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ORIGINAL ARTICLE

Comparison of adult shift and non-shift workers' physical activity and sleep behaviours: cross-sectional analysis from the Household Income and Labour Dynamics of Australia (HILDA) cohort

Matthew J. Fenwick[1,2] · Stina Oftedal[1,2] · Tracy L. Kolbe-Alexander[3,4,5] · Mitch J. Duncan[1,2]

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Abstract

Aim This study compares the pattern of physical activity and sleep between shift and non-shift workers using a novel physical activity–sleep index. By drawing from a diverse occupational population, this research aims to reduce any occupational specific biases which are prevalent in shift-work research.

Subject and methods Current data included 7607 workers (shift workers $n = 832$) from the Household Income and Labour Dynamics of Australia cohort study. The combined physical activity–sleep index comprised three physical activity components and three sleep health components: achieving moderate (1pt) or high (2pts) IPAQ classification; accruing ≥30% of physical activity as vigorous intensity (1pt); meeting sleep duration recommendations on a work night (1pt); and non-work night (1pt); and reporting no insomnia symptoms (1pt) (higher score = healthy behaviour, max. 6). Generalised linear modelling was used to compare behaviours of shift and non-shift workers.

Results Findings showed shift workers reported significantly lower activity–sleep scores (3.59 vs 3.73, $p < 0.001$), lower sleep behaviour sub-score (2.01 vs. 2.22, $p < 0.001$) and were more likely to report insomnia symptoms ($p < 0.001$) compared to non-shift workers. No difference was reported for overall physical activity (shift = 1.58 vs. non-shift = 1.51, $p = 0.383$).

Conclusion When viewed in conjunction using the combined activity–sleep index, shift workers displayed significantly poorer combined behaviours when compared to non-shift workers.

Keywords Occupational health · Health Behaviour · Population Health · Shiftwork · Physical activity · Sleep

Introduction

Shift workers have an increased risk of chronic disease, including type 2 diabetes, hypertension, cardiovascular disease, selected cancers and all-cause mortality, compared to their day worker counterparts (Gu et al. 2015; Knutsson and Kempe 2014; Manohar et al. 2017; Moreno et al. 2019; Torquati et al. 2018; Wang et al. 2015). Shift work is typically defined as working outside the usual 6 am to 6 pm working day, and often involves some component of night work (Kecklund and Axelsson 2016; Torquati et al. 2019). Being awake for long periods at night predisposes individuals to a variety of biological and social factors which impacts on their ability to engage in adequate physical activity and achieve good sleep health (i.e. a duration, quality and timing of sleep that leaves a person feeling refreshed during the day) (Buysse 2014; Neil-Sztramko et al. 2014). These risk factors include disrupted circadian rhythms due to the non-diurnal working roster of shift work (Akerstedt and Wright

✉ Mitch J. Duncan
Mitch.Duncan@newcastle.edu.au

1 School of Medicine & Public Health; Faculty of Health and Medicine, The University of Newcastle, University Drive, Callaghan, NSW 2308, Australia

2 Priority Research Centre for Physical Activity and Nutrition, The University of Newcastle, University Drive, Callaghan, NSW 2308, Australia

3 School of Health and Wellbeing, University of Southern Queensland, Road Ipswich, Salisbury, QLD 4305, Australia

4 School of Human Movement and Nutrition Sciences, The University of Queensland, Brisbane, Australia

5 Division of Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa

Jr. 2009) and reduced opportunity for exercise and social activity (Atkinson and Davenne 2007; Atkinson et al. 2008). As a consequence of the greater chronic disease risk, shift workers are an identified 'at risk' population (Boggild and Knutsson 1999). Yet shift work remains an essential aspect of the labour force, with an estimated 2.0 million Australians (19%) employed in shift work, with similar proportions in the EU (21%) and USA (18%) (Alterman et al. 2013; Australian Bureau of Statistics 2019; Parent-Thirion et al. 2016).

