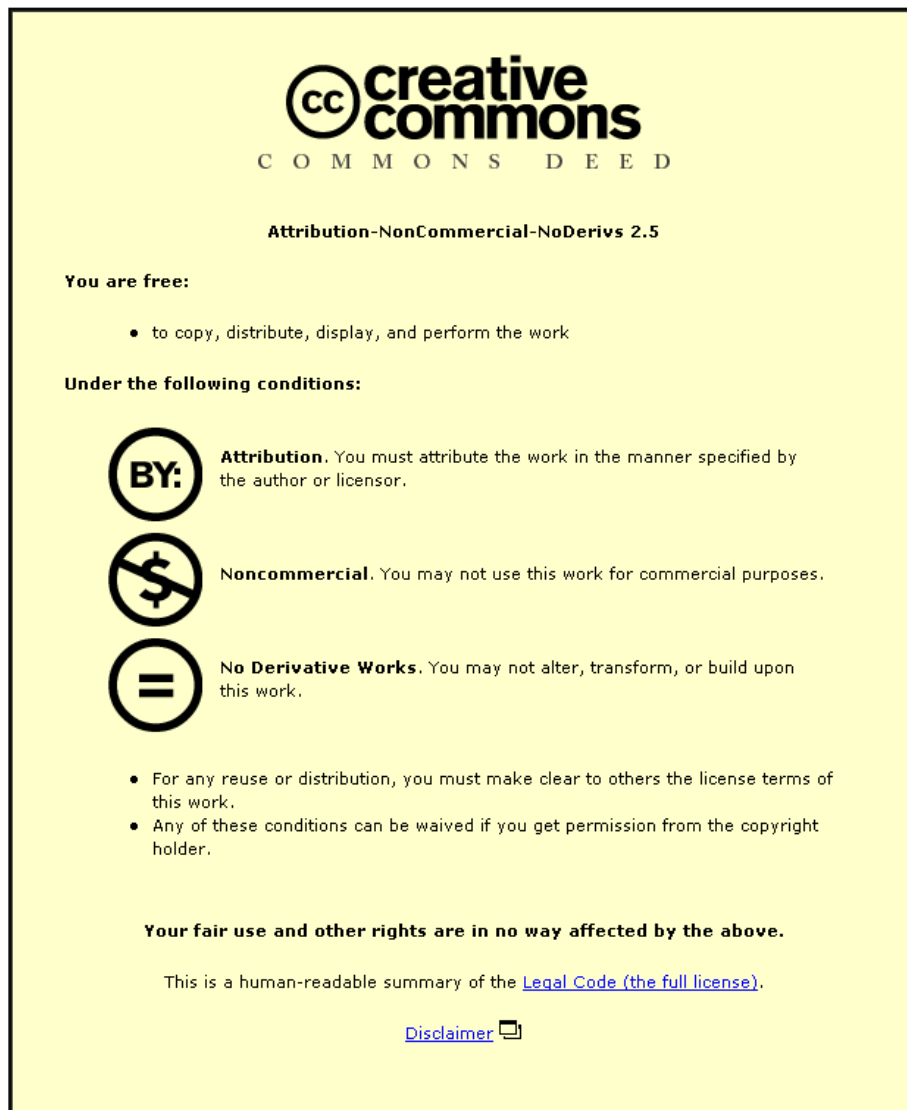


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Four-Week Pedometer-Determined Activity Patterns in Normal Weight, Overweight and Obese Adults

Stacy A Clemes*, Sarah L Hamilton and Martin R Lindley

Department of Human Sciences
Loughborough University
Loughborough
Leicestershire
UK
LE11 3TU

*Corresponding author

Corresponding author telephone: +44 (0)1509 228170

Fax: +44 (0)1509 223940

Email: S.A.Clemes@lboro.ac.uk

Abstract word count: 200 (excluding subheadings)

Main text word count: 2500 (excluding title page, abstract, in-text citations, tables, figure and references)

Number of tables: 3

Number of figures: 1

ABSTRACT

Objective: To assess pedometer-determined ambulatory activity in normal-weight, overweight and obese UK adults.

Methods: 86 normal-weight ($\text{BMI} < 25 \text{ kg/m}^2$) (age = 34 ± 12.1 years), 91 overweight ($\text{BMI} 25\text{--}29.9 \text{ kg/m}^2$) (age = 40.6 ± 13.6 years), and 75 obese ($\text{BMI} \geq 30 \text{ kg/m}^2$) (age = 41.2 ± 12.4 years) participants, from the East Midlands, provided four-weeks of continuous pedometer-determined activity data, during the winter in 2006. Activity levels and patterns were assessed for all three groups.

