The Contribution of Commuting to Total Daily Moderate-to-Vigorous Physical Activity

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ABSTRACT

Background: Actively commuting to and from work can increase moderate-to-vigorous physical activity (MVPA) and increase adherence to physical activity (PA) guidelines; however, there is a lack of evidence on the contribution of mixed-mode commutes and continuous stepping bouts to PA. Many commuting studies employ the use of self-reported PA measures. This study objectively determines the contribution of MVPA during commuting to total MVPA, using cadence to define MVPA, and to explores how the length of stepping bouts affects adherence to PA guidelines.

Methods: Twenty-seven university staff wore an activPAL™ activity monitor for seven days and kept an activity diary. The activPAL™ quantified MVPA and bouts duration and the activity diary collected information about commute times and the modes of commute. Twenty-three participants with at least four days of data were included in the final analysis.

Results: The median total time per day spent in MVPA was 49.6 (IQR: 27.4-75.8) minutes and 31% of the total time was accumulated during commuting (15.2 (4.11-26.9)) minutes. Walking and mixed-mode commuters spent more time in MVPA (37.6 and 26.9 minutes respectively), compared to car commuters (5.8 minutes). Seventeen out of the 23 participants achieved more than 30 minutes of MVPA per day, with five achieving this in their commute alone. A significant positive association was found between commute time spent in MVPA and total MVPA ($p<0.001$).

Conclusion: Commuting can be a major contributor to total MVPA, with the mode of commute having a significant role in the level of this contribution to total MVPA.

Keywords: travel to work, objective measurement, active modes of commute, activity monitoring.

INTRODUCTION

Physical inactivity is the fourth leading risk factor for chronic, non-communicable diseases, increasing the risk of ischaemic heart disease, type 2 diabetes, and some cancers (Scholes & Mindell, 2013; World Health Organisation [WHO], 2009). Physical inactivity refers to not meeting the physical activity (PA) recommendations for adults – this is typically a minimum of 30 minutes of moderate-to-vigorous physical activity (MVPA) daily (WHO, 2009). Meeting PA recommendations are known to be associated with a reduction in a number of health outcomes, such as cardiovascular diseases, cancers, and an increased risk of premature mortality (Lee et al., 2012; WHO, 2018). Despite these benefits, a considerable proportion of the world's population are physically inactive (Scholes & Mindell, 2013; WHO, 2018).

Risk factors that contribute to low levels of PA include, but are not limited to, the increasing sedentariness of occupations, which involves little or no level of light to moderate PA (Church et al., 2011), reduced household and leisure time activities, and an increase in car use (WHO, 2009; Public Health England [PHE], 2016). The UK PA guidelines for adults recommend at least 150 minutes of moderate intensity PA per week, in bouts of 10 minutes or more (Department of Health [DH], 2011). This recommendation is similar to that of the United States of America; however, the minimum bout length has been removed from the American PA's guidelines (2018 Physical Activity Guidelines Advisory Committee, 2018). Moderate intensity activities include walking and cycling; and these activities can be incorporated into daily travel by replacing car or bus journeys (DH, 2011).

Walking and cycling are considered as active modes of commuting (Shannon et al., 2006), and it has been recognised that active commuting is a feasible way of incorporating greater levels of PA into daily life (National Institute for Health and Care Excellence [NICE], 2012). Other studies have included the use of public transport as an active mode of commuting, as parts of the journey may involve walking or cycling (Shannon et al., 2006; Flint, Cummins, & Sacker, 2014). In general, the literature has classified commuting as being either active or passive; however, the situation is more complex as commuting by car can have an active component; for example, driving to work and after parking the car and walking to the office may involve a large active component.