Two modifiable behaviours which promote better health outcomes and reduce chronic disease risk are physical activity and good sleep health (St-Onge et al. 2016; Warburton and Bredin 2017). Well established evidence demonstrates that longer durations of moderate and vigorous intensity physical activity (MVPA) reduces the risk of many chronic diseases, with greater benefits obtained through participation in vigorous intensity physical activity (Lee et al. 2012; Rey Lopez et al. 2019; Shiroma et al. 2014). Also, both shorter and longer than recommended sleep durations, poor sleep quality and sleep disturbances are associated with increased chronic disease risk (Buysse 2014). Although many studies typically examine these components of sleep separately (i.e., sleep duration, or sleep quality), it is now recognised that overall sleep health is important for reducing the risk of poor health outcomes (Lallukka et al. 2018).

Previous research demonstrates shift workers report shorter sleep duration on work days compared to day workers, with no difference on non-work days (Clark et al. 2017; Varela-Mato et al. 2017). Furthermore, while evidence exists that total physical activity does not significantly vary between shift and non-shift workers, there is mixed results on the level of engagement of moderate-to-vigorous intensity physical activity (Loprinzi 2015; Neil-Sztramko et al. 2016; Roskoden et al. 2017). Current evidence suggests many of these variations in physical activity intensity are attributed to occupational demands, rather than shift work directly (Kolbe-Alexander et al. 2019); however, further research is required to better understand these differences.

Existing studies that examine the physical activity and sleep of shift workers, have reported these behaviours separately (Flahr et al. 2018; Kecklund and Axelsson 2016), with few studies examining both physical activity and sleep within the same study (Clark et al. 2017; Kolbe-Alexander et al. 2019; Varela-Mato et al. 2017). It is important to examine physical activity and sleep together as they are known to co-occur, with a bi-directional relationship occurring between these behaviours (Ding et al. 2015; Kline 2014; Oftedal et al. 2019; Rayward et al. 2017). Furthermore, there is growing interest in how the overall pattern of physical activity and sleep can influence health and wellbeing (Duncan et al. 2018; Grgic et al. 2018; Keadle et al. 2019; Kline 2014; Rosenberger et al. 2019). Exploring the differences in health behaviour patterns between shift workers and non-shift workers can inform the development of potential interventions for shift workers. Therefore, the primary aim of this study was to examine differences in a combined physical activity–sleep health score between shift and non-shift workers. The secondary aims were to compare the physical activity and sleep behaviour as separate behaviours between shift and non-shift workers.

Methods

Participants

Human ethics approval for the HILDA study is retained under the Human Research Ethics Committee of The University of Melbourne [ID: 1647030]. Data from 23,415 survey participants were taken from wave 17 of the Household Income and Labour Dynamics of Australia (HILDA) study which is an annual longitudinal survey of Australian households. Participants under 18 years old ($n = 5482$), not in the work force ($n = 7074$), with a non-defined working structure outside shift or non-shift work ($n = 1509$) were excluded, leaving 9350 adult workers (*S. Fig. 1*). Only participants with complete data were included in the final analysis ($n = 7607$).

Work schedule

Work schedule was determined by the single item question 'Which of these best describes your current work schedule in your job?', with seven response options of 'A regular daytime schedule', 'A regular evening shift', 'A regular night shift', 'A rotating shift', 'On call', 'Split shifts' or 'Irregular shifts'. Responses were subsequently collapsed into day/non-shift work ('A regular daytime schedule', $n = 6775$) and night/rotating shift work ('A regular night shift' or 'A rotating shift', $n = 832$). A key determinant of shift work was work which involved circadian disruption (Sallinen and Kecklund 2010). Whilst 'On call', 'Split shifts' or 'Irregular shifts' could disrupt circadian rhythms, HILDA does not collect additional defining information on these schedules; therefore, a pragmatic decision was made to omit these work schedules. Participants also reported the number of hours worked in an average week.

Physical activity behaviours

Physical activity was assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF) which quantifies the duration and frequency of walking, moderate and vigorous intensity physical activity in the previous week. Using standard IPAQ metabolic equivalent tasks (MET) values of 3.3, 4.0 and 8.0 for walking, moderate and

vigorous intensity physical activity, respectively, weekly MET-minutes of walking, moderate, vigorous and total weekly MET-minutes was calculated (Craig et al. 2003). Standard IPAQ scoring protocols were used to classify participants' physical activity as low, moderate or high (Bauman et al. 2009; Craig et al. 2003).

