Sigurd Aal Sellæg

Objectively measured exposure to occupational physical activities in "Home Service"

Accelerometer-based measurements among homecare health workers

Master's thesis in Physical Activity and Health- Movement Science
Supervisor: Prof. Øystein Nordrum Wiggen
Co-supervisor: Ph.d candidate Svein Ove Tjøsvoll & Prof. Marius Steiro Fimland

May 2021

Master's thesis

NTNU
Norwegian University of Science and Technology
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SINTEF

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The exposure of occupational physical activities (OPA) in «Home services»

Homecare health workers

High levels of OPA
High prevalence of musculoskeletal disordes (MSD) and sickness absense

High levels of OPA

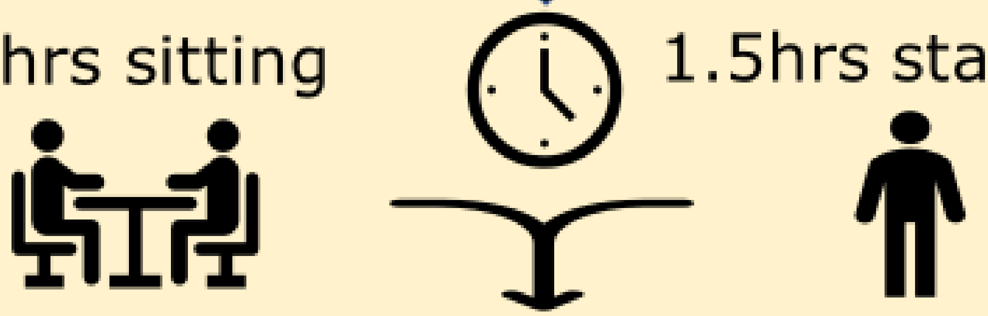
MSD, sickness absence, cancer and mortality, CVD events and mortality, knee disorders, LBP, fatigue, reduced work ability, disability pension+++

Exposure to OPA

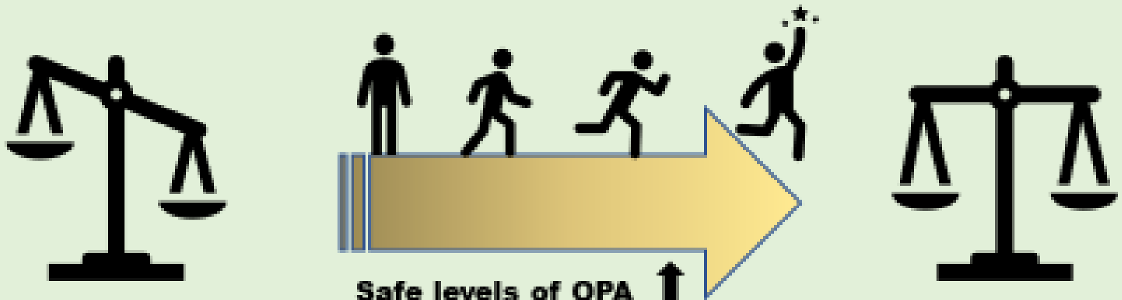
Measured in 62 homecare health workers using accelerometers

3hrs sitting

1.5hrs standing



Homecare workers have a need for guidance on safe levels of OPA!



Acknowledgements

Finalising this thesis ends the last chapter of my five-year long student life at the faculty of Medicine and Health Sciences, department of Neuromedicine and Movement Science, NTNU. Many of my fellow students have become close friends during this educational adventure highly appreciated. I am proud of ending this period as part of a professional researcher group conducting exclusive research.

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Sigurd Aal Sellæg   May 16th. 2021.

Abbreviations

CVD - Cardiovascular disease

BMI - Body mass index (kg/m^2)

HCW - Health care worker

LBP - Low back pain

LTPA - Leisure time physical activity

MSD - Musculoskeletal disorders

OPA - Occupational physical activity

PA - Physical Activity

SB - Sedentary behaviour

VO_{2max} - Maximal oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$)

Abstract

Background

Health care workers report exposure to high levels of occupational physical activities (OPA), have high prevalence of sickness absence and musculoskeletal disorders (MSD). The literature on the exposure to OPA of homecare health workers are non-existing. Thus, the aim of this study was to assess the exposure to OPA of homecare health workers with objective measurements.

Method

Data collection consisted of a standardized questionnaire, anthropometric measurements, physical capacity test, and accelerometer-based measurements assessing OPA. Participants were recruited from three different units of "Home service". Accelerometer data was processed using Acti4 software.

Results

62 homecare health workers were enrolled in this study. A total of 1500 working hours of accelerometer measurements were carried out showing the primary part of the working hours (50%) were spent in SB. For the rest of their workday, time spent in more physical active positions were nearly evenly distributed between standing (24.9%) and dynamic activities (23%). The homecare health workers were exposed to awkward positions, such as arm inclination >30° (36%) and forward bending >60° (4%).

Conclusion

The exposure to OPA of homecare health workers based on the accelerometer-based measurements shows the primary part of the workday being sedentary, and the remaining being evenly distributed between static and dynamic activities. Because of their high rates of MSD and sickness absence, and the limited research-based knowledge on their exposure to OPA, further research are needed to inform better preventative workplace interventions for this working population.

Kewords: accelerometer, homecare health workers, occupational physical activities, arm inclination, forward bending

Sammendrag

Bakgrunn

Ansatte i helsesektoren rapporterer om fysisk krevende arbeid, og har høy prevalens av sykefravær og muskel- og skjelett lidelser. Det finnes ingen tidligere studier innenfor Hjemmetjenestens fysiske arbeidsbelastning og aktivitetsnivå på jobb. Hensikten med forskningen er å kartlegge aktivitetsnivå og arbeidsbelastning i Hjemmetjenesten.

Metode

Datainnsamlingen bestod av et standardisert spørreskjema, antropometriske målinger, en fysisk kapasitetstest og akselerometer-baserte målinger av fysisk arbeidsbelastning. Deltakere ble rekruttert fra tre ulike enheter ved Hjemmetjenesten. Akselerometerdata ble prosessert i Acti4 programvare.

Resultat

Totalt 1500 arbeidstimer er målt ut ifra akselerometermålingene. Ansatte i Hjemmetjenesten tilbringer mesteparten av arbeidstimene (50%) stillesittende. Resterende tid (47.87%) er tilbrakt i mer fysiske aktiviteter, som stående (24.9%), og (23%) i mer dynamiske aktiviteter. Ansatte i Hjemmetjenesten er utsatt for ugunstige posisjoner, som arm elevasjon >30° (36%) og fremoverlent arbeid >60° (4%).

