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Ecological momentary assessment of physical activity and sedentary behaviour in shift workers and non-shift workers: Validation study

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ABSTRACT

This study examined the criterion validity of an ecological momentary assessment (EMA)-reported physical activity and sedentary time compared with accelerometry in shift workers and non-shift workers. Australian workers ($n = 102$) received prompts through a mobile EMA app and wore the Actigraph accelerometer on the right hip for 7–10 days. Participants received five EMA prompts per day at 3-hour intervals on their mobile phones. EMA prompts sent to shift workers (SW-T) were tailored according to their work schedule. Non-shift workers (NSW-S) received prompts at standardised times. To assess criterion validity, the association of EMA-reported activities and the Actigraph accelerometer activity counts and number of steps were used. Participants were 36 ± 11 years and 58% were female. On occasions where participants reported physical activity, acceleration counts per minute (CPM) and steps were significantly higher (β = 1184 CPM, CI 95%: 1034, 1334; β = 20.9 steps, CI 95%: 18.2, 23.6) than each of the other EMA activities. Acceleration counts and steps were lower when sitting was reported than when no sitting was reported by EMA. Our study showed that EMA-reported physical activity and sedentary time was significantly associated with accelerometer-derived data. Therefore, EMA can be considered to assess shift workers' movement-related behaviours with accelerometers to provide rich contextual data.

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Accelerometer; Ecological Momentary Assessment (EMA); physical activity; sedentary behaviour; shift work

Introduction

Shift work involves any work done outside 9 am to 5 pm during weekdays (Costa, 2003), to accommodate the demand of a 24/7 economy. This can encompass work in the early morning, evening and night or rotating shifts (Rampling et al., 2022). While shift work is important in many industries like healthcare, transport, manufacturing and mining, it has been associated with adverse health outcomes (Q. J. Wu et al., 2022). Several systematic reviews indicate that shift work is related to increased risk of metabolic syndrome (Sooriyaarachchi et al., 2022), cardiovascular diseases (Torquati et al., 2018), cancers (Wei et al., 2022), type 2 diabetes (Ismail et al., 2021) and other adverse health outcomes (Su et al., 2021). Lifestyle behaviours are considered in part to be related to the increased risk of diseases and adverse health outcomes in shift workers (Nea et al., 2015).

Evidence on the impact of shift work on lifestyle behaviours including physical activity and sedentary behaviour present mixed results. When compared to non-shift workers, studies have reported negative (Mansouri et al., 2022), positive (Peplonska et al., 2014) and no influence (Hulsegge et al., 2017; Lauren et al., 2020) on the impact of level of physical activity. For example, shift work was associated with high-intensity physical activity using the 7-day physical activity recall questionnaire, among police officers (Ma et al., 2011). In another study using accelerometers, shift workers in the healthcare industry spent more time walking than non-shift workers. However, there were no differences in other types of physical activity (Loef et al., 2018). Similarly, some studies showed that sedentary behaviour did not differ between shift and non-shift workers (Alves et al., 2017), while others reported it to be less in shift workers than non-shift workers (Loef et al., 2018; Loprinzi, 2015), and some showed it to be more in shift workers (Mansouri et al., 2022). Measurement tools used to assess physical activity and sedentary behaviour may contribute to these equivocal results (Loef et al., 2018). Our recent systematic review shows a range of self-report tools, including the Active Australia Questionnaire, Workforce Sitting Questionnaire and International Physical Activity Questionnaire (IPAQ) that were used (Monnaatsie et al., 2021).

Monitoring physical activity and sedentary behaviour by self-report measures remains the most practical method for research studies especially for national surveillance systems (Prince et al., 2020). However, retrospective self-report measures present recall and social desirability biases (Althubaiti, 2016; Cleland et al., 2018). Accelerometers such as ActiGraph, activPAL and Actical accelerometers were also used less

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frequently than self-report measures (Monnaatsie et al., 2021). Accelerometers are designed to record acceleration and posture and consequently algorithms were developed to assess sitting, physical activity intensity and sleep-related behaviours (Skender et al., 2016). The use of accelerometers overcomes the recall-based limitations of retrospective self-report measures and provides accurate measurements of both physical activity and sedentary behaviour (Byrom et al., 2016; Pulsford et al., 2023). However, they also have limitations including the challenge to record the contexts of behaviour being assessed (Pulsford et al., 2023). Another disadvantage of accelerometers is that they are often not waterproof and need to be removed during water-based activities. Thus, individuals might forget to wear the accelerometer for a day(s) or part of day, resulting in non-wear time and missing data (Migueles et al., 2017). Recently, more studies are using real-time reporting of behaviours, using smartphones or web-based application commonly known as Ecological Momentary Assessment (EMA) (Knell et al., 2017).

