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Biomechanical Load during Patient Transfer with Assistive Devices: Cross-sectional Study

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Practioner´s Summary

Frequent patient transfer is associated with an increased risk of back pain and injury among healthcare workers. This analysis compares the level of physical load during patient transfer with commonly used assistive devices. The results show that the ceiling-lift and intelligent bed are associated with lower physical load.

Abstract

This study utilized a cross-sectional design to perform measurements of muscle activity (EMG) and forward - and lateral trunk inclination angle during a full workday among 52 female healthcare workers from 16 different departments at five Danish hospitals. Using linear mixed models, the 95th percentile ranks of the normalized root mean square (nRMS) values were analyzed for the different types of assistive devices.

Compared to no assistive device (mean nRMS 27.9%, 95% CI 24.8-31.0%), the use of intelligent beds (23.9%, CI 20.2-27.6%) and ceiling-lifts (24.0%, CI 20.3-27.7%) led to lower erector spinae normalized EMG across all types of patient transfers. Conversely, the use of bedsheets (30.6%, CI 27.1-34.2%), sliding-sheets (30.3%, CI 26.8-33.9%) and sliding-boards (33.5%, CI 29.5-37.6%) were associated with higher levels of erector spinae EMG.

Consistent use of ceiling-lifts and intelligent beds reduces the physical workload and may thereby decrease the risk of musculoskeletal disorders among healthcare workers.

Keywords

Electromyography; patient transfer; low back pain; healthcare; fatigue.

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1. Introduction

The yearly prevalence of work-related musculoskeletal disorders (MSDs) among healthcare workers is high; estimated to about 55% for low back pain (LBP) (Boakye et al., 2018; Davis and Kotowski, 2015). Among healthcare workers, musculoskeletal complaints are most commonly reported in the low back followed by the neck and shoulders (Davis and Kotowski, 2015; Ribeiro et al., 2017), with idiopathic injuries constituting the majority of these complaints (Oranye and Bennett, 2018). Factually, back injuries among nurses and nurses´ aides occur at six times the rate of other groups within the field of healthcare (Cohen-Mansfield et al., 1996), and they generally experience LBP more frequently than the general working population (Guo et al., 1995; Hoy et al., 2012).

Following this, yet another negative consequence that partially stems from the high prevalence of MSDs, is the reported levels of job (dis)satisfaction among healthcare workers. The results from a survey performed in 5 different countries - including more than 43,000 nurses - show that up to 54% below the age of 30 plan to leave their job within 1 year due to physical and psychological challenges related to the profession (Aiken et al., 2001). Among these physical challenges, heavy manual lifting during patient transfer is arguably one of the greatest contributors to the high workload experienced by this workforce. Indeed, the Cultural and Psychosocial Influences on Disability- study, including office workers, nurses and other blue-collar workers from 18 different countries, showed that nurses have the highest prevalence of heavy (>25kg) manual lifting (Coggon et al., 2012), indicating that appropriate assistive devices may not be used as much as would be considered appropriate. The obvious question following this is whether or not this translates into undesirable outcomes: In addition to the studies reporting associations between certain lifting positions (e.g. twisting and bending of the spine) and risk of MSDs (Burdorf and Sorock, 1997;

Ribeiro et al., 2017), there are strong indications that frequent patient handling is associated with increased risk of musculoskeletal pain and injury (Andersen et al., 2014; Eriksen, 2004; Retsas and Pinikahana, 2000; Ribeiro et al., 2017; Sherehiy et al., 2004; Smedley et al., 1997).

Because multidisciplinary interventions that encompass multiple aspects of the biopsychosocial model are inherently difficult to structure, perform and analyze, the biomechanical part of the puzzle has historically been singled out and emphasized in the literature. For example, a prospective study - including more than 5000 healthcare workers - showed that consistent use of assistive devices is associated with 40-50% reduced risk of back injury among female healthcare workers (Andersen et al., 2014). However, this study did not account for the different types of assistive devices. Although the literature is controversial and the quality of evidence generally low (Freiberg et al., 2016; Richardson et al., 2018), the idea to decrease the biomechanical load and fatigue development during patient transfer by utilizing assistive devices in situations where it is advantageous, has shown to be a promising direction within the biomechanical aspect of the issue (Alamgir et al., 2008; Chhokar et al., 2005; Collins et al., 2004; Engst et al., 2005; Evanoff et al., 2003; Koppelaar et al., 2012; Smedley et al., 1995). Specifically, the most commonly single-item assistive device investigated is the ceiling-lift, with interventions reporting positive results in terms of reducing biomechanical load and MSDs following implementation (Alamgir et al., 2008; Chhokar et al., 2005; Edlich et al., 2004; Marras et al., 2009; Silverwood and Haddock, 2006).

