**RESEARCH ARTICLE**                                                                                          **Open Access**

# Physical exposure during patient transfer and risk of back injury & low-back pain: prospective cohort study

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## Abstract

**Background:** Work-related musculoskeletal disorders (MSDs) are common among healthcare workers. Because frequent patient transfer has been associated with increased risk of MSDs, we aim to quantify the physical load associated with commonly-used assistive devices and to investigate associations between accumulated physical exposure and risk of MSDs.

**Methods:** By applying an exposure matrix based on objective measurements of electromyography and trunk flexion on a large ($n = 1285$) prospective cohort, intensity of low-back pain (LBP) and odds of back injury at 1-year follow-up were modelled using linear models and logistic regressions, respectively. The cohort was divided into groups according to physical exposure; i.e. low (1st quartile), moderate (2nd and 3rd quartiles) and high (4th quartile) exposure.

**Results:** Exposure profiles are provided for 9 groups of assistive devices, with ceiling lifts and intelligent beds eliciting the lowest physical exposure. In the fully-adjusted model, we report differences in LBP intensity at follow-up between the low and moderate exposure groups ($p = 0.0085$). No difference was found between the moderate and high exposure groups ($p = 0.2967$). Likewise, we find no associations between physical exposure and odds of back injury at 1-year follow-up, with a prevalence of 11, 13 and 11% for the three groups, respectively.

**Conclusions:** Low physical exposure during patient transfer was prospectively associated with lower intensity of LBP. Consistent use of assistive devices associated with low physical exposure, namely ceiling-lifts and intelligent beds, may play a role in reducing the incidence of MSDs among healthcare workers.

**Keywords:** Patient transfer, Biomechanical load, Low-back pain, Back injury, Healthcare

## Background

Work-related musculoskeletal disorders (MSDs) are more frequently reported among healthcare workers compared to other professions [1–4], and 37% of Danish healthcare workers report being hindered in their profession because of pain [5]. Low-back pain (LBP) is the most commonly-cited musculoskeletal complaint among this subgroup of the working population, with a 1-year prevalence ranging between 28 and 96% [1, 6, 7]. In addition to the individual burden of LBP [8], the socio-economic costs – e.g. sickness absence and loss of productivity – are likewise alarmingly high [9–11], making the current situation in the healthcare industry a societal issue with far-reaching implications. The severity of the situation is furthermore highlighted by the current global shortage of nurses; estimated to increase by 2030 [12–15]. Thus, identifying risk factors with the goal of improving the local working environment is vital for the profession.

The need for identification of potential risk factors and preventative interventions is furthermore reflected

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in the fact that the afore-mentioned high prevalence of work-related MSDs among healthcare personnel goes back several decades [16–18]. Likewise, the notion that a high frequency of manual patient transfers is associated with increased risk of low-back injury cannot be considered a new finding [19, 20].

Because individualized and/or multimodal approaches are inherently difficult to apply to large populations of the workforce, most interventions to date have focused on identifying possible risk factors that apply to the healthcare profession as a whole [21]. Several of these interventions have focused on the negative consequences of high physical loads throughout the workday [22–24]. For example, a recent prospective cohort study reported that an accumulated high volume of physical workload was associated with increased risk of overall poor health [22]. Following this, some of the most promising interventions aiming to reduce the physical load among healthcare workers seem to be the ones focusing on decreasing the frequency and/or intensity of manual lifting [25–29]. This is often and most successfully done by increasing the use of assistive devices during patient transfers, as previous studies have reported associations between frequent use and decreased risk of MSDs [30–32]. However, it is currently unknown whether this effect is mainly due to single/specific assistive devices, or if it is related to consistent use of a combination of various assistive devices. Following this, context-specific information based on biomechanical measurements on the physical risk factors associated with patient transfer and the accompanying benefits of utilizing specific assistive devices when appropriate, is lacking. Thus, quantifying the biomechanical exposure associated with the use of different assistive devices would be highly relevant when investigating the risk of back injury and LBP in this population.

Therefore, by combining technical measurements of muscle activity and trunk inclination during patient transfers with a prospective questionnaire design, we sought to create an exposure-matrix to identify associations between biomechanical load during patient transfer and the odds of back injury and LBP among healthcare workers.

