Preventive Medicine Reports 24 (2021) 101597

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Review article

Physical activity and sedentary behaviour in shift and non-shift workers: A systematic review and *meta*-analysis

Malebogo Monnaatsie [a,b,c,*], Stuart J.H. Biddle [b], Shahjahan Khan [d], Tracy Kolbe-Alexander [a,b,e,f]

[a] School of Health and Wellbeing, University of Southern Queensland, Ipswich, Queensland, Australia
[b] Physically Active Lifestyles (PALs) Research Group, Centre for Health Research, University of Southern Queensland, Springfield, Queensland, Australia
[c] Department of Sport Science, Faculty of Education, University of Botswana, Gaborone, Botswana
[d] School of Sciences and Centre for Health Research, University of Southern Queensland, Toowoomba, Queensland, Australia
[e] Division of Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, University of Cape Town, South Africa
[f] School of Human Movement and Nutrition Sciences, The University of Queensland, Brisbane, Australia

ARTICLE INFO

Keywords:
Shift work
Moderate-to-vigorous physical activity
Sedentary behaviour
Self-report measures
Device-based measures

ABSTRACT

Research examining the prevalence, physical activity (PA) and sedentary behaviour (SB) in shift workers show mixed results. This systematic review and *meta*-analysis aimed to compare PA and SB in shift workers with non-shift workers following the PRISMA guidelines. Ebscohost megafile ultimate (CINHAL, E-journals, Academic search ultimate, health source consumer edition, SPORT Discus), PubMed, Scopus, Web of Science, and Science Direct databases were searched up to April 2021. Cross-sectional and baseline data from longitudinal studies reporting PA and SB in full time workers were eligible. Data on participants characteristics and time spent in PA and SB and/or prevalence of workers meeting PA guidelines were extracted and pooled with random effects model. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) 10-item checklist was adapted and used. A total of 49 studies met inclusion criteria and 21 studies included for *meta*-analysis. The prevalence of meeting physical activity guidelines (OR 0.84, 95% CI: 0.68, 1.03) and standardized mean difference (SMD) of time spent in moderate-to-vigorous physical activity (SMD −0.1, 95% CI: −0.4, 0.20) were similar in shift and non-shift workers. Time spent in sedentary behaviour was lower in shift workers than non-shift workers (SMD −0.2, 95% CI: 0.50, −0.001). While the differences in PA are not so evident between shift and non-shift workers, the prevalence of sufficient PA was low in both groups. These preliminary findings provide support for inclusion of physical activity and sedentary behaviour in health promotion interventions targeted at shift workers.

1. Introduction

Shift work is defined as work outside normal daytime working hours (7 a.m. and 6p.m.) (Caruso, 2014). Shift work can include evening shifts around (2 pm till 12 am), night shift (7 pm to 7 am) or rotating between day, evening and night shifts (Depner et al., 2014). Different industries may use different time schedules from the aforementioned ones. Shift work is common in industries that require 24/7 workforce and accounts for 20–25 % of occupations worldwide (Caruso, 2014; Presser, 2005). Approximately 15.6% Australians work shifts (Statistics, 2020), and about 20% of the workforce in Europe and U.S. work in shifts (Parent-Thirion et al., 2017; statistics USBol, 2018).

A rising number of shift workers in the workforce is a concern, as shift work is associated with a wide range of health problems (Kecklund and Axelsson, 2016). Shift workers are at increased risk of cardiovascular disease (Torquati et al., 2018), cancers (Hansen, 2017; Liu et al., 2018) and have higher prevalence of overweight and obesity than those who only work during the day (Antunes et al., 2010; Hulsegge et al., 2020). The risk of any cardiovascular disease (CVD) morbidity was 17% higher among shift workers than day workers (Torquati et al., 2018). There appears to be a dose–response relationship as the risk of CVD in shift workers increases by 7.1% for every additional five years of shift

* Corresponding author at: University of Southern Queensland, 37 Sinnathamby Blvd, Springfield Central QLD 4300, Queensland, Australia.
E-mail addresses: Malebogo.monnaatsie@usq.edu.au (M. Monnaatsie), stuart.biddle@usq.edu.au (S.J.H. Biddle), Shahjahan.Khan@usq.edu.au (S. Khan), tracy.kolbe-alexander@usq.edu.au (T. Kolbe-Alexander).

https://doi.org/10.1016/j.pmedr.2021.101597
Received 14 June 2021; Received in revised form 5 October 2021; Accepted 9 October 2021
Available online 12 October 2021

work (Torquati et al., 2018). Also, shift workers are more likely to have other adverse health outcomes, including poor mental health (Khan et al., 2018), and disturbed sleep (Kervezee et al., 2020).

Several physiological and behavioral mechanisms contribute to the negative health outcomes. Many shift workers experience circadian rhythm disruptions, due to the variations in sleep timing, meal timing and light exposure (James et al., 2017). The disruption of circadian rhythm tends to result in sleep deprivation, excessive sleepiness during wake hours, and insomnia symptoms. Therefore, the evidence supports that insufficient sleep maybe a mechanism of adverse health outcomes among shift workers (Kecklund and Axelsson, 2016). In addition to sleep disturbances and circadian misalignment adverse health outcomes in shift workers can also be attributed, in part, to habitual levels of physical activity and sedentary behaviour (Kervezee et al., 2020; Hulsegge et al., 2017).

The findings from previous research comparing physical activity and sedentary behaviour levels in shift workers have shown mixed results, which might be due to the measurement tools used. Several studies used self-report measures and observed no differences in overall physical activity levels between shift and non-shift worker (Loef et al., 2017; Vandelanotte et al., 2015). Self-report measurement remains a practical means for assessing lifestyle behaviours, even though it is widely recognized that participants tend to over-estimate their physical activity (Sylvia et al., 2014). As such, verifying their results with device-based measures is essential. Devices represent the best method for measuring physical activity and sedentary behaviour and is widely used in epidemiological studies (Welk et al., 2004). Loef et al. (Loef et al., 2018) found no differences between shift and non-shift workers' physical activity using device-based measures.

Shift workers were less physically active than non-shift workers (Ma et al., 2011; Loprinzi, 2015), supporting the hypothesis that leisure-time physical activity opportunities are generally decreased when working shifts (Kolbe-Alexander et al., 2019). For example, adults in the NHANES study asked to describe their work hours as regular evening, regular night shift, rotating shift or another schedule revealed that those working shifts were less physically active than those working regular hours (Loprinzi, 2015). On the other hand, previous research shows that shift workers are more active than non-shift workers (Hulsegge et al., 2020; Marqueze et al., 2013).

Shift work is common in most industries, for example health care, information technology, mining, police, security forces, transportation, construction and manufacturing (power plants, oil refinery, and steel industry) (Rydz et al., 2020). The discrepancy in physical activity is likely due to differences in shift schedules, job tasks and variations in definition of shift work, than as a result of differences in shift and non-shift workers. For instance, truck drivers and information technology shift workers are likely to spend more time sitting at work, thus they could spend more time active during leisure time to make up for more time spent sedentary at work. On the other hand, hospital workers may spend more time walking and standing at work, therefore they are likely to spend more time sitting during leisure time. Normal day workers mainly perform office-desk related jobs, spending more time seated. Truck drivers from Brazil who worked irregular shifts (25.8%), were more physically active ($\geq$150 min) than non-shift workers (3.8%) (Marqueze et al., 2013). Compared to day workers, those working evening shifts engaged in less moderate to vigorous physical activity than night shift workers (Loprinzi, 2015); while those working in rotating shifts engaged in more light-intensity physical activity than non-shift workers (Marqueze et al., 2013). It can be concluded that work schedules distinctively influence physical activity in shift workers (Atkinson et al., 2008).

In addition to physical inactivity, substantial amount of evidence has linked time spent in sedentary behaviour with adverse health outcomes and all-cause mortality (Vincent et al., 2017; Ekelund et al., 2019). Sedentary behaviour is low energy sitting, reclining, or lying during waking hours (Tremblay et al., 2017). There is a paucity of research investigating sedentary behaviour in shift workers. Loprinzi (Loprinzi, 2015) showed that sedentary behaviour was lower in shift workers than non-shift workers in a sample of American adults. Conversely, Hulsegge et al (Hulsegge et al., 2017) reported that those working shifts spend more time in uninterrupted sedentary periods (7.2%, 95% CI 2.3,12.1) than non-shift workers (5.9%, 95% CI −10.1, −1.7). Notably, hospital shift workers spent less time sedentary at work than non-shift workers (Loef et al., 2018). In the same study, sedentary time appeared to be even less in nurses who worked shifts than those who only worked during the day (Loef et al., 2018). The two studies used different populations, with Loef et al (Loef et al., 2018) and colleagues studying hospital workers and various occupations sampled in Hulsegge's et al study (Hulsegge et al., 2017). Thus, the evidence suggests that most hospital workers, including nurses, spend more time standing and walking than office workers.