EMA is a self-report method that involves repeated assessment of a behaviour in real time and the natural environment and is context specific (Degroote et al., 2020). In comparison to traditional self-report measures (e.g., survey recall), EMA eliminates recall bias and provides more contexts of movement behaviours that cannot be captured by devices (Knell et al., 2017). Recently, EMA methods employed smartphone applications to signal people to complete surveys to self-report their daily activities (Burke & Naylor, 2022). Smartphone EMA surveys provide the flexibility in designing data collection and can be customised to individual participants (de Vries et al., 2021). Additionally, using smartphones in EMA studies provides an opportunity to match timestamped EMA data with device-based measures of physical activity and sedentary behaviour (Kracht et al., 2021).

Shift work presents unique work factors, atypical work hours and challenges. Therefore, understanding shift worker behaviour routines and context is vital to finding opportune intervention times and strategies suitable for their atypical work hours (Huggins et al., 2022). EMA has potential to expand our understanding of contextual and work factors. EMA has been validated previously in adults, children, office workers and older adults (Dunton et al., 2012; Knell et al., 2017; Maher et al., 2018; Pannicke et al., 2020; Weatherson et al., 2019). EMA showed more comparable results to device measures than retrospective self-report methods (Knell et al., 2017). Assessing physical activity and sedentary behaviour is based on the presumption that measurement tools are valid and reliable (Lines et al., 2020). Determining the validity, accuracy and quality of the methods is essential to correctly interpret results because measurement error may seriously impact study results (Bakker et al., 2020).

Despite EMA being validated in children and some adult populations, there is a paucity of data on the validity of EMA as an assessment tool for physical activity and sedentary behaviour in shift workers. Should EMA be a valid tool to assess physical activity and sedentary behaviour in shift workers, it would help to overcome challenges they face such as non-standard work patterns. Therefore, the primary aim of this study was to determine the validity of mobile EMA to physical activity and sedentary behaviour. Secondarily, we compared the validity of EMA between shift and non-shift workers.

Methods and materials

Study design

This study uses multiple EMA assessments (Reichert et al., 2020), among full-time shift and non-shift workers living in Brisbane, Australia. Participants were recruited from various workplaces via word of mouth by the research team and previously enrolled participants. The flyers were handed out at their workplaces and social media (Twitter and Facebook) posts. Eligible participants were provided with detailed information about the purpose and procedures of the study. Full-time workers ($n = 102$) were included for analysis, of which 51 were non-shift workers and 51 non-shift workers (rotating with some night work); the majority were nurses and paramedics, while most of non-shift workers were office workers. This study was approved by the University of Southern Queensland's Human Research Ethics Committee (H19REA056).

Data collection

The participants signed the consent form and were sent the link to download the EMA app and given instructions on how to use the EMA app. Participants were then given an Actigraph accelerometer and instructions on how to wear the device. Shift workers were enrolled in the study for 7–10 days to ensure data collected included their full shift rotation incorporated day, afternoon, evening and night shifts, as well as non-workdays. The non-shift workers participated for 7 days, allowing for measurement of activity during week and weekend days (Warren et al., 2010). A second meeting with participants was arranged to collect the accelerometers to download data. Participants were provided feedback at the end of the intervention and post assessment. The feedback included information related to their accelerometer data, including time spent sedentary and in physical activity, together with the results of their EMA responses. Participants also received health promotion materials and advice related to healthy lifestyles.

Measures

Questionnaire

Demographic information including age, gender, and marital status was obtained with a questionnaire. Marital status was coded as living with partner (married or living together) or not living with partner (single, widowed, separated or divorced). Health status was assessed with asking participants to describe their general health (excellent, good, average, poor very poor). Shift work status was assessed by asking participants to indicate their work shifts.

Anthropometric measures

Participants' body weight was measured using a Seca digital scale and height with a Seca 213 portable stadiometer (Seca GmbH & Co. Germany) (World Health Organisation [WHO],

1995). Height and weight were used to calculate Body Mass Index (BMI) using the standard formula, combining weight (kilograms) and height (metres^2). Waist circumference (to the nearest 0.5 cm) was measured by placing the measuring tape at the level of the last rib (Ross et al., 2020).