Following this, a cost-effective method to evaluate the biomechanical load – the reduction of which constitutes the assumed mechanism behind the successful implementation in the abovementioned studies - includes the use of surface electromyography (EMG), as this method represents an estimate of muscle activity (Farina et al., 2004). Furthermore, accelerometry is often used in combination with EMG to quantify the kinematic changes in body positions including free-living dynamic movements (Cleland et al., 2013; Korshøj et al., 2014; Skotte et al., 2014; Stemland et al., 2015; Vähä-Ypyä et al., 2018). However, even though previous studies report associations between frequent use of assistive devices and decreased risk of MSDs (Andersen et al., 2014; Boocock et al., 2019; D'Arcy et al., 2012; Holtermann et al., 2015), it is currently unknown if this effect is due to a general use or, perhaps more likely, the result of consistent use of specific assistive devices. Likewise, the current body of literature is mostly based on laboratory studies, simulated patient transfers and recordings of short durations, which undermines the importance of work-related organizational, contextual and psychosocial influencers (Kucera et al., 2019; Schoenfisch et al., 2019).

Therefore, the aim of this study was to quantify levels of muscle activity and trunk inclination during patient transfer with or without the use of assistive devices during a full day in a real-life working environment, hereby creating a load-matrix for the assistive devices most commonly used in hospitals. The novelty lies in the fact that this study seeks to identify and rank specific assistive devices based on their associated physical load, whereas most previous studies have considered the general use of (all) assistive devices. We hypothesize that levels of muscle activity will vary significantly between different assistive devices, with the more technically advanced devices (i.e. lifts and those used for bariatric patients or less self-reliant patients) resulting in the lowest level of physical load.

2. Methods

We have previously published a protocol article that describes the methods used in the present study in detail (Vinstrup et al., 2017). Therefore, the following paragraphs will refer to this publication and include essential information in order for the reader to achieve an overview of the study design and methods. Using the methods described below, we report bilateral measurements of muscle activity from the erector spinae musculature as well as measurements of trunk inclination. The results of the present study will furthermore be used in a future analysis of risk factors for back injury among healthcare personnel, combining the technical measurements presented herein with prospective questionnaire data from a large cohort of Danish hospital workers.

2.1 Study design and participants

This study utilized a cross-sectional design to perform measurements of muscle activity and trunk inclination during a full workday at Danish hospitals. A total of 52 female health care workers (mean ± SD; age 42 ± 10y; height 167 ± 6cm; body mass 67 ± 12kg) spanning 16 different departments from five hospitals across two different regions of Denmark volunteered to participate in the study. Criteria for exclusion were measurements of blood pressure >160/100, pregnancy, life-threatening diseases/ailments as well as an estimated low number (<5) of full patient transfers during the work day. As the written information was sent out prior to enrolment, none of the participants were excluded on the day of testing (Table 1).

2.2 Ethics

In line with the Helsinki Declaration, all participants were informed about the content of the study protocol before providing written informed consent. The information was given both written and verbally before commencement of data collection. The study was approved by the Danish National Committee on Biomedical Research Ethics (The local ethical committee of Frederiksberg and Copenhagen; H-3-2010-062) and the Danish Data Protection Agency (j.nr. 2015-41-4232).

2.3 Data collection

Before starting the shift, the participant met the research leader in the assigned room. After once again acknowledging the conditions of the study and signing informed consent, the participant underwent application of the equipment as well as the normalization procedures described below. Likewise, aside from the aforementioned demographic information, the participant was asked to rate her current low-back- and neck/shoulder pain on a scale from 0-10, presented in the form of a visual analog scale (VAS). Following this, the research leader accompanied the participant throughout her workday, recording all cases of patient transfer and confirmed the signal strength as well as the application of the equipment whenever possible before each transfer. That is, measurements were only performed during active patient transfers, which would vary in terms of physical demands and therefore influence the use of assistive devices. In order to get a detailed picture of the variables influencing such lifting/transfer scenarios, the total number of participating personnel, as well as level of patient self-reliance (defined as the ability to perform adjustments/transfers independently; rated on a 5-point Likert scale ranging from “not at all” to “completely”), sex and anthropometrics of the patient were recorded. Additionally, Borg´s category-ratio scale (CR-10), a widespread tool for measuring effort and exertion, was used to quantify perceived exertion during patient transfer (Williams, 2017).