Results: The normal-weight group had a significantly higher mean step count (10247 steps/day) than the overweight (9095 steps/day) and obese (8102 steps/day) participants ($p < 0.05$). No differences in step counts were observed between the overweight and obese groups. A consistent reduction in activity was observed on Sundays in all groups, with this reduction being two-fold greater in the overweight and obese groups (~ 2000 steps/day) when compared with the normal-weight group (~ 1000 steps/day).

Conclusions: With the increasing prevalence of obesity in the UK, changes in the activity levels of those at risk are needed. The issuing of pedometers to overweight and obese individuals, with the instruction to increase their ambulatory activity on all days of the week, with particular emphasis on Sunday activity, could be a good starting point in tackling the problem of obesity in the UK.

Keywords: Normal weight, Overweight, Obesity, Walking, Ambulatory activity, Pedometer, Body Mass Index, Sunday

INTRODUCTION

Approximately 24% of males and females living in the UK were classified as obese in 2004 (body mass index [BMI] ≥ 30 kg/m² [World Health Organisation, 2000]) compared to 14% of males and 17% of females classified as obese in 1994 (Department of Health, 2005). Obesity represents a major public health problem, with individuals having an elevated risk of developing chronic conditions such as type 2 diabetes, hypertension, some cancers, and coronary heart disease (James, 2004).

Lack of physical activity is widely documented as a major risk factor for obesity (Hill and Melanson, 1999), and despite attempts to disseminate this knowledge to the general population (Chief Medical Officer, 2004), it has been reported that approximately three-quarters of females and two-thirds of males, living in the UK, do not attain activity levels required for health benefits (Department of Health, 2005) (undertaking a minimum of 30 minutes of at least moderate intensity activity, at least five times per week (Chief Medical Officer, 2004)). Increasing the population's level of physical activity has therefore become a high public health priority (Department of Health, 2004).

Walking has been described as an ideal form of exercise (Morris and Hardman, 1997), it is fundamental to most of our daily activities (Tudor-Locke and Myers, 2001), and is reportedly the most prevalent form of leisure-time physical activity in both the UK (Chief Medical Officer, 2004) and US (Simpson et al., 2003). Despite its prevalence, it has been suggested that walking, or ambulatory activity, is typically under reported in questionnaire-based surveys of physical activity (Ainsworth et al., 1993; Richardson et al., 1994; Tudor-Locke and Myers, 2001). Pedometers provide an inexpensive, accurate and reliable, objective measure of ambulatory activity by counting the number of steps taken per day. They enable the accumulative measurement of occupational, leisure-time and household activity, along with activity required for everyday transportation (Hornbuckle et al., 2005).

The use of pedometers in both research and by members of the public is rapidly increasing (Crouter et al., 2003) yet the majority of research published investigating

pedometer-determined activity has been conducted on US adults. To date, little research has been published investigating pedometer-determined activity in healthy, free-living UK adults. From the research available, Clemes et al.(2007) reported that mean daily step counts, measured in normal-weight and overweight UK adults were higher, by approximately 3000 to 4000 steps/day, than those observed in US adults. With the growing problem of obesity worldwide, and as physical activity is a key component for the treatment and prevention of obesity (Grundy et al., 1999), it is essential to understand habitual activity levels and patterns in different populations to aid in the formulation of appropriate, population-specific, public health messages.

Currently no data exist that describe pedometer-determined activity levels of obese individuals living in the UK. The aim of the current study therefore was to add to the understanding of ambulatory activity levels in UK adults by assessing daily step counts across days of the week in another, larger, sample of normal-weight and overweight individuals while adding a group of obese individuals to the comparison.

METHODS

Participants

254 participants from the East Midlands region in the UK were recruited via word of mouth and through advertisements in local media. Participants were recruited using a sampling frame that was developed to achieve an equal spread of individuals across the age range of 18 to 65 years. The sampling frame also ensured that, at the study outset, the sample contained similar numbers of individuals classified as either normal-weight ($\text{BMI} < 25 \text{ kg/m}^2$), overweight ($\text{BMI} 25\text{--}29.9 \text{ kg/m}^2$) or obese ($\text{BMI} \geq 30 \text{ kg/m}^2$).

A health screen completed at baseline confirmed that participants were all in good general health and none had any physical illnesses or disabilities that might affect their normal daily routine. The study received ethical approval from the Loughborough University Ethical Advisory Committee, and participants provided written informed consent.

Measurements of body mass and BMI

Body mass (kg) and height (cm) were directly measured without shoes using electronic weighing scales (Tanita UK Ltd) and a wall-mounted stadiometer (Seca UK) prior to the monitoring period. BMI was calculated as kg/m^2 .