Ecological momentary assessment

The *SEMA* [3] app (Koval et al., 2019) available for iOS and Android devices delivered EMA prompts five times a day, at 3-hour intervals. The study period for shift workers was 7–10 days and 7 days non-shift workers, inclusive of work and non-workdays. Each participant received approximately 35–38 prompts depending on their individual length of study. Upon receiving the EMA prompt, participants completed the short survey on their phones for 1–2 min which disappeared after 30 minutes if unanswered.

The survey began with: *What were you doing in the few minutes before receiving this message?* Participants responded by choosing from the 11 options provided; *watching television, using mobile phone/computer, eating/drinking, exercise or physical activity, work duties, socializing, driving/travelling, sleeping and household/garden chores, caring for children and other*. Supplementary Figure S1 shows the EMA questions from mobile app. When they chose the exercise or physical activity option, the survey further requested them to report the type of physical activity. If participant's response option of the current activity included any activity that can be done sitting like using mobile/computer, caring for children, socializing or other, they were then asked to report if they were sitting or not. The survey also included questions about the location and time spent to do the activity. Survey responses were downloaded from the SEMA website in CSV files. The EMA prompting scheduled differed between the shift workers and non-shift workers and were delivered as follows:

(1) SW-T group ($n = 51$): Five tailored prompts were set according to each participant's work and awake patterns every 3 hours.
(2) NSW-S ($n = 51$): Five standardized EMA prompts were sent to participants every 3 hours between 10 am and 10 pm.

Device-based measure of physical activity and sedentary behaviour. Actigraph GT3X-BT (Actigraph corp Pensacola, FL) devices were used to measure physical activity and sedentary time. Participants were requested to wear the accelerometer on the right hip attached with an adjustable belt for a consecutive 7–10 days during waking hours (Morris et al., 2018). The Actigraph accelerometer recorded data at 30 Hz and data were downloaded in 1-minute epochs (John & Freedson, 2012). Cut points (sedentary <100 counts per minute CPM, light 100–1951 CPM, moderate 1952–5724 CPM and vigorous ≥ 5725 CPM) were used to classify activity intensity (Freedson et al., 1998) and vector magnitudes from Sasaki et al. (2011). Accelerometer data from valid wear time, defined as at least 10 hours of wear time per day, for at least four days, were included in analysis (Tudor-Locke et al., 2015). The accelerometer vector magnitude (counts per minute) and steps per minute recorded in the 15 minutes before receiving the EMA prompts were time stamped with the corresponding EMA data. The 15 minutes prior to each prompt was used based on previous research that assessed EMA validity in African American older adults (Maher et al., 2021). Additionally, we conducted sensitivity analyses using a time window ranging from 5 to 30 minutes before the prompt. Given the results remained unchanged, we chose to present the findings based on a 15-minute time window to maintain comparability with previous studies. EMA responses were excluded if the accelerometer activity values were zero (Dunton et al., 2012; Maher et al., 2021).

Statistical analysis

Descriptive statistics with mean and standard deviations for continuous variables, frequencies and percentages for categorical variables were reported. Accelerometer data were then time matched with corresponding EMA data. Box plots were constructed to show the variability and correspondence of EMA-reported activities with the matching accelerometer data. To determine the difference between the groups, Kruskal–Wallis test was used for the accelerometer and EMA data.

Linear regression was used to assess the association of EMA-reported physical activity and sedentary time. The dummy coded EMA-reported activities (10-level categorical variable) and sitting (yes/no) were used as the independent variables, and concurrent counts and steps per minute (measured by accelerometer) as the dependent variables. Categorical variables can be included in a regression approach by means of dummy variables (Holgersson et al., 2014). For the model testing differences in EMA-reported activities, contrasts were examined between the sleeping as the lowest intensity activity with the other EMA-reported activities (mobile/computer, watching TV, work duties, caring for children, socialising, chores, physical activity, others, eating/drinking and travelling and drinking). We regressed EMA-reported sitting versus no sedentary time with accelerometer-derived data. Analyses were performed using IBM SPSS Statistics version 27.0.

Results

Participant characteristics

We aimed to recruit the same number of workers in each group (shift and non-shift workers). Once we reached the equal number ($n = 55$) of workers, we stopped recruiting. In total, 110 workers were enrolled in the study, of which 8 with EMA issues were excluded for analysis. The majority of participants were female (58%), living with partner (60%) and overweight (27.9 ± 5.7 kg/m^2). The average age of participants was 36 (±10.6) years. Shift workers in our study were younger (30.5 ± 8.4 years) than non-shift workers (42.1 ± 11.3 years) on average. There were no demographic differences between shift and non-shift workers. The majority of the shift workers employed in health care (88%) comprising of mainly paramedics and

nurses doing rotating shifts. The non-shift workers were predominantly office workers (~90%).