The inconsistency of the findings suggests the need for a comprehensive review comparing physical activity and sedentary behaviours in shift and non-shift workers. While public health physical activity and sedentary behaviour guidelines exist (Bull et al., 2020), it remains unclear how shift work affects achieving these targets. Previous reviews have looked at nurses' occupational physical activity levels (Chappel et al., 2017), physical activity interventions in shift workers (Flahr et al., 2018), with Lassen et al (Lassen et al., 2018) investigating interventions promoting healthier food and/or physical activity practices in those working shifts. Therefore, detailed information about whether shift work influences physical activity and sedentary behaviour of workers is lacking. The primary aim of this systematic review and *meta*-analysis, is to compare physical activity and sedentary behaviour levels in shift and non-shift workers. Outcomes of this review could inform development of health promotion interventions for shift workers. Insights into physical activity levels and sedentary behaviours can also inform policies on health and wellbeing in companies with shift work populations. If policy makers can better understand the prevalence of physical activity and sedentary behaviour in shift workers, they might support opportunities for health promotion in the workplace.

2. Methods

We conducted a systematic review and *meta*-analysis comparing physical activity and sedentary behaviour in shift and non-shift workers following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Charrois, 2015). The protocol was registered with the PROSPERO database (CRD42020177839). A completed PRISMA checklist is presented in Fig. 1.

2.1. Search strategy

We searched the following databases: Ebscohost megafile ultimate (CINHAL, E-journals, Academic search ultimate, health source consumer edition, SPORT Discus), PubMed, Scopus, Web of Science, and Science Direct up to November 2020 and updated in April 2021. The search strategy was developed with the assistance of a research librarian using Population Intervention Comparison Outcome (PICO) strategy (Cumpston et al., 2020). The population was limited to shift workers, and comparators were non-shift workers or normal day workers. The outcomes included sedentary behaviour and physical activity. These are some of the following keywords: sedentary behaviour, sedentary behaviour, inactivity or exercise, shift work, non-shift worker, day work, with truncations used where appropriate. The full search strategy is available as an online supplementary Appendix A (Table A.1).

2.2. Selection criteria

For studies to be eligible, they had to meet the pre-determined inclusion criteria: 1) cross-sectional study or baseline data from longitudinal, intervention studies, or cohort studies, 2) reported time spent in

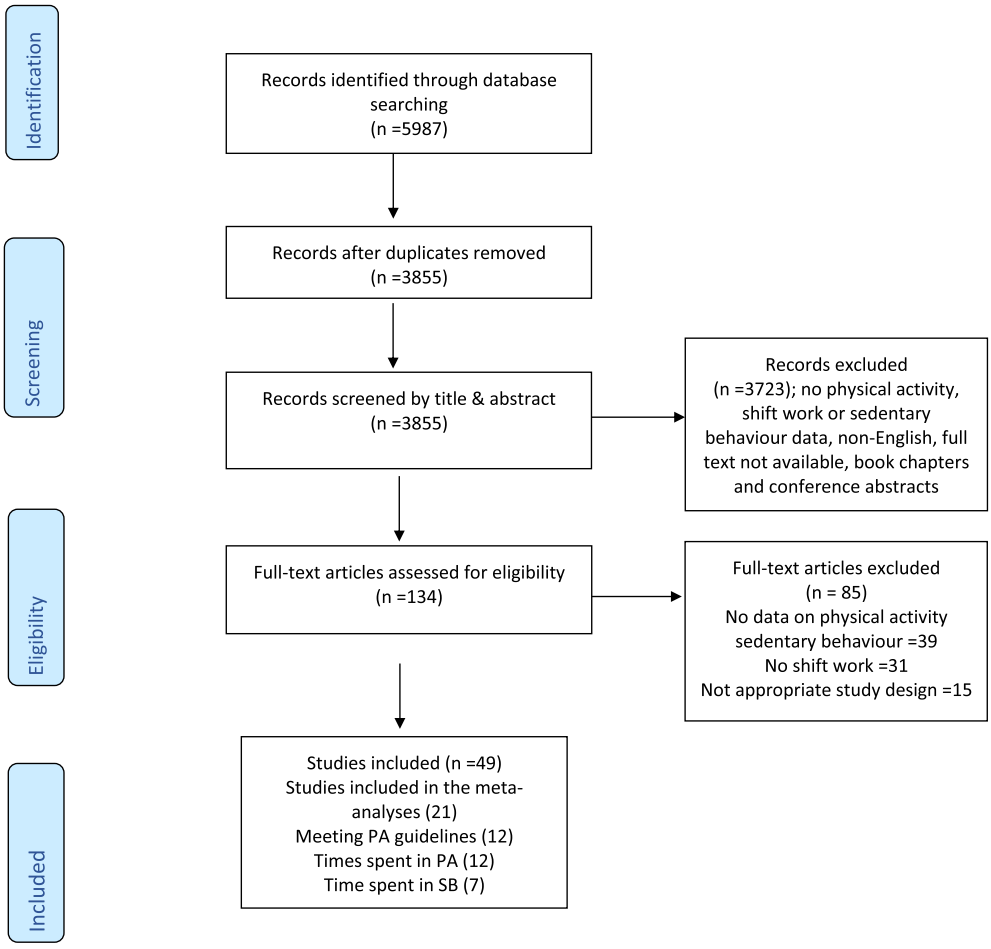

Fig. 1. PRISMA flow chart showing study screening process. PRISMA indicates Preferred Reporting Items for Systematic Reviews and Meta-analyses; PA, physical activity; SB, Sedentary behaviou.

(mean minutes/hours, percentages per day or week) physical activity and sedentary behaviour; and prevalence of workers meeting physical activity guidelines, at least 150–300 min of moderate-intensity aerobic physical activity, or at least 75–150 min of vigorous-intensity aerobic physical activity, as per the recent World Health Organisation guidelines (Bull et al., 2020); 3) include shift and non-shift workers. Book chapters, non-English articles, grey literature and conference proceedings were excluded. One author (MM) scanned the titles and abstracts to exclude 3723 articles from the 3,855 screened abstracts. Two authors (MM and TKA) then screened the 134 full texts articles to determine study eligibility. Any discrepancies were discussed between the two reviewers (MM and TKA) before a final decision on inclusion was made.

Data extraction

The two reviewers (MM and TKA) independently extracted data on author and publication year, study design, location and workplace, age, gender, type, and definition of shift work and any discrepancies were discussed between the two reviewers. Shift work included any arrangement of working hours other than the standard daylight hours (7/8 a.m.–5/6p.m.), while non-shift work includes normal work hours between 7/8 a.m.–5/6p.m. (Costa and Folkard, 2010). Data from selected studies were synthesised into a tabular format. Consistent with our study aim to compare physical activity and sedentary behaviour in shift and non-shift workers, we extracted physical activity and sedentary behaviour outcomes, including the prevalence of workers meeting physical activity guidelines and time spent in physical activity and sedentary behaviour. Point estimates and proportions for physical activity and sedentary behaviour were reported for most studies. Although some studies reported other Physical activity outcomes and sedentary behaviour outcomes other than prevalence of workers meeting physical activity guidelines and time spent in physical activity per day, and time spent in sedentary behaviour per day. Data were extracted according to the most reported outcomes in the studies to allow for synthesis and comparisons between shift and non-shift workers. To estimate the proportions of workers who meet physical activity guidelines, the mean prevalence and total sample of both shift and non-shift workers were extracted. Mean and standard deviations for time spent in physical activity and sedentary behaviour outcomes were selected for the *meta*-analysis. When not reported, standard deviations were calculated from standard of errors, 95% confidence intervals, or percentiles and means and sample size. If pertinent data were absent, we contacted authors on two separate occasions, and the necessary information was requested via e-mail. Nine authors were contacted, and only four responded, thus excluding the five studies without a response.

2.3. Quality assessment

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) quality assessment tool based on the checklist for reporting observational studies (von Elm et al., 2008) was adapted and has been previously used by Gilson et al (Gilson et al., 2019). The STROBE provides general reporting recommendations to improve the quality for descriptive observational studies and can be used for cross-sectional studies that were mainly included in our study (Vandenbroucke et al., 2007). The quality checklist (6–10 items) was scored for each of the following: sample population described and sample size sufficient, measurement tools appropriate, including devices, analyses

and variables reported and results reported in the studies. Each item was marked as "yes" (1 point), and "no" or "unclear" (0 point) low or unclear response or "n/a" for an item not applicable in the study. A composite overall score for each study was then calculated for each study and based on items rated with affirmative answer $\geq$ 75% =Good, 50–75%=Fair, <50%=Poor (Torres-Castro et al., 2021).

2.4. Data analysis

Due to anticipated heterogeneity, random effects *meta*-analysis was used. Heterogeneity was measured by the I^2 statistic, with values above 75% considered as high (Higgins et al., 2003).

For the *meta*-analysis, first, we pooled data on each physical activity category (time estimates and proportions of workers meeting physical activity guidelines) in shift and non-shift workers. The odds ratio was used to estimate the effect size on the proportions of shift and non-shift workers who meet physical activity guidelines. A comparative *meta*-analysis of pooled percentages of time spent in physical activity per day between shift and non-shift workers was conducted, yielding Hedges' g effect size (Haidich, 2010). Next, a *meta*-analysis of pooled percentages of time spent in sedentary behaviour per day between shift and non-shift workers was also conducted. We conducted subgroup analyses to investigate differences between physical activity and sedentary behaviour assessment methods (i.e., self-reported vs. device-based measures). Further we conducted sensitivity analyses excluding outlier studies one by one. Analyses were performed using Comprehensive Meta-analysis version 3.3 (CMA; Biostat Inc., Eaglewood, USA).