Pedometer-determined activity

All participants were issued a New Lifestyles Digi-Walker SW-200 pedometer (New Lifestyles, Inc., Lees Summit, MO) and daily step log. This pedometer has been shown to accurately detect steps taken in both free-living conditions (Schneider et al., 2004) and under controlled laboratory conditions using normal-weight (Crouter et al., 2003; Le Masurier and Tudor-Locke, 2003; Schneider et al., 2003), overweight and obese (Swartz et al., 2003) individuals. Participants were instructed to wear the pedometer throughout waking hours for a period of four weeks, only removing when either bathing, showering or swimming. The appropriate position to wear the pedometer, on the waist band in-line with the midline of the thigh, was shown to participants at the outset. Pedometer accuracy was confirmed with each participant upon issue by means of a 20 step test (acceptance criteria: plus/minus two steps). Each night before going to bed participants recorded the number of steps displayed in their log. The pedometer was then reset ready for the following day.

All participants were encouraged not to make any changes to their typical daily routine of work and leisure activity. Upon finishing the study all completed a brief post-study questionnaire inquiring whether they had suffered from any ill health, not worn the pedometer for a full day, or made any changes to their normal routine, diet, or general activity levels during the study period.

Statistical analyses

Statistical analyses were conducted using SPSS for Windows version 14. The normal-weight, overweight and obese participants were analysed as three separate groups. Mean step counts were calculated over the four-week study for each group. Mean step counts reported on each day, of the 28-day monitoring period, were also calculated to enable any activity patterns to be identified. In addition, mean step counts reported on each specific day of the week were calculated using the four sets of data available for each

day of the week. Using this data a repeated-measures ANOVA with Bonferroni corrected post hoc comparisons were applied to test whether mean step counts differed between days. Effect size of steps per day was calculated (Field, 2005) to ascertain the size of the differences in step counts between days of the week. Differences in mean step counts and demographic variables between the three groups were tested using one-way ANOVAs, with Bonferroni post hoc comparisons, while the relationship between age and BMI was analysed using Pearson's correlation. Statistical significance was set at $p < 0.05$.

RESULTS

Participants

Of the 254 participants starting the study, two were lost at follow-up. Participants completing the study ($n = 252$) all reported, on the post-study questionnaire, no changes to their daily routine occurring throughout the four-week monitoring period.

Participants provided 6976 person-days of pedometer data, of a possible 7056 (98.9% compliance) over the four-week study. There were no significant differences between the three BMI groups in terms of the number of days in which daily step counts were recorded (sample mean = 27.7 ± 1.0 days, $F = 0.74$, $p = 0.48$).

The demographic characteristics of the three BMI groups, and of the complete sample, are shown in Table 1. Mean step counts reported by the three groups differed significantly ($F = 10.2$, $p < 0.001$), with the normal-weight group reporting a significantly higher mean daily step count compared to the overweight ($p = 0.04$) and obese ($p < 0.001$) groups. Mean step counts did not differ significantly between the overweight and obese participants ($p = 0.11$) (Table 1).

Insert Table 1 about here

Activity patterns over different days of the week

There was a significant trend for all three BMI groups to report a decrease in activity on a Sunday, with this trend being particularly pronounced in the overweight and obese groups (Figure 1). Mean step counts reported on a Sunday by these groups were significantly lower than those reported on all other days (all $p < 0.001$) (Table 2). As post hoc analyses showed no other significant day-of-the-week effect other than Sunday versus all other days, a comparison of the mean daily step count for Monday to Saturday versus Sunday was undertaken using a paired t-test for the overweight ($t = 7.5$, $p < 0.001$, effect size = 0.62) and obese ($t = 5.8$, $p < 0.001$, effect size = 0.56) groups. In comparison, mean step counts reported on a Sunday, by the normal-weight group, were significantly lower than those reported on Tuesday ($p = 0.002$) and Wednesday ($p < 0.001$) only.

Insert Figure 1 about here

Insert Table 2 about here

Figure 1

Mean daily step counts (SE) reported on each day of the week over the four week monitoring frame by normal-weight, overweight and obese participants from the East Midlands, assessed in winter 2006.

Between group differences

Mean step counts reported on each day of the week by the three BMI groups differed significantly (Table 2), with post hoc analyses revealing that the normal-weight group reported significantly higher mean step counts than the obese group on all days of the week (all $p < 0.05$). When compared with the overweight group, the normal-weight group reported significantly higher step counts on Saturday and Sunday only (both $p < 0.05$). There were no differences in mean step counts reported by the overweight and obese groups on any day of the week.