Overall EMA compliance

On average, 64% of the prompts sent to participants were completed and 36% missed. Of the five prompts sent per day, participants answered the first prompt of the day frequently, and the last prompt was the least answered. Working at night resulted in less prompts answered than day and evening shifts in the shift work group. Non-shift workers answered more prompts during weekdays than weekends (non-workdays). There were no differences in overall completed prompts, missed prompts and time spent to complete the prompts between the two work groups ($p > 0.05$).

Accelerometer-based summaries

The average wear time was 6 (± 1.7) days in all workers and similar in shift and non-shift workers. Shift workers and non-shift workers spent an average of 217.5 (SD = 111.0) minutes and 234.0 (SD = 209.0) minutes on MVPA per week respectively ($p = 0.08$). Similarly, there were no differences in shift and non-shift workers' steps ($p = 0.12$), with 7143.1 (SD = 2201.3) and 7033.1 (SD = 2892.4) steps respectively. However, light-intensity physical activity was different ($p = 0.04$) between the shift (29.8%) and non-shift workers (33.9%). Workers spent ~ 64% of the time sedentary, and it was similar in the two groups (Supplementary Table S1).

Validity of EMA

Out of the 2917 completed EMA prompts, 2318 EMA prompts were time matched with accelerometer data. As shown in Figures 1 and 2, accelerometer activity counts and steps were highest in the two groups when physical activity was reported in the EMA app. In addition, the accelerometer activity counts were lower when sitting was reported. The median acceleration activity counts for EMA-reported physical activity in the SW-T group and NSW-S were 636 (25^{th}-75^{th}: 80–1279) and 1004 (25^{th}-75^{th}: 447–2365), respectively. The steps were also higher in EMA-reported physical activity than all other activities in the two groups with the median of 9.4 (25^{th}-75^{th}: 0.0–19.6) in SW-T and 16.3 (25^{th}-75^{th}: 4.1–25.1) in NSW-S.

EMA-reported sleep and mobile/computer use corresponded with the lowest activity counts in both the groups (see Figures 1 and 2). Another activity that showed lower acceleration counts than other EMA-reported activities was watching television. The median acceleration counts and steps were lowest when participants reported that they were sitting. In the SW-T, the median acceleration counts were 202 (25^{th}-75^{th}: 10.8–480) and 97 (25^{th}-75^{th}: 6.4–357) in the NSW-S group when sitting was reported. Similarly, the steps were lower with EMA-reported sitting than not sitting, 97 (25^{th}-75^{th}: 6.4–357) in the NSW-S group when sitting was reported.

The accelerometer-derived acceleration counts differed between all the EMA-reported activities and the reference activity (sleep) except for watching TV and using mobile/computer with the shift work (SW-T) and non-shift workers (NSW-S). On occasions where participants reported physical activity, the corresponding acceleration was highest in NSW-S ($B = 1405$