Konklusjon

Kartleggingen av fysisk aktivitet og belastende stillinger i Hjemmetjenesten, viser at hovedandelen av arbeidsdagen tilbringes stillesittende, og resterende relativt likt distribuert mellom statisk og dynamiske aktiviteter. På grunn av deres høye grad av muskel- og skjelettlidelser og sykefravær, og den begrensede forskningsbaserte kunkapen om deres eksponering til ugunstige arbeidsposisjoner, er det behov for ytterligere forskning for å informere bedre forebyggende intervensjoner på arbeidsplassen for denne yrkesgruppen

Nøkkelord: Akselerometer, Hjemmetjenesten, Arbeidsbelastning, Arm elevasjon, Fremoverlent,

CONTENT

1.0 Background

Physical activity (PA) is widely known for promoting good health (1, 2). Leisure time physical activity (LTPA) is a broad description of activities one participates in during free time, while occupational physical activity (OPA) is associated with the performance of working related with a job. Some differences between these definitions are their duration, recovery, and intensity of it (1). The various dimensions of PA (e.g., intensity, duration, frequency of different postures and movements) affect different body systems and functions (e.g., aerobic capacity, muscle strength, range of movement, balance, coordination) determining the need for recovery (2, 3). Health will only be affected positively if the combination of these dimensions is balanced (3, 4). PA that is balanced benefits both physical and mental health, thus improving people`s general wellbeing (1, 4). When the correct balance of PA is not achieved, in e.g., if the activity is too frequent it can lead to fatigue without sufficient recovery, excessive mechanical force can cause musculoskeletal injury , and static postures for prolonged periods can cause varicose veins (5). These are some of the known characteristics of OPA. Increasing evidence shows that exposure to high levels of OPA does not improve health and can be detrimental (3). This is referred to as the Physical Activity Paradox (3), which strengthen the need for assessing OPA for physical active workers.

Over the last years well known methods have been developed for measuring physical exposures objectively with high accuracy previously listed (6); Ovako working postures analysis system (OWAS), the rapid entire body assessment (Reba), assessment technique for postural loading on the upper body (Luba), and the Quick exposure check (QEC). International guidelines have also been developed regarding working postures such as ISO-11226 and EN-1005-4 used in procedures for risk assessment. The assessment model of awkward position from the Norwegian Labor Inspection Authority distinguish between three risk areas: red, yellow and green (7). The boundaries between the areas are not absolute, and specific cut-off points are scarce. The Norwegian Institute of Environmental Work suggests only a specific limitation for unsupported arm inclination >60° of more than an hour (8). The existing guidelines may be too vague for the workers in need, and assessment of OPA gain importance as the exposure level of OPA increases. Several recommendations and indications of relationships between the exposure to OPA and its health outcomes are based on self-reports known for varying validity (9, 10). A meta-analysis comparing direct versus self-reported measures for assessing physical activity in adults highlights the need for valid objective measurements (11). This is supported by an umbrella review emphasising the need for objective measurements of OPA (12), and the strength using multiple measurements assessing the different categories of PA (13) are widely known. This indicates a need for more use of multiple and objective measurements when assessing OPA for physical active workers. High quality longitudinal studies using objective measurements, in terms of intensity, frequency, and duration of postural patterns are of great importance for physical active workers (10-17).

An occupational group doing a variety of physical work tasks is the homecare health workers in "Home Services". Their aim is to promote health, prevent illness, and injury, and their goal is to maintain quality of life by giving users help to be able to live in their own homes for as long as they want to. Some of their daily basis work tasks involves feeding, diaper changes, medicine treatment, supporting patients when moving, changing clothes, and providing comfort. This occupation involves physical exposure to lifting, sitting, standing, carrying, walking, forward bending, kneeling, and working with arms elevated. Professions within healthcare have high prevalence of musculoskeletal disorders (MSD) and report exposure to high levels of (OPA) (9, 18-20). However, research on objectively measured exposure of OPA among homecare health workers are non-existing. The existing literature on the exposure of OPA within the sector of healthcare are mainly focused on health care workers (HCWs) in hospital units, or nurses and/or single organizational units (17-19, 21-24). Nevertheless, homecare health workers and HCWs consists of nurses, health professionals, and health workers all employed in the health sector. Thus, the occupational organization and work demands do not differ.

In Norway, an estimated cost of 250 billion NOK, - each year is caused by MSD in various context of medical treatment, disability pension and sick leave (9, 25). This is the most common cause to sick leave in Norway, and affects almost one fifth of the population (25). In 2020, HCWs had the highest rate of sickness absence among other occupational groups (26). HCWs sustain MSD during the course of their working routine (23), and the most common complaints among these, mainly nurses, are back, neck, shoulder, and knee complaints (20). The prevalence of musculoskeletal pain in Norwegian nurses has previously been reported as 88.8% (22). In fact, low back pain (LBP) and neck pain are numbers one and four on the global ranking of health problems causing years lived with disability (9), and the point prevalence in Norway ranging from 15% to 20% (27). Physical load at the workplace, even posturing without any force exertion, is proposed as dominant cause of musculoskeletal symptoms with manual material handling such as; carrying, lifting, pushing, pulling, and whole body vibrations known to be associated with pain (6, 14, 15, 19). These awkward positions includes exposure to higher levels of OPA, such as kneeling, arm elevation and forward bending (7, 8). The level of intensity, duration of exposure time, and frequency in the shift between force levels, are previous suggested as important dimensions when assessing OPA (19). There are many societies facing an aging population, insight into determinants of sustainable employability gain more importance in e.g., standards of living and productivity (2, 12). Facilitating and designing work which appropriately stresses workers physically will benefit both individuals and societies (2, 12, 28).

