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Associations between trunk flexion and physical activity of patient care workers for a single shift: A pilot study

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Abstract.
BACKGROUND: Trunk flexion and occupational physical activity are parameters that have been used to assess and characterize jobs with high physical demands.
OBJECTIVE: Characterize the physical load of trunk flexion and physical activity of patient care unit (PCU) workers during a single work shift.
METHODS: Participants wore an accelerometer to measure physical activity and an inclinometer to assess trunk flexion during a single work shift, which was compared using correlation and linear regression analyses.
RESULTS: Participants spent 74% of their work time upright between –10° to 20° and 19% of their time flexed between 20° to 45°. On average workers spent 3% and 5% of their time, in the extreme postures of less than –10° and greater than 45°, respectively. Participants spent 99% of their shift below moderate and vigorous activity. The largest correlation found was between the number of forward trunk flexions to 20° degrees per shift and minutes in lifestyle activity ($r = 0.6$, $p < 0.001$). No correlations between minutes of moderate or vigorous physical activity and trunk flexion were observed.
CONCLUSIONS: This study suggests that the physical demands of patient care unit workers as measured through trunk flexion are associated with lifestyle and light levels of physical activity.

Keywords: Posture, workload, ergonomics, and bending

1. Introduction

Patient care unit (PCU) workers suffer numerous adverse health outcomes that have been related to the physical demands of their work. Musculoskeletal symptoms and injuries in particular are highly

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prevalent among PCU workers [1, 2]. The 1-year prevalence rate of low back pain in nursing workers has been reported to be approximately 60% [3, 4]. Additionally, the prevalence of musculoskeletal symptoms reported for the previous 12 months among nursing workers ranged between 10% to 15% [5]. Furthermore, in acute care hospitals, back injuries due to sprains or strains have been reported as the most common injuries associated with days away from work [3, 6]. For these injuries, patient handling activities were reported as the main cause [6, 7].

Patient care unit workers are exposed to physical demands including patient handling tasks such as, lifting, repositioning and manual transferring of patients. These tasks are physically demanding and impose mechanical loads on the back that increase the probability for the development of low back pain and disability [8–10]. Supporting the weight of the torso during simple bending puts large strains on the low back. Furthermore, inclinometer measurements of trunk flexion have been associated with an increased prevalence of low back pain [11, 12]. Punnett et al. [13], found that back disorders were associated with trunk flexion between 20° to 45° (OR = 4.9) and flexion greater than 45° (OR = 5.9) among 1335 automobile assembly workers. Physiological studies also demonstrated that these postures increase heart rate and oxygen consumption [14].

In addition to work-related injuries, scientific literature has reported high rates of cardiovascular diseases and all-cause mortality among workers of physically demanding jobs, including health care workers [14–16]. High physical job demands, often assessed using occupational physical activity (OPA) metrics, have been associated with high energy expenditure, oxygen consumption, and higher risk for CVD disease [17]. Furthermore, high physical activity at work has been associated with a higher risk for ischemic heart disease among nurses [18].

Trunk flexion and occupational physical activity are parameters that have been largely used to assess and characterize jobs with high physical demands [11–13, 19–22]. Trunk flexion has been usually measured using observational methods, including pen and paper based observation methods, videotaping and computer-aided analysis [23]. As an alternative, the use of wearable sensors has been increasingly accepted because they are less labor-intensive compared to observational methods [24]. Occupational physical activity has also been assessed at a population level using mainly two different methods, questionnaires [25] and direct measurements collected through motion detectors (e.g., accelerometers). Motion detectors provide a more accurate and feasible method for getting detailed information about physical activity levels than questionnaires [26, 27].

While trunk flexion and OPA both have physiological implications, the relationship between trunk flexion and physical activity while evaluating a physically demanding work environment such as PCU work is not well established [28]. Previous studies have described trunk flexion [29–31] or OPA [32], among nursing home nurses and personal support workers. Only one study [28] analyzed upper arm and trunk postures in registered nurses stratifying by OPA levels. A better understanding of this relation will allow us to comprehend the contribution of trunk flexion at work on OPA levels. An improved understanding of how trunk flexion and physical activity are related may provide a better understanding of the contribution of these two parameters on the occurrence and etiology of disease among PCU workers. These associations will be useful in implementing integrated ergonomic and health intervention to promote health in physically demanding jobs.