Active commuting has been associated with a reduction in body mass index (BMI) and percentage body fat (Flint & Cummins, 2016; Flint et al., 2014; Flint, Webb, & Cummins, 2016; King & Jacobson, 2017; Martin, Panter, Suhrcke, & Ogilvie, 2015; Mytton, Ogilvie, Griffin, Brage, Wareham, & Panter, 2018; Mytton, Panter, & Ogilvie, 2016), reduced levels of hypertension and type 2 diabetes (Honda et al., 2015; Laverty, Mindell, Webb, & Millett, 2013), reduced risk of cardiovascular disease (Celis-Morales et al., 2017; Gordon-Larsen et al., 2009; Hamer & Chida, 2008; Laverty, Mindell, Webb, & Millett, 2013; Lerssrimongkol, Wisetborisut, Angkurawaranon, Jiraporncharoen, & Lam, 2016; Panter et al., 2018), and metabolic syndrome (Garcia-Hermoso et al., 2018; Kuwahara et al., 2016; Sandaragani et al., 2018; Steell et al., 2017). It is also known that an increased walking pace is associated with a reduced risk of all-cause and CVD mortality (Stamatakis et al., 2018). Travelling by public transport might not involve the same degree or intensity of PA as commuting by walking and cycling only; however, there is evidence showing that travelling by public transport contributes to obesity reduction (Flint et al., 2014; King & Jacobson, 2017). There is limited evidence to show the impact of mixed-mode journeys and the role of using public transport as an active mode of commuting (Flint et al., 2014).

Commuting studies that measure physical behavior have tended to use self-reported measures, such as questionnaires and travel activity diaries (Audrey, Procter, & Cooper, 2014; Sahlqvist, Song, & Ogilvie, 2012). Few commuting studies have used objective measures, such as body-worn activity monitors, to measure physical behavior (Audrey et al., 2014; Panter, Griffin, & Ogilvie, 2012; Sahlqvist et al., 2012; Yang et al., 2012). The most common device used in commuting studies has been the ActiGraph accelerometer, which provides information on activity intensity using cut-point thresholds (Freedson, Melanson, & Sirard, 1998).

Cadence, defined as the rate of stepping has been used as an alternative method of estimating MVPA (Chastin et al., 2009; Dall, McCorie, Granat & Stansfield, 2013; Slaght, Sénéchal, Hrubeniuk, Mayo, & Bouchard, 2017). MVPA has often been defined as a cadence of 100 steps per minute or more (Marshall et al., 2009; Rowe et al., 2011; Tudor-Locke & Rowe, 2012); however, other studies have defined MVPA as 76 steps/min (Dall et al., 2013) and 109 steps/min within healthy populations (Chastin et al., 2009; Rafferty, Dolan, & Granat, 2016). Only one previous study on commuting has used cadence to quantify MVPA in commuting (Rafferty et al., 2016); however, this study did not take into account the modes of commute and the length of stepping bouts.

Previous studies on commuting have not captured all the elements listed in the UK PA guidelines, particularly with regards to the length of the stepping bouts in estimating MVPA. In the 2003-2004 NHANES study, Troiano et al. (2008) used Actigraph accelerometer cut-point thresholds and compared total accumulated MVPA, irrespective of bout length, to MVPA calculated using modified 10-minute bouts (where interruptions of two minutes below the threshold was allowed). Although this study looked at total MVPA and did not consider commuting time, the authors found that when bout length was taken into consideration adherence to PA recommendations in adults was less than 5%. In addition, Chastin et al. (2009), showed that the compliance to PA guidelines in a group of 78 postal workers decreased from eight participants to one participant when a minimum stepping bout length of 10 minutes was used.

The aim of this study was to objectively determine the contribution of MVPA during commuting to total MVPA, using cadence to define MVPA. A secondary aim was to explore how the length of stepping bouts affected adherence to PA guidelines.

METHODS

Study population

Participants (n=27) recruited were staff at the School of Health Sciences, University of Salford. The study was approved by the University of Salford Ethics Committee (HST1617-202).

Measurements and data collection

Participants were asked to complete an activity diary and wear an activity monitor, the activPAL™ (PAL Technologies Ltd, Glasgow, Scotland, UK), for seven consecutive days. The monitor was attached to the front of the thigh using waterproof dressing and worn continuously for a seven-day period (except when bathing or swimming). The activPAL™ classifies posture as time spent sitting/lying, standing, and stepping, on a second-by-second basis. The monitor has been validated for posture, step count, and cadence in a range of populations (Grant, Ryan, Tigbe, & Granat, 2006; Ryan, Grant, Tigbe, & Granat, 2006; Grant, Dall, Mitchell, & Granat, 2008; Busse, Van Deursen, & Wiles, 2009; Maddocks, Petrou, Skipper, & Wilcock, 2010; Harrington, Welk, Donnelly, 2011).