## Methods

In relation to this project we have previously published a protocol describing the technical measurements in detail [33] as well as a descriptive article on the relative biomechanical load associated with the included assistive devices [34]. Therefore, the present article refers to these publications and directs its focus on the methods related to the development of exposure profiles.

### Study design and participants

The survey used in the present study was partially based on the 2018 round of the Danish Work Environment Cohort Study (DWECS) - from which we have previously reported associations between pain, stress and sleep among healthcare workers [35–37] - and included questions concerning lifestyle-, health- and factors related to the work environment. While the entire questionnaire exists only in Danish, the questions used in this study have been translated and included in this section; containing questions specific to the work environment of healthcare workers. The baseline questionnaire was sent out to 3329 healthcare workers during the summer of 2017 with a 1-year follow-up. For the purpose of this analysis, a total of 1285 was included as they fulfilled the criteria corresponding to the population from which the technical measurements were collected: Females working as nurses, nurses´ aides and assistants, physio- or occupational therapists, radiographer or porter, engaging in daily patient transfers including patients who were not completely self-reliant and having experienced no back injury within the previous year and with LBP intensity < 6 (0–10). From this cohort, 710 (55%) responded to the follow-up questionnaire and were included in the analysis. Because both the presence and intensity of LBP are strong predictors of future LBP [38], we included only healthcare workers with low pain levels and who were injury-free in order to determine if low biomechanical load would be associated with a preventative effect against LBP. Table 1 shows baseline demographics, work-, health- and lifestyle variables for all healthcare workers and for the low, moderate and high exposure groups.

This study utilizes the combination of technical measurements and a prospective questionnaire design. Measurements of bilateral erector spinae electromyographic activity (EMG) and trunk forward- & lateral flexion (actigraphy) during patient transfers throughout an entire workday were acquired from 52 female healthcare workers, using wireless equipment (TeleMyo DTS Telemetry, Noraxon, AZ, USA). EMG values consisted of normalized (% of max), 95th percentile ranks from the merged value of the erector spinae muscles [34].

The results from the technical measurements were used to create an exposure profile for each individual assistive device, comprised of weighted means from EMG- and accelerometer data. "No assistive device" was used as reference and given the value "1". All other assistive devices were assigned exposure profiles relative to this value, based on their combined values from EMG- and accelerometer data in the following manner: The normalized values were divided by the reference to achieve a fraction (e.g. nRMS ceiling-lift/"no assistive device"; $24.0/27.9 = 0.86$), and the average of the EMG- and accelerometer values was calculated. In order to weigh the contribution from EMG and kinematics more equally and hereby emphasize the former [39], the average of

**Table 1** Baseline demographics, work-, health- and lifestyle variables for all healthcare workers and for the low, moderate and high exposure groups