In this study, occupational physical activity and trunk flexion were measured during a work shift among PCU workers from two hospitals from Boston, MA. We hypothesized that PCU workers who have larger amounts of trunk flexion will also have greater minutes of moderate and vigorous physical activity during a work shift as indicated through positive and significant correlations.

2. Methods

2.1. Participants and study design

Fifty participants were recruited via e-mail sent to all workers and poster advertisements as part of the "Be Well Work Well" pilot study in six patient care units from two large teaching hospitals in Boston [32, 33]. Eligible participants worked in the thoracic intensive care, orthopedic, burn and trauma, cardiac and cardiac step-down type units. A sample of 40 nurses and 10 patient care assistants volunteered to participate with similar number of subjects from the 6 units.

For these participants, we measured directly their physical activity with an accelerometer for seven days and their trunk flexion with an inclinometer for a single shift during the week. We considered that a single shift was enough to explore the association between physical activity and trunk flexion among PCU workers, given the fact that they belong to quite specialized units and treat patients daily with similar characteristics within units. Physical activity data for the whole seven days are presented elsewhere [32]. At the end of the shift each participant rated the exertion level for the current and a typical shift using the Borg perceived exertion scale [34]. The scale had a response scale from 6 to 20, which correlates to participant's heart rate [35, 36], giving an idea how heavy and strenuous the shift was perceived. All participants provided written consent and all protocols and forms were approved by the applicable institutional review board for protection of human subjects.

2.2. *Physical activity*

To measure physical activity, participants wore an accelerometer (GT3X accelerometer Actigraph, Pensacola, FL) on the right hip with an elasticized belt. The accelerometers recorded data in 1-minute intervals, providing the number of counts for each minute. A count was defined as any activity with accelerations above the threshold of 0.016317 m/s^2. Number of counts per minute has been highly correlated with energy expenditure [37]. We assigned each minute to the different levels of physical activity based on the definition of Freedson and colleagues [37] for sedentary (0–100 counts per minute), lifestyle (101–759 counts per minute), light (760–1952 counts per minute), moderate (1953–5724 counts per minute), and vigorous (>5725-counts per minute). The internal clock of the accelerometer was synchronized with the inclinometer used to measure torso flexion.

2.3. *Trunk flexion*

To measure trunk flexion, participants wore a triaxial accelerometer data-logger (G-Link 2.4 GHx Wireless, Microstrain, Williston, VT), during a single shift. The trunk postural data logger was placed on each participant's torso on the back, centered at T1 level below the C7 vertebrae. This placement minimized interference of wearing the device and the participant's work activities. The placement was vetted with several patient care workers prior to data collection. The device logged data at five samples per second. The angles were calculated with respect to the reference posture defined as the posture recorded while participants stood erect looking straight ahead with their arms resting at their sides.

The alignment of the inclinometer's axes with the anatomical planes was achieved using data collected from participants performing three slow bows (or vertical push-ups against the wall if a participant was uncomfortable with unsupported torso flexion), a 10-second pause while standing up straight, one single bow, another 10-second pause while standing up straight, and then three bows. Since the inclinometers logged data from the moment they were initialized to the time their data were downloaded, Participants completed the reference posture and alignment movements at the beginning and at the end of data collection to denote the time that data collection started and ended. During data processing, these three bows were easily identified through visual display of the signals.

Once parsed and processed, the postural data were then categorized into 4 groups of trunk postures (1) Extension: $<-10^\circ$, (2) upright: -10° to 20°, (3) flexed: $> 20^\circ$ to 45°, and (4) extreme flexion: $> 45^\circ$, typical ranges described in the literature [13, 19]. We then calculated the duration in minutes in each category and the frequency of bending per hour within categories.

In addition, we categorized the exposure for back disorders as high, medium and low exposures. Low exposure for back disorders were classified as trunk flexion $<15^\circ$ during 86% of the work shift [12]. High exposure for back disorders was defined as keeping a trunk flexion $>20^\circ$ during 33% of the work shift [13, 38]. All other trunk flexion postures were classified as medium risk.