Sleep health behaviours

Three indicators of sleep were assessed: (1) sleep duration on work-days, (2) sleep duration on non-work days and (3) presence of insomnia symptoms. Two items were used to assess sleep duration on work and non-work days among shift and non-shift workers and three items to assess insomnia symptoms. The exact wording of the items is shown in supplementary material A.

Participants were classified as either meeting or not meeting age-appropriate sleep duration, on work and non-work days separately, according to the sleep health foundation guidelines (Hirshkowitz et al. 2015). For those aged <65 years, 7–9 hours sleep per night was considered 'meeting' recommendations, for those aged ≥65 years, 7–8 hours of sleep was considered meeting recommendations (Hirshkowitz et al. 2015). Sleeping either shorter or longer than recommended duration was combined into 'not meeting age-appropriate sleep duration' due to the low proportion of non-shift ($n = 333$, 6.6%) and shift workers ($n = 42$, 7.7%) reporting longer than recommend sleep durations.

A dichotomous indicator of insomnia symptoms was created based on the frequency of difficulties initiating and maintaining sleep and overall sleep quality. Participants reported the frequency that they 'Had trouble sleeping because you cannot get to sleep within 30 minutes' and 'Had trouble sleeping because you wake up in the middle of the night or early in the morning' on a five-point scale of 'Not during past month', 'Less than once a week', 'Once or twice a week', 'Three or four times a week' and 'Five or more times a week'. Sleep quality was assessed using a single item 'In the past month, how would you rate your sleep overall', with participants responding either 'very good', 'fairly good', 'fairly bad' or 'very bad' sleep quality. Participants were classified as having insomnia symptoms if they reported difficulty getting to sleep or maintaining sleep three or more times a week *AND* fairly bad or worse sleep quality, while those not meeting these criteria were classed as not having insomnia symptoms (Buysse et al. 2006; Lichstein et al. 2003).

Combined physical activity/sleep health measure

A combined physical activity and sleep index was created, comprising three physical activity components and three sleep health components. The total score ranged from 0 to 6, with 6 reflecting more positive health behaviours. Given the dose response relationship between higher levels of physical activity and reduced risk of mortality (Rhodes et al. 2017), and evidence that accumulating a greater proportion of total physical activity in vigorous intensity physical activity confers additional health benefits (Shiroma et al. 2014), a higher physical activity score reflected both of these aspects. Using standard IPAQ protocols (Bauman et al. 2009), individuals who were classified as low, moderate or high received a score of zero, one or two points, respectively. Additionally, any participant who accumulated 30% or more of their physical activity through vigorous intensity physical received an additional point, irrespective of the total volume of physical activity reported. Sleep health behaviour was also scored from zero to three and criteria included: one point for meeting age-appropriate sleep duration during work days, one point for meeting age appropriate sleep duration during non-work days (Hirshkowitz et al. 2015) and one point for reporting no insomnia symptoms.

Socio-demographic, behavioural and health-risk indicators

Participants reported their age, sex and occupational level which was subsequently classified as either 'managers and professionals', 'blue collar workers' and 'white collar workers' (Australian Bureau of Statistics 2013; Duncan et al. 2010). Highest level of education was classified as 'high school completion', 'certificate/diploma' and 'bachelor's degree or higher'. Marital status dichotomised into 'partnered' (married/de-facto) or 'not partnered' (single, widowed, separated or divorced).