| Variable | All | | | Low | | | Moderate | | | High | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | % | Mean | SD | % | Mean | SD | % | Mean | SD | % |
| N | 1285 | | | 321 | | | 643 | | | 321 | | |
| Female | | | 100 | | | 100 | | | 100 | | | 100 |
| Age (y) | 46.8 | 11.3 | | 45.3 | 11.3 | | 46.3 | 11.6 | | 49.1 | 10.3 | |
| BMI | 24.9 | 4.6 | | 25.0 | 4.7 | | 25.2 | 4.9 | | 24.3 | 3.6 | |
| Smokers | | | 9.0 | | | 9.3 | | | 8.9 | | | 7.8 |
| Years in profession | 17.8 | 11.9 | | 16.1 | 11.0 | | 17.6 | 12.3 | | 19.6 | 11.6 | |
| Working hours/week | 34.7 | 3.4 | | 34.8 | 3.3 | | 34.7 | 3.3 | | 34.7 | 3.5 | |
| LBP within the previous 4 weeks (0–10) | 1.5 | 1.6 | | 1.5 | 1.6 | | 1.5 | 1.7 | | 1.4 | 1.6 | |
| Back injuries within the previous 12 months | 0 | | | 0 | | | 0 | | | 0 | | |
| **Frequency of patient transfers with more than 1 healthcare worker:** | | | | | | | | | | | | |
| 0/4 | | | 3.5 | | | 2.9 | | | 2.2 | | | 6.7 |
| 1/4 | | | 19.4 | | | 12.8 | | | 25.2 | | | 14.3 |
| 2/4 | | | 30.8 | | | 29.1 | | | 35.0 | | | 23.9 |
| 3/4 | | | 26.4 | | | 35.8 | | | 25.8 | | | 18.4 |
| 4/4 | | | 19.9 | | | 19.4 | | | 11.9 | | | 36.8 |
| **Frequency of patient transfers with patients being so self-reliant that no assistive device is necessary:** | | | | | | | | | | | | |
| 0/4 | | | 17.5 | | | 32.9 | | | 13.8 | | | 9.8 |
| 1/4 | | | 31.3 | | | 30.4 | | | 34.7 | | | 25.4 |
| 2/4 | | | 30.9 | | | 23.0 | | | 34.2 | | | 32.1 |
| 3/4 | | | 20.3 | | | 13.7 | | | 17.3 | | | 32.7 |
| 4/4 | | | 0 | | | 0 | | | 0 | | | 0 |
| **Level of leisure-time physical activity within the previous 12 months:** | | | | | | | | | | | | |
| Sedentary | | | 5.1 | | | 4.7 | | | 6.1 | | | 3.7 |
| Light exercise > 3/week | | | 63.4 | | | 60.4 | | | 66.1 | | | 61.4 |
| Moderate exercise > 3/week | | | 28.3 | | | 30.8 | | | 25.0 | | | 31.5 |
| Vigorous exercise several times per week | | | 3.2 | | | 4.1 | | | 2.8 | | | 3.4 |

the two kinetic values was used to calculate the exposure profile; i.e. the average of forward- and lateral flexion represented a flexion value (e.g. 22.3/36.5 = 0.61 and 24.8/32.1 = 0.77 for forward- and lateral flexion, respectively; averaging 0.69), which was then used to calculate the average of the combined EMG- and accelerometer values (e.g. nRMS (0.86) and trunk flexion (0.69) = 0.77 for the ceiling-lift). The normalized mean values utilized in creating the present exposure matrix are found in the descriptive article related to this project, in which descriptions of the included assistive devices as well as demographics of the participants who partook in the field measurements, are found [34]. In short, the measurements entailed 14 different assistive devices which were subsequently grouped according to function; e.g. the wheelchair and walking-rollator were characterized as "walking aids" whereas the turner transfer and stand-assist were characterized as "standing aids". Additionally,

the ceiling-lift and accompanying sling were regarded as one, resulting in a total of 9 groups of assistive devices (Table 2).

By using the exposure profile of each assistive device (technical measurements) and the quantification of frequency of use (survey information), each participant was assigned individual exposure values. Therefore, the individual exposure values were created by initially identifying the relative EMG, forward- and lateral flexion values (i.e. exposure value) inherent to each assistive device, multiplied with the frequency of use for each participant. That is, the more frequent the participant used an assistive device with a certain profile, the closer the participant's exposure value would be to that of the specific assistive device. The participants were then grouped into quartiles based on their exposure, and the two middle quartiles (25–75%) were grouped to represent the norm. Following this, we tested associations between low exposure (1st quartile; $n = 175$), moderate (2nd and 3rd quartiles, $n = 349$) and high (4th quartile, $n = 186$) and the outcomes described in the following.

## Outcome variables
Back injury and LBP at follow-up were assessed by the following survey questions:

1. *Rate your average pain for the low back within the previous 4 weeks (0–10).*
2. *Have you injured your back during patient transfer within the previous 12 months? (yes/no) (Recall if the accident happened suddenly and unexpected)*

## Control variables
We include 9 groupings of assistive devices (Table 2), all of which included in the questionnaire survey. The quantitative use of each individual assistive device was

**Table 2** Exposure profiles for assistive devices

| Assistive device | Index | EMG | Forward flexion | Lateral flexion |
|---|---|---|---|---|
| No assistive device | **1** | 1 | 1 | 1 |
| Hospital bed | **0.8600** | 0.9211 | 0.5492 | 1.0486 |
| Intelligent bed | **0.8246** | 0.8566 | 0.6792 | 0.9060 |
| Bed sheet | **1.0289** | 1.0968 | 1.0065 | 0.9155 |
| Walking aids | **1.0200** | 0.9892 | 1.0440 | 1.0573 |
| Masterturner | **0.8582** | 0.9606 | 0.7903 | 0.7215 |
| Sliding sheet | **1.0109** | 1.0860 | 1.0455 | 0.8259 |
| Ceiling-lift | **0.7762** | 0.8602 | 0.6123 | 0.7721 |
| Sliding board | **1.0264** | 1.2007 | 1.0788 | 0.6253 |
| Standing aids | **0.8517** | 0.9283 | 0.8372 | 0.7130 |