Furthermore, the use of various assistive devices was recorded and grouped (Figure 1). The participants were instructed to perform their patient transfers as usual without consideration to their participation in the study, and hence to use the assistive device they would normally deem appropriate for the situation.

2.4 Experimental design

EMG signal sampling and analysis

Surface EMG measurements of muscle activity were recorded using wireless equipment (TeleMyo DTS Telemetry, Noraxon, AZ, USA). The sampling rate was set at 1500 Hz with a bandwidth of 10–500 Hz. The amplifier had a 16-bit A/D converter and a common mode rejection ratio >100 dB. Prior to placing the electrodes (Blue Sensor N-00-S, Ambu A/S, Ballerup, Denmark; measuring area; 95 mm^2, typical AC impedance; 600 ohm, combined offset instability and internal noise; <15 μV) bilaterally on the erector spinae muscles (longissimus, two finger widths lateral from L1; iliocostalis; one finger-width medial from the line of the posterior spinae iliaca superior to the lowest point of the rib at the level of L2 with an inter-electrode distance of 20mm) (Hermens et al., 2000), the skin was cleaned and prepared with scrubbing gel (Acqua gel, Meditec, Parma, Italy). Following application of the equipment, the EMG normalization procedure consisted of maximal voluntary contractions (MVC) for the erector spinae muscles performed in the Biering-Sorensen position (Biering-Sørensen, 1984; Burden, 2010; Jackson et al., 2017), as this was made possible at all workplaces. The MVCs were performed twice in the morning and twice in the afternoon, and the highest recorded value was used for subsequent normalization. Further, this procedure allowed inferences to be made about the accumulation of fatigue at the end of the workday by comparing measurements obtained during the morning and afternoon, respectively (Sorbie et al., 2017).

During data analysis, all raw surface EMG signals were visually checked and digitally filtered by a Butterworth fourth-order high-pass filter (10 Hz cut-off frequency) and subsequently smoothed using a root mean square (RMS) filter with a moving window of 500 ms. For each individual muscle and each patient transfer, the 95th percentile rank of the smoothed RMS signal was normalized (nRMS) to the maximal moving RMS (500-ms time constant) EMG obtained during MVC. The 95th percentiles of nRMS represents an estimate of the highest physiological levels of muscle activity (Jonsson, 1982; Trask et al., 2008). The nRMS values of the four erector spinae muscles were merged and assistive devices were grouped according to function; e.g. wheelchair and rollator were merged into “walking aids” whereas stand-assist lift, turner transfer and stand-assists were merged into “standing aids”. Additionally, the ceiling-lift and accompanying sling were regarded as one assistive device (Table 2). Figure 1 illustrates commonly-used assistive devices and their utility.

Accelerometer sampling and analysis

Trunk inclination was continuously measured using an accelerometer (3D DTS accelerometer sensor, Noraxon, Arizona, USA). The EMG- and accelerometer data were sampled synchronously, using the 16-channel 16-bit PC-interface receiver (TeleMyo DTS Telemetry, Noraxon, Arizona, USA). The accelerometer was positioned on the low back; 1 cm. above the sacroiliac joint. The dimension of the probes was 3.4 cm x 2.4 cm x 3.5 cm. Calibrations were performed in the upright/vertical static position, maintained for 5 seconds and performed in the morning and again in the afternoon (Villumsen et al., 2015). Acceptable accuracy as well as high sensitivity and specificity of upper trunk inclination during low to medium speed movement have been reported; hereby enabling the use of accelerometry in the assessment of trunk inclination during the present conditions (Brandt et al., 2018; Korshøj et al., 2014). During subsequent analysis, the accelerometer signals were digitally lowpass filtered using a 4th order zero-lag Butterworth filter (3 Hz cutoff frequency) and converted from acceleration to inclination. The 95th percentile ranks of the momentary trunk inclination (flexion/extension- and left/right side-bending) were calculated with respect to the gravitational line.