3. Results

3.1. Study selection and included participants

The electronic database search identified 3,855 articles (excluding duplicates) and these were screened by title and abstract. One hundred and thirty-four full texts were reviewed by 2 reviewers and 85 were excluded, leaving a total of 49 articles meeting eligibility criteria (Fig. 1). Studies were excluded in languages other than English; with an inappropriate study design; when no physical activity, shift work or sedentary behaviour data presented; when full text not available; and book chapters and conference abstracts.

Studies were conducted in 18 countries between 2001 and 2021. Sample size ranged from 9 to 185,958 participants, with participants' age ranging between 18 and 81 years. Two-thirds of the studies (70%) included males and females, and 23% only had females. Thirty-six studies included both shift and non-shift workers. About 50% (n = 24) of studies included healthcare workers, with other industries included (e.g., drivers, police, manufacturers, chemical plant workers). The shift systems and schedules varied considerably, with shift work described as morning, evening/afternoon and night shifts, rotating, irregular, and fixed shifts. All study characteristics are available as online supplementary Appendix A (Tables A.2–A.5).

The measured point estimates outcomes reported physical activity in minutes per day, hours per week and MET-hours per week. The primary outcomes included sedentary behaviour in minutes per day or hours per week. Studies that were not included in the *meta*-analyses reported physical activity frequency (presented as scores 1 and 2; 1 = yes and 2 = no) or (with scores 1 = never, 2 = 2 times a week, 3–4 times a week and 4 = almost every day). Other three studies reported step counts recorded by pedometers. One study reported number of sweaty hours per day, while other 2 studies reported kilojoules. One study that was excluded reported prevalence of sedentary lifestyle as (yes and no for 1 h of fast walking per week).

3.2. Quality assessment

Out of the 10 score items, study score items ranged from 6 to 10, depending on the outcome assessed and measurement tools (self-report vs devices). From the all the studies (n = 49), 38 met 75% answer rating their quality as "good" and only 11 studies met the 50–75% rating indicating "fair" quality. The mean score across all the selected items was 89%. More than 90% of studies reported appropriate study design (item 1A) and 86% had a sufficient sample size (item 1B). The number of days assessed for device-based studies and those that have excluded insufficient wear time was rated 65%. All studies reported physical activity and/or sedentary behaviour (item 4D). The quality scoring for each study is available as online Supplementary Material (Table A.6).

3.3. Measurement of physical activity and sedentary behaviour

Physical activity self-report measures: The self-report instruments used to quantify physical activity included the International Physical Activity Questionnaire (IPAQ), IPAQ-short form, Baecke questionnaire, Multimedia Activity Recall for Children and Adults (MARCA), Active Australia questionnaire, 7-day Physical Activity Recall Questionnaire, and Positive Health Behaviour Scale (PHBS) and Behavioural risk Factor Surveillance system (BRFSS) (Table 1).

Physical activity device-based measures: Six studies reported time spent in physical activity derived from wearable devices. These included the ActiGraph GT3X and ActiGraph wGT3X-BT to assess light intensity and moderate-to-vigorous intensity physical activity. Moderate-to-vigorous physical activity was also calculated from a waist-worn Actical accelerometer in minutes per day (Tables 1 and 2).

Sedentary behaviour self-report measures: Two studies used self-report measures to assess sedentary behaviour including the Workforce Sitting Questionnaire and domain specific questionnaire, see Table 3.

Sedentary behaviour device-based measures: Five studies used devices including the Actigraph model 7164 and ActiGraph GT3X with sedentary behaviour recorded as counts per minute between 0 and 99. Mean daily sedentary minutes were calculated at an intensity less than 1.0 metabolic equivalents for data derived from Actical accelerometer (Table 3).

3.4. Physical activity outcomes

3.4.1. Prevalence of meeting guidelines

The proportions of shift workers and non-shift workers meeting *physical activity guidelines* were 41% and 46%, respectively. The mean range was 8% to 63.4% in shift workers who meet physical activity guidelines, whereas the range was 3% to 67.7% in non-shift workers.

3.4.2. Time spent in physical activity

The average mean *time spent* in physical activity was similar for shift workers and non-shift workers (17%). Physical activity reported according to domains showed that occupational related physical activity is the primary contributor of total physical activity in both shift workers and non-shift workers. Transport related physical activity accounted for only 0.5% of total physical activity in both groups. Time spent in physical activity per day was 13.2% and 14.2% in shift workers and non-shift workers respectively. The self-report data showed that those working in shifts spent 24.5% time in physical activity compared to 22.9% in regular day workers.

3.4.3. Time spent in sedentary behaviour

The mean *time spent* in sedentary behaviours was 2% higher in non-shift workers (39%) than shift workers (37%). Sedentary behaviour at work was similar in shift and non-shift workers and accounted for 4% of total sedentary behaviour per day. Both devices and self-report measures showed that those working regular shift spent more time in sedentary behaviour than non-shift workers.

Table 1
Prevalence of workers meeting physical activity guidelines.

Author, year	Occupation	Shift groups	Measurement tool	Meeting PA guidelines Shift workers (%)	Meeting PA guidelines Non-shift worker(%)
(Alves et al., 2017)	Poultry processing	early morning, day, night shift	IPAQ short	26.9	51.9
(Marqueze et al., 2013)	Truck drivers	Irregular, day shift	IPAQ	25.8	3.8
(da Silva et al., 2015)	Poultry processing	Day, night shift	Modified IPAQ	39.0	30.8
(Panczyk et al., 2018)	Nurses & midwives	shift and non-shift	(PHBS)	50.2	50.9
(Park and Suh, 2020)	Various industries	day and shift workers	IPAQ-SF	46.3	58.5
Chin et al., 2016 (Nam and Lee, 2016)	Nurses	Day, non-day	BRFSS (CDC,2013)	36.0	41.9
(Ma et al., 2011)	Police	Day, afternoon, midnight shift	Questionnaire	63.4	67.0
(Sugiura et al., 2020)	Health care support	Fixed daytime, shift worker	Questionnaire	54.6	66.4
(Hulsegge et al., 2020)	Industrial production	Morning, afternoon, night and non-shift	Questionnaire	58.0	56.0
(Hulsegge et al., 2021)	Manufacturing industries	Shift worker, non-shift worker	Questionnaire	58.0	58.0
(Neil-Sztramko et al., 2016) (	Various industries	Shift worker, day worker	Questionnaire	15.9	15.5
Loef et al., 2020)	Health care workers	Shift and non-shift workers	Actigraph GT3X	46.2	36.2

Legend: PA (physical activity), IPAQ (International Physical Activity Questionnaire), IPAQ-SF (International Physical Activity Questionnaire-Short Form), BRFSS Behavioural risk Factor Surveillance system, PHBS (Positive Health Behaviours Scale), Various industries: manufacturing, accommodation and food sector, chemical plants, firefighters, retail, Questionnaire: used when the type/name of questionnaire was not described.

Table 2
Time spent in moderate-to-vigorous physical activity in minutes per day in shift and non-shift workers.

Author, year	Occupation	Shift groups	Measurement tool	Time spent in PAShift workerMean (SD)	Time spent in PANon-shift workerMean (SD)
(Peplonska et al., 2014)	Nurses and midwives	Rotating night, day shifts	IPAQ	26.0 (11.0)	20.9 (9.9)
(Vandelanotte et al., 2015)	Various industries	Shift, non-shift, non-night shift	IPAQ	26.8 (9.7)	24.9 (9.4)
(Vlahoyiannis et al., 2021	Nurses	Morning, rotating shift worker	IPAQ	15.5 (15.7)	12.4 (13.5)
(Hulsegge et al., 2017)	Various industries	Day worker, night and non-night shift	Questionnaire	13.9 (9.0)	15.8 (7.3)
(Loef et al., 2017)	Various industries	Shift, non-shift workers	Questionnaire	21.3 (13.6)	18.8 (2.2)
(Tada et al., 2014)	Nurse	rotating	Questionnaire	25.2 (35.1)	24.7 (35.7)
(Clark et al., 2017)	Various industries	Shift/night and not shift/night	Active Australia Questionnaire	12.5 (8.4)	11.5 (7.5)
(van de Langenberg et al., 2019)	Health care workers	nightshift worker, day worker	Actigraph GT3X	40.1 (35.2)	38.2 (26.8)
Lauren et al., 2020)	Nurses and medical staff	Day and night shift	Actigraph wGT3X-BT	12.8 (6.7)	14.3 (5.5)
(Loef et al., 2018)	Hospital shift workers	Shift, non-shift worker	Actigraph GT3X	11.7 (6.5)	12.5 (6.2)
(Loprinzi, 2015)	Various industries	Daytime, evening, night, rotating shift	Actigraph	25.8 (3.2)	28.5 (0.7)
(Neil-Sztramko et al., 2016)	Various industries	Shift worker, day worker	Actical accelerometer	10.1 (10.1)	10.2 (6.4)

Legend: PA (physical activity), IPAQ (International Physical Activity Questionnaire), SD (Standard Deviation), Various industries: manufacturing, accommodation and food sector, chemical plants, firefighters, retail, Questionnaire: used when the type/name of questionnaire was not reported.

3.5. Meta-analyses

Data were pooled from 12 studies for prevalence of shift and non-shift workers meeting physical activity guidelines. Estimates of time spent in the physical activity and sedentary behaviour *meta*-analysis included 12 and 7 studies, respectively.