There exists uncertainty in the health outcomes of exposure to high levels of OPA, and the dose-response and evidence-based associations are deficient (12, 29). High levels of OPA are associated with several aspects of negative influence on health, in e.g., increased risk for cardiovascular disease and mortality, reduced work ability, increased sickness absence and risk for disability pension (12, 28-

31). Previous research has found that the duration of high-intensity LTPA decreases with increased work-related fatigue in workers reporting high exposure to OPA (32). Identical physical work task demands affects older workers different than younger workers, since resting heartrate increases with age, while both maximum heartrate and aerobic capacity decrease with age (33). All these factors related to high OPA constitute an inter-dependent causal chain to long-term health problems and sickness absence (31). Occupational standing is linked to both lower limb and low back complaints, and arm inclination and neck rotation/flexion are associated with shoulder pain and neck pain (9, 19, 24, 30). More than 10% of the workday with unsupported arm inclination >60° may lead to increased risk for shoulder pain (34). Occupational kneeling and squatting are well documented as a risk factor for knee disorders (16, 34-36). Occupational exposure to forward bending of the back is a well-known risk factor for LBP and sickness absence (12, 37). Regardless of PA, sedentary behavior (SB) as either overall SB, sitting time, screen time or leisure time spent sitting, is independently associated with severe health outcomes (38). High levels of OPA was associated with an increased risk of ischemic heart disease in a prospective study among nurses (39). Previous research within HCWs have shown that total time spent walking is considerable, but not in the extent that reaches WHO recommendations of PA (9). A trend of decreased sedentary time at work amongst older HCWs have been found (24). Previous research among HCWs found a significant association between arm inclination >30° and shoulder pain at baseline and after six months (18), which are consistent with the findings amongst male power line technicians (24). A significant association has also been found between kneeling/squatting and forward bending with LBP within manually occupations (6). Others have found a negative association between the duration of sitting at work and LBP intensity, and positive association between duration of standing at work and LBP intensity within HCWs (19). However, the literature agrees that the maximal duration of these postures seems to be the most prominent risk factor for LBP (17-19, 24), while frequency is the most important risk factor regarding trunk flexion (6). A recent Danish research (14) investigated the exposure to OPA of childcare workers using accelerometers and found exposure to awkward positions.

Despite the available literature on OPA, its characteristics can be vastly different between occupations due to their occupational organization. The homecare worker population has been scarcely studied and their exposure to OPA has to my knowledge never been objectively assessed. Thus, recent studies indicate a negative effect on health from OPA, however the mechanisms and the dose-response relationship are still unclear. *Hence, the aim of this research was to assess the exposure to OPA of homecare health workers using accelerometers. This includes measurements of higher levels of OPA, such as kneeling, arm inclination, and forward bending, as well as assessing general PA behaviour during work.*

2.0 Methodology

This observational study was conducted during the pandemic of SARS-CoV-19. As experienced, the pandemic has influenced both individuals, occupations, and societies. Luckily, this study was feasible with a specific focus on infection control. In practice, all members of the researcher group throughout the data collection used disinfection, wore face masks, and kept one meter distance during the physical meetings with the homecare health workers. We were all aware of the risk in e.g., spread of infection, and limited our close contacts to the best of our ability.

2.1 Study population and ethical aspects

Participants were recruited from three institutions in Home Services, "Hjemmetjenesten", Trondheim municipality. The homecare health workers were given information about the study aim and received a written consent prior to participation, informing them of their rights in accordance with the Helsinki Declaration. This study is part of a larger research project in cooperation with NTNU & SINTEF which has been approved by REC (Regional Committee for Medical and Health Research in Norway). Exclusion criteria for the homecare workers were any physical challenges hindering normal PA, diagnosis of cardiovascular diseases, pregnancy, fever, known allergies to plastic/tape/bandages, and ≥50% employment. To be included in the final analysis, they had to have a minimum of two days of work of at least four hours in duration from the accelerometer data.

2.2 Data collection

Prior to the data collection, all homecare health workers were invited to information meetings where the aim and procedure of this research were explained in detail. The data collection methods conduct questionnaire, anthropometric measurements, capacity test, and accelerometer measurements, and was done in autumn 2020 from 06.10.2020-09.12.2020. All participants were treated anonymously using anonymous ID numbers throughout the data collection. The homecare health workers filled out a standardized questionnaire prior to field data collection.

2.2.1 Anthropometric measurements and capacity test

Anthropometric measurements were done for body weight (Bathroom scale, model EB1610H, Clas Ohlson ltd, Hampton wick, Kingston Upon Thames, UK) and body height by a wall mounted SECA 206 measuring tape (SECA Medical Measuring Systems and Scales, Birmingham, UK). An EkblomBak submaximal physical capacity test was conducted to estimate physical capacity, measured as VO_{2max}. This test has earlier been described (40) and has been validated for both adult genders. The Borg rating of perceived exertion was used to measure physical exertion levels (41) together with Garmin HRM-Dual[tm] (Garmin ltd, Schaffhausen, Switzerland) or Polar H10 (Polar Electro, 2021) used for assessing heartrate. The EkblomBak tests were performed using an electronically braked ergometer-cycle, Monark 839E or Monark 939E (Monark AB Vaberg, Sweden).

2.2.2 Individual, psychological, and social factors

Occupational and socio-demographics characteristics were assessed by a self-administered, standardized version of HUNT4 questionnaire at baseline. Questionnaire data were exported to an Excel spreadsheet (Excel 2010; Microsoft Corporation, Albuquerque, USA) upon answering. The questionnaire included variables such as; age, sex, education, current seniority, working environment and demands, sick leave, current smoking habits, fatigue, and perceived health. The questionnaire also asked for PA participation and exertion. Based on the outcome of height and weight, the corresponding body mass index (BMI, kg/m^2) was calculated in line with the latest updated guidelines from WHO (42). Sick leave the last 12 months was reported, and if yes, total sick leave last 12months >2weeks was reported. Physical demand was treated as a Likert scale, "yes" as 1, and "no" as 0, where the homecare health workers were asked if their work demand very hard working. The subjects were asked if they have had persistent pain in the musculoskeletal system the last three months. If yes, pain was addressed in the following regions of the body; jaw, neck, shoulders, chest, upper back, elbow, lower back, hip, wrist fingers, knees, calves, ankles, and in which side of the body the pain exists. They were also asked if the pain have prevented doing activities of daily living during both work and leisure.

2.2.3 Assessment of OPA

OPA was measured using five tri-axial Axivity AX3 (3-Axis Logging Accelerometer; Axivity Ltd, Newcastle upon Tyne, UK) accelerometers attached onto the dominant side of the participants, using medical tape. The Axivity AX3 is a small, wireless, and waterproof accelerometer. For better fixation, the sensors were covered with transparent adhesive film (Oposite Flexifix; Smith & Nephew plc, London, UK). The sensors were mounted on the; (i) upper back with the upper part of accelerometer at the level of T1/T2, skewed slightly to the dominant side, ii) upper arm, laterally and 3cm distal to the deltoid insertion of the humerus, (iii) the thigh, at the most muscular part of the quadriceps femoris 10cm above the proximal part of patella, (iv) the calf, on the lateral side of the calf 5 cm below the head of fibula, and (v) the hip, 10 cm below the iliac crest on the lateral side. The accelerometers were set to record at 25 Hz at ± 8g for 6 days. In addition, the participants filled out an activity diary each day of accelerometer measurements including time and stop for each leisure, working, and sleep period, time of the reference jump, and if any sensors were removed. Accelerometers was synchronized by participants performing a reference jump standing still for 15 seconds, then a single jump before standing still for 15 seconds. If any of the participants got an allergic or any other bodily reaction or discomfort to the accelerometers such as disturbed sleep or skin irritation, they could remove the accelerometers whenever wanted. The accelerometer-data was downloaded to a computer for further processing.