Exposure profiles based on the weighted contribution of EMG, forward- and lateral flexion values obtained during full-day field measurements of patient transfers performed in hospitals [34]

assessed with the following question, with five possible response options ranging from 0/4 (almost never) to 4/4 (every time): "*How often do you use this assistive device during patient transfer?*"

Frequency of patient transfers was evaluated with the question:

"*How many patients do you transfer per day?*" with possible responses ranging from 1) none, 2) less than one per day (e.g. 2–3 per week), 3) 1–2 per day, 4) 3–4 per day, 5) 5–6 per day, 6) 7–8 per day. 7) 9–10 per day to 8) more than 10 per day.

Frequency of patient transfers performed together with one or more colleagues was evaluated with the question: "*How often are you more than one care worker to do the transfer?*" with five possible response options ranging from 0/4 (almost never) to 4/4 (every time).

Finally, self-reliance of the patients was evaluated by asking "*How many of your patients are so self-reliant that it is not necessary to use assistive devices during transfers?*", again with five response options again ranging from 0/4 (virtually none) to 4/4 (all patients).

## Covariates
In the results section we report fully-adjusted associations between individual exposure values and the outcomes of back injury and low-back pain. The analyses control for the following possible confounders relating to the individual, psychosocial- and work environment as well as to the patient transfer scenario itself:

Age, body mass index, smoking, education, physical activity during leisure time, pain intensity < 6 and no back injury within the previous 12 months at baseline, seniority, working hours, overall mental health as well as work-related attitudes towards justice, teamwork, influence, emotional demands, clarity of tasks as well as management recognition and support. For example, the latter was evaluated by the questions "*do you feel your work is recognized and appreciated by management?*" and "*do you get the help and support you need from management?*"

Furthermore, we also adjusted for frequency and number of personnel participating in the patient transfer as well as patient self-reliance.

## Statistics
All associations were modelled using the General Linear Mixed Model of SAS version 9.4, which can be used for both logistic regression and linear models. Back injury was modelled as a binary outcome (yes/no) during 1-year follow-up, i.e. logistic regression. LBP intensity was modelled as a continuous outcome at 1-year follow-up, i.e. a linear model. Both analyses were controlled for the covariates mentioned previously, and results are reported as odds ratio (OR) and least square mean

differences, respectively, for the lower and upper quartiles in relation to the two middle quartiles (reference). All estimates are provided with 95% confidence intervals and corresponding *P*-values, with the significance level set to $P < 0.05$.

## Results

We report exposure profiles for 9 groups of assistive devices, showing that ceiling lifts, intelligent beds, standing aids, masterturners, and hospital beds - in ascending order - all elicit low exposure relative to "no assistive device". Contrastingly, assistive devices characterized by a more manual approach to patient transfer (e.g. bed sheet, sliding sheet and sliding board) exhibit higher values of physical exposure (Table 2). Additionally, the incidence of back injuries at follow-up were similar between groups; i.e. 11, 13 and 11%, for the low, moderate and high exposure groups, respectively.

The odds of LBP and back injury at follow-up between groups are shown in Tables 3 and 4, presented as odds ratios (OR) and based on the minimally- and fully-adjusted models, respectively: With the moderate exposure group as reference, we find no significant differences in OR when comparing the low- and high exposure groups ($p > 0.05$). In contrast, we report a significant difference in low-back pain at follow-up between the low and moderate exposure groups ($-0.47$, $p = 0.0219$ and $-0.50$, $p = 0.0085$ in the minimally- and fully-adjusted models, respectively). Lastly, no difference was found between the moderate- and high exposure groups ($p > 0.05$).

## Discussion

The main finding of this study is that low levels of physical exposure during patient transfer are associated with lower odds of LBP at 1-year follow-up, whereas no associations were found between exposure and the outcome of back injury.