2.5 Statistics

Data were analyzed using linear mixed models (Proc Mixed, SAS version 9.4) with repeated measures. The 95th percentile rank of the nRMS and trunk inclination angles were the dependent variables and use of assistive device was the independent variable. Analyses were controlled for the type of patient transfer, age of the nurse, number of nurses, height of the nurse, body mass of the nurse, body mass of the patient, and self-reliance of the patient (level 2-5). Patients completely self-reliant were excluded from the analyses. Estimates are least square means and 95% confidence intervals for each assistive device, as well as differences of least square means and 95% confidence intervals for the difference between each assistive device and no device. A paired t-test was used to analyze differences in MVC values performed in the morning and afternoon, respectively.

The significance level was set to 0.05.

Table 1: Demographics, pain intensity, erector spinae strength and level of physical exertion.

	Mean	SD
Age (y)	42	10
Height (cm)	168	6
Body mass (kg)	67	12
Years as healthcare worker (n)	15	9
Pain intensity (0-10)		
Low back	0.6	1.0
Neck/shoulder	0.5	1.0
Erector spinae maximal strength (N)		
Morning	247	62
Afternoon	229	65
Physical exertion during patient handling (0-10)	2.7	1.3

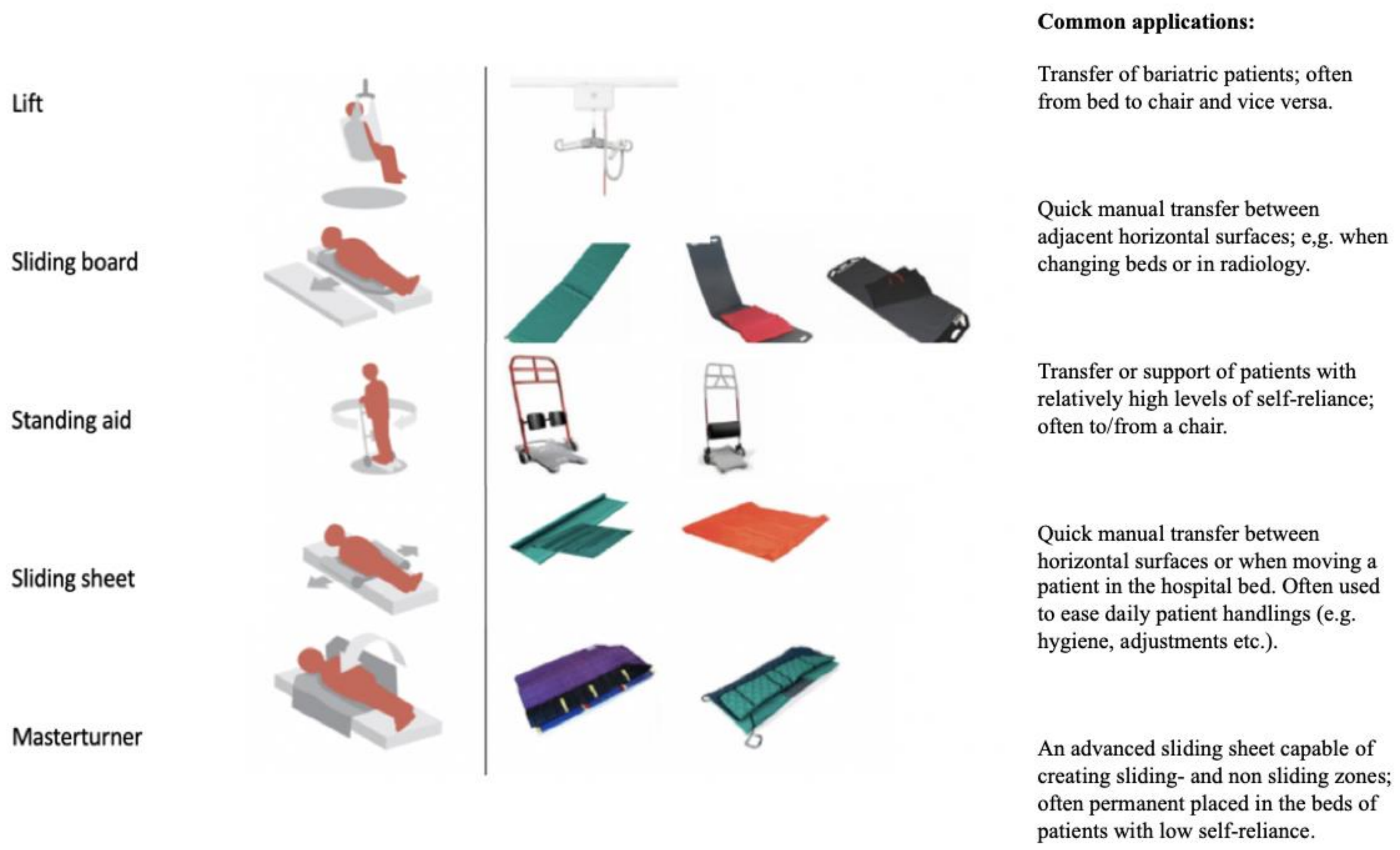

Figure 1: Illustration of commonly used assistive devices (adapted with permission from Forflytningsportalen, Region Midtjylland)

3. Results

A total of 540 full patient transfers and use of 14 different assistive devices were recorded, with 53% of the transfers performed without the use of an assistive device.

The participants reported low pain intensity (mean <1 for both low back and neck/shoulder, scale 0-10) and rated the average perceived exertion during patient transfer as 2.7 ± 1.3 (mean ± SD), corresponding to light/moderate on the Borg CR10 scale (Table 1). Additionally, the force produced during the maximal voluntary contractions were lower in the afternoon (mean ± SD; 229 ± 65N) than in the morning (247 ± 62N) ($p<0.05$).