Body mass index was calculated from self-reported height and weight data and categorised as <18.5 kg/m^2, 18.5–24.9 kg/m^2, 25.0–29.9 kg/m^2 and ≥30 kg/m^2 (Grossschadl et al. 2012). Smoking status was assessed using a single item and categorised as 'never smoked', 'previous smoker' and 'current smoker'. Alcohol consumption was measured by the frequency of weekly consumption (in days), and was categorised as 'non-drinker', 'infrequent drinker' (<5 days per week) and 'frequent drinker' (≥5 days per week). Dietary consumption behaviours were measured by a core food score (0 to 19) and non-core food score (0 to 12), where a higher score indicates greater dietary variety and adherence to dietary recommendations, and a greater consumption of discretionary foods, respectively (Oftedal et al. 2020). Core food consumption was evaluated by the frequency of consumption of sources of protein and grains, fruit and vegetables, low fat dairy and reduced salt intake (Oftedal et al. 2020). Non-core food consumption was evaluated by frequency of consumption of confectionary and cake, take-away food, snack food and processed meats (Oftedal et al. 2020). Self-rated health was assessed using a single item 'In general, would you say your health is: excellent, very good,

good, fair and poor'. These responses were collapsed into 'excellent to very good health', 'good health' and 'fair to poor health'. Participants self-reported one or more clinically diagnosed chronic disease, including heart disease, hypertension, any other serious circulatory condition (e.g. stroke), cancer, diabetes (type 1 or 2), chronic bronchitis or emphysema, arthritis or osteoporosis, asthma, depression, anxiety or any other mental illness. The presence of one or more of these chronic conditions was dichotomised as either 'no chronic disease' or 'one or more chronic diseases'. Mental health was assessed via the Mental Health Inventory-5 (MHI-5) questionnaire (Berwick et al. 1991) which was scored from 0 to 100 with higher scores reflecting better mental health (i.e. fewer symptoms of depression and anxiety) (Cuijpers et al. 2009).

Statistical analysis

Participant characteristics of shift and non-shift workers were examined and compared using Pearson's chi-squared tests for categorical variable and t-test for continuous variables. Generalised linear models were used to examine associations between the type of work schedule and the activity–sleep index, activity score, accumulating >30% of activity in vigorous activity, sleep score and the separate components of the sleep score. The choice of model was informed by residual diagnostics. Associations between shift type and the IPAQ classification of physical activity level (low, moderate, high) was examined using multinomial logistic regression. As studies have reported differences between shift and non-shift workers in walking activity (Loef et al. 2018; Loprinzi 2015), and mixed results for moderate and vigorous intensity activity (Neil-Sztramko et al. 2016; van de Langenberg et al. 2019; Varela-Mato et al. 2017), exploratory analyses also examined differences between shift type and the following activity outcomes: MET-minutes of walking, MET-minutes of moderate intensity activity and MET-minutes of vigorous intensity activity. Analyses were adjusted for the following covariates: age, sex, highest education, occupation, hours worked, marital status, core food consumption, non-core food consumption, alcohol consumption, smoking status, MHI-5 score, self-rated health, presence of chronic illness and BMI category. These covariates were selected to reduce the risk of confounding as they are commonly associated with both physical activity and sleep and may differ between shift and non-shift working populations. All analyses were conducted using STATA 15 (StataCorp., TX) and an alpha level of 0.05.

Results

Descriptive statistics of the study population, stratified by work schedule, are reported in Table 1. Shift workers represented 10.9% ($n = 832$) of the participants. Demographic characteristics of included and excluded participants are reported in Supplementary Table 1. In brief, included participants were younger, tertiary educated, consumed more alcohol and rated their health better than excluded participants

When assessing the combined patterns of physical activity and sleep health, shift work was significantly associated with a decreased activity–sleep score compared to non-shift work (shift: M = 3.59, SE = 0.05; non-shift: M = 3.73, SE = 0.02, $p = 0.006$) (Table 2). The results of the full model including the associations between covariates with the activity–sleep score are shown in Supplementary Table 3.

Shift workers and non-shift workers displayed similar physical activity scores (shift: M = 1.58, SE = 0.04; non-shift: M = 1.51, SE = 0.01, $p = 0.107$) (Table 2). However, shift workers were more likely be classed in the high IPAQ classification compared to non-shift workers (OR = 1. 41, 95% CI 1.17, 1.71) but there was no association between work schedule and moderate IPAQ classification (OR = 1.09, 95% CI 0.89, 1.33) (*S. Table 4*). Shift workers were less likely to accumulate >30% vigorous intensity activity compared to non-shift workers (OR = 0.81, 95% CI 0.69, 0.95) (Table 3).