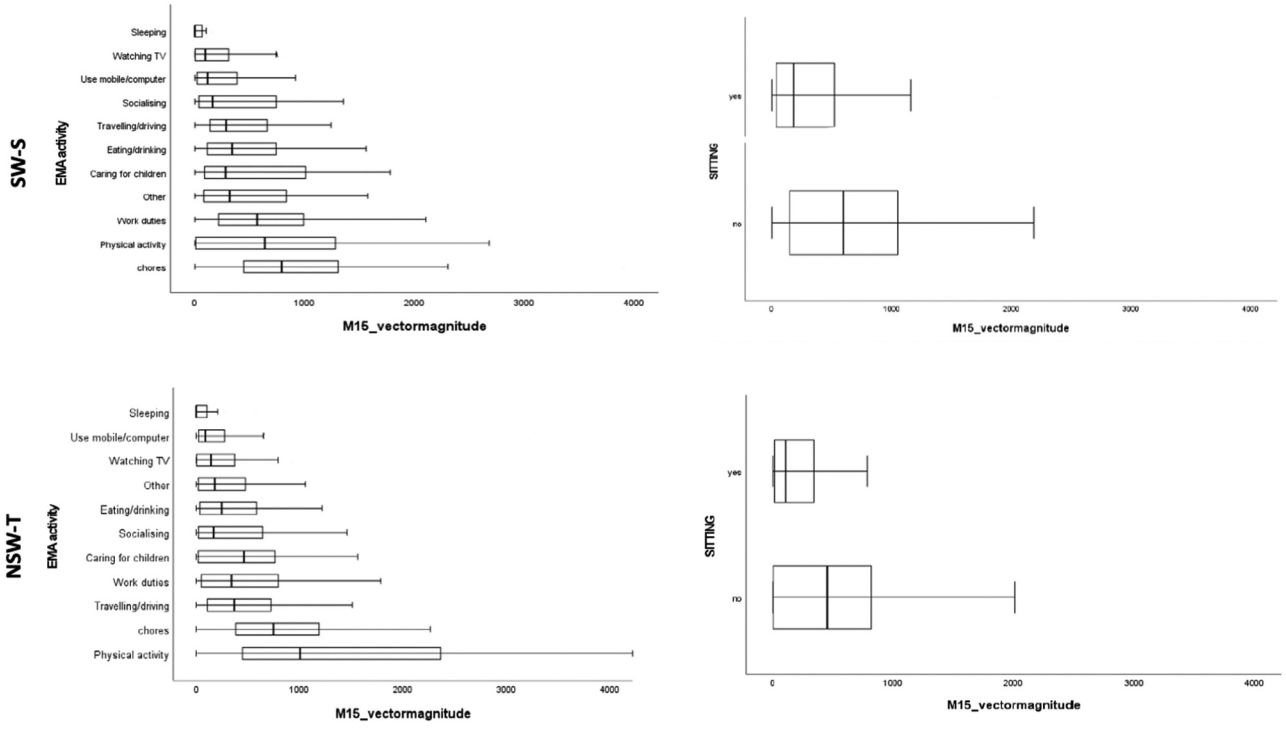

Figure 1. Accelerometer-derived vector magnitude (acceleration counts per minute) with matching EMA-reported activities and sedentary time. *Note*: SW-S, shift workers with tailored prompts; NSW-S, normal day workers who received standardized prompts M15_vector magnitude; activity counts recorded 15 minutes before EMA.

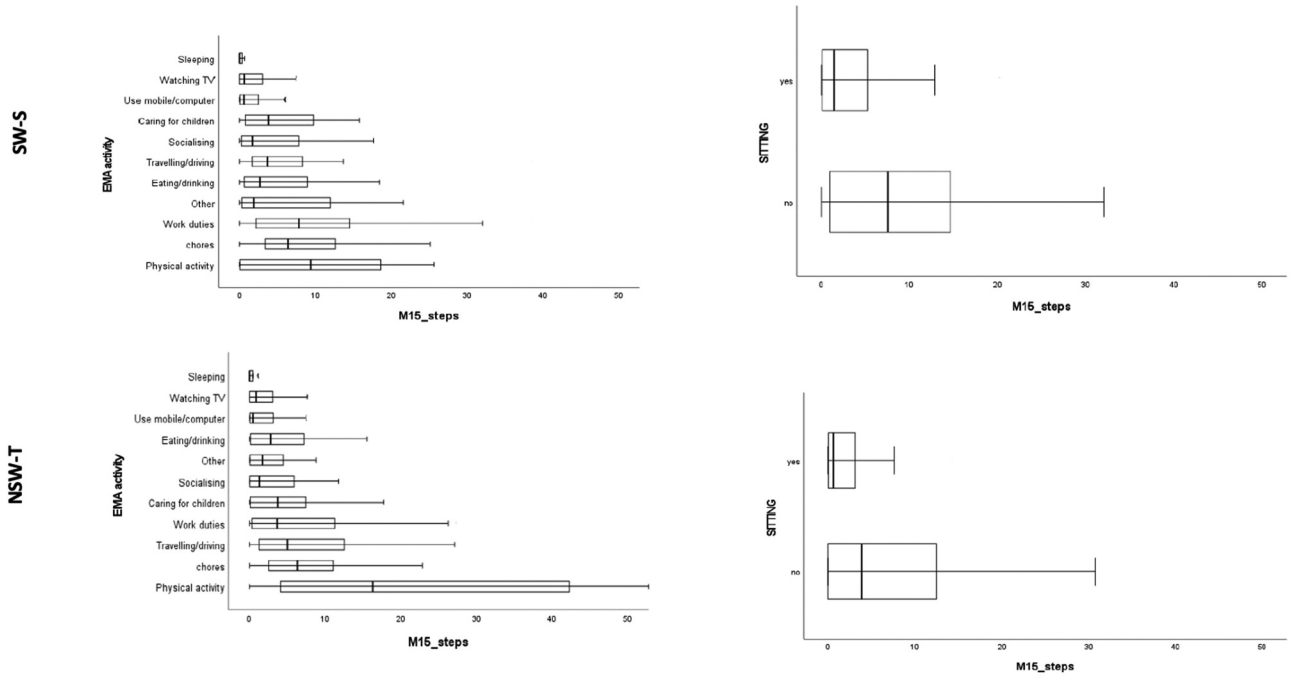

Figure 2. Accelerometer-derived steps with matching EMA-reported activities and sedentary time. *Note*: SW-S, shift workers with tailored prompts; NSW-S, normal day workers who received standardized prompts M15_steps; steps recorded 15 minutes before EMA prompt.