Additionally, we provide exposure profiles for the most commonly utilized assistive devices and show that use of the more comprehensive systems, e.g. ceiling-lifts and intelligent beds, generally result in low biomechanical load during patient transfers.

### Risk of back injury and LBP

Regarding the odds of sustaining a back injury due to accumulated high workload, our results are somewhat in contrast to a number of studies showing decreased injury rates with the implementation of various lifting policies designed to limit manual handling [25, 27, 28, 40–43]. Several of these studies investigate and credit the ceiling-lift [25, 27, 44–46], which we presently show to elicit the lowest biomechanical load among the included assistive devices. However, these results contrast the findings of recent systematic reviews; showing that manual handling training by itself does not lower the risk of musculoskeletal injuries [21, 47]. Therefore, assuming that (increased) use of appropriate assistive devices constitutes the main implementation-strategy of manual handling training, it is unlikely that any effect of increasing the use of assistive devices is due solely to a decrease in physical workload. In this study, this notion is further supported by the finding that the high exposure group did not experience increased odds of adverse outcomes at follow-up. Although somewhat counter-intuitive when viewed through a biomechanical lens, this finding gives thought to the hypothesis that individuals with relatively high levels of physical capacity - through experience - share a less catastrophizing view on manual lifting and may indeed benefit from a progressively increasing workload [48, 49].

In the case of LBP, our finding that low biomechanical exposure during patient transfers is associated with a decrease in pain intensity, is adding to an already confused body of research: As is the case with the outcome of back injury, there is presently no convincing evidence of efficacy for any single intervention preventing LBP in workers [21, 50–52]. Despite this apparent conundrum, appropriate use of assistive devices during patient transfers has been associated with decreased risk of MSDs [26, 31]. However, several distinct work-related factors, including but not limited to work pace, night shifts, standing work, sitting work, static postures, emotional demands, social relations at work, frequent low mood, job strain- and dissatisfaction etc., have also been shown to influence the risk of MSDs [11, 31, 53–56]. In fact, nurses themselves attribute more than 50% of their

**Table 3** Physical exposure and odds of back injury & LBP at follow-up. Values are based on the minimally-adjusted model and presented as odds ratios (OR) and differences between least square means (LSM), respectively. CI; confidence intervals

| Exposure | Back Injury | | LBP | |
|---|---|---|---|---|
| | OR (95% CI) | *p*-value | LSM (95% CI) | *p*-value |
| 2nd & 3rd quartiles (comparator) | 1 | | 1.93 | |
| 1st quartile | 1.28 (0.63–2.57) | 0.4970 | − 0.47 (− 0.87 - (− 0.06)) | 0.0219 |
| 4rd quartile | 1.32 (0.66–2.66) | 0.4295 | − 0.24 (− 0.63–0.16) | 0.2379 |

Adjusted for age and frequency of patient transfer

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**Table 4** Physical exposure and odds of back injury & LBP at follow-up. Values are based on the fully-adjusted model and presented as odds ratios (OR) and differences between least square means (LSM), respectively. CI; confidence intervals

| Exposure | Back Injury | | LBP | |
|---|---|---|---|---|
| | OR (95% CI) | *p*-value | LSM (95% CI) | *p*-value |
| 2nd & 3rd quartiles (comparator) | 1 | | 1.81 | |
| 1st quartile | 1.14 (0.52–2.51) | 0.7367 | − 0.50 (− 0.89 - (− 0.13)) | 0.0085 |
| 4rd quartile | 1.36 (0.63–2.92) | 0.4309 | − 0.19 (− 0.57–0.18) | 0.2967 |

Adjusted for age, body mass index, smoking, education, physical activity, LBP, back injury, frequency of patient transfer and number of participating personnel, patient self-reliance, seniority, working hours, overall mental health and work-related attitudes towards justice, teamwork, influence, emotional demands, clarity of tasks as well as management recognition and support

work-related injuries to inadequate instruction and staffing [57]; illustrating the prevailing attitudes and beliefs among healthcare workers.