The activity diary was used to collect information on the mode of commute and the duration of each journey to and from work. For each journey, participants recorded the time they left the house, how they travelled to work (including detail on mixed-mode journeys), the time they got to work, the time they left work, how they travelled home, and the time they arrived at home.

Data cleaning and reduction

Event files containing activities over the seven-day period were obtained from the activPAL™ and were visually examined to ensure that there was at least 4 working days of complete (sleep, waking, and working hours) data for each participant. Incomplete days, at the start and end of the recording period, were removed. Workdays were identified and extracted data were used in the analysis. A MATLAB (MathWorks Inc. MA, USA) script was used to extract all stepping events from the event file. These stepping events were loaded into an Excel file for further analysis. For each stepping event, the duration, number of steps, and cadence of the stepping event were calculated.

The activity diary was used to determine the mode of commute and commute time. The mode of commute was categorised into: walking, car, and mixed-mode (for those who travelled to or from work using more than one mode of commute). Commute time was defined as travel time to and from the place of employment, and non-commute time as all the time outside of commute. MVPA was defined as a period of walking with a cadence of at least 100 steps/min (Marshall et al., 2009; Rowe et al., 2011; Tudor-Locke & Rowe, 2012).

Commute time spent in MVPA, non-commute time spent in MVPA, and total time spent in MVPA were calculated with no restriction on stepping bout length. Only stepping bouts greater than 10 minutes were included to determine adherence to PA guidelines. Analyses were also carried out using a minimum bout length of 0-minute, 1-minute, 2-minutes, and 5-minutes; other definitions of MVPA cadence for a healthy population, 76 steps/min (Dall et al., 2012) and 109 steps/min (Rafferty et al., 2016), were also tested.

Statistical analysis

Data analysis were carried out using SPSS Statistics (Version 24.0). Analysis, using the Shapiro-Wilk test, showed the data to be non-normally distributed; therefore, non-parametric tests were used in the analysis and results are presented as medians and interquartile ranges (IQR). Differences in commute time spent in MVPA between different modes of commute (car, walk, and mixed-mode) were analysed using the Kruskal-Wallis test. Mann-Whitney-U tests were conducted to determine the difference between each pair of the commute modes. Differences in number of commute steps and non-commute steps between cadence >100 steps/min and <100 steps/min were analysed using the Mann-Whitney-U test. Spearman's rank of correlation coefficient was calculated to compare the total number of steps and commute time and non-commute in MVPA. A significance level of $p < 0.05$ was used.

RESULTS

Twenty-seven participants were recruited; however, four participants were excluded because they did not have complete activPAL™ data and this included the only cyclist in the study population. Of the 23 participants included in the analysis, 13 (57%) commuted by car, three (13%) by walking, and seven (31%) commuted using more than one mode (mixed-mode journeys). All participants maintained the same mode of commute throughout the data collection period.

The median total daily step count was 10,639 (IQR: 7884-13,556) steps and the number of steps taken at MVPA (irrespective of bout length) was 5731 (3020-9020) steps; with 33% of steps taken at MVPA being accumulated during commuting for all participants. The median total daily time spent in MVPA was 49.6 (27.4 -75.8) minutes with all commutes contributing 31% of that time (15.2 minutes). The median commute time spent at any intensity was 23.7 (14.2-43.2) minutes per day. The median contribution of commute time in MVPA to total MVPA was 14% for car commuters, 36% for mixed-mode commuters and 61% for walking commuters. The walking commuters had a median of 37.6 (29.9-38.7) minutes per day of

MVPA, mixed-mode commuters had 26.9 (14.2-40.8) minutes, and car commuters had 5.8 (2.8 –15.2) minutes.

