variable.
[b] Categorical variable.
[c] Number of cases (sample size) without missing data according to measurement level.

References

Aagestad, C., Tyssen, R., Johannessen, H.A., Gravseth, H.M., Tynes, T., Sterud, T., 2014. Psychosocial and organizational risk factors for doctor-certified sick leave: a prospective study of female health and social workers in Norway. BMC Publ. Health 14 (1). https://doi.org/10.1186/1471-2458-14-1016.

Andersen, L.L., Clausen, T., Mortensen, O.S., Burr, H., Holtermann, A., 2012. A prospective cohort study on musculoskeletal risk factors for long-term sickness absence among healthcare workers in eldercare. Int. Arch. Occup. Environ. Health 85 (6), 615–622. https://doi.org/10.1007/s00420-011-0709-5.

Bevan, S., 2015. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Pract. Res. Clin. Rheumatol. 29 (3), 356–373. https://doi.org/10.1016/j.berh.2015.08.002.

Bevan, S., Quadrello, T., McGee, R., Mahdon, M., Vavrovsky, A., Barham, L., 2009. Fit for Work? Musculoskeletal Disorder and the European Workforce. The Work Foundation, London.

Bohannon, R.W., 1999. Horizontal transfers between adjacent surfaces: forces required using different methods. Arch. Phys. Med. Rehabil. 80 (7), 851–853.

Clausen, T., Tufte, P., Borg, V., 2014. Why are they leaving? Causes of actual turnover in the Danish eldercare services. J. Nurs. Manag. 22 (5), 583–592. https://doi.org/10.1111/j.1365-2834.2012.01484.x.

Davis, K.G., Kotowski, S.E., 2015. Prevalence of musculoskeletal disorders for nurses in hospitals, long-term care facilities, and home health care: a comprehensive review. Hum. Factors J. Hum. Factors Ergon Soc. 57 (5), 754–792. https://doi.org/10.1177/0018720815581933.

Engkvist, I.L., Hjelm, E.W., Hagberg, M., Menckel, E., Ekenvall, L., 2000. Risk indicators for reported over-exertion back injuries among female nursing personnel. Epidemiol. Camb. Mass 11 (5), 519–522.

Engst, C., Chhokar, R., Miller, A., Tate, R.B., Yassi, A., 2005. Effectiveness of overhead lifting devices in reducing the risk of injury to care staff in extended care facilities. Ergonomics 48 (2), 187–199. https://doi.org/10.1080/00140130412331290826.

Eriksen, W., 2004. Work factors as predictors of intense or disabling low back pain; a prospective study of nurses' aides. Occup. Environ. Med. 61 (5), 398–404. https://doi.org/10.1136/oem.2003.008482.

Garg, A., Owen, B., Beller, D., Banaag, J., 1991a. A biomechanical and ergonomic evaluation of patient transferring tasks: wheelchair to shower chair and shower chair to wheelchair. Ergonomics 34 (4), 407–419. https://doi.org/10.1080/00140139108967325.

Garg, A., Owen, B., Beller, D., Banaag, J., 1991b. A biomechanical and ergonomic evaluation of patient transferring tasks: bed to wheelchair and wheelchair to bed. Ergonomics 34 (3), 289–312. https://doi.org/10.1080/00140139108967314.

Heneweer, H., Staes, F., Aufdemkampe, G., van Rijn, M., Vanhees, L., 2011. Physical activity and low back pain: a systematic review of recent literature. Eur. Spine J. 20 (6), 826–845. https://doi.org/10.1007/s00586-010-1680-7.

Holtermann, A., Clausen, T., Jørgensen, M.B., Burdorf, A., Andersen, L.L., 2013. Patient handling and risk for developing persistent low-back pain among female healthcare workers. Scand. J. Work. Environ. Health 39 (2), 164–169. https://doi.org/10.5271/sjweh.3329.

Hussain, A., Rivers, P.A., Glover, S.H., Fottler, M.D., 2012. Strategies for dealing with future shortages in the nursing workforce: a review. Health Serv. Manag. Res. 25 (1), 41–47. https://doi.org/10.1258/hsmr.2011.011015.

Jensen, L.D., Ryom, P.K., Christensen, M.V., Andersen, J.H., 2012. Differences in risk factors for voluntary early retirement and disability pension: a 15-year follow-up in a cohort of nurses' aides. BMJ Open 2 (6), e000991. https://doi.org/10.1136/bmjopen-2012-000991.

Karstad, K., Jørgensen, A.F.B., Greiner, B.A., et al., 2018a. Danish Observational Study of Eldercare work and musculoskeletal disorderS (DOSES): a prospective study at 20 nursing homes in Denmark. BMJ Open 8 (2), e019670. https://doi.org/10.1136/bmjopen-2017-019670.

Karstad, K., Rugulies, R., Skotte, J., et al., 2018b. Inter-rater reliability of direct observations of the physical and psychosocial working conditions in eldercare: an evaluation in the DOSES project. Appl. Ergon. 69, 93–103. https://doi.org/10.1016/j.apergo.2018.01.004.

Koppelaar, E., Knibbe, J.J., Miedema, H.S., Burdorf, A., 2009. Determinants of implementation of primary preventive interventions on patient handling in healthcare: a systematic review. Occup. Environ. Med. 66 (6), 353–360. https://doi.org/10.1136/oem.2008.042481.