3.5.1. Prevalence of workers meeting physical activity guidelines

Although shift workers were less likely to meet physical activities guidelines than non-shift workers, this difference was not statistically significant (OR 0.84, 95% CI:0.68, 1.03 (Fig. 2a). For the self-reported physical activity *meta*-analysis, the difference between shift and non-shift workers who meet physical activity guidelines was still not significant (OR 0.81, 95% CI: 0.67, 0.99) and heterogeneity was high (I^2 = 96.3%) (Fig. 2b). There were insufficient data to pool results by device-based measures.

We did further analysis by removing one study (25) from all the studies included for meeting physical activity guidelines with a significant small effect size (OR 0.075). The overall effect size was increased from 0.84 to 0.87.

3.5.2. Time spent in physical activity

The difference in time spent in moderate-to-vigorous physical activity were not significant between shift and non-shift workers (SMD −0.1, 95% CI: −0.4, 0.20) (Fig. 3a). A separate analysis was conducted to compare time spent in moderate-to-vigorous physical activity in shift and non-shift workers by self-report measures. After removing one study (Loprinzi, 2015), with an unusually smaller effect size the heterogeneity was decreased substantially (from I^2 = 98.8 to I^2 = 85.4).

The results with self-report measures showed a non-significant difference between shift and non-shift workers (SMD 0.21, 95% CI: 0.00, 0.34) (Fig. 3b). Similar to overall results of time spent in moderate-to-

Table 3
Time spent in sedentary behaviour in minutes per day in shift and non-shift workers.

Author, year	Occupation	Shift groups	Measurement tool	Time spent in SBShift workerMean (SD)	Time spent in SBNon-shift workerMean (SD)
(Vandelanotte et al., 2013)	Various industries	Shift, non-shift, non-night shift	Workforce sitting questionnaire	36.1 (18.4)	37.2 (16.9)
(Clark et al., 2017)	Various industries	Regular hours, night work	Questionnaire	29.6 (16.6)	34.2 (16.3)
(Hulsegge et al., 2017)	Various industries	Day worker, night and non-night shift	Questionnaire	49.4 (18.2)	45.8 (16.4)
(Lauren et al., 2020)	Nurses and medical staff	Day and night shift	Actigraph wGT3X-BT	21.5 (9.0)	18.9 (5.2)
(Loef et al., 2018)	Hospital shift workers	Shift, non-shift worker	Actigraph GT3X	53.3 (12.0)	60.5 (16.5)
(Loprinzi, 2015)	Various industries	Daytime, evening, night, rotating shift	Accelerometer	31.8 (10.4)	35.0 (4.0)
(Neil-Sztramko et al., 2016)	Various industries	Shift worker, day worker	Actical accelerometer	39.5 (20.2)	40.0 (13.7)

Legend: SB (sedentary behaviour), IPAQ (International Physical Activity Questionnaire), SD (Standard Deviation), Various industries: manufacturing, accommodation and food sector, chemical plants, firefighters, retail, Questionnaire: used when the type/name of questionnaire was not reported.

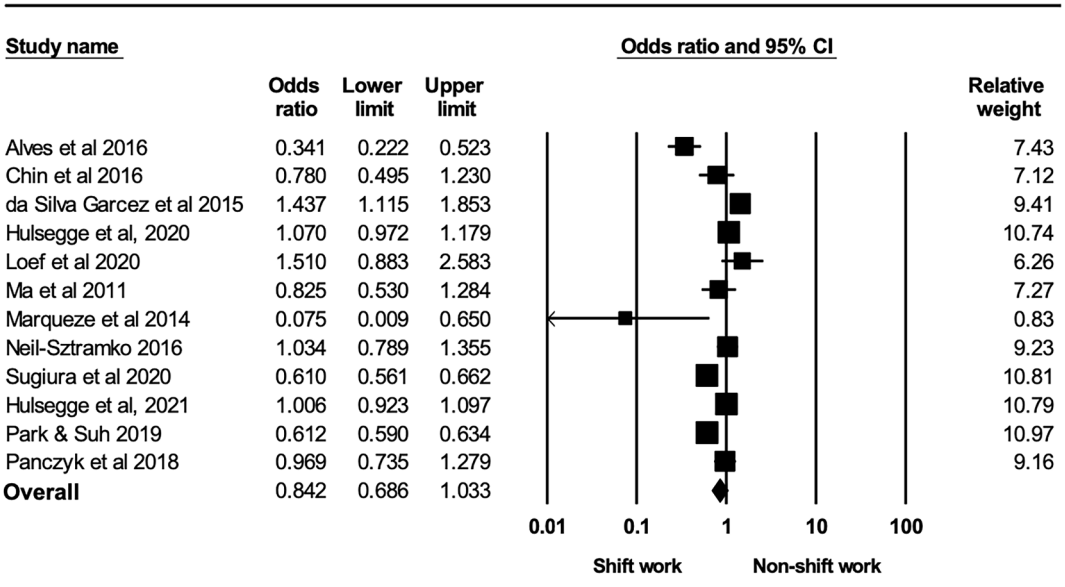

Fig. 2a. Forest plot of workers who meet physical activity guidelines (all studies).

vigorous physical activity analysis by device data shows non-significant differences (SMD −0.40, 95% CI: −1.16, 0.37) (Fig. 3c).

3.5.3. *Time spent in sedentary behaviour*

The *meta*-analysis results of the pooled data demonstrated that shift workers spend significantly less time in sedentary behaviour than non-shift workers (SMD −0.2, 95% CI: −0.50, −0.001) (Fig. 4a). A sufficient number of studies were available to compare the time spent in sedentary behaviour measured by devices. The difference between shift and non-shift workers was non-significant (SMD −0.23, 95% CI: −0.56, −0.09) (Fig. 4b). There were insufficient data to pool results by self-reported sedentary behaviour.

4. Discussion

This study aimed to compare physical activity and sedentary behaviour in shift and non-shift workers. Our findings show that habitual levels of physical activity were similar for shift and non-shift workers, and only 41% of shift workers meet physical activity guidelines. Similar to the shift work population, a significant number of adults are inactive. Globally, over a quarter of adults (27.5%) were reported to be insufficiently active (Guthold et al., 2018). For the shift worker, this puts an increased risk of developing diseases linked to inactivity as they are already identified as a risk group. Another major finding is that time spent in sedentary behaviour was significantly less in shift workers, although only a few studies were included.

Our findings demonstrated that compared to data using measurement devices, self-reported data showed that shift workers spent more time in physical activity than non-shift workers (SMD 0.21, 95% CI: 0.00, 0.34). Studies (Vandelanotte et al., 2015; Marqueze et al., 2013; Peplonska et al., 2014) included in our analysis used questionnaires where participants were asked to recall how often they had performed physical activity. It is possible that shift workers may have overreported their physical activity levels. Similar to most of our included studies, health workers (involved in shift work) reported higher physical activity compared with measures using the ActiGraph accelerometer (Zafiropoulos et al., 2019). Self-report measures can result in recall bias when compared to device-based measures (Sylvia et al., 2014). There is a need to use measurement tools that are feasible and capture the patterns of physical activity and sedentary behaviour in shift workers in real time.

It should be noted that our analyses included only overall physical activity in both shift and day workers. The similarity in shift workers and non-shift workers' physical activity levels could be a result of the type of activity reported. Even though not confirmed in our review, shift

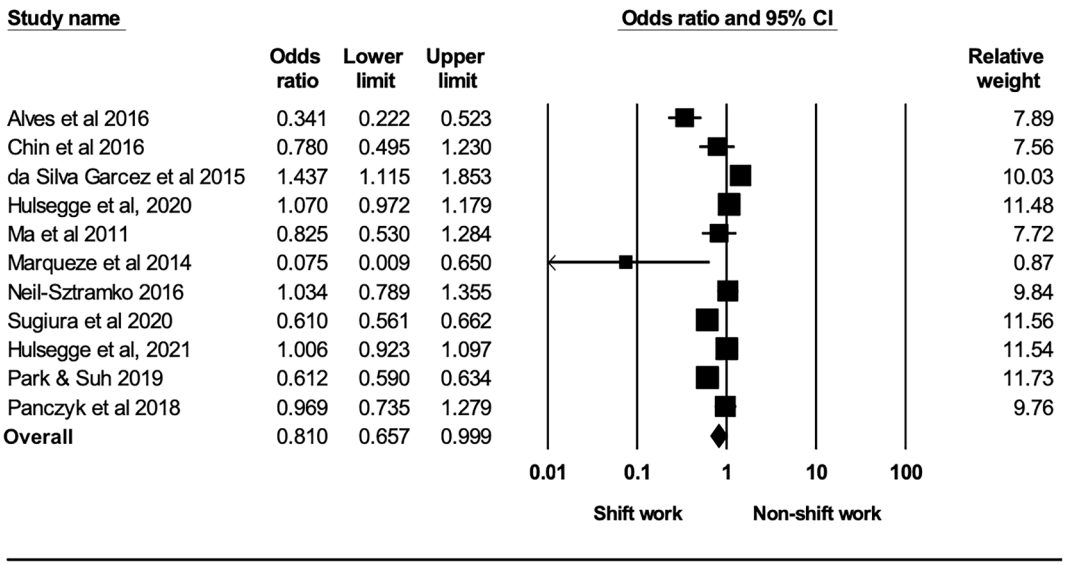

Fig. 2b. Forest plot of workers who meet physical activity guidelines (self-report).