Commute and non-commute steps were classified into different cadence bands: At a cadence of over 110 step/min, there was a far greater proportion of stepping during commuting compared to other cadence bands (Figure 1). However, using a difference test, the Mann-Whitney U test showed that there was no statistically significant difference in the distribution of commute steps between cadence >100 steps/min and <100 steps/min (p=0.075).

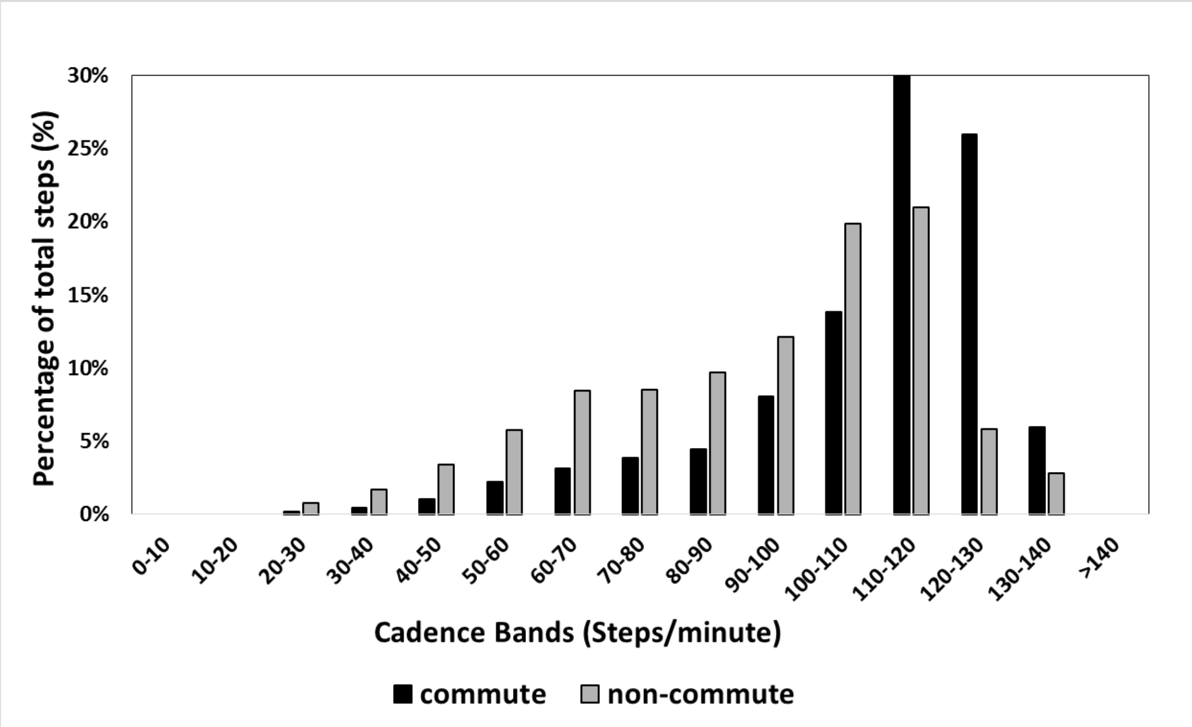

Figure 1: Cadence Distribution of commute and non-commute steps

Stepping during commuting and non-commuting varied according to lengths of stepping bout (Figure 2). Non-commute stepping was predominantly accumulated in shorter bout lengths. Stepping bouts of greater than 210 seconds were only undertaken whilst commuting, with a higher number of steps accumulated in bouts over 300 seconds.