Based on the apparent controversy - likely originating from low-quality studies aiming to identify one intervention to rule them all - it is evident that multiple factors contribute to the high prevalence of MSDs in this population of the workforce [31, 53, 54, 58]. With the present analysis we add to the literature by showing that - even when accounting for several known confounders - consistent and appropriate use of technologically-advanced assistive devices may provide a small protective effect against increases LBP among healthcare workers. Within the complex model of the biopsychosocial approach to health and its growing role within healthcare [59, 60], it is therefore not unlikely that the "bio"-aspect can be improved upon by diminishing the accumulative physical load throughout a day, month and career [22–24].

## Perspectives

We have previously reported that healthcare workers in Danish hospitals utilize assistive devices during less than half of patient transfers [34]. It may seem counter-intuitive of a working population characterized by experiencing a high prevalence of MSDs and end-of-day fatigue, to perform the majority of patient transfers without the use of assistive devices. However, because the most commonly-reported barriers for appropriate use of assistive devices include time-restraints and equipment availability [61–63], it is likely that these factors modulate and indeed question which assistive device, if any, is appropriate in the multi-faceted situation that constitutes the patient transfer scenario. Following this, a recent prospective study by Kucera and colleagues investigated multiple factors associated with appropriate use of assistive devices, and found that – in addition to the frequently reported staff- and equipment availability [64] – patient characteristics such as medical condition, mobility level and the presence of physical- or mental impairments were associated with the use of assistive devices [62]. Likewise, a 2019- Cochrane Review indicates that patients influence the healthcare personnel's

practice and performance in numerous ways [65], and several studies illustrate how a myriad of work-related factors (e.g. self-efficacy, organizational safety climate, adequate guidance, job strain – and dissatisfaction, time-restraints, easiness of use, equipment location and compatibility, patient preference etc.) influence whether or not healthcare workers engage in the use of appropriate assistive devices [54, 57, 62, 63, 66].

Collectively, the overall message is therefore that a broad array of situational-specific factors contributes to the decisions made by healthcare workers during patient transfer. As indicated by the ever-increasing number of largely ineffective single-mode interventions, it seems evident that the multi-factorial issue at hand is hardly solved by one type of intervention alone [50, 66–69].

## Strengths and limitations

Limitations of this study primarily include the inherent recall- and non-response bias that accompanies prospective questionnaire designs [70], potentially resulting in over-representation of individuals more conscious of their health [71]. Additionally, the innate uncertainty when reporting subjective outcomes such as injury and pain intensity should not be overlooked [72]. Regarding drop-out, the response-rate at follow-up is well within what is considered normal for questionnaire surveys [73, 74], and differences between responders and non-responders have been elucidated previously [30]. The potential issue regarding generalizing physical exposure associated with specific assistive devices based on technical measurements on a subgroup of healthcare workers as well as the inherent limitations of using EMG- and kinematic measurements as indicators of biomechanical exposure, have also been discussed previously [34].

Strengths of this study include the combination of technical measurements with a prospective design, which allows for applying objectively measured indicators of biomechanical exposure to a large cohort of healthcare workers. Furthermore, the exposure matrix presented for commonly-used assistive devices is believed to prove highly useful in everyday practical settings, as it provides a level of detail novel to the field.

## Conclusion
Low physical exposure during patient transfer is prospectively associated with lower odds of LBP at follow-up. Consistent use of assistive devices associated with lower exposure, e.g. ceiling-lifts and intelligent beds, may be important in reducing the high prevalence of MSDs among healthcare workers. Hospitals aiming to improve the local work environment could therefore benefit from further implementing specific assistive devices.

### Abbreviations
LBP : Low-back pain; MSD: Musculoskeletal disorder; EMG: Electromyography; nRMS : Normalized root mean square; OR: Odds ratio

### Authors' contributions
Conceptualization: LLA. Data collection: JV. Data analysis: JV, MDJ, LLA, PM. Draft: JV. Review and editing: MDJ, LLA, PM. The authors read and approved the final manuscript.

### Availability of data and materials
Researchers interested in the data should contact the project leader Lars L. Andersen.

### Ethics approval and consent to participate
In line with the Helsinki Declaration, all participants were informed about the content of the study protocol before providing written informed consent. For the technical measurements, 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). All data was de-identified and analyzed anonymously.

### Consent for publication
N/A.

### Competing interests
There are no conflicts of interest.

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