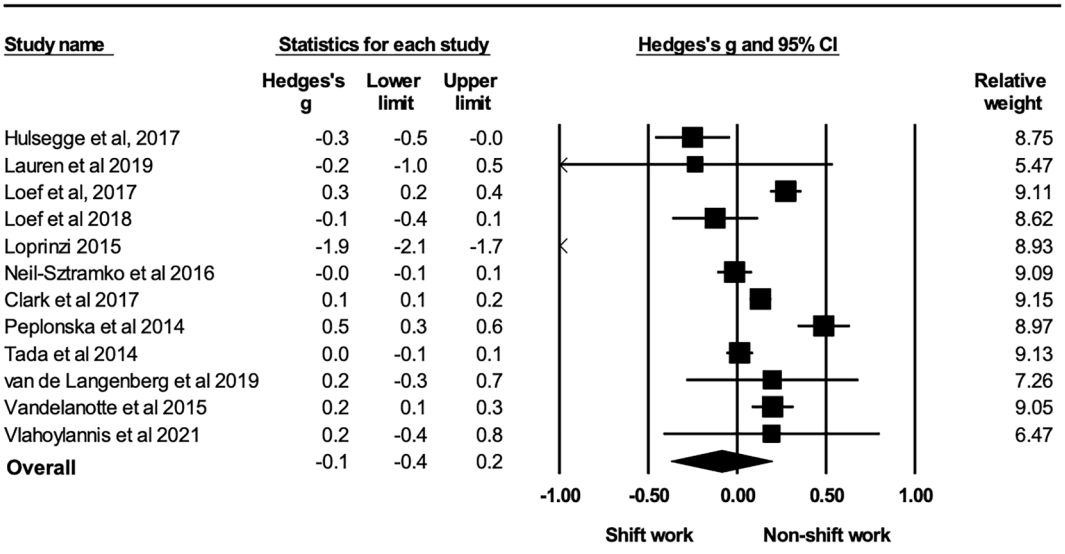

Fig. 3a. Forest plot of time spent in physical activity (all studies).

workers may have reported high occupational physical activity which is common in shift work occupations like health care and manufacturing. Normal day workers may have reported higher leisure time physical activity as their work times allow for more opportunities for physical activity and participation in sports. This might lead to total physical activity being similar in the two groups. For example, occupational activity was shown to contribute more than leisure-time physical activity to total daily energy expenditure in health care workers (Peplonska et al., 2014). Similarly, recent Australian data showed that shift workers were more likely to report low leisure-time physical activity than occupational physical activity (Vandelanotte et al., 2015). Thus, these factors need to be identified in large controlled prospective studies, to include and report the type of physical activity.

There is emerging and inconclusive evidence on the role of occupational physical activity on health outcomes (Cillekens et al., 2020). The 'physical activity paradox' states that increased physical activity in shift workers because of high occupational activity may not benefit workers' health (Gupta et al., 2020). For example, in one study investigating physical activity levels in shift workers, there were no significant associations between shift work and non-occupational physical activity (Loef et al., 2017). Thus, shift workers may still be at higher risk of diseases than day workers if most of their reported activities are from occupational physical activity. However, a recent study (Dalene et al.) using a large data set of Norwegian adults showed that occupational physical activity might reduce the risk of non-communicable diseases, suggesting that any physical activity, regardless of the domain, is beneficial to the health of workers.

Our findings suggest that those working shifts are less sedentary than those working normal day hours (SMD −0.2, 95% CI: −0.50, −0.001). Like our results, Loprinzi (Loprinzi, 2015) reported that rotating shift workers engaged in less sedentary behaviour than non-shift workers when assessed by an accelerometer. One of the most important factors in investigating sedentary behaviours is measurement tools. Out of the seven studies, five used devices, and our quality scoring show that 76%

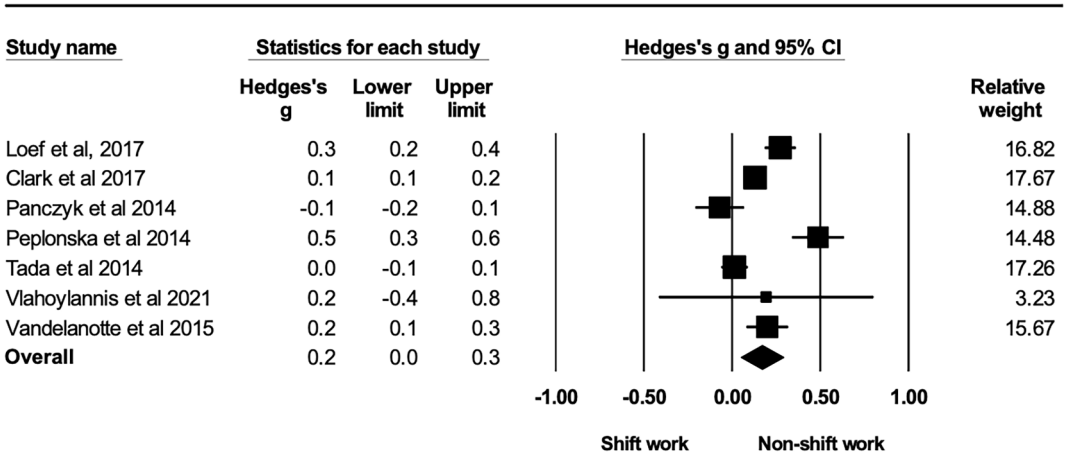

Fig. 3b. Forest plot of time spent in physical activity (self-report measures).

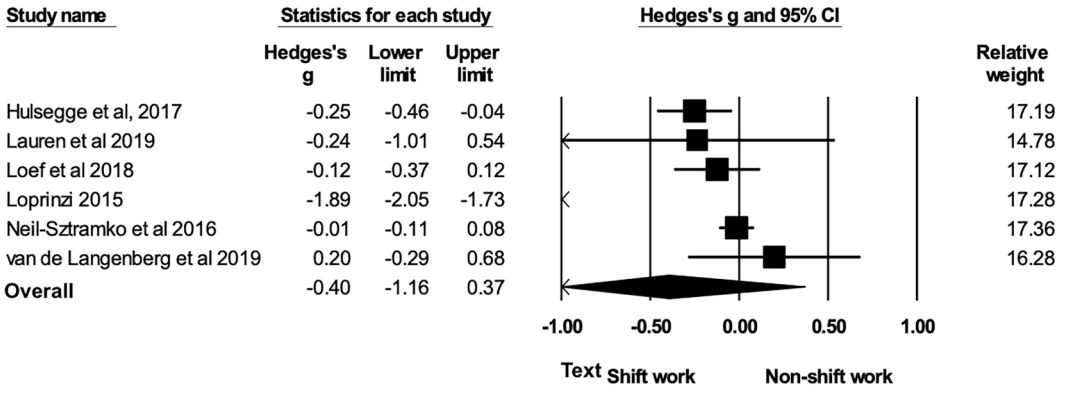

Fig. 3c. Forest plot of time spent in physical activity (devices).

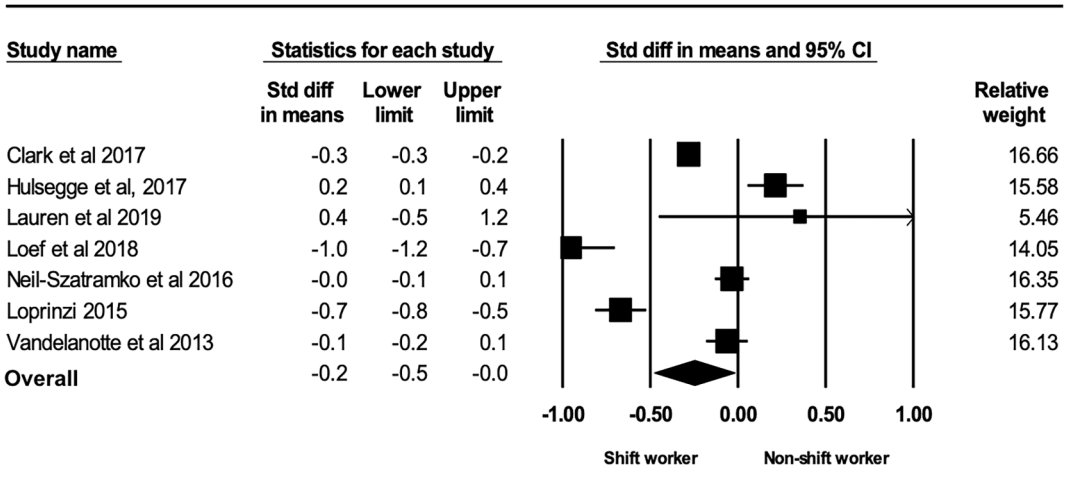

Fig. 4a. Forest plot of time spent in sedentary behaviour (all studies).

of the studies reported sedentary time that excludes sleeping time (Table 4). Thus, these results should be interpreted with caution as some of the time spent sedentary behaviour may be indistinguishable from sleep (Barone Gibbs and Kline, 2018).