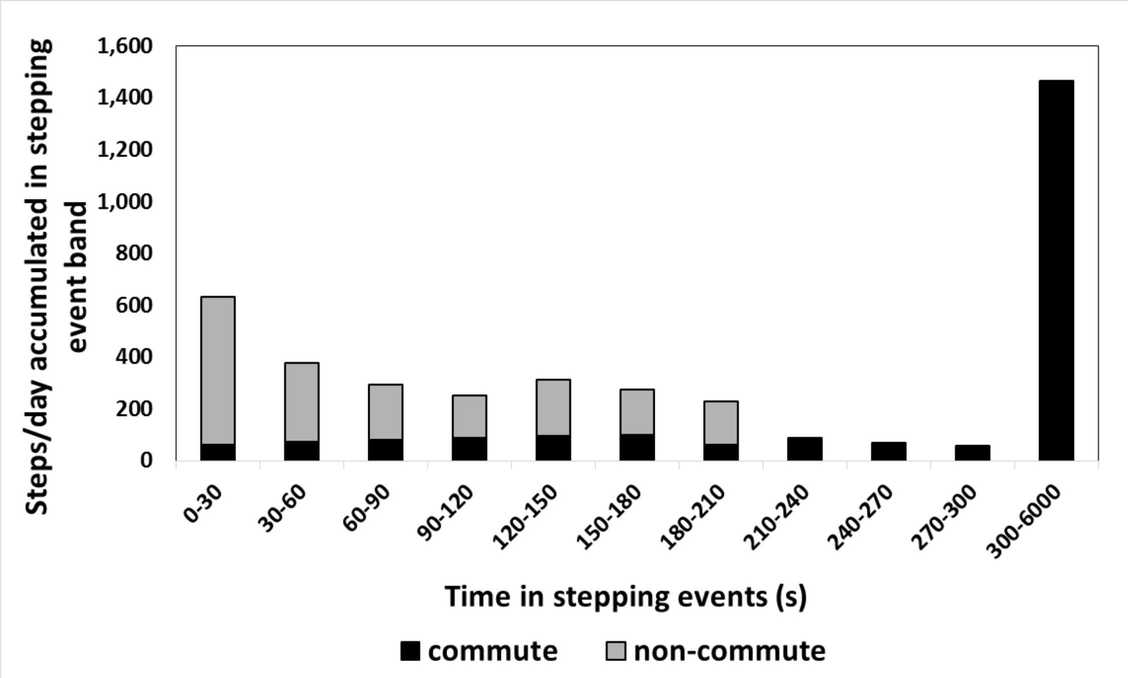

Figure 2: Stepping bout distribution of commute and non-commute steps

Figure 3 shows the distribution of commute and non-commute time spent in MVPA, defined as cadence greater than 100 steps/min for all stepping bouts, in different modes of commute for all participants. Seventeen of the 23 participants achieved a minimum of 30 minutes of MVPA per day and five (all mixed-mode or walking commuters) achieved at least 30 minutes of MVPA in their commute alone.