The influence of age on mean daily step counts within each group

The normal-weight participants were significantly younger than the overweight ($p = 0.002$) and obese groups ($p = 0.001$) (Table 1), and a ~~significant yet~~ weak ($R^2 = 0.05$, $p < 0.01$) relationship between age and BMI was observed. To investigate the influence of age further, within each BMI group participants were divided into one of three age categories (18-29 years, 30-45 years and 46-65 years) as previously applied by (Tudor-Locke et al., 2004b). Within each age category, normal-weight participants took more steps than both the overweight and obese individuals, with the differences between the normal-weight and obese groups being statistically significant across all age categories (Table 3).

Insert Table 3 about here

Gender differences in mean daily step counts within each group

Within the three BMI groups, males and females did not differ significantly in terms of age, BMI or mean step counts (all $p > 0.05$). In addition, mean step counts reported on each day of the week did not differ significantly between males and females in all groups.

DISCUSSION

The aim of the current study was to investigate pedometer-determined activity levels and patterns in a sample of normal-weight, overweight and obese UK adults. There was a significant trend for activity to decrease on a Sunday in the sample studied, which is

consistent with observations made in US adults (not stratified by BMI) (Bassett et al., 2000; Tudor-Locke et al., 2004a; Tudor-Locke et al., 2005). In the current study, the reduction in activity reported on a Sunday was particularly pronounced in the overweight and obese groups, supporting previous observations in a smaller sample of overweight UK adults (Clemes et al., 2007). Clemes et al. (2007) reported a decrease of approximately 2220 steps/day occurring on a Sunday in comparison with all other days of the week in a sample of 63 overweight adults. Similarly, the overweight ($n = 91$) and obese ($n = 75$) participants surveyed in the current study decreased their activity by 2125 and 2064 steps/day, respectively, on a Sunday in comparison with all other days.

A significant day-of-the-week effect was also observed in the normal-weight participants surveyed ($n = 86$), with mean step counts reported on a Sunday being significantly lower than those reported on Tuesday and Wednesday. This finding differs to that reported by Clemes et al. (2007) who observed no significant day-of-the-week effect on the step counts of 59 normal-weight UK adults. This difference could be attributable to the time of year in which the studies were conducted as seasonal changes in activity have been reported in US adults (Tudor-Locke et al., 2004a). Participants in the current study were monitored during the winter months, whilst the study conducted by Clemes et al. (2007) took place during the summer months.

The reduction in activity seen on a Sunday in the participants surveyed is of particular concern considering the numerous studies published documenting that energy intake increases over the weekend period (Lyons et al., 1989; Soares et al., 1989; de Castro, 1991; Jula et al., 1999; Haines et al., 2003; O'Dwyer et al., 2005). The reported increase in energy intake that occurs over the weekend coupled with the reduction in ambulatory activity reported on a Sunday, particularly in our overweight and obese participants, suggests that weekends are a time of positive energy imbalance in these at-risk groups. It would be interesting for future studies to collect information regarding energy intake in addition to daily step counts with the view of making comparisons between the two.

The step counts observed in our sample of normal-weight, overweight and obese adults appear to be higher, by approximately 2000-3000 steps/day in all groups, when

compared with step counts of US adults stratified by BMI (Tudor-Locke et al., 2001; Tudor-Locke et al., 2004b), adding support to the suggestion that ambulatory activity levels should be assessed in different populations to aid in the development of population-specific activity interventions (Clemes et al., 2007).

Unlike other studies investigating reported physical activity levels in UK adults, the current study found no significant differences in activity levels between males and females (Department of Health, 2005; Harrison et al., 2006). This failure to observe any gender differences could be attributable to the sample size, as the previous studies reporting gender differences were large population-based surveys, or to the method of data collection (self report versus pedometer).

It is not surprising that the normal-weight participants reported a significantly higher mean step count than the overweight and obese participants, as physical activity is a key component of preventing and treating obesity (Grundy et al., 1999). The normal-weight participants took on average 1216 steps/day more than the overweight group, which corresponds to a 10-12 minute walk. The normal-weight group took 2411 steps/day more than the obese group, which is equal to walking for 20-24 minutes. Focussing on this difference, 2411 steps is equal to walking the distance of one mile for most people (Hill et al., 2003). Walking an extra mile a day, either all at once or accumulated over the course of the day in the form of lifestyle activities (for example, taking the stairs) has been estimated to result in an energy expenditure of approximately 100 kcal/day (Hill et al., 2003). According to Hill et al. (2003) an estimated 90% of the US population are gaining weight owing to a positive energy imbalance of ≤ 100 kcal/day, and they speculate that by encouraging individuals to walk an extra mile per day, could theoretically abolish the 'energy gap' and hence weight gain for most of the population.