In terms of workplace sectors, 50% of studies included in the review used health care professions, and mainly nurses, which might explain

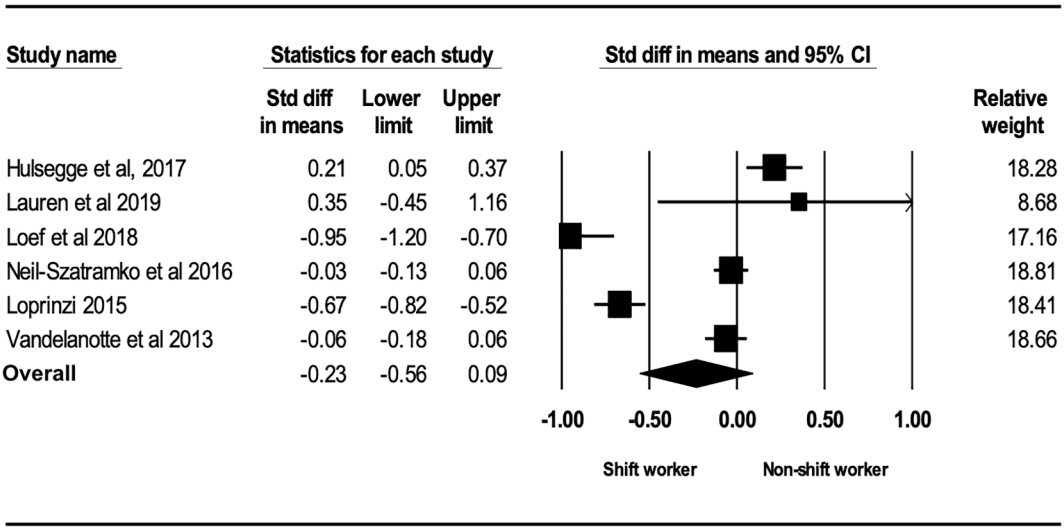

Fig. 4b. Forest plot of time spent in sedentary behaviour (devices).

Table 4
Quality assessment (10 items) and percentage scoring for each item.

Item	Criterion	Description	(%)
1A	Sample	Are the study design and population sufficiently described?	(90)
1B	Sample	Is sample size sufficient to give a good estimate of target behaviour(s) for the population?	(86)
2A	Measurement	are the number of days assessed sufficient (≥4) to give a good estimate of target behaviour(s) for the population? (device-based measures)	(65)
3A	Analyses	Is consideration given to excluding participants with insufficient wear time (for device-based measures)?	(65)
3B	Analyses	Are data analysed using inclonometry or pattern recognition algorithms, as opposed to accelerometer counts (for device-based measures)?	(82)
4A	Variables	Are data reported for specific shift work?	(93)
4C	Variables	Are daily times reported in absolute (hours or minutes/day) and relative (percentage) terms?	(83)
4D	Variables	Are sedentary/sitting and physical activity data reported?	(100)
4E	Variables	Does reported sedentary/sitting time exclude sleeping time?	(76)
5E	Results	Are results reported in sufficient detail regarding both central tendency and variability of the target behaviour(s)?	(77)

low sedentary time in shift workers. Other studies have investigated various occupations, including drivers, manufacturing workers, police, poultry workers, with different tasks and shift types. Further, it is not surprising that shift workers reported lower sedentary time than non-shift workers because most normal day workers are office jobs characterised by prolonged sitting periods. Shift workers in transportation and technology are still less likely to report high sitting time than those working in blue-collar and hospital settings where physically demanding occupations are less (Smith et al., 2016). Thus, it is better to compare sedentary behaviour levels in non-shift workers with shift workers in industries with sedentary tasks. The new WHO recommendations support breaking long periods of sitting at work and replace it with some physical activity (Dempsey et al., 2020). In industries where more time is spent in prolonged standing, in both shift and non-shift work, it would be advisable to alternate between sitting and standing to provide recovery and prevent fatigue (Waters and Dick, 2015).

Our review shows that few studies investigated sedentary behaviours in both shift and non-shift workers. Given the large contribution of the workplace to sedentary behaviours (Haslam et al., 2019), more research is needed to investigate the sedentary behaviours of shift workers. Prolonged sitting is prevalent in industries such as hotels, transport and communications involving shift work (Messenger, 2018). Reducing sedentary time may still be most effective when targeted at shift workers in customer service call centres, those using information technology, and drivers.

In the present review, shift work schedules were defined with different hours from the traditional regular working period from morning to afternoon and sometimes referred to irregular or fixed working hours. For example, Alves (Alves et al., 2017) and colleagues defined work schedules as the fixed morning, fixed day and evening shifts while Hulsegge et al (Hulsegge et al., 2017) defined the schedules as day, night and non-night shift work. It is likely that our results could have also been influenced by heterogeneity in study variables like shift schedules and types. The definitions of shift work schedules should be standardised across studies in future research.

Physical activity and sedentary behaviour are both complex and multidimensional behaviours. As such it was difficult to compare physical activity and sedentary behaviour in shift workers when reported by different types, measurement tools, schedules and different tasks performed at work. Adhering to consistent measurement tools to assess physical activity and sedentary behaviour could increase the comparability of results across studies. There is need to standardise definitions of shift work and shift schedules and to report all the various factors that influence physical activity and sedentary behaviour patterns in future studies.

4.1. *Strengths and limitations*

To date, there has not been a review on levels of physical activity in shift workers. Therefore, there are limitations in our ability to compare our results to those of prior research. Our systematic review and *meta*-analysis included studies with both device and self-report measures. We were also able to review studies from several countries and many industries involved in shift work. Therefore, it was possible to do comparisons by measurement tools as physical activity and sedentary behaviour outcomes were measured by both self-report and devices. The search strategy was thorough but included studies that were reported in English only, relevant publications in other languages may have been missed. Because few studies reported domain-based data, our results only reflect total physical activity and sedentary behaviour outcomes.

5. Concluding remarks

In conclusion, while physical activity levels do not differ between shift and non-shift workers and shift workers spending more time sitting, there is evidence that results might have been influenced by heterogeneity in the studies included. With workers spending most of their waking time at work, occupational factors can significantly influence physical activity and sedentary behaviours and may even be more complex in shift workers (Caruso, 2014). The rapid economic development in the world continues to increase the demand for shift work, resulting in many people working in shifts (Rajaratnam and Arendt, 2001). Intervention strategies are needed to ameliorate physical inactivity and health problems that are evident in shift workers. Furthermore, few workplace interventions have targeted shift workers (Flahr et al., 2018). Further research on the determinants of physical activity and sedentary behaviour in shift workers is needed.

CRediT authorship contribution statement

Malebogo Monnaatsie: Conceptualization, Methodology, Writing – original draft. **Stuart J.H. Biddle:** Methodology, Supervision. **Shahjahan Khan:** Formal analysis, Writing – review & editing. **Tracy Kolbe-Alexander:** Conceptualization, Methodology, Supervision.

Declaration of Competing Interest

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

Acknowledgements

We thank Dr. Tricia Kelly, University of Southern Queensland research librarian, for her guidance in creating the search strategy used in this review.

Funding

This work is part of the lead author's PhD research project supported primarily by the University of Botswana staff scholarship and University of Southern Queensland.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2021.101597.

References

Caruso, C.C. 2014. Negative impacts of shiftwork and long work hours. Rehabil Nurs. 39 (1), 16-25. Epub 2013/06/20. doi: 10.1002/rnj.107. PubMed PMID: 23780784; PubMed Central PMCID: PMCPMC4629843.

Depner, C.M., Stothard, E.R., Wright, K.P., Jr. 2014. Metabolic consequences of sleep and circadian disorders. Curr Diab Rep. 14(7), 507. Epub 2014/05/13. doi: 10.1007/s11892-014-0507-z. PubMed PMID: 24816752; PubMed Central PMCID: PMCPMC4308960.

Presser, H.B. 2005. Working in a 24/7 economy: Challenges for American families: Russell Sage Foundation.

Statistics AB. Working arrangements. https://wwwabsgovau/statistics/labour/earnings-and-work-hours/working-arrangements/aug-2020.

Parent-Thirion, A., Biletta, I., Cabrita, J., Llave, O.V., Vermeylen, G., Wilczynska, A., et al. 2017. 6th European Working Conditions Survey: 2017 update: Publications Office of the European Union.

statistics USBol. Labor Force Statistics from the Current Population Survey. Work schedules (flexible and shift schedules). 2018.

Kecklund, G., Axelsson, J., 2016. Health consequences of shift work and insufficient sleep. BMJ. 355, i5210 https://doi.org/10.1136/bmj.i5210.

Torquati, L., Mielke, G.I., Brown, W.J., Kolbe-Alexander, T. 2018. Shift work and the risk of cardiovascular disease. A systematic review and meta-analysis including dose-response relationship. Scand. J. Work Environ. Health 44(3), 229-3Epub 2017/12/17. doi: 10.5271/sjweh.3700. PubMed PMID: 29247501.

Hansen, J. 2017. Night shift work and risk of breast cancer. Curr. Environ. Health Rep. 4 (3), 325-3Epub 2017/08/05. doi: 10.1007/s40572-017-0155-y. PubMed PMID: 28770538.

Liu, W., Zhou, Z., Dong, D., Sun, L., Zhang, G. 2018. Sex differences in the association between night shift work and the risk of cancers: a meta-analysis of 57 articles. Dis Markers 2018, 7925219. Epub 2019/01/02. doi: 10.1155/2018/7925219. PubMed PMID: 30598709; PubMed Central PMCID: PMCPMC6287141.

Antunes, L.C., Levandovski, R., Dantas, G., Caumo, W., Hidalgo, M.P. 2010. Obesity and shift work: chronobiological aspects. Nutr. Res. Rev. 23(1), 155-168. Epub 2010/02/04. doi: 10.1017/s0954422410000016. PubMed PMID: 20122305.