2.4. *Statistical analyses*

Two analyses were completed to test the hypothesis that a PCU worker's increased trunk flexion is associated with increased minutes of moderate or vigorous levels of physical activity during one workshift. First, we compared differences of mean minutes at different levels of physical activity per shift with the low, medium, and high exposure categories using the non-parametric Kruskal-Wallis test. Second, we tested for association between physical activity and the different ranges of trunk postures using a Spearman's rank correlation. We also applied step-wise multiple regressions to evaluate the effect of potential covariates (e.g., age, job title, body mass index, type of shift, and musculoskeletal pain in the last 7 days) on the statistically significant correlations between pairs of parameters. All analyses were carried out in STATA version 11 (StataCorp, College Station, TX).

Table 1
Demographics and self-reported perceived exertion for the 47 participants with complete measurements

Individual Characteristics	N	%
Gender		
Female	41	87
Male	6	13
Job		
Nurse	39	83
Patient care assistant	8	17
Shift Length (hours)		
8	22	47
10	1	2
12	24	51
	Mean	S.D.
Age (years)	42	13
BMI (kg/m^2) (N = 36)	26	4
Perceived Exertion Scale$	Score	S.D.
Current shift	13*	2
Typical shift	15+	2

$Scales ranged from 6 (no exertion at all) to 20 (maximal exertion). *Somewhat hard (you feel tired but can continue). +Hard (heavy).

Table 2
Duration of time in various trunk postures across the participants ($n = 47$)

	Mean	SD	P^*_{25}	P^*_{50}	P^*_{75}
Total time in a Trunk Posture of (minutes):					
<–10°	20	25	4	14	27
–10° to 20°	444	113	345	433	536
>20° to 45°	114	82	70	96	141
>45°	27	17	14	24	34
Percentage of working time with a Trunk Posture of:					
<–10°	3	4	1	2	4
–10° to 20°	74	12	69	74	80
>20° to 45°	19	11	10	17	22
>45°	5	3	2	4	6
Bends per hour					
To 20°	124	54	89	114	156
To 45°	34	18	19	30	49

*Percentile.

3. Results

Complete accelerometer and inclinometer data were collected on 47 of the 50 participants (Table 1) covering 47 single shifts that ranged between 8 and 12 hours in duration distributed between day, evening, and night shifts. Data from three PCU workers were unrecoverable due to instrumentation initialization errors. Participants with successful measurements had a mean age of 42 years (range: 23–68 years), were predominantly females with a Female to Male ratio of 7 : 1. Thirty five participants worked during day shifts (from 7 am to 11 pm) and fifteen in night shifts (from 7 or 11 pm to 7 am).

3.1. *Directly measured trunk flexion and physical activity*

On average, PCU workers spent 74% of the shift in an upright trunk posture (that is between 10° of extension to 20° of flexion) and 19% of their time in a flexed trunk posture (20° to 45°). PCU workers spent 3% of the shift in extension greater than 10° and 5% in extreme trunk flexion (that is greater than 45°). In terms of bending frequency, we recorded on average 124 bends per hour from upright to flexed postures and 34 bends per hour from flexed to extreme flexion. The mean durations of trunk excursions into flexed and extreme flexion postures were 21 and 20 seconds, respectively (Table 2).

When categorizing trunk flexion into the low, medium, and high exposure groups, eleven participants spent 86% of the shift with a trunk flexion less than 15° and were considered in the low exposure according to Fathallah's criteria [12]. Seven PCU workers spent 33% of their work time with a trunk flexion greater than 20° and were considered in high exposure group according to Punnet and Keyserling criteria [13, 38]. Twenty-nine workers had flexion profiles that were between these low and high exposure definitions and, hence, were considered in medium exposure group.

For the 47 participants 99% of their shift was spent below moderate and vigorous activity with 53% of the time associated with sedentary activities (Table 3). On average the participants had 6 minutes of moderate and less than 0.5 minutes of vigorous activity, during the shift (Table 3).