The five most frequently observed tasks were repositioning in bed (17%), transfer from chair to bed (14%), transfer from bed to chair (13%), miscellaneous patient activity in the bed (13%) and transfer from one bed to another (11%). Following this, across all transfers and patients, the most frequent number of personnel engaging in the task was 2 (49%), followed by 1 (29%), 3 and 4 (both 11%). The patients were generally characterized by having low levels of self-reliance; i.e. 43% were labelled as having very low level, 40% as not being self-sufficient at all and 12% as having moderate levels of self-reliance; corresponding to 4, 5 and 3 on the Likert-Scale, respectively.

3.1 Erector spinae muscle activity and trunk inclination

Compared to no assistive device (95th percentile mean 27.9%, 95% CI 24.8-31.0%), the use of intelligent beds (23.9%, CI 20.2-27.6%) and the ceiling-lifts (24.0, CI 20.3-27.7%) showed significantly lower erector spinae muscle activity across all types of patient transfers ($p=0.0004$ and $p=0.0028$, respectively). Conversely, the use of bed sheets (30.6, CI 27.1-34.2), sliding sheets (30.3, 26.8-33.9) and sliding boards (33.5, CI 29.5-37.6) resulted in higher levels of erector spinae muscle activity ($p=0.0063$, $p=0.0240$ and $p=0.0004$, respectively).

Additionally, the intelligent bed, hospital bed and ceiling-lift showed lower levels of trunk flexion whereas use of the masterturner and sliding board showed lower levels of left/right side-bending (all $p<0.05$ compared to no assistive device) (Table 3). No differences in erector spinae muscle activity were observed between right and left side.

Table 2: nRMS (%MVC) values for erector spinae muscles across all assistive devices and associated trunk flexion (degrees).

Values are reported as 95th percentile ranks and 95% confidence interval.

Assistive device	%MVC (nRMS)	95% CI	Flexion/Extension	95% CI	Left/Right Side Bending	95% CI
No assistive device	27.9	24.8 - 31.0	36.5	23.3 - 49.6	32.1	27.7 - 36.6
Hospital bed	25.7	21.3 - 30.1	20.0	0.6 - 39.4	33.7	22.5 - 44.9
Intelligent bed	23.9	20.2 - 27.6	24.8	9.1 - 40.5	29.1	21.6 - 36.7
Bed sheet	30.6	27.1 - 34.2	36.7	21.7 - 51.8	29.4	22.5 - 36.3
Walking aids	27.6	23.3 - 31.9	38.1	19.9 - 56.3	34.0	23.9 - 44.0
Masterturner	26.8	23.2 - 30.4	28.8	13.3 - 44.4	23.2	15.8 - 30.6
Sliding sheet	30.3	26.8 - 33.9	38.2	22.8 - 53.5	26.5	19.3 - 33.8
Ceiling-lift	24.0	20.3 - 27.7	22.3	6.5 - 38.2	24.8	17.0 - 32.6
Sliding board	33.5	29.5 - 37.6	39.4	21.8 - 56.9	20.1	10.8 - 29.4
Standing aids	25.9	21.7 - 30.2	30.6	11.7 - 49.4	22.9	12.3 - 33.6

Table 3: Comparison of trunk flexion and erector spinae muscle activity when using assistive devices vs. no assistive device.