CPM, 95%: 1179.7, 1630.5) and ($B = 775.7$ CPM, 95%: 546.7, 1004.6) in SW-T (Table 1).

Comparisons of the corresponding accelerometer-derived steps with EMA-reported activities and EMA-reported sleep (reference activity) showed significant differences with the eight EMA-reported activities (socialising, eating/drinking, travelling, other, caring for children, work duties, chores and physical activity) with both the SW-T group and NSW-S.

The steps were significantly higher than sleep with EMA-reported physical activity, chores work duties and travelling/driving in the NSW-S, and with 7 EMA-reported activities including physical activity in the SW-T (Table 1). Accelerometer-derived accelerations and steps were significantly higher when participants reported no sitting with EMA than sitting (Table 1). There were no differences in association between EMA and acceleration counts or steps between the SW-T and NSW-S (Supplementary Tables 2).

Discussion

The aim of this study was to evaluate mobile EMA application for assessing physical activity and sedentary time in shift and non-shift workers. The main finding of our study was that EMA-reported physical activity and sitting were strongly associated with accelerometer-derived data, thus supporting criterion validity. Compared to other EMA-reported activities, acceleration counts and steps were higher with EMA-reported physical activity. Similarly, acceleration counts and steps were lower when participants reported that they were sitting. There were differences in the association of EMA and accelerometer data between shift and non-shift workers. Other important findings were EMA-reported chores also corresponded with more acceleration counts and steps, while sleep, watching television and using a mobile phone or computer corresponded with the lowest steps and acceleration counts.

Collectively, these findings indicate that participants accurately report their current activity on EMA surveys. Similar to previous EMA studies investigating the validity of EMA against accelerometer, assessing physical activity and sedentary time was sufficiently associated with accelerometer data (Maher et al., 2018, 2021; Ponnada et al., 2021). The ActiGraph accelerometer can measure steps, sedentary time, and time spent in moderate-to-vigorous intensity physical activity (Yao et al., 2022). Accelerometry has better validity to the doubly labelled water than self-report measures (Plasqui et al., 2013). Given that the Actigraph accelerometer has been found to be valid (Chomistek et al., 2017; Kelly et al., 2013) and shows a strong association with EMA-reported physical and sedentary behaviours, EMA could be used as a cheaper alternative to accelerometry. In a study where accelerometer estimates of physical activity and sedentary behaviour were compared with other self-report measures (IPAQ and BRFSS), the EMA measure showed stronger correlations and agreement to accelerometer estimates than IPAQ and BRFSS (Knell et al., 2017). Although the use of accelerometers is gaining popularity in research, there are some challenges that limit effective use including variability in device placement and methods to process data (Welk et al., 2019). Further, the Actigraph may not be accurate for assessing low- and high-intensity activities due to the acceleration counts that cannot be correlated with energy expenditure (W. J. Wu et al., 2023). Thus, some activities like standing has small acceleration counts may have been recorded as sitting. Therefore, it is necessary to exercise caution when interpreting these results.

The Actigraph counts that we used in our study allow for translation of counts to time for the assessment of physical

Table 1. Description of acceleration activity counts (CPM) and steps in the 15 minutes before prompts corresponding with EMA-reported activities according to all workers and groups.