Table 3
Minutes and percent of time in each physical activity level during a single shift across the participants ($n = 47$)

	Mean	SD	P_{25}	P_{50}	P_{75}
Minutes per shift at:					
Sedentary	329	101	257	311	404
Lifestyle	226	66	183	223	267
Light	61	35	37	55	79
Moderate	6	8	1	3	8
Vigorous	0	0	0	0	0
Percent of the Shift:					
Sedentary	53	11	45	54	59
Lifestyle	36	8	33	37	40
Light	10	5	6	9	13
Moderate	1	1	0	0	1
Vigorous	0	0	0	0	0

Table 4
Number of minutes at various levels of physical activity per shift averaged (and standard deviation) across the participants in the three exposure categories. Kruskal-Wallis test for differences among risk categories for low back pain

	Exposure group						
	Low (*n* = 11)		Medium (*n* = 29)		High (*n* = 7)		*p*-value
	Mean	SD	Mean	SD	Mean	SD	
Minutes per shift at:							
Sedentary	314	107	337	101	322	102	0.8
Lifestyle	201	49	229	61	253	99	0.3
Light	59	30	61	39	63	27	1.0
Moderate	7	10	6	7	4	5	0.7

Table 5
Spearman's correlation (r_s) coefficients and *p*-values between the different parameters of trunk posture and directly measured physical activity during a single shift (*n* = 47)

	Physical activity categories							
	Sedentary		Lifestyle		Light		Moderate	
	r_s	*p*-value	r_s	*p*-value	r_s	*p*-value	r_s	*p*-value
Minutes between 20° to 45°	0.3	0.08	**0.5**	**<0.001**	0.1	0.5	0.1	0.7
Minutes >45°	0.1	0.4	**0.3**	**0.04**	**0.3**	**0.04**	0.1	0.6
Number of bends from upright to flexion (20°)/hour	–0.1	0.4	**0.3**	**0.02**	0.2	0.1	0.1	0.5
Number of bends from flexed to extreme flexion (45°)/hour	–0.2	0.2	0.2	0.1	**0.3**	**0.05**	0.1	0.6
Number of bends from upright to flexion (20°)/shift	0.2	0.2	**0.6**	**<0.001**	0.3	0.07	0.2	0.2
Number of bends from flexion to extreme flexion (45°)/shift	0.1	0.6	**0.4**	**0.005**	**0.4**	**0.01**	0.2	0.3
Perceived exertion								
Current shift	0	1	0.1	0.4	0.2	0.1	0	0.9
Typical shift	**–0.5**	**<0.001**	–0.1	0.6	0	1	–0.2	0.2

Bold values indicate significant correlations ($p < 0.05$).

3.2. Associations between trunk flexion and physical activity

The minutes of time spent by the PCU workers in different physical activity categories did not vary significantly across participants grouped into low, medium, or high exposure groups (Table 4).

The strongest correlation observed between trunk flexion and minutes at various physical activity levels was observed between number of bends from upright to flexed trunk posture of 20° degrees per shift (r_S: 0.6, p = <0.001) and minutes in lifestyle activity (Table 5 and Fig. 1a). There were no statistically significant correlations between the number of bends to flexed trunk posture with minutes in sedentary activity, light activity and moderate activity. The duration of trunk excursions into a flexed posture (i.e. between 20° to 45°) correlated with the minutes of lifestyle activity (r_S: 0.5, p = <0.001). The number of forward trunk bends from flexed to extreme flexion of 45° degrees per shift correlated also with minutes in lifestyle activity and minutes in light activity (r_S: 0.4, $p = 0.005$ and 0.4, $p = 0.01$ respectively: Table 5). The perceived exertion scale for a typical shift correlated only with minutes of sedentary activity (r_S: –0.5, p = <0.001: Table 5 and Fig. 1b).

Multiple linear regression models used to evaluate the impact of the presence of potential confounders and covariates (age, job title, body mass index, type of shift (day/night) and musculoskeletal pain in the last 7 days) on the correlation between pairs of parameters with the largest correlations showed their coefficients remained statistically significant (Table 6).