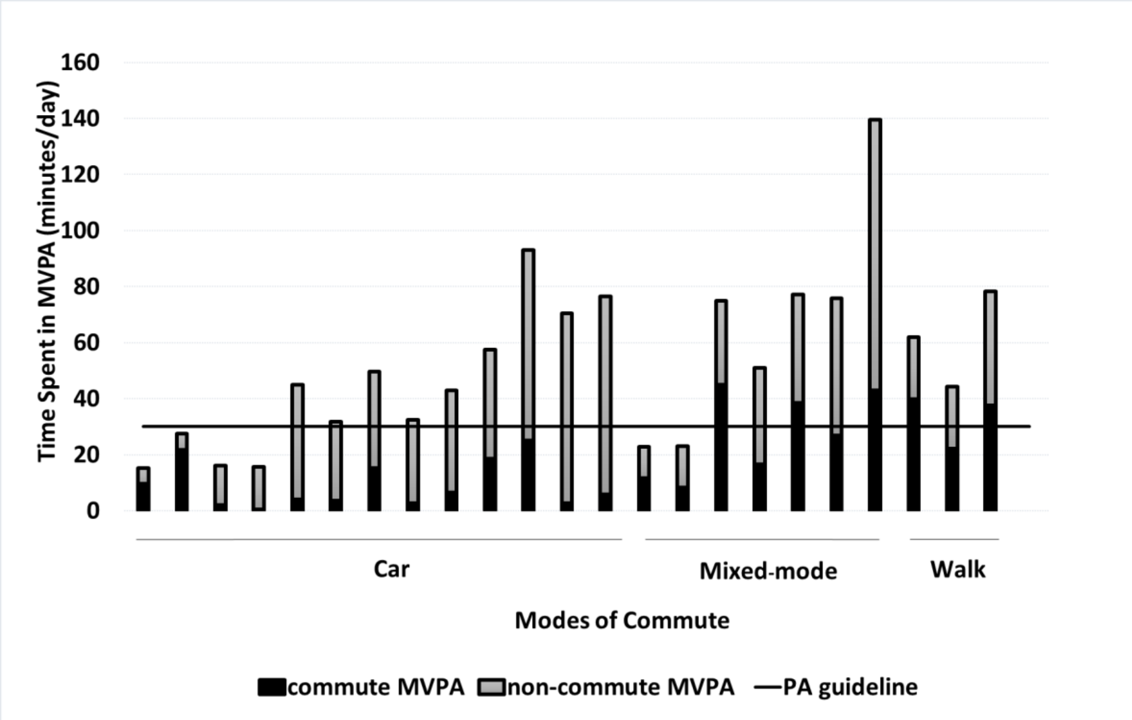

Figure 3: Commute time and non-commute time in MVPA at ≥100step/min for all stepping bouts for all subjects grouped by commute mode.

With regards to adherence to PA guidelines that recommends 30 minutes of MVPA per day on at least 5 days a week in bouts of greater than 10 minutes (DH, 2011), seven participants met these guidelines with one participant, a walking commuter, meeting this guideline from their commute alone (Figure 4). The participants with continuous bouts of greater than 10 minutes were primarily mixed-mode and walking commuters.

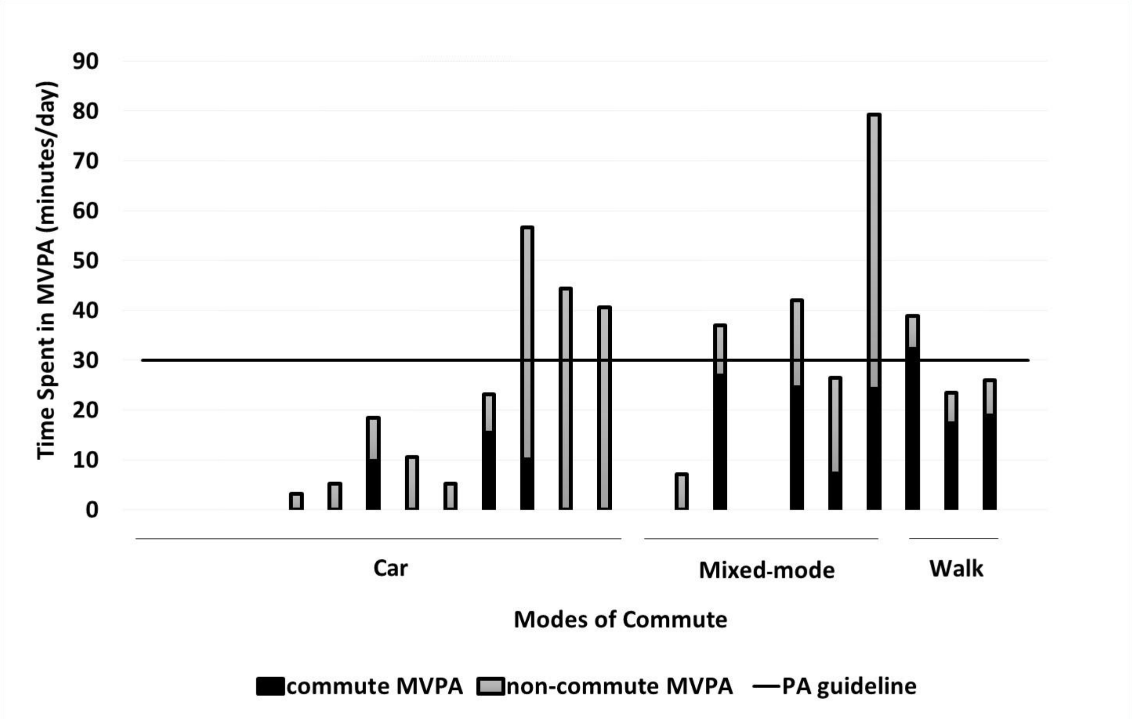

Figure 4: Commute time and non-commute time in MVPA at ≥100step/min and at stepping bouts greater than 10 minutes for all subjects grouped by commute mode.