Values illustrate differences reported as percentage points of %MVC (nRMS) and degrees (flexion/bending).

Assistive device	**nRMS, differences**	**p-value**	**Flexion/Extension**	**p-value**	**Left/Right Side Bending**	**p-value**
No assistive device (comparator)						
Hospital bed	-2.16	0.1913	-16.45	**0.0288**	1.56	0.7708
Intelligent bed	-4.03	**0.0004**	-11.71	**0.0154**	-3.02	0.3793
Bed sheet	2.76	**0.0063**	0.24	0.9574	-2.71	0.3891
Walking aids	-0.26	0.8727	1.61	0.8108	1.84	0.7001
Masterturner	-1.08	0.3220	-7.65	0.1143	-8.95	**0.0092**
Sliding sheet	2.45	**0.0240**	1.66	0.7273	-5.60	0.0991
Ceiling-lift	-3.90	**0.0028**	-14.15	**0.0128**	-7.33	0.0702
Sliding board	5.64	**0.0004**	2.88	0.6792	-12.04	**0.0139**
Standing aids	-1.95	0.2414	-5.94	0.4296	-9.22	0.0841

4. Discussion

This field study investigated muscle activity as well as trunk forward- and lateral flexion during patient transfers in Danish hospitals using EMG and actigraphy, respectively. Based on measurements performed throughout full workdays, we found significant differences between assistive devices. Generally, the use of more technically-advanced assistive devices such as the ceiling-lift and intelligent bed resulted in the lowest levels of muscle activity (decreases of approx. 4 percentage-points compared to no assistive device), whereas the sliding sheet and sliding boards – characterized by a more manual hands-on approach - showed the highest levels (increases of 2 - 6 percentage-points). Interestingly, while the degree of trunk flexion was lowest during patient transfers performed with ceiling lift and hospital beds, manual assistive devices (i.e. masterturner and sliding board) were associated with less side-bending of the trunk.

The abovementioned results are in line with our initial hypothesis; i.e. assistive devices used primarily for bariatric patients and for those exhibiting overall low levels of self-reliance, are generally associated with lower levels of muscle activity. However, even though the recorded differences were rather miniscule, even small decreases in muscular activation will contribute to an accumulated decrease in physical load throughout a day/week/month. Contrastingly, we report that assistive devices commonly utilized for patients with higher physical capacity and who are therefore capable of engaging in the transfer alongside the assigned personnel, are generally associated with higher levels of muscle activity. However, these patterns also question the direction of the observed causality; i.e. the reported differences between assistive devices are likely to be highly influenced by the type of patient and patient transfer during which they are used. Likewise, considering the relatively large confidence intervals presented in table 2 (predominantly indicative of inter-personal differences and the varying patient transfer scenarios during which a specific assistive device is used), any unmediated practical application should be implemented with caution. For many of the patient transfer scenarios, it is not always feasible to utilize advanced devices such as the ceiling-lift or intelligent bed: For example, during daily repositioning in bed or when transferring the maim patient who is unable to use the sling that accompanies the ceiling-lift, the quick use of sliding sheets/boards is often the most feasible solution. Therefore, in addition to providing insight into the physical load associated with individual assistive devices, it is likely that the presented results also serve to illustrate the inherent differences between types of patient transfers, patients of various physical capacity and the choice of assistive device that best serves this combination in a practical and time-efficient manner. However, despite the fact that several organizational, contextual and interpersonal factors are known to influence the use of assistive devices (Kucera et al., 2019), the biomechanical insights provided herein should not be neglected.