2.3 Definition of Acti4 output parameters

Sitting is defined as length of periods sitting. Sitting is detected if inclination of thigh is above 45° and lying is not detected. **Standing (still)** is detected if inclination of the thigh is less than 45° and no movement of the thigh is detected. **Moving** is a left-over activity used if none of the activities lie, sit, stand, walk, run, stairs, cycle or row is detected. It will normally correspond to a standing posture that is neither detected as standing still nor walking. **Walking** is detected if the standard deviation in the thigh`s longitudinal axis is between ,1G and 0.72G and the mean forward/backward angle is less than the (individual) stair threshold angle. **Inclination arm (>30°, >60°, >90°)** are length of periods (h) with arm inclination above 30°/60°/90°. Periods with lying are excluded in the calculations. **Forward Inclination of the trunk (>20°, >30°, >60°**) are length of periods (h) with forward trunk inclination, also known as forward bending, above 20°/30° and 60°. These parameters detect the time in which the inclination of the trunk in the forward plane is above the angles 20°,30° and 60°. These parameters tell the inclination of the trunk when in a forward position generally as a result of combined flexion and lateral flexion, also known as forward bending. **Kneeling** is detected when one or both lower legs are nearly horizontal. Moreover, the angle U between the horizontal plane and dorsal axis of the lower leg would be positive around 70-90°. **Stairs** is lengths of periods walking/running stairs. Walking stairs is detected if the standard deviation in the thigh`s longitudinal axis is between .1G and 0.72G and the mean forward/backward angle is between the "stair threshold" angle and 40°. **Running** are lengths of periods running. Detected if standard deviation in the thigh`s longitudinal axis is above 0.72G and the mean forward/backward angle is less than "stair threshold" angle. **Cycling** are length of periods cycling. Cycling is detected if the standard deviation in the thigh`s longitudinal axis is above .1G and the mean forward/backward angle is above 40° and the inclination is below 90°.

2.4 Illustration of awkward positions

In *figure 1*. The basic anatomical position and inclination of the arms 30°, 60°, and 90° are shown to illustrate these postures for the understanding of further analysis.

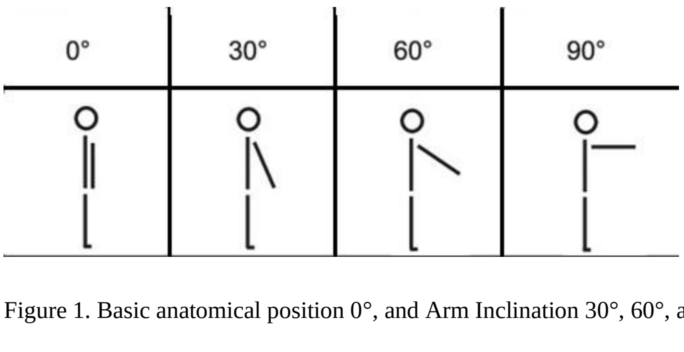

Figure 1. Basic anatomical position 0°, and Arm Inclination 30°, 60°, and 90°

In *figure 2*, the basic anatomical position and forward inclination of the trunk 20°, 30°, and 60° are shown to illustrate these postures for the understanding of further analysis.

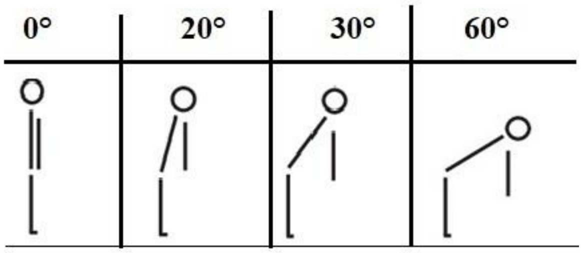

Figure 2. Basic anatomical position 0°, and forward inclination of the trunk 20°, 30°, and 60°

2.5 Data processing

The questionnaire data were exported to an Excel spreadsheet (Excel 2010; Microsoft Corporation). Anthropometric data were subsequently entered in an Excel spreadsheet during data collection, and carefully double-checked for error.

The raw data was downloaded using Axivity software (AX3-GUI, Omgui Software) and processed using the costume-made MATLAB software, Acti4, developed at the National Research Centre for Working Environment, Copenhagen, Denmark, and the Federal Institute for Occupational Safety and Health, Berlin, Germany (10). This software uses a 5 Hz 4th order Butterworth filter and low-pass filter the accelerometer data, and further splits it up into 2s sequences with 50% overlap (10). It also separates the day into three categories: leisure time, sleep time and working hours. The different periods are identified by the activity diary. The time before and after work, leisure time, was defined as time away from work not including sleep. The hours spent in the primary occupation was defined as work period i.e., during work. Only accelerometer measurements from "working hours" was used for the analysis for occupational physical demands. Thus, non-working days were excluded from the analysis, as were periods of sleep and non-wear, as well as periods not coded in the diary. Further, Acti4 is designed to use the triaxial accelerometer signal to identify physical behaviours; lying, sitting, standing, walking, moving (standing with small movements), running, cycling, walking in stairs and rowing, walking on stairs (10, 43). Acti4 have been validated for detection of arm inclination and forward bending (18, 24, 44) and kneeling/squatting (16), and previously described to assess the different categories of PA with both high specificity and sensitivity (10). SB was defined as lying and sitting whilst dynamic movements were defined as standing, moving, walking, running, cycling, and walking in stairs. Additionally, higher levels of OPA were defined as above 30° arm elevation, above 20° forward bending and kneeling.

2.6 Statistical analysis

The descriptive data were generated from eligible homecare health workers for each variable and presented as mean and standard deviation (SD). Statistical analysis was performed with IBM SPSS Statistics 25 (IBM SPSS Statistics for Windows, Version 25.0, IBM Corp, New York, US) and Microsoft Excel (Excel 2010; Microsoft Corporation). All processed data were imported into SPSS and time spent in different PA categories were averaged across days, calculated as percentage of working hours and as minutes per workday to represent the exposure to OPA.