Hulsegge, G., van Mechelen, W., Paagman, H., Proper, K.I., Anema, J.R. 2020. The moderating role of lifestyle, age, and years working in shifts in the relationship between shift work and being overweight. Int. Arch. Occup. Environ. Health 93(6), 697-705. Epub 2020/02/11. doi: 10.1007/s00420-020-01519-4. PubMed PMID: 32040711; PubMed Central PMCID: PMCPMC7320962.

Khan, S., Duan, P., Yao, L., Hou, H. 2018. Shiftwork-mediated disruptions of circadian rhythms and sleep homeostasis cause serious health problems. Int. J. Genom. 2018, 8576890. Epub 2018/04/03. doi: 10.1155/2018/8576890. PubMed PMID: 29607311; PubMed Central PMCID: PMCPMC5828540.

Kervezee, L., Kosmadopoulos, A., Boivin, D.B. 2020. Metabolic and cardiovascular consequences of shift work: The role of circadian disruption and sleep disturbances. Eur. J. Neurosci. 51(1), 396-412. Epub 2018/10/26. doi: 10.1111/ejn.14216. PubMed PMID: 30357975.

James, S.M., Honn, K.A., Gaddameedhi, S., Van Dongen, H.P.A. 2017. Shift Work: disrupted circadian rhythms and sleep-implications for health and well-being. Curr. Sleep Med. Rep. 3(2), 104-112. Epub 2017/04/27. doi: 10.1007/s40675-017-0071-6. PubMed PMID: 29057204.

Hulsegge, G., Gupta, N., Holtermann, A., Jørgensen, M.B., Proper, K.I., van der Beek, A.J. 2017. Shift workers have similar leisure-time physical activity levels as day workers but are more sedentary at work. Scand. J. Work Environ. Health. 43(2), 127-135. Epub 2016/12/doi: 10.5271/sjweh.3614. PubMed PMID: 27973676.

Loef, B., Hulsegge, G., Wendel-Vos, G.C., Verschuren, W.M., Vermeulen, R.C., Bakker, M. F., et al. 2017. Non-occupational physical activity levels of shift workers compared with non-shift workers. Occup. Environ. Med. 74(5), 328-335. Epub 2016/11/23. doi: 10.1136/oemed-2016-103878. PubMed PMID: 27872151; PubMed Central PMCID: PMCPMC5520260.

Vandelanotte, C., Short, C., Rockloff, M., Di Millia, L., Ronan, K., Happell, B., et al. 2015. How do different occupational factors influence total, occupational, and leisure-time physical activity? J. Phys. Act Health 12(2), 200-207. Epub 2014/02/11. doi: 10.1123/jpah.2013-0098. PubMed PMID: 24508923.

Sylvia, L.G., Bernstein, E.E., Hubbard, J.L., Keating, L., Anderson, E.J. 2014. Practical guide to measuring physical activity. J. Acad. Nutr. Diet. 114(2), 199-208. Epub 2013/12/03. doi: 10.1016/j.jand.2013.09.018. PubMed PMID: 24290836; PubMed Central PMCID: PMCPMC3915355.

Welk, G.J., Schaben, J.A., Morrow Jr., J.R., 2004. Reliability of accelerometry-based activity monitors: a generalizability study. Med. Sci. Sports Exerc. 36 (9), 1637–1645. Epub 2004/09/09 PubMed PMID: 15354049.

Loef, B., van der Beek, A.J., Holtermann, A., Hulsegge, G., van Baarle, D., Proper. K.I. 2018. Objectively measured physical activity of hospital shift workers. Scand. J. Work Environ. Health 44(3), 265-273. Epub 2018/01/23. doi: 10.5271/sjweh.3709. PubMed PMID: 29355291.

Ma, C.C., Burchfiel, C.M., Fekedulegn, D., Andrew, M.E., Charles, L.E., Gu, J.K., et al. 2011. Association of shift work with physical activity among police officers: the Buffalo cardio-metabolic occupational police stress study. J. Occup. Environ. Med. 53(9), 1030-1036. Epub 2011/08/26. doi: 10.1097/JOM.0b013e31822589f9. PubMed PMID: 21866054.

Loprinzi, P.D. 2015. The effects of shift work on free-living physical activity and sedentary behavior. Prev Med. 76, 43-47. Epub 2015/04/22. doi: 10.1016/j.ypmed.2015.03.025. PubMed PMID: 25895842.

Kolbe-Alexander, T.L., Gomersall, S., Clark, B., Torquati, L., Pavey, T., Brown, W.J. 2019. A hard day's night: time use in shift workers. BMC Public Health 19(Suppl 2), 452. Epub 2019/06/05. doi: 10.1186/s12889-019-6766-5. PubMed PMID: 31159755; PubMed Central PMCID: PMCPMC6546613.

Marqueze, E.C., Ulhôa, M.A., Moreno, C.R. 2013. Effects of irregular-shift work and physical activity on cardiovascular risk factors in truck drivers. Rev. Saude Publica. 47(3), 497-505. Epub 2013/12/19. doi: 10.1590/s0034-8910.2013047004510. PubMed PMID: 24346562.

Rydz, E., Hall, A.L., Peters, C.E., 2020. Prevalence and recent trends in exposure to night shiftwork in Canada. Annals Work Exposures Health 64 (3), 270–281.

Atkinson, G., Fullick, S., Grindey, C., Maclaren, D., 2008. Exercise, energy balance and the shift worker. Sports Med. 38 (8), 671–685. https://doi.org/10.2165/00007256-200838080-00005. PubMed PMID: 18620467.

Vincent, G.E., Jay, S.M., Vandelanotte, C., Ferguson, S.A. 2017. Breaking up sitting with light-intensity physical activity: implications for shift-workers. Int. J. Environ. Res. Public Health 14(10). Epub 2017/10/17. doi: 10.3390/ijerph14101233. PubMed PMID: 29035315; PubMed Central PMCID: PMCPMC5664734.

Ekelund, U., Tarp, J., Steene-Johannessen, J., Hansen, B.H., Jefferis, B., Fagerland, M.W., et al. 2019. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. BMJ 366, l4570. Epub 2019/08/23. doi: 10.1136/bmj.l4570. PubMed PMID: 31434697; PubMed Central PMCID: PMCPMC6699591 and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Tremblay, M.S., Aubert, S., Barnes, J.D., Saunders, T.J., Carson, V., Latimer-Cheung, A. E., et al. 2017. Sedentary behavior research network (SBRN) - terminology consensus project process and outcome. Int. J. Behav. Nutr. Phys. Act 14(1), 75. Epub 2017/06/11. doi: 10.1186/s12966-017-0525-8. PubMed PMID: 28599680; PubMed Central PMCID: PMCPMC5466781.

Bull, F.C., Al-Ansari, S.S., Biddle, S., Borodulin, K., Buman, M.P., Cardon, G., et al. 2020. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br. J. Sports Med. 54(24), 1451-1462. Epub 2020/11/27. doi: 10.1136/bjsports-2020-102955. PubMed PMID: 33239350; PubMed Central PMCID: PMCPMC7719906.

Chappel, S.E., Verswijveren, S.J.J.M., Aisbett, B., Considine, J., Ridgers, N.D., 2017. Nurses' occupational physical activity levels: a systematic review. Int. J. Nurs. Stud. 73, 52–62. https://doi.org/10.1016/j.ijnurstu.2017.05.006.

Flahr, H., Brown, W.J., Kolbe-Alexander, T.L. 2018. A systematic review of physical activity-based interventions in shift workers. Prev. Med. Rep. 10, 323-331. Epub 2018/06/06. doi: 10.1016/j.pmedr.2018.04.004. PubMed PMID: 29868387; PubMed Central PMCID: PMCPMC5984233.

Lassen, A.D., Fagt, S., Lennernäs, M., Nyberg, M., Haapalar, I., Thorsen, A.V. et al. 2018. The impact of worksite interventions promoting healthier food and/or physical activity habits among employees working 'around the clock' hours: a systematic review. Food Nutr. Res. 62. Epub 2018/08/08. doi: 10.29219/fnr.v62.1115. PubMed PMID: 30083088; PubMed Central PMCID: PMCPMC6073101.

Charrois, T.L. 2015. Systematic reviews: what do you need to know to get started? Can. J. Hosp. Pharm. 68(2), 144-148. Epub 2015/05/13. doi: 10.4212/cjhp.v68i2.1440. PubMed PMID: 25964686; PubMed Central PMCID: PMCPMC4414076.

Cumpston, M.S., McKenzie, J.E., Thomas, J., Brennan, S.E. 2020. Current practice in systematic reviews including the 'PICO for each synthesis' and methods other than meta-analysis: protocol for a cross-sectional study. F1000Research. 9.

Costa, G., Folkard, S. 2010. Shift work and extended hours of work. 1233-1245.

von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gøtzsche, P.C., Vandenbroucke, J.P. 2008. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J. Clin. Epidemiol. 61(4), 344-349. Epub 2008/03/04. doi: 10.1016/j.jclinepi.2007.11.008. PubMed PMID: 18313558.

Gilson, N.D., Hall, C., Holtermann, A., van der Beek, A.J., Huysmans, M.A., Mathiassen, S.E., et al. 2019. Sedentary and physical activity behavior in "blue-collar" workers: a systematic review of accelerometer studies. J. Phys. Act Health 16(11), 1060-1069. Epub 2019/08/31. doi: 10.1123/jpah.2018-0607. PubMed PMID: 31469366.