	Activity counts (CPM)						Steps					
	All workers (*n*=102)		SW-T (*n*=51)		NSW-S (*n*=51)		All workers (*n*=102)		SW-T (*n*=51)		NSW-S (*n*=51)	
EMA-reported activity	Mean difference	95% CI	Mean difference	95% CI	Mean difference	95% CI	Mean difference	95% CI	Mean difference	95% CI	Mean difference	95% CI
Sleeping	93.9	ref	85.6	ref	ref	ref	ref	ref	0.6	ref	ref	ref
Phone/computer	130.5	6.2, 254.8	126.4	−48.7, 301.5	144.3	−56.6, 345.2	1.8	−0.4, 4.1	1.4	−1.7, 4.5	1.6	−2.0, 5.2
Watching TV	136.0	7.7, 264.4	172	−4.7, 349.1	110.7	−82.1, 303.5	1.4	−0.9, 3.8	2.3	−0.8, 5.5	1.7	−1.8, 5.2
Socializing	313.7*	159.6, 467.8	284.9*	72.9, 496.8	289.5*	57.7, 521.3	4.9	2.1, 7.7	4.4	−0.7, 9.4	4.4	−0.7, 9.6
Eating/drinking	332.1*	196.4, 467.8	396.4*	212.7, 580.0	278.9*	68.0, 489.7	4.3*	1.9, 6.8	5.2*	1.4, 8.9	4.3	0.05, 8.4
Travelling	361.7*	219.3, 504.1	300.1*	108.9, 491.4	415.0*	188.1, 641.9	6.3*	3.7, 8.9	5.3*	2.1, 8.6	3.7	−0.2, 7.5
Others	370.8*	222.1, 519.6	442.9*	249.2, 636.7	247.4*	1.7, 493	5.6*	2.9, 8.3	6.9*	3.5, 10.4	3.9	−0.5, 8.4
Caring for children	395.8*	197.9, 593.7	428.9*	143.9, 713.9	360.9*	76.5, 646.3	4.4*	0.9, 8.0	5.2*	1.8, 8.6	7.0*	2.9, 11.1
Work duties	513.9*	394.2, 633.7	582.5*	424.1, 740.8	398.7*	205.8, 591.5	7.8*	5.7, 10.0	8.9*	6.1, 11.7	6.1*	2.6, 9.6
Chores	775.9*	637.9, 913.8	823.9*	629, 1018.4	712.0*	501.8, 922.2	8.2*	5.7, 10.7	9.7*	6.3, 13.2	7.1*	3.3, 10.9
Physical activity	1184.4*	1034.7, 1334	775.7*	546.7, 1004.6	1405.1*	1179.7, 1630.5	20.9*	18.2, 23.6	12.7*	8.6, 16.8	25.8*	21.7, 29.9
Sitting	−353.9	ref	−332.9	ref	−303.7	ref	−5.7	ref	−5.5	ref	−5.0	ref
No Sitting	650.6*	579.2, 722.0	658.5*	578.6, 738.5	563.3*	418, 707	9.3*	8.8, 10.5	9.3*	7.9,10.7	8.6*	5.9, 11.2

SW-T, shift workers with tailored prompts; NSW-S, normal day workers who received standardized prompts; CPM, count per minute. 95% CI: Confidence Interval. Note. (Reference = EMA-reported sleep and sitting) *p<0.05.

activity with activity counts (Sasaki et al., 2011). Majority studies have used cutpoints for data analysis and provide data associated with meeting the physical activity guidelines (Mielke et al., 2023). However, other options like the use of machine leaning can be considered to provide more information on activity types and posture especially for sitting patterns (Greenwood-Hickman et al., 2021; Mielke et al., 2023). Therefore, combing EMA with devices can provide unique opportunity to collect information on how participants meet the physical activity guidelines and combine with, context and ecologically valid data capitalizing on the strengths of the two methods (Bedard et al., 2012; Goldstein et al., 2021).

Similar to our study, five prompts per day were sent to participants (Weatherson et al., 2019), whereas other studies used 6 prompts per day for 10 days (Maher et al., 2018) and 8 prompts in a 4-day EMA protocol (Dunton et al., 2012). While all these studies showed good validity, the EMA protocols differed. Therefore, it is important to standardize EMA reporting in future studies for comparability and measurement in EMA studies. Participants were enrolled in the study for 7–10 days and received five prompts per day, thus presenting a potential participant burden. However, each survey was completed in less than 1 minute, and thus limiting participant burden. While we did not assess participants' perceptions of EMA, other studies have shown favourable results on acceptability of this tool (Nam et al., 2020). In a review protocol of health-related behaviours, 60–79.99% was regarded as moderate (Kwasnicka et al., 2021), thus our study compliance of 64% is acceptable.