The requirements for meeting the PA guidelines were altered by changing the values for the cadence used to define MVPA and the minimum stepping bout length (Table 1). The total time spent in MVPA decreased as the length of stepping bout increased for all cadences. However, the total time spent in MVPA during commute was similar for all cadences.

Cadence	Length of stepping bouts (minutes)	No of participants that met the PA guidelines	Participants that met PA guidelines in commute alone	Total time contributing to PA guidelines (minutes)	Commute time contributing to PA guidelines (minutes)
76 steps/min					
	0	22	6	77.7	21.5
	1	18	5	53.5	17.7
	2	17	5	45.8	15.7
	5	9	3	31.4	11.4
	10	7	1	21.5	8.1
100 steps/min					
	0	17	5	53.1	17.7
	1	15	5	45.6	16.5
	2	14	5	41.5	15.1
	5	9	3	30.0	11.2
	10	7	1	21.1	8.1
109 steps/min					
	0	12	4	38.0	15.0
	1	12	4	34.5	14.4
	2	11	4	32.1	13.4
	5	9	2	24.8	10.3
	10	7	1	18.0	7.8

Table 1: Adherence to PA guidelines using different criteria for MVPA and different minimum stepping bout lengths.

There was a significant difference in commute MVPA for all modes of commute (p= 0.005) using the Kruskal-Wallis test. Further analysis using the Mann-Whitney-U tests to determine the difference on each pair of the groups showed that there was a significant difference between the car and walking commuters (p=0.013) and the car and mixed-mode commuters (p=0.008); however, there was no significant difference between walking and mixed-mode commuters (p=0.732). There was a significant moderate positive relationship (r=0.65; p<0.001) between commute time in MVPA, and total steps per day. Also, there was a positive relationship between non-commute time in MVPA (r=0.88; p<0.001) and total steps per day.

DISCUSSION

Main findings

In this study, commuting contributed 33% of total MVPA and 34% of the total steps taken daily. The mode of commute played a significant role in the accumulation of the total MVPA. For walking commuters, 54% of their total MVPA was accumulated during commute, which was much larger than other commute modes. Adherence to PA guidelines was low among the participants when the minimum 10 minutes stepping bout length was applied, with seven out of the 23 participants meeting the recommendations.

There was a significant positive relationship with both commute time and non-commute time in MVPA and total MVPA; however, causality cannot be established due to the cross-sectional design of this study. A statistically significant difference was observed between commute time spent in MVPA and the three modes of commute. Further analysis on each pair of the commute modes showed that the significant differences in commute time in MVPA were between the car and mixed-mode commuters, and the car and walking commuters; however, there was no significant difference between the commute time spent in the walking category and the mixed-mode category.

Comparison with other studies

Our findings are consistent with other commuting studies that have reported that commuting contributes to total PA (Audrey et al., 2014; Sahlqvist et al., 2012; Yang et al., 2012); however, these studies used the Actigraph accelerometer that uses a count threshold for defining MVPA, rather than cadence.. The walking and mixed-mode commuters in our study accumulated more MVPA than car commuters, and this is consistent with other studies that have found greater activity levels in people that commute by walking or public transport than car commuters (Audrey et al., 2014; Flint et al., 2016; Flint & Cummins, 2016).

The use of the activPAL™ in this study made it possible to quantify MVPA in commuting by using the cadence of stepping. The use of cadence in quantifying MVPA has been described in the literature as a more practical way of measuring MVPA (Chastin et al., 2009). Compared to a threshold on some value of the acceleration signals, cadence places emphasis on the rate of stepping and this can be used to estimate intensity (Slaght et al., 2017). Previous studies have employed the use of the hip-worn Actigraph accelerometer, which provides information on activity intensity using cut-point thresholds (Matthews et al., 2008; Ridgers et al., 2012); however, the Actigraph has been reported to overestimate light intensity activities and underestimate vigorous activities (Bassett, 2012; Granat, 2012).