Vandenbroucke, J.P., Von Elm, E., Altman, D.G., Gøtzsche, P.C., Mulrow, C.D., Pocock, S. J., et al., 2007. Strengthening the reporting of observational studies in epidemiology (STROBE): explanation and elaboration. PLoS Med. 4 (10), e297.

Torres-Castro, R., Vasconcello-Castillo, L., Acosta-Dighero, R., Sepúlveda-Cáceres, N., Barros-Poblete, M., Puppo, H., et al. 2021. Physical activity in children and adolescents with chronic respiratory diseases: a systematic review and meta-analysis. J. Phys. Act Health 18(2), 219-229. Epub 2021/01/14. doi: 10.1123/jpah.2020-06PubMed PMID: 33440346.

Higgins, J.P., Thompson, S.G., Deeks, J.J., Altman, D.G. 2003. Measuring inconsistency in meta-analyses. BMJ 327(7414), 557-560. Epub 2003/09/06. doi: 10.1136/bmj.327.7414.557. PubMed PMID: 12958120; PubMed Central PMCID: PMCPMC192859.

Haidich, A.-B., 2010. Meta-analysis in medical research. Hippokratia. 14 (Suppl 1), 29.

Alves, M.S., Andrade, R.Z., Silva, G.C., Mota, M.C., Resende, S.G., Teixeira, K.R., et al., 2017. Social jetlag among night workers is negatively associated with the frequency of moderate or vigorous physical activity and with energy expenditure related to physical activity. J. Biol. Rhythms 32 (1), 83–93.

da Silva Garcez, A., Canuto, R., Vieira Paniz, V.M., Anselmo Olinto, B., Macagnan, J., Liane Henn, R., et al. 2015. Association between work shift and the practice of physical activity among workers of a poultry processing plant in Southern Brazil. Nutr. Hosp. 31(5), 2174-2181. Epub 2015/05/02. doi: 10.3305/nh.2015.31.5.8628. PubMed PMID: 25929390.

Panczyk, M., Woynarowska-Sołdan, M., Żmuda-Trzebiatowska, H., Gotlib, J., 2018. Health-enhancing behaviours of nurses in Poland and their association with shift work and age. Collegian 25 (3), 255–261.

Park, H., Suh, B. 2020. Association between sleep quality and physical activity according to gender and shift work. J. Sleep Res. 29(6), e12924. Epub 2019/11/30. doi: 10.1111/jsr.12924. PubMed PMID: 31782219.

Nam, S., Lee, S.-J., 2016. Occupational factors associated with obesity and leisure-time physical activity among nurses: a cross sectional study. Int. J. Nurs. Stud. 57, 60–69.

Sugiura, T., Dohi, Y., Takagi, Y., Yoshikane, N., Ito, M., Suzuki, K., et al., 2020. Impacts of lifestyle behavior and shift work on visceral fat accumulation and the presence of atherosclerosis in middle-aged male workers. Hypertension Res. 43 (3), 235–245.

Hulsegge, G., Proper, K.I., Loef, B., Paagman, H., Anema, J.R., van Mechelen, W., 2021. The mediating role of lifestyle in the relationship between shift work, obesity and diabetes. Int. Arch. Occup. Environ. Health 1–9.

Neil-Sztramko, S.E., Gotay, C.C., Demers, P.A., Campbell, K.L., 2016. Physical activity, physical fitness, and body composition of Canadian shift workers: data from the Canadian Health Measures Survey Cycles 1 and 2. J. Occup. Environ. Med. 58 (1), 94–100.

Loef, B., van der Beek, A.J., Hulsegge, G., van Baarle, D., Proper, K.I., 2020. The mediating role of sleep, physical activity, and diet in the association between shift work and respiratory infections. Scand. J. Work Environ. Health 46 (5), 516.

Peplonska, B., Bukowska, A., Sobala, W. 2014. Rotating night shift work and physical activity of nurses and midwives in the cross-sectional study in Łódź, Poland. Chronobiol. Int. 31(10), 1152-1159. Epub 2014/09/13. doi: 10.3109/07420528.2014.957296. PubMed PMID: 25216072.

Vlahoyiannis, A., Karali, E., Giannaki, C.D., Karioti, A., Pappas, A., Lavdas, E., et al., 2021. The vicious circle between physical, psychological, and physiological characteristics of shift work in nurses: a multidimensional approach. Sleep Breath. https://doi.org/10.1007/s11325-021-02381-5. PubMed PMID: 33864583. Epub 2021/04/18.

Tada, Y., Kawano, Y., Maeda, I., Yoshizaki, T., Sunami, A., Yokoyama, Y., et al. 2014. Association of body mass index with lifestyle and rotating shift work in Japanese female nurses. Obesity (Silver Spring). 22(12), 2489-2493. Epub 2014/09/25. doi: 10.1002/oby.20908. PubMed PMID: 25251576.

Clark, B.K., Kolbe-Alexander, T.L., Duncan, M.J., Brown, W., 2017. Sitting time, physical activity and sleep by work type and pattern—The Australian Longitudinal Study on Women's Health. Int. J. Environ. Res. Public Health 14 (3), 290.

van de Langenberg, D., Vlaanderen, J.J., Dollé, M.E., Rookus, M.A., van Kerkhof, L.W., Vermeulen, R.C., 2019. Diet, physical activity, and daylight exposure patterns in night-shift workers and day workers. Ann. Work Exposures Health 63 (1), 9–21.

Lauren, S., Chen, Y., Friel, C., Chang, B.P., Shechter, A., 2020. Free-living sleep, food intake, and physical activity in night and morning shift workers. J. Am. College Nutr. 39 (5), 450–456.

Vandelanotte, C., Duncan, M.J., Short, C., Rockloff, M., Ronan, K., Happell, B., et al., 2013. Associations between occupational indicators and total, work-based and leisure-time sitting: a cross-sectional study. BMC Public Health 13 (1), 1–8.

Guthold, R., Stevens, G.A., Riley, L.M., Bull, F.C., 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1· 9 million participants. Lancet Global Health 6 (10), e1077–e1086.

Zafiropoulos, B., Alison, J.A., Heard, R., 2019. Physical activity levels of allied health professionals working in a large Australian metropolitan health district - an observational study. J. Multidiscip. Healthc. 12, 51–62. https://doi.org/10.2147/JMDH.S189513. PubMed PMID: 30655673.

Cillekens, B., Lang, M., van Mechelen, W., Verhagen, E., Huysmans, M.A., Holtermann, A., et al. 2020. How does occupational physical activity influence health? An umbrella review of 23 health outcomes across 158 observational studies. Br. J. Sports Med. 54(24), 1474-1481. Epub 2020/11/27. doi: 10.1136/bjsports-2020-102587. PubMed PMID: 33239353.

Gupta, N., Dencker-Larsen, S., Lund Rasmussen, C., McGregor, D., Rasmussen, C.D.N., Thorsen, S.V., et al., 2020. The physical activity paradox revisited: a prospective study on compositional accelerometer data and long-term sickness absence. Int. J. Behav. Nutr. Phys. Activity 17 (1), 93. https://doi.org/10.1186/s12966-020-00988-7.

Dalene, K.E., Tarp, J., Selmer, R.M., Ariansen, I.K.H., Nystad, W., Coenen, P., et al. Occupational physical activity and longevity in working men and women in Norway: a prospective cohort study. The Lancet Public Health. doi: 10.1016/S2468-2667(21)00032-3.

Barone Gibbs, B., Kline, C.E., 2018. When does sedentary behavior become sleep? A proposed framework for classifying activity during sleep-wake transitions. Int. J. Behav. Nutr. Phys. Activity 15 (1), 81. https://doi.org/10.1186/s12966-018-0712-2.

Smith, L., McCourt, O., Sawyer, A., Ucci, M., Marmot, A., Wardle, J., et al. 2016. A review of occupational physical activity and sedentary behaviour correlates. Occup. Med. (Lond). 66(3), 185-192. Epub 2016/03/27. doi: 10.1093/occmed/kqv164. PubMed PMID: 27016747.

Dempsey, P.C., Biddle, S.J.H., Buman, M.P., Chastin, S., Ekelund, U., Friedenreich, C.M., et al. 2020. New global guidelines on sedentary behaviour and health for adults: broadening the behavioural targets. Int. J. Behav. Nutr. Phys. Act 17(1), 151. Epub 2020/11/27. doi: 10.1186/s12966-020-01044-0. PubMed PMID: 33239026; PubMed Central PMCID: PMCPMC7691115.

Waters, T.R., Dick. R.B. 2015. Evidence of health risks associated with prolonged standing at work and intervention effectiveness. Rehabilitation nursing: the official journal of the Association of Rehabilitation Nurses. 40(3), 148-165. Epub 2014/07/07. doi: 10.1002/rnj.166. PubMed PMID: 25041875.

Haslam, C., Kazi, A., Duncan, M., Clemes, S., Twumasi, R., 2019. Walking Works Wonders: a tailored workplace intervention evaluated over 24 months. Ergonomics 62 (1), 31–41. https://doi.org/10.1080/00140139.2018.1489982.

Messenger J. Working time and the future of work. ILO future of work research paper series. 2018.

Rajaratnam, S.M.W., Arendt, J., 2001. Health in a 24-h society. Lancet 358 (9286), 999–1005. https://doi.org/10.1016/S0140-6736(01)06108-6.