Concerning sitting, our study findings are consistent with the findings of previous studies where participants accurately reported sitting behaviours (Dunton et al., 2011; Romanzini et al., 2019). In an EMA study of office workers aged 40 years, activPAL accelerometer-derived data were shown to have good agreement with EMA-reported sedentary time (Weatherson et al., 2019). Despite using a different criterion instrument (activPAL) for measuring sedentary behaviour, similar to our study, Weatherson and colleagues had accelerometer data time stamped in the 15 minutes before the EMA prompt. Thus, both studies show EMA is valid in assessing sedentary time. The Actigraph activity count threshold for identifying sedentary behaviours is < 100 counts per minute (cpm), which approximately corresponds to the energy cost of < 1.5 METs (Matthews et al., 2008). However, the activPAL has better agreement compared to direct observation for sedentary behaviour has high reliability and validity for sedentary behaviour estimate (Kim & Kang, 2019; Koster et al., 2016). It is better at measuring posture and postural transitions (Byrom et al., 2016; Chastin et al., 2018). Therefore, our results for the validity of EMA in assessing sedentary behaviour should be interpreted with caution. In addition, the accelerometer did not capture other sedentary behaviour domains including TV viewing, screen-use and transport-related. However, EMA-reported use of mobile/computer and watching television showed lower acceleration counts than other EMA-reported activities.

In this study, EMA-reported physical activity was not categorised according to intensity or domain. In a study where physical activity intensity was reported, EMA survey did not correspond to the intensity of physical activity in college students (Bruening et al., 2016). Brueining and colleagues concluded that social desirability and/or perception biases may be at play, and other factors like participant's fitness level could affect perception of intensity levels (Bruening et al., 2016). Future EMA studies for workers should consider structuring EMA surveys to assess physical activity intensity levels, after fully explaining types of intensity to participants in order to specify if workers are sufficiently active.

Our results suggest that there were no differences in EMA validity between shift and non-shift workers. The similarity may emerge because both shift and non-shift workers may have accurately reported their activities on the EMA survey, thus EMA-reported activities sufficiently associated with device data in the two groups. In contrast to our study, EMA tailored to meal timing increased the correspondence of EMA and device data for energy and nutrient measures (Martin et al., 2012). However, we did not find any other study to compare the findings with our study as most EMA studies assessing physical activity and sedentary behaviours in workers did not adapt EMA to work schedules. For example, in a study using EMA in a workplace intervention, the EMA surveys were sent only across the 5 working days (Weatherson et al., 2019). Previous evidence suggests that EMA is a helpful tool to adapt to shift worker's schedules (de Vries et al., 2021).

While it was not the focus of this study, the EMA survey was able to report additional activities, including socialising, taking care of children and travelling. Therefore, showing the ability of EMA surveys to monitor types of activities is important in order to elucidate the health risks associated with various activities on work and non-workdays. This study provides evidence supporting EMA as a valid measure of physical activity and sedentary behaviour in shift workers, therefore could be used in workplace health promotion interventions. Assessing physical activity and sedentary behaviour with EMA in worker's naturalistic settings and in real time could be useful to evaluate work-related determinants. Consequently, EMA may be used investigate psychological drivers and work factors associations with lifestyle behaviours, which in turn can better inform public health and policymakers on strategies to promote physical activity and reduce sedentary behaviours (Reichert et al., 2020).

Strengths

Our study provided intensive longitudinal datasets near or in real-time, minimizing retrospective biases. After time-matching accelerometer and EMA data, substantial data points were available. Most previous studies evaluating the validity of EMA did not tailor EMA prompts to individual participants work schedules as was done in our study. In our study, we adapted the timing of EMA surveys in accordance to shift workers work and shift patterns. Thus, allowing for flexibility and highly adaptable measurements using EMA in the shift work population was sufficient.

Limitations

One of the limitations of this study was that we matched accelerometer data with EMA before a prompt; thus, we could not determine if responding to EMA disrupts activities. Determining the use of EMA to influence activities could be

used for intervention studies in order nudge or change movement related behaviours. Additionally, the EMA survey prompts set from 10 am to 10 pm could have resulted missing physical activity and sedentary behaviour early morning and late night in non-shift work and shift workers who received standardized prompts. We did not assess participants' perception of the EMA survey questions and prompts.

Conclusion

The aim was to assess validity of EMA for assessing physical activity and sedentary behaviour in workers. The findings of this study showed that EMA-reported physical activity and sedentary behaviour was accurately associated with accelerometer-derived data in shift and non-shift workers. EMA provides a valid and cheaper alternative measure of physical activity and sedentary compared to other self-report measures and can be used in both surveillance and health promotion studies to provide real-time support. Using mobile EMA opens up opportunities for reaching a large number of participants at a relatively low cost. The findings of the study showed that an EMA tailoring approach was possible and can be integrated into intervention studies to provide tailored feedback and support in real-time and in a real-world setting.

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