In the present study we found that 53% of the patient transfers were performed without the use of assistive devices, which is adding to the current literature where both higher (Andersen et al., 2014; Jakobsen et al., 2019) and lower (Lee et al., 2010) frequencies of use have been reported. Despite the fact that this number does not tell the tale of whether or not the use of an assistive device may have been appropriate on several of these occasions, the literature does indicate that more frequent use is associated with lower staff fatigue and physical demands (Yassi et al., 2001) as well as decreased risk of low back injury (Andersen et al., 2014; D'Arcy et al., 2012; Garg and Kapellusch, 2012). However, the rate of perceived exertion during patient transfer was generally reported as low/moderate, which is less than one might expect based on the relatively high percentage of patient transfers performed without assistive device as well as in contrast to other studies (Hui et al., 2001; Jakobsen et al., 2015; Vieira et al., 2006). Despite this finding, 70% of Danish hospital workers do report being tired (defined as somewhat tired, very tired or completely exhausted) after a normal workday (National Research Centre for the Working Environment, 2018). Likewise, here we report the presence of fatigue at the end of the workday which has previously been associated with the accumulation of physical exposures (Bláfoss et al., 2019), an unproportioned high frequency of back injuries occurring at end of the workday (Hui et al., 2001; Ryden et al., 1989) as well as with increased risk of sickness absence (Roelen et al., 2013; Sagherian et al., 2017). Although many factors might influence this, it is not unlikely that at least part of the accumulated fatigue is a result of insufficient use of appropriate assistive devices and that further implementation of these will diminish the accumulation of fatigue observed at the end of the workday (Vøllestad and Sejersted, 1988).

Considering the multitude of situational-specific variables and the limitations mentioned below, the results of the present study supports the use of ceiling-lifts as an effective means to diminish the physical load experienced by the healthcare worker during challenging patient transfers: The ceiling-lift constitutes an advanced assistive device which has shown promise in reducing the risk of musculoskeletal injury among healthcare personnel (Alamgir et al., 2008; Aslam et al., 2015; Engst et al., 2005; Garg et al., 1991; Keir and MacDonell, 2004; Lee et al., 2013; Marras et al., 2009; Zhuang et al., 1999). Similarly - although not nearly as extensively investigated - the intelligent bed has undergone significant technological advancement as well as received increased attention (Ghersi et al., 2018, 2016), and the present study indicates that further implementation alongside the ceiling-lift may provide a reduction of the biomechanical risk factors (i.e. heavy lifting in trunk flexion) associated with patient transfer.

4.1 Strengths and limitations

Limitations of the present study include the use of normalized EMG as a proxy for muscular load due to individual motor variability and the non-linear relationship between level of EMG activity and load (Madeleine et al., 2008, 2001; Mirka, 1991). However, because this study used a relatively large sample size and a repeated-measures design to compare the relative level of muscle activity associated with various assistive devices, any methodology-related variability is very unlikely to systematically affect the results in any direction. Another potential limitation of the current study is linked to the validity and reliability of accelerometers in measuring trunk inclination. While methods including opto-electrical motion analysis are considered gold standard when recording kinematics, these are very problematic to utilize in field studies. However, accelerometer measurements are considered valid and reliable when assessing slow-medium speed movements, and has recently shown high sensitivity in discriminating between activities during dynamic and free living work-and leisure time activities (Korshøj et al., 2014; Lugade et al., 2014; Stemland et al., 2015). Additionally, the issue regarding of standardization of patient transfers performed with and without assistive device provides cause for ambivalence: While most patient transfers performed without assistive device may simply reflect situations where the healthcare worker was transferring a patient who was relatively self-reliant, standardizing the transfers would severely limit the practical transference to real-life patient transfer scenarios. Therefore, even though we statistically adjusted for the general type of patient transfer, it is likely that several inherent differences between patient transfer scenarios and their accompanying effects on the assistive device chosen, and the results therefore cannot fully encompass the multiple aspects present during such a complex scenario. Strengths include the fact that measurements were performed throughout a full workday, reflecting real-life patient transfer scenarios with and without the use of assistive devices. Furthermore, the normalization procedures performed before and after the workday not only strengthens the robustness of the results, but also gives rise to the possibility of evaluating the effect of a workday on indicators of muscular fatigue. Likewise, the relatively large sample size and associated high number of recorded patient transfers analyzed in a repeated measures design further strengthens the results.

5. Conclusion

Commonly used assistive devices were associated with varying degrees of muscle activity and trunk flexion. More frequent use of ceiling-lifts and intelligent beds is likely to decrease the physical workload among healthcare workers and thereby possible the risk of MSDs. However, caution is needed when generalizing these results as inherent differences between various types of patient transfers will affect the practical utility of each assistive device.

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Conflicts of interest

There are no conflicts of interest.

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