3.0 Results

3.1 Demographics

3.1.1 Participant flow chart

The participant flowchart of this research is presented in *Figure 3*. In total, 62 homecare health workers are enrolled in this research.

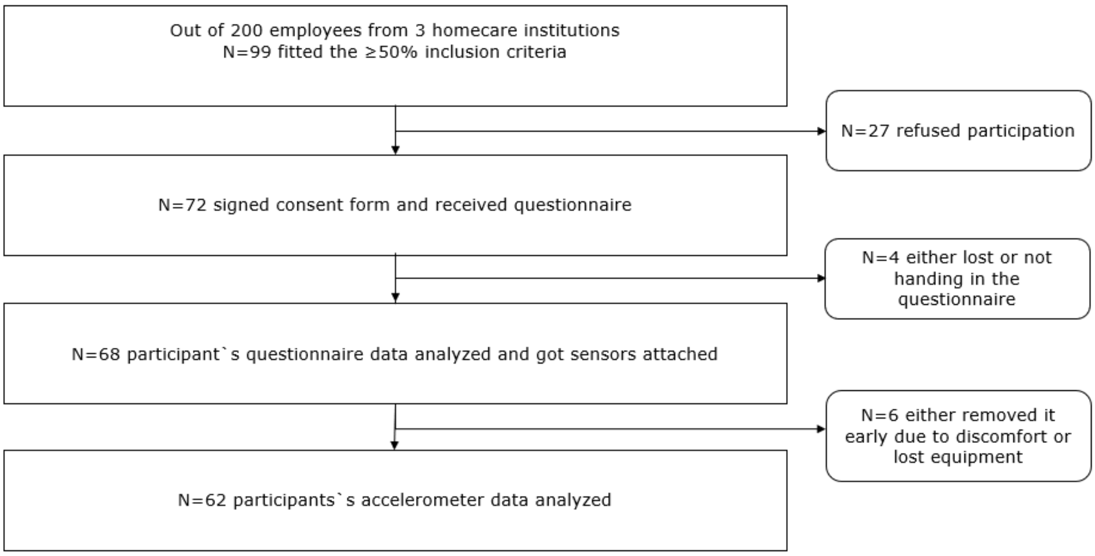

Figure 3. Participant flow chart

3.1.2 Descriptive statistics

Health characteristics and demographics of the 68 homecare health workers that completed the questionnaire in this study are presented in *table 1*. The homecare health workers were female dominant in average age of mid-thirties, classified as overweight (42), and report exposure to high levels of OPA. 4 out of 5 have had sick leave last 12months and 3 out of 5 had experiences of persistent bodily pain in the musculoskeletal system for at least 3 months during the last year. The homecare health workers have highest prevalence of shoulder, neck, and LBP.

Table 1. Descriptive data table for homecare health workers (N=68). Values are mean and standard deviations (SD).

Variable	N (%)	Mean (SD)
Male	20 (32)	
Female	48 (78)	
Age		34.9 (10.7)
BMI		26.4 (4.1)
VO2max		38.5 (10.3)
Seniority		6.3 (7.5)
Self-reported physical demands		0.8 (0.4)
Education		
Low	8 (13)	
Medium	9 (15)	
High	43 (72)	
Sick leave last 12M	49 (82)	
>2weeks	19 (32)	
Pain last 3M		
No	27 (40)	
Yes	41 (60)	
Jaw	7 (10)	
Neck	26 (38)	
Shoulder	29 (43)	
Chest	5 (7)	
Upper back	13 (19)	
Elbow	3 (4)	
Lower back	21 (31)	
Hip	8 (12)	
Wrist fingers	7 (10)	
Calves	4 (6)	
Ankles, feet	4 (6)	

Age=years, seniority=years, BMI= body mass index (kg/m^2), VO_{2max}= $mL \cdot kg^{-1} \cdot min^{-1}$, low education= three years high school, medium education= apprenticeship or advanced craft certificate, high education= college and/or university.

3.2 Accelerometer measurements

The accelerometer-based measurements of OPA are presented in *Table 3*, *Table 4*, and *Table 5*. A total of 1500 working hours of accelerometer measurements were carried out on 62 homecare health workers that completed the measurements. On average, 3.2 working days (SD=0.7) were measured per homecare health workers, with an average of 450.3 min (SD=30.2) working hours per day.

3.2.1 Exposure to SB

Table 3. Exposure to sedentary behaviour and standing during working hours measured by accelerometers. Presented as percentage of working hours (%). Values are mean and standard deviation (SD).

Variable	Mean	SD
Lie	2.7	2.5
Sit	47.8	4.4

Results from the accelerometer-based measurements showed that the homecare health workers in total were exposed to 192.5 minutes in SB in average each workday, including 9.5 minutes lying (SD 32.5) and 183 minutes sitting (SD 49.8).

3.2.2 Exposure to more dynamic movements

Table 4. Exposure to more dynamic movements during working hours measured by accelerometers. Presented as percentage of working hours (%). Values are mean and standard deviation (SD).

Variable	Mean	SD
Standing	24.9	2.3
Moving	11.2	1.2
Walking	9.6	1.1
Running	0.1	0.0
Stairs	1.7	0.2
Cycling	0.7	0.2

The homecare health workers were exposed to standing in 97.35 minutes (SD 32.2) each workday. The exposure of more dynamic activities were 43.18 minutes of moving (SD 16.5), 38.23 minutes of walking (SD 13.8), 4.4 minutes of climbing stairs (SD 2.2) and 2.7 minutes of cycling (SD 2.7) each workday.

3.2.3 Exposure to awkward positions

Table 5. Exposure to awkward positions during working hours measured by accelerometer presented as percentage of working hours (%). Presented as mean and standard deviation (SD).

Variable	Mean	SD
Kneeling	0.1	0.1
Arms elevated >30°	36	0.9
Arms elevated >60°	4	0.4
Arms elevated >90°	0.6	0.1
Forward bending >20°	32	0.6
Forward bending >30°	18	0.5
Forward bending >60°	4	0.2

The accelerometer-based measurements showed average duration of time spent kneeling 3.4 minutes (SD 5.1) for the homecare health workers. Further, the results shows that the homecare health workers were exposed to 138 minutes (SD 48.5) with arm elevation >30°, 21minutes (SD 20.7) with arm elevation >60°, and 4 minutes (SD 7.7) with arm elevation >90° in average each workday. Further, the homecare health workers were exposed to forward bending >20° in 120 minutes (SD 36.6), forward bending >30° in 68 minutes (SD 26.8) and 18 minutes (SD 12.7) in forward bending >60°.