4. Discussion

The goal of this pilot study was to characterize directly measured minutes of physical activity (PA) levels of PCU workers and directly measured metrics of trunk posture during a single shift in order to explore the relation between trunk postures, and minutes of PA. Overall, a wide variability in the distribution of trunk postures measured across the workers was found and resulted in a range of low, medium and high risk for reporting low back

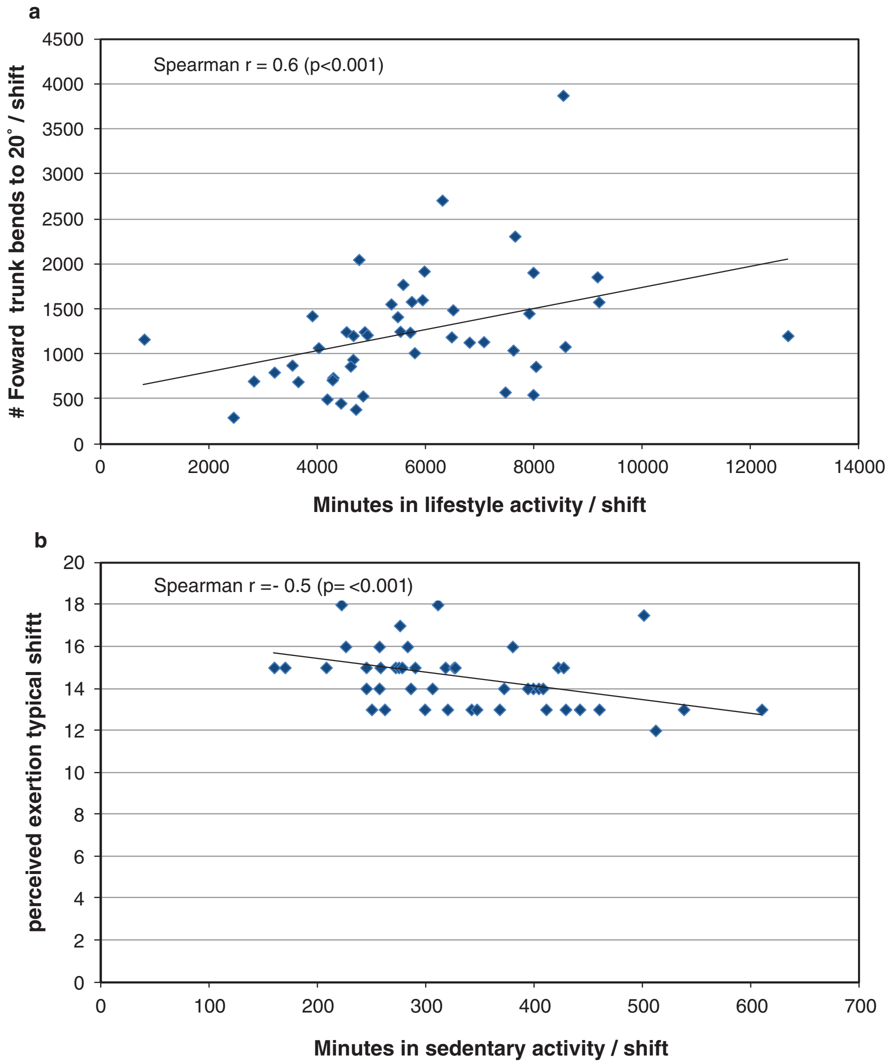

Fig. 1. a) and b): Directly measured minutes of lifestyle activity while at work was positively correlated with the number of forward trunk bends to 20° (Fig. 1a). Conversely, perceived exertion during a typical shift was negatively correlated with minutes in sedentary activity during the shift (Fig. 1b).

pain. However, the amount of moderate and vigorous physical activity for participants was quite small and hence did not vary significantly across these exposure categories. Only 6 minutes of moderate activity or greater were measured during a single shift with no significant correlation with trunk flexion metrics.