We found that the adherence to PA guidelines among the participants was similar to Rafferty et al. (2016) who also used the activPAL™, where a total of 18 participants achieved the minimum recommendation, with five participants reaching this in their commute alone. Using the definition of MVPA and continuous stepping bout of 10 minutes or more resulted in only seven participants adhering to the PA guidelines. This is supported by the finding by Troiano et al. (2008), who found that compliance with PA guidelines is generally low when bout length is considered. A reduction in the number of participants complying with PA guidelines indicates that the stricter the definition of continuous walking, the more unlikely people are to meet these guidelines. These observations suggest that the recommendation of walking continuously for 10 minutes or more might not be achievable in free-living environments, due to different factors that can interrupt continuous walking; for example, stopping at traffic lights or waiting to cross the road (Chastin et al., 2009).

What this study adds

This study found that during commuting, stepping occurs at a higher cadence with longer bout lengths when compared to stepping during non-commuting. An explanation for this observation could be as a result of the steps taken during commuting involving a greater intensity, due to the importance of arriving at work in a timely manner or the urgency to be on time for a bus, train or tram.. Furthermore, the results in this study showed that more steps were accumulated continuously between bouts of 30 seconds to 2 minutes (Figure 2); however, only during commute did participants walk continuously for 5 minutes or more. Although this could have been as a result of highly active commuters, these observations suggest that commuting involves stepping at a higher cadence and for longer bouts compared to during non-commuting periods. Consequently, these results imply that the steps taken during commuting and non-commuting differ based on intensity and bout length.

Relaxing the definitions of the minimum level of cadence did not significantly affect the total MVPA accumulated during commuting. This could be due to people walking at higher cadence during commuting and therefore. Although the increase in bout lengths reduced the total amount of MVPA time contributing to PA guidelines, the contribution of commute time to PA guidelines did not change.

Strengths and Limitations of the Study

An important strength of this study was the use of a validated activity monitoring device, the activPAL™, which allows for the quantification of MVPA using event-based analysis of stepping. There has been only one previous study (Rafferty et al., 2016) that has quantified MVPA during commuting using this device, and the results obtained in this study are comparable; however, the study by Rafferty et al. (2016) did not include analysis of stepping bout length and information on the commute mode. The current study is the first to consider cadence, stepping bout length, and mode of commute.

The main limitation of this study was the relatively small sample population in a similar cohort of people, which makes it hard to generalise the findings. Although the population was homogenous, they had different activity levels, with a wide range of total MVPA time from 15.3 minutes for a car commuter to 136.8 minutes for a mixed mode commuter. Another limitation was that the study did not account for any stops on the way to or from work; that is, if the trip was a direct or an indirect. In addition, in the mixed commute mode category, time spent commuting in each mode was not known. The use of an activity diary was used to collect information about commute times, which can result in response bias as some participants may enter an approximate time rather than the actual times of commute. However, with the events file downloaded from the activPAL™, the commute times reported in the activity diary were manually checked against the activPAL™ data to eliminate some of this bias. For example, if a participant reported in the activity diary that the departure time from home was 8am but from the activPAL™ data, there was no activity at 8am until 8.05am; then the departure time will be adjusted to 8.05am.

Interpretations and Implications

Meaningful contributions to the adherence to PA guidelines are achieved during commuting and can be incorporated into everyday life. This study has raised the question of the definition of MVPA and continuous stepping bouts in free-living settings. A review of the USA's PA guidelines was carried out in 2018: the 10-minutes bout was removed from the guidelines, as it reported that accumulating recommended volumes of PA at any bout length has beneficial impacts on health (2018 Physical Activity Advisory Committee, 2018). As a result of this review, the prevalence of people who were meeting the new guidelines increased (Lyden, 2019). There is a need for future research to consider the consequences of the bout length of PA with health-related outcomes. Also, further research with a larger sample size is needed to establish the association between commute time and total PA to help determine the relationship between commute MVPA and health outcomes.

CONCLUSION

Commuting to and from work can provide a significant contribution to total MVPA accumulated during the day and can make a major contribution to adherence to PA guidelines. Mode of commuting has a significant effect on the level of MVPA accumulated during travel; therefore, the promotion of active commuting could be an important way of improving PA and the health of the populations.

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