4.0 Discussion

To the authors knowledge, this is the first study to objectively investigate the exposure of OPA during several consecutive workdays of homecare health workers. The presented findings contain information of physical work demands among homecare health workers going beyond the existing literature. Therefore, the findings from this research are considered valuable for improving our knowledge about not only the need for, but also where to target effective, and preventive workplace interventions among homecare health workers. A total of 1500 working hours of accelerometer measurements were carried out on 62 homecare health workers. On average, 3.2 working days (SD=0.7) were measured per homecare health worker, with an average of 450.3 min (SD=30.2) working hours per day. The main findings of this study were that homecare health workers spent the primary of their workday in SB, including 47.8% sitting. Further, 24.9% was spent standing still whilst their exposure to dynamic movements was 22.9% in total. The homecare health workers were exposed to 36% arm inclination >30° and 4% forward bending >60° each workday.

4.1 SB, standing and dynamic movements

Results from the accelerometer-based measurements shows that homecare health workers spent 50% in SB each workday, including lying 2.7%, and sitting 47.8% (see Table 3). Further, 24.9% was spent standing (see Table 4). The homecare health workers were exposed to 192.5 minutes of SB, including 9.5 minutes of lying and 183 minutes of sitting. Their exposure to standing was 97.4 minutes per workday. This is more than previous research on transportation, cleaning and manufacturing workers (45), other blue-collar occupations (9), and child care workers (14) with similar objective measurements of SB. For blue collar-workers overall, prolonged sitting occur much more often during leisure than work (9). A normal workday for a homecare health worker in general involves exposure to static activities, such as driving to patients and doing office-related tasks (logging, planning, coursing). This may cause higher exposure levels to SB. Other occupations spending too little time in SB having insufficient rest and recovery (cleaners, manufacturers) or prolonged SB (drivers) would be of more concern (38). However, there is growing evidence for an association between prolonged sitting and deleterious health outcomes, independently of the extent of PA (38, 45). In fact, previous study have shown both increased (43) and reduced (18) intensity of LBP with increased duration of sitting during work in HCWs and blue-collar workers. SB as either sitting time, screen time, overall SB, or leisure time spent sitting, has independently being associated with all-cause mortality, CVD or mortality, cancer (colon, breast, colorectal, epithelial ovarian, endometrial) or mortality and diabetes type 2 in a systematic review and meta-analysis (38). However, these detrimental health outcomes associated with SB decreases among individuals who participates in higher levels of PA compared to lower levels of PA.

The exposure to standing were higher for homecare health workers than for child care workers (standing 23%) (14), and lower than manufacturing being exposed to static standing for 168 minutes, as much as 38% (45). The health outcome of occupational standing may be vague. Occupational standing, even in shorter bouts, are associated with increase in fatigue, discomfort, and pain in lower extremities and lower back (6, 20, 38). On the other hand, to little walking or standing can cause harmful effects on cardiometabolic health and inadequate stimuli of force can lead to muscle and bone loss (15). For the homecare health workers, lower exposure to occupational standing could decrease their level of exposure to OPA.

The percent working time spent in more dynamic activities were 23%, as 11.2% moving, 9.6% walking, 0.1% running, 1.7% climbing stairs and 0.7% cycling (see Table 4). This includes exposure of 43.18 minutes of moving, 38.23 minutes of walking, 4.4 minutes of climbing stairs, 2.7 minutes of cycling each workday. The exposure of running (0.12 minutes) for the homecare health workers was too low to further be considered. Previous research has shown other occupational groups having higher exposure to standing and walking in e.g., manufacturers (standing 38% and walking 34%), childcare workers (moving 13% and walking 15%), and cleaners (standing 26% and walking 45%) (9, 14, 45). In total, the homecare health workers spent primary of their workday in SB, and about half the day in nearly equal amount between standing and dynamic activities. Their participation in LTPA could be limited due to their work-related fatigue from the exposure to OPA (32). Thus, it could be useful to raise their awareness of SB and reduce their exposure to prolonged static postures, such as sitting and standing still. This could be by breaking up the duration of prolonged static postures with small bouts of dynamic activities, being beneficial for their health (3, 38). A more organizational remedy could be implementation of a reward for those homecare health workers being physical active in e.g., active transportation and/or taking the stairs instead of the elevators. This would be a cost-effective strategy feasible for increasing the exposure to dynamic activities, which may decrease their levels of exposure to SB.

4.2 Exposure to awkward positions

High exposure to occupational kneeling acts as a risk factor for knee pain and disorders (34-36). The proposed exposure limit for kneeling of zero exposures highlights that even minor levels of occupational standing are associated with LBP (6). For the homecare health workers, exposure to higher intensity physical demands like kneeling (0.06%, 3.4 minutes) have been found from the accelerometer-based measurements (16). Although the physiological mechanisms underlying kneeling are known in e.g., provoking tissue strain, no evidence-based conclusion for this population can be made on the risk. There is need for additional research investigating occupational kneeling with accelerometer-based measurements during several, full working days within a variety of occupational groups. Future research should investigate the dose-response relationship between the exposure to occupational kneeling and knee disorders (16). However, the existing literature within occupational kneeling (6, 34-36) substantiate kneeling as a risk factor for MSD. For the homecare health workers, reducing their exposure to kneeling may decrease their levels of exposure to OPA, prevalence of MSD and LBP.

Percentage time spent with arm inclination above 30°, 60°, and 90° for the homecare health workers were 36, 4, and 0.6% respectively. This includes exposure of 138 minutes with arm inclination >30°, 21 minutes with arm elevation >60°, and 4 minutes with arm elevation >90°. Compared to previous research conducting accelerometer-based measurements assessing OPA, duration of arm inclination >30° in percent of workday was 47% in electricians, 45% in hairdressers (46), and 39.8% in painters and 32% in machinists (47). The homecare health workers have slightly lower exposure to arm inclination >60° than childcare workers (5%) (14), and considerably lower than occupations like paver, finishing and machine operators having 10-12% of the workday with the arm elevated >60° (48). Their levels of exposure to arm inclination >90 is lower than previous research on construction 2.8% and health care workers 1.5% (18), car mechanics 4.7% and painters 9% (47), and electrician students 8% (46). There exists a variety of exposure levels between occupations. Thus, aggregation of

OPA in occupations can be vague, in e.g., expected higher level of exposure to arm inclination in cleaners and hairdressers, due to their various occupational physical demands.