Koppelaar, E., Knibbe, J.J., Miedema, H.S., Burdorf, A., 2011. Individual and organisational determinants of use of ergonomic devices in healthcare. Occup. Environ. Med. 68 (9), 659–665. https://doi.org/10.1136/oem.2010.055939.

Koppelaar, E., Knibbe, J.J., Miedema, H.S., Burdorf, A., 2013. The influence of individual and organisational factors on nurses' behaviour to use lifting devices in healthcare. Appl. Ergon. 44 (4), 532–537. https://doi.org/10.1016/j.apergo.2012.11.005.

Kuorinka, I., Jonsson, B., Kilbom, A., et al., 1987. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. 18 (3), 233–237.

Lagerström, M., Hansson, T., Hagberg, M., 1998. Work-related low-back problems in nursing. Scand. J. Work. Environ. Health 24 (6), 449–464.

Mäntyselkä, P.T., Kumpusalo, E.A., Ahonen, R.S., Takala, J.K., 2002. Direct and indirect costs of managing patients with musculoskeletal pain-challenge for health care. Eur. J. Pain 6 (2), 141–148. https://doi.org/10.1053/eujp.2001.0311.

March, L., Smith, E.U.R., Hoy, D.G., et al., 2014. Burden of disability due to musculoskeletal (MSK) disorders. Best Pract. Res. Clin. Rheumatol. 28 (3), 353–366. https://doi.org/10.1016/j.berh.2014.08.002.

McGill, S., Kavcic, N., 2005. Transfer of the horizontal patient: the effect of a friction reducing assistive device on low back mechanics. Ergonomics 48 (8), 915–929. https://doi.org/10.1080/00140130412331331389.

Miranda, H., Punnett, L., Gore, R., Boyer, J., 2011. Violence at the workplace increases the risk of musculoskeletal pain among nursing home workers. Occup. Environ. Med. 68 (1), 52–57. https://doi.org/10.1136/oem.2009.051474.

Miranda, H., Punnett, L., Gore, R.J., ProCare Research Team, 2014. Musculoskeletal pain and reported workplace assault: a prospective study of clinical staff in nursing homes. Hum. Factors 56 (1), 215–227.

Noble, N.L., Sweeney, N.L., 2018. Barriers to the use of assistive devices in patient handling. Workplace Health & Saf. 66 (1), 41–48. https://doi.org/10.1177/2165079917697216.

Nyborg, T., Branchearbejdsmiljørådet Social & Sundhed, 2015. Forflytningsguiden: Til Ansatte, Elever Og Studerende I Ældreplejen, På Sygehuse Og I Leve- Og Bomiljøer. Kbh. BAR Social & Sundhed - BrancheArbejdsmiljøRådet.

Omura, Y., Yamagami, Y., Hirota, Y., Nakatani, E., Tsujimoto, T., Inoue, T., 2019. Evaluation of the effectiveness of the sliding sheet in repositioning care in terms of working time and subjective fatigue: a comparative study with an experimental design. Int. J. Nurs. Stud. 99, 103389. https://doi.org/10.1016/j.ijnurstu.2019.103389.

Pejtersen, J.H., Kristensen, T.S., Borg, V., Bjorner, J.B., 2010. The second version of the copenhagen psychosocial questionnaire. Scand. J. Publ. Health 38 (3 Suppl), 8–24. https://doi.org/10.1177/1403494809349858.

Saarni, S.I., Härkänen, T., Sintonen, H., et al., 2006. The impact of 29 chronic conditions on health-related quality of life: a general population survey in Finland using 15D and EQ-5D. Qual. Life Res. 15 (8), 1403–1414. https://doi.org/10.1007/s11136-006-0020-1.

Schoenfisch, A.L., Myers, D.J., Pompeii, L.A., Lipscomb, H.J., 2011. Implementation and adoption of mechanical patient lift equipment in the hospital setting: the importance of organizational and cultural factors. Am. J. Ind. Med. 54 (12), 946–954. https://doi.org/10.1002/ajim.21001.

Schoenfisch, A.L., Kucera, K.L., Lipscomb, H.J., et al., 2019. Use of assistive devices to lift, transfer, and reposition hospital patients. Nurs. Res. 68 (1), 3–12. https://doi.org/10.1097/NNR.0000000000000325.

Skotte, J.H., Essendrop, M., Hansen, A.F., Schibye, B., 2002. A dynamic 3D biomechanical evaluation of the load on the low back during different patient-handling tasks. J. Biomech. 35 (10), 1357–1366.

Twisk, J.W.R., 2006. Applied Multilevel Analysis: A Practical Guide. Cambridge Univ. Press, Cambridge.

Vos, T., Barber, R.M., Bell, B., et al., 2015. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 386 (9995), 743–800. https://doi.org/10.1016/S0140-6736(15)60692-4.

Zhuang, Z., Stobbe, T.J., Hsiao, H., Collins, J.W., Hobbs, G.R., 1999. Biomechanical evaluation of assistive devices for transferring residents. Appl. Ergon. 30 (4), 285–294.

Zhuang, Z., Stobbe, T.J., Collins, J.W., Hsiao, Hongwei, Hobbs, G.R., 2000. Psychophysical assessment of assistive devices for transferring patients/residents. Appl. Ergon. 31 (1), 35–44. https://doi.org/10.1016/S0003-6870(99)00023-X.