These results suggest that within the context of PCU worker, the physical demands of the job while perceived to be moderate to high in terms of the exposure to trunk flexion are actually of low intensity physical activity levels. Trunk flexion was associated at best with lifestyle and light levels of physical activity. Furthermore, the job demands as denoted by the frequency of bends to flexion and extreme flexion may be more associated with fatigue as defined by work physiology than with moderate or vigorous levels of physical activity. In our study the frequencies of trunk flexion to 20° and to 45° were 2.1 and 0.6 bends per minute, respectively. The frequency multiplier within the NIOSH Lifting equation for these rates is based on the psychophysical experiments of Snook and Ciriello [39] and is assumed to be more associated with muscle fatigue rather than challenges to the physiological expenditure [40]. While the scientific literature support that high intensity physical activity at work is detrimental for workers health, these data indicate that the type of activity these workers

Table 6
Multiple linear regression models for minutes in lifestyle and light activity as main outcome and different parameters for trunk posture as main predictor. All analyses were adjusted for job title and presence of musculoskeletal pain ($n = 47$)

Outcome	Main predictor			Job title (nurse = 1, PCA = 0)		MSK pain last 7 days (yes = 1, no = 0)	
	R^2	B (SE)	p	B (SE)	P	B (SE)	p
Minutes in lifestyle							
Minutes between >20° to 45°	0.6	0.38 (0.08)	<0.001			**45 (16)**	**0.01**
Number of bends from upright to flexion (20°)/shift	0.7	**0.06 (0.01)**	<0.001	**60 (26)**	**0.03**	**31(15)**	**<0.001**
Number of bends from flexion to extreme flexion (45°)/shift	0.5	0.14 (0.4)	<0.01			**42 (19)**	**0.03**
Minutes in light activity							
Number of bends from flexion to extreme flexion 45°/shift	0.4	**0.06 (0.02)**	<0.01				

Bold values indicate significant correlations ($p < 0.05$).

experience at work is in the range of low intensity physical activity [41, 42].

The negative correlation between perceived exertion and minutes of sedentary activity within a shift suggests that the perceived exertion of the shift is related to the total time of non-sedentary activity and may hence misclassify self-reported occupational physical activity as moderate or vigorous. In these workers, a large amount of their non-sedentary time is below moderate or vigorous levels of physical activity; however, the same individuals report high levels of moderate and vigorous levels of OPA (presented in Umukoro et al., 2013). PCU workers' perceived exertion incorporates many of the different physical demands of the job, which may be any non-seated activity such as standing and bending, which are bellow moderate or vigorous levels of physical activity. It also needs to be noted that the perceived exertion for the current shift was not as intense as a typical shift. This issue might affect the total amount of minutes of physical activity at work. However, that will not change the association found between trunk flexion and low levels of physical activity.

We did not measure lifting and the load of lifting in this study but trunk flexion does measure with a high degree of accuracy the load on the low back [43]. Large trunk flexions have been related to an increase in low back loads [44]. Because of this, measuring trunk flexion relative to gravity is often used to quantify back loading in ergonomic workplace evaluation [19, 45, 46]. Measuring trunk flexion is an economical and very feasible method for measuring exposure to bending, an identified risk factor for low back pain [47, 48].

Physical activity was measured using an accelerometer. This is a validated methodology known to provide reliable exposure estimates, but there are some concerns regarding its limitation for capturing physical activity while adopting static postures (lifting or bending over) [49, 50]. This restriction may have led to an underestimation of the physical activity measured at work; however, the frequency of bending as measured through the inclinometer supports the lower level of physical activity measured here. Overall, this pilot study contributes to improving the scientific community's understanding of the interaction between physical activity levels and physical load in a dynamic and physically demanding work environment such as a hospital setting. Furthermore, we tested associations between total minutes of activity and did not normalize these minutes across the different shift lengths in Table 4. We did analyze the data with both absolute and normalized data still observed no significant differences.

The results need to be considered within the limitations of the study methods. First, these results are limited to PCU workers who work under similar circumstances. The small number of workers limited our statistical power in detecting trends and associations. However, we saw some associations between trunk flexion with lifestyle and light physical activity levels. Further studies with a larger sample size and measures per workers during multiple work days are recommended to assess the association between physical loads and physical activity and corroborate our findings.

Overall, PCU workers required to perform a significant number of trunk flexions to 20° and 45° during a shift. Even though, these demands can be considered as high, their physical activity related to those are low due to low frequency of the trunk flexion. These findings agree with the results on a previous study that found a small contribution of physical activity at work towards moderate and vigorous levels of physical activity [32]. Interventions aimed in improving PCU workers health need to consider OPA and job demands in order to develop tailored interventions in this working population.

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Conflict of interest

The authors have no conflict of interest to report.

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