The prospective dose-response relationship between exposure to arm inclination, shoulder disorders and sickness absence based on objective measurements are still unclear. A Swedish researcher group, with long time experiences among 40 occupations with accelerometer-based measurements, report that an exposure to arm inclination >60° for more than 10% of the workday may act as an risk for developing shoulder disorders (34). Previous research of HCWs and construction workers shows a significant association between arm inclination >30 and LBP at baseline and after six months (18), which are consistent among male power line technicians (24). Further, work with prolonged arm inclination >60° and >90° have been associated with shoulder pain among female students, mainly hairdressers (46). There has also been found negative associations between arm inclination and shoulder pain in construction and HCWs (18). A possibility could be that workers with e.g., shoulder pain may find it difficult to stay in jobs with high levels of such mechanical exposures, or those employees may have learned to avoid such work as a response to pain. It seems that these levels of exposure to OPA, even being lower than for other occupations, may act as a risk for developing MSD for the homecare health workers having high prevalence of MSD. Although we cannot conclude with the dose-response on the exposure to arm inclination, our advice would be to reduce these exposures for the homecare health workers and implement preventative strategies for known exposure to these awkward positions.

The percentage time spent forward bending above 20°, 30°, and 60° for the homecare health workers were 32, 18, and 4% respectively. This includes exposure of 120 minutes in forward bending >20°, 68 minutes in forward bending >30°, and 18 minutes in forward bending >60° each workday. A research based on the same methodology as in the precent study, has shown lower exposure to forward bending >60° in manufacturing workers (3.1%), and an evenly duration among cleaners (4.6%) (45). High occupational exposure to forward bending is known as a risk factor for sickness absence and LBP (19, 24, 44). The physiological mechanisms underlying forward bending is increased load on the lower back, caused by an increase in the torque resulting in increased shear forces and disc compression (44). Some of the research within this literature are based on self-reports known for its weaknesses (11, 13) and the actual dose-response remains unknown. A proposed exposure limit to forward bending of 17.74 postures/day exists as an risk factor for LBP (6). However, accelerometer-based research investigating the association between forward bending >60° and LBP did not confirm a positive association (44). Additional research with objective measurements of forward bending in a variety of occupations on the risk of exposure to forward bending are needed. With the existing literature, we cannot make conclusions based on the risk for the homecare health workers. In practice, complete avoidance of their exposure to forward bending may not be feasible in e.g., supporting patients suiting compression stockings, supporting/lifting patients during movement and other related work tasks. Our cautionary advice would be reducing the exposure to forward bending for the homecare health workers and informing them about the correct execution of such awkward postures. The potential of facilitating cooperation between the employees whenever suitable should be considered. This could be in e.g., sharing the mechanical load, when the workers are going to perform these awkward postures, such as moving and suiting users known with high need of assistance.

Further, the homecare health workers enrolled in this study had an average age of 34.9yrs and seniority of 6.32yrs reporting high occupational demands (0.76). Above 80% of the homecare health workers experienced sick over the past year and 60% reported feelings of pain in the musculoskeletal system, with highest occurrence in shoulder (42.6%), neck (38.2%) and LBP (30.9%). Previous research on HCWs found that older workers had similar or even higher physical demands as younger coworkers (24). Relative physical strain as percentage of heart rate reserve, has shown to be higher for older than younger HCWs. This research has its weaknesses from its cross-sectional design without following age-related changes over time. A false rise of a healthy worker survival effect causing overestimation of physical capacity, hence underestimation of relative physical strain, may be. However, shifting into lighter work could be a preventive strategi to reduce the physical demands and remain employed. For homecare health workers, physical demands may need to be reduced as the employees aging to reduce their risk for MSD, as the maintenance of muscular strength with age may be insufficient to protect a potential detrimental muscle activity pattern.

Previous research in health professionals found that the females have 1.9 times higher risk for developing MSD than males (20), with the highest occurrence in nurses. High levels of OPA was associated with an increased risk of ischemic heart disease in a prospective study among nurses, showing most effect on those being sedentary during leisure time (39). High levels of OPA also increases the risk for long-term sickness absence (31), this association is based on self-reports earlier mentioned (11, 17). In another meta-analysis, there has been found that men engaging in higher levels of OPA compared to lower, have an 18% increased risk for all-cause mortality even after adjustment for LTPA (29). In addition, the first umbrella review of its kind on the health effects of OPA, with 23 health-related outcomes based on 17 systematic reviews, suggests beneficial health outcomes from high levels of occupational physical activity (12). However, this review states a varied evidence base of very low to moderate quality substantiate the need for higher quality-based research assessing OPA. The specific physiological mechanisms and the evidence-based conclusions on OPA are scarce (12, 28, 29). It may be that the nature of OPA, with all related factors and its individual impact, all contributes to different associations and links on the exposure of OPA. The fact that men and women respond different to physical activity (1, 33), substantiates a different respond to OPA by gender can be and that subgroup analysis should be considered in future research of OPA (12). This states the need for new guidelines regarding PA, since fulfilling the demands with OPA may confer a health risk and not provide the intended health benefits.

4.3 Physical Activity Paradox and the "Goldilocks" principle

In a research paper on the PA paradox, several reasons on why OPA does not confer the cardiovascular health benefits that LTPA does are listed (3). For the homecare health workers, their job often requires static loading, awkward postures, and monotonous positions, leading to elevation of the blood pressure acting as a CVD risk factor (29). Their job is often performed with limited time available without sufficient recovery, and experience lack of rest periods within and between working days, and report limited control over their occupation. These congestions may lead to fatigue over time increasing CVD risk, and the levels of fatigue due to OPA can limit their LTPA preventing health benefits (9). Maintaining or even improving cardiovascular health and fitness seems strenuous for homecare health workers as their exposure to OPA may be of too long duration and low intensity (3, 28). WHO`s recommendations regarding PA (2) do not differentiate between OPA and LTPA (28). Without knowing, the homecare health workers can be in need for more breaks during work and/or in need for participating in LTPA to improve or even maintain their health (2, 12). A Proposed solution to OPA is the "The Goldilocks Principle" (4) used by professional athletes in different sports for decades (1, 33). This principle is trying to define and coin the "just right" amount, as in the fairy-tale of "Goldilocks", safe levels of OPA. The principle arguing that the benefits of PA in leisure and work only can be seen when all the different aspects of PA are "just right" (4). There is however uncertainty about what is "just right". Scaling work to the individuals could be of importance and provide increased working life longevity (24). In a recent systematic review and meta-analysis (49) workplace interventions is found to provide health benefits that OPA limits in working-age women. It may seem like a paradox itself, homecare health workers being responsible for other individual's health and well-being without focusing on their own. However, future research should prioritize to assess OPA in a variety of occupations with high levels of OPA. Finding the "just right" levels of OPA would be of great importance in an individual and societal order.