Relative to non-shift workers, shift workers had a significantly lower sleep score (shift: M = 2.01, SE = 0.03; non-shift: M = 2.22, SE = 0.01, $p < 0.001$; Table 2). A lower proportion of shift workers met age-appropriate sleep duration guidelines on work nights (OR = 0.51, 95% CI 0.48, 0.55) compared to non-shift workers; however, no significant difference was observed for non-work days (OR = 0.91, 95% CI 0.77, 1.07) (Table 3). Shift workers were significantly more likely to report insomnia symptoms or sleep difficulties than non-shift workers (OR = 1.40, 95% CI 1.12, 1.75) (Table 3).

Exploratory analyses comparing shift and non-shift workers MET minutes of walking, moderate and vigorous intensity physical activity are presented in Supplementary Table 2. Shift workers reported significantly more walking activity (M = 1181.4, SE = 38.5) compared with non-shift workers (M = 862.5, SE = 13.4, $p<0.001$). No differences were observed between shift workers moderate or vigorous physical activity (Moderate: M = 807.0, SE = 48.0; Vigorous: M = 1055.2, SE = 78.8) when compared with non-shift workers (Moderate: M =720.3SE = 15.5, $p = 0.08$; Vigorous M = 1179.0, SE = 25.5, $p = 0.136$).

Discussion

The aim of this study was to compare the combined physical activity and sleep behaviours of shift workers using a novel activity–sleep score. Results indicate shift workers displayed a significantly lower activity–sleep score compared to non-shift workers, suggesting that shift workers engage in a

Table 1 Descriptive demographics of HILDA sample population stratified by shift type

Participant Characteristics		Shift work $N = 832$	Non-shift work $N = 6775$	p-value
Age (years ± SD; range 18–83)		37.78 (13.85)	41.65 (13.36)	<0.001
Gender n(%)	Male	427 (51.3%)	3,469 (51.2%)	0.95
	Female	405 (48.7%)	3,306 (48.8%)	
Occupation n(%)	Managers	208 (25.0%)	2,967 (43.8%)	<0.001
	White collar	368 (44.2%)	2,048 (30.2%)	
	Blue collar	256 (30.8%)	1,760 (26.0%)	
Hours worked per week (± SD; range 1 - 80)		36.84 (13.61)	37.74 (12.84)	0.060
Education n(%)	High School	283 (34.0%)	1,906 (28.1%)	<0.001
	Cert/Diploma	340 (40.9%)	2,360 (34.8%)	
	University	209 (25.1%)	2,509 (37.0%)	
Current partner n(%)	No partner	321 (38.6%)	1,864 (27.5%)	<0.001
	Has partner	511 (61.4%)	4,911 (72.5%)	
Alcohol consumption n(%)	Frequent drinker	68 (8.2%)	873 (12.9%)	<0.001
	Infrequent drinker	644 (77.4%)	5,105 (75.4%)	
	Non/previous drinker	120 (14.4%)	797 (11.8%)	
Smoking status n(%)	Current smoker	158 (19.0%)	1106 (16.3%)	0.098
	Previous smoker	198 (23.8%)	1765 (26.1%)	
	Never smoked	476 (57.2%)	3904 (57.6%)	
Core-food consumption (score ± SD)	0–19[‡]	11.19 (3.00)	11.65 (3.02)	<0.001
Non-core food consumption (score ± SD)	0–12[†]	4.99 (2.38)	4.73 (2.34)	0.002
BMI n(%)	<18.5 kg/m^2	17 (2.0%)	91 (1.3%)	0.080
	18.5–24.9 kg/m^2	300 (36.1%)	2610 (38.5%)	
	25.0–29.9 kg/m^2	292 (35.1%)	2460 (36.3%)	
	≥30 kg/m^2	223 (26.8%)	1614 (23.8%)	
Self-rated health status n(%)	Fair/Poor	97 (11.7%)	675 (10.0%)	0.31
	Good	296 (35.6%)	2445 (36.1%)	
	Excellent/Very Good	439 (52.8%)	3655 (53.9%)	
Chronic disease n(%)	No chronic disease	527 (63.3%)	4327 (63.9%)	0.77
	1 or more chronic diseases	305 (36.7%)	2448 (36.1%)	
Mental Health Index-5	0–100	73.635 (17.129)	74.816 (15.991)	0.046