4.4 Strength and limitation

A major strength of this research is its contribution to the very limited scientific literature on homecare health workers. In fact, none of the literature that the author has identified has investigated the exposure to OPA with accelerometer-based measurements of homecare health workers. The use of objective measurements of OPA earlier mentioned (13) provides valid measurements of PA (10, 11). This reduce the probability of biased information, in e.g., recall bias and self-estimation bias, depending on self-reported physical activity being less valid and reliable than objectively measured data (9) not recommended for determining and detection of PA (12). The acti4 software used in this present study provides good specificity and sensitivity in detection of different types of PA (10). The combinational use of questionnaire and device-based measurements previous recommended (13), contributed to a detailed assessment of the exposure to OPA for the homecare health workers.

Collecting data from several full working days using five accelerometers per homecare health workers increased the accuracy of the estimates. Thus, we consider our results to be accurate.

One of the weaknesses in this research is the sample size of 62 participants. This was mainly an effect of a small time-window for data collection, or it could be of the high demand of wearing up to five accelerometers on their body for almost six days. Another limitation is that recruitment of subjects only took place in Trondheim municipality, which may not represent all homecare health workers of Norway. This does not mean that the organization of “Home Service” nor their exposure to OPA differs from Trondheim municipality compared to other municipalities in Norway. A potential weakness of this study is selection bias, in which 62 out of 99 eligible homecare health workers participated in this study. Here, the healthy worker effect may be in e.g., healthy workers are more likely to participate than others. Thus, it is possible that the participating homecare health workers were healthier than the ones not participating, with a respectively low average age in this study population. Since exposure variation between months, years, and seasonal changes may occur in this occupation, there could have been more repeated whole-day measurements to cover the variation of exposure to OPA. For instance, homecare health workers are more likely to choose active transportation at work during warm summer rather than cold autumn and winter months. In this research, assessment of OPA derives from kinematic-based measurements. This could act as a potential weakness not including measurements of external load and forces of the homecare health workers. Using TRACK as randomly workplace observations could have detected their exposure to lifting and carrying, which not are detected by the accelerometers. Previously, this instrument have been described and shown to have an overall high inter-rater reliability for childcare workers in real-life settings (50), and could have strengthened the quality of this study.

Several national restrictions in e.g., closed training facilities, and close-contact limits due to the pandemic of SARS-CoV-2, may have resulted in altered individual PA behavior. Thus, participants may have participated in less PA and more SB. However, the occupational organization of homecare health workers remained independently of the pandemic. Although the pandemic may have influenced the results in some way or another, we consider the results from the accelerometer-based measurements over several workdays highly valuable and to be noted for further implications.

4.5 Implications

It seems that the homecare health workers may have limited control over their job agenda, in e.g., duration and work speed, as they visit and take care of several patients each day pointed in a time schedule. In fact, many of the homecare health workers mentioned difficulties finding time for personal needs during work. This may lead to even more inappropriate working postures with their experience of time as a factor of stress as even higher levels of OPA, fatigue and exhaustion (20, 28, 31, 32). This may result in high prevalence of MSD and sickness absence for the homecare health workers. We state the importance of reducing their levels of stress as a negative component in their occupational environment. For the homecare health workers, this may decrease their total exposure levels to OPA and its inter-dependent causal chain to long-term health problems. For this population and its units, we advise cost-effective and simple strategies and interventions feasible for practical implications. This could be by raising their awareness of OPA and facilitating healthy occupational environments in e.g., rewarding physically active workers, reducing their level of stress, scaling work to individuals and sharing higher workload as best as possible. Outside of the workplace, increased participation in LTPA should be a focus as it has shown to be protective against mortality and CVD for populations with exposure of high levels of OPA (12, 29). It is reason to believe that the homecare health workers are best in caring of patients and users. However, it may seem that they forget focusing on their own.

These findings provide valuable information on the exposure of OPA in the occupation of homecare health workers. The existing risk assessment tools and guidelines on safe levels of OPA provide information for workers being exposed to OPA. However, well-defined cut-off points for awkward positions based on the intensity, frequency and duration of these postures are almost non-existing. The limited literature on the evidence-based dose-response relationships of OPA highlights the need for new guidance on safe exposure levels of OPA. Implementing safe levels of OPA would benefit both societies and individuals. In general, the empirical evidence of OPA and its contribution to the PA paradox should be assessed by high quality longitudinal research using several measurements including accelerometers. We state the need for future research and its opportunity to facilitate safe levels of OPA for physically active workers, such as homecare health workers. Additional research should try to assess the complexity of OPA and its individual health outcome, since it seems that OPA may not be tailored to the individual person in e.g., physical capacity, age, gender, fatigue. The existing literature on OPA differ in outcome variables (12). A common agreement among the outcome variable(s) of OPA are needed and should include duration, frequency, and intensity of the exposure based on objective measurements (6, 10, 11, 13, 17). The “just right” levels of OPA remains unknown and are of great importance for future research. Guidance on safe levels of OPA may exists first when the empirical evidence of the PA paradox is confirmed.

5.0 Conclusion

This research is the first of its kind assessing the exposure of OPA of homecare health workers. Based on objective measurements, the homecare health workers spent the primary part of their workday in SB (50%). For the rest of their workday, time spent in more physical active positions were nearly evenly distributed between standing (24.9%) and dynamic activities (23%). The homecare health workers were exposed to awkward positions, such as arm inclination >30° (36%) and forward bending >60° (4%).

Assessment of OPA among homecare health workers contributes to new knowledge useful for further research on OPA in physical active workers. The potential benefits and risks of the exposure to OPA highly depend on individual factors such as age, health status, and physical limitations due to MSD. However, the occupational variety in the level of exposure to OPA highlights the need for specific assessments of OPA, since the exposure levels to OPA differ between occupational group as well as individuals. It may seem that the workers exposed to high OPA suffer the negative health outcomes of OPA and not benefiting from the positive health outcomes of PA in LTPA. The potential in assessment of OPA in a variety of occupations are of great importance in reducing costs related to high OPA for improved disease preventing in physical working populations. A solution could be to fit the physical work demands and its recovery time, with LTPA to the individual workers needs and capacities. However, there is a great need for further research.

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