Table 2 Comparison of activity and sleep index scores between shift and non-shift workers

	Non-shift M (SE)	Shift M (SE)	p-value
Activity–sleep score	3.73 (0.02)	3.59 (0.05)	0.006
Physical activity sub-score	1.51 (0.01)	1.58 (0.04)	0.107
Sleep sub-score	2.22 (0.01)	2.01 (0.03)	< 0.001

Analysis conducted using generalized linear models (Gaussian family, identity link) and adjusted for the following covariates; age, sex, highest level of education, occupation, hours worked per week, marital status, core and non-core food consumption, alcohol consumption frequency, smoking status, MHI-5 score, self-rated health, chronic illness and BMI

poorer overall pattern of sleep and physical activity. Specifically, although shift worker was more likely to be classified as highly active, they were less likely to engage in at least 30% vigorous intensity physical activity, less likely to meet age-appropriate sleep duration on workdays and more likely to report insomnia symptoms. To our knowledge, this is the first study to examine how shift and non-shift workers differ in their overall pattern of physical activity and sleep behaviours. These findings are novel as previous studies have demonstrated that shift workers display both reduced physical activity behaviour and poorer sleep patterns when examined as separate behaviours (Flahr et al. 2018; Kecklund and Axelsson 2016; To et al. 2013). However few studies examine the overall pattern of activity–sleep between these groups. This simple yet descriptive snapshot of shift worker activity–sleep health provides initial insight on potential behaviours to target in intervention seeking to improve the activity–sleep behaviours of shift and non-shift workers.

Current findings indicate that shift workers reported poorer indicators of sleep health, evidenced by being more likely to report insomnia symptoms (22.5% compared to

Table 3 Comparison of shift and non-shift workers sleep health behaviour and physical activity behaviour

	Non-shift workers ($N = 6775$)	Shift workers ($N = 832$)	Non-shift workers	Shift workers	
	N(%)	N(%)	Ref	OR (95% CI)	*p*-value
≥30% vigorous physical activity	3392 (41.5%)	392 (37.5%)	REF	0.81 (0.69, 0.95)	0.026
Meeting age -appropriate sleep duration on work night	4531 (66.1 %)	433 (52.2%)	REF	0.51 (0.48, 0.55)	< 0.001
Meeting age-appropriate sleep duration on non-work night	4984 (73.6%)	581 (69.8%)	REF	0.91 (0.77, 1.07)	0.282
Presence of insomnia symptoms	1207 (17.8%)	187 (22.5%)	REF	1.40 (1.12, 1.75)	< 0.001

A generalised linear model (Binomial family, logit link) was used to attain odds ratios (OR) and were adjusted for the following covariates; age, sex, highest level of education, occupation, hours worked, marital status, core and non-core food consumption, alcohol consumption frequency, smoking status, MHI-5 score, self-rated health, chronic illness and BMI.

17.8% for non-shift workers; OR = 1.40) and less likely to meet age-appropriate sleep durations on work days (52.2% compared to 66.1%; OR = 0.51). These findings support existing literature which report that shift workers are more likely to report poor sleep quality (Akerstedt 2003; Akerstedt and Wright Jr. 2009) and are significantly less likely to meet sleep duration guidelines during work days (Vincent et al. 2016). Importantly, reduced sleep duration was only reported on working days, with no significant difference observed on non-work days. This finding is consistent with suggestions that the effect shift work has on sleep duration is greatest during periods involving work nights, but is less profound during periods of non-work nights (Kecklund and Axelsson 2016). As sleeping less than seven hours per night is associated with adverse health outcomes, such as increased risk of mortality and cardio-metabolic disease (Itani et al. 2017; Vincent et al. 2017) and an increased likelihood of occupational accidents and injury (Kecklund and Axelsson 2016), these findings suggest that among shift workers who report short sleep on work days, interventions which promote increased sleep duration on work nights have the potential to provide health and occupational benefits. However, it is acknowledged that shift work is likely one of many barriers inhibiting good sleep, with others including family and social commitments (Paterson et al. 2019; Vincent et al. 2020).

Shift workers were less likely to accumulate 30% of their activity as vigorous intensity activity, but more likely to be classified as highly physically active. This appears to be due to their increased volume of walking as there were no between-groups difference for moderate or vigorous physical activity (*S.* Table 2). The higher levels of walking among shift workers and a lack of difference between shift and non-shift workers in moderate and vigorous intensity physical activity is consistent with previous studies (Loef et al. 2018; Loprinzi 2015; Neil-Sztramko et al. 2016; van de Langenberg et al. 2019; Varela-Mato et al. 2017). In light of the greater mortality risks observed in shift workers and the health benefits obtained from accumulating greater proportions of overall activity in vigorous intensity activity (Gu et al. 2015; Lee et al. 2012; Rey Lopez et al. 2019; Shiroma et al. 2014), increasing the proportion of physical activity in vigorous intensity that shift workers engage in could be a useful intervention target. This is not to discount the well documented health benefits associated with walking and moderate intensity activity, which may be most beneficial for those currently not engaged in regular exercise. Importantly, the measure of activity used in the current study was unable to distinguish the domain of activity (e.g. occupational, transport, leisure). Examining the activity domain in future studies is likely to help better understand the activity–sleep patterns shift workers engage in given that other studies have reported significant differences in the activity levels between shift and non-shift workers depending on the domain of activity examined (Esquirol et al. 2009; Loef et al. 2018; Roskoden et al. 2017).

Strengths and limitations

Strengths of the study include examining the novel activity–sleep index which included multiple indicators of sleep health, as many existing studies only examine average sleep duration. As the study population were workers, the ability to discriminate and assess sleep between work and non-work days was an important element in reporting on indicators of sleep health. Finally, as the HILDA study is designed to collect detailed nationally representative data on household income and labour dynamics it is well suited to examining the different occupational exposures such as shift work.

An important consideration of the results presented is the cross-sectional nature of the study, and magnitude of the effects observed. Although shift workers displayed significantly poorer activity–sleep scores, physical activity and sleep health measures, the magnitude of these differences were modest. In addition, all data were self-reported and is subject to recall bias, which may be overcome through the

use of accelerometers in future studies (Loef et al. 2018; Reid et al. 2018; Skotte et al. 2014). Finally, the exclusion of irregular, on-call and split-shift workers may limit the generalisability of these findings and may result in potentially similar at-risk workers not being represented within the study data.

Conclusion

Using a novel measure for combined physical activity and sleep, shift workers reported significantly poorer combined physical activitysleep health behaviours compared to non-shift workers. In particular, shift workers were more likely to report shorter sleep on work days and insomnia symptoms, less likely to be highly active and report less vigorous intensity activity than non-shift workers. To explore these activity–sleep behaviours in greater depth, future research should include activity domains (e.g., occupational, transport, leisure) and objective measurement of both sleep and physical activity.

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Data availability This paper uses unit record data from Household, Income and Labour Dynamics in Australia Survey [HILDA] conducted by the Australian Government Department of Social Services (DSS). The findings and views reported in this paper, however, are those of the author[s] and should not be attributed to the Australian Government, DSS, or any of DSS' contractors or partners.

Code availability Not applicable

Declarations

Ethical statement This paper is an observational study, as such The University of Newcastle Research Ethics Committee has confirmed that no ethical approval is required. The data used in this research is drawn from the HILDA research project which has been approved by the Human Research Ethics Committee of The University of Melbourne [ID: 1647030].

Ethics approval Not Applicable

Consent to participate Not Applicable

Consent for publication All authors have read and agreed to the published version of the manuscript.

Conflict of interest The authors declare no conflicts of interest associated with this study.

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