Study limitations and strengths

A limitation of the current study is that participants were only recruited from the East Midlands region, it would be interesting for future research to measure pedometer-determined activity levels from individuals living in a number of locations throughout the UK. A second limitation, common to pedometers, is that they only record lower

body movements and thus, do not capture any occupational, leisure time, or household activities that only involve upper body movements. Nor do they capture activities such as swimming or cycling. Therefore, in this study, we are only measuring day-to-day ambulatory activity. A further potential limitation is the pedometer used. Whilst Swartz et al. (2003) reported no effect of BMI group on the accuracy of the Digi-Walker SW-200 pedometer, Crouter et al. (2005) have reported reductions in the accuracy of this pedometer in obese individuals. We attempted to overcome this limitation by checking pedometer accuracy using a 20 step test with each participant at the study outset.

This study adds to the limited information currently available on pedometer-determined activity levels of free-living adults from the UK, and it is the first of its kind to analyse pedometer-determined activity patterns in an obese sample of adults. The four-week monitoring frame used in the current study increases the likelihood that we have captured participants habitual activity and any reactivity effects, a potential validity threat to short-term studies, have been minimised (Eastep et al., 2004; Clemes et al., 2008).

Conclusion

The normal-weight participants assessed in the current study reported a significantly higher mean daily step count than both the overweight and obese groups, and this trend remained when participants were further stratified by age group. No differences in step counts were observed between the overweight and obese participants. Pedometer-determined activity levels dropped on a Sunday in all participants surveyed, however this reduction was approximately two-fold greater in the overweight and obese groups when compared to the normal-weight group. With the increasing prevalence of obesity in the UK, efforts are needed by the government, society and individuals to make changes to physical activity levels. Further research is required to identify effective interventions to increase physical activity in the general population and in population sub-groups (Harrison et al., 2006). The issuing of pedometers to overweight and obese individuals, with the instruction to increase their ambulatory activity on all days of the

week, with particular emphasis on Sunday activity, could be a good starting point in tackling the problem of obesity in the UK.

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Table 1

Mean (SD) demographic data and step counts for normal weight, overweight and obese participants (along with the means for the complete sample) from the East Midlands, assessed in winter 2006.

	Normal weight (n = 86) 58 females, 28 males	Overweight (n = 91) 52 females, 39 males	Obese (n = 75) 52 females, 23 males	All (n = 252) 162 females, 90 males
Age (years)	34.0 (12.1) ^{a, b}	40.6 (13.6) ^a	41.2 (12.4) ^b	38.5 (13.1)
Height (cm)	168.7 (9.1)	169.5 (8.6)	166.6 (8.6)	168.4 (8.8)
Weight (kg)	63.9 (8.9) ^{a, b}	79.2 (9.3) ^{a, c}	93.7 (15.5) ^{b, c}	78.3 (16.5)
BMI (kg/m ²)*	22.4 (2.0) ^{a, b}	27.5 (1.4) ^{a, c}	34.2 (3.6) ^{b, c}	27.7 (5.3)
Mean step count (steps/day)	10247 (3191) ^{a, b}	9095 (2950) ^a	8102 (2894) ^b	9192 (3127)

* BMI – Body mass index, calculated by weight in kilograms divided by height in meters squared.

^{a, b, c} between group differences, measures with the same superscript letter were significantly different from one another, following post hoc analyses (all $p < 0.05$).

Table 2

Mean (SD) daily step counts calculated for each day of the week, for normal weight, overweight and obese participants (along with the means for the complete sample) from the East Midlands, assessed in winter 2006.

	Normal weight (n = 86) 58 females, 28 males	Overweight (n = 91) 52 females, 39 males	Obese (n = 75) 52 females, 23 males	Between group differences (<i>p</i> value)	All (n = 252) 162 females, 90 males
Monday	9912 (3463) ^a	9385 (3424)	8510 (3804) ^a	0.044	9304 (3584)
Tuesday	10629 (3640) ^a	9682 (3763)	8658 (4058) ^a	0.005	9700 (3878)
Wednesday	10890 (4121) ^a	9727 (3583)	8385 (3552) ^a	<0.001	9725 (3883)
Thursday	10090 (3516) ^a	9085 (3380)	8419 (3524) ^a	0.009	9230 (3522)
Friday	10386 (3804) ^a	9494 (3527)	8427 (3207) ^a	0.002	9481 (3606)
Saturday	10580 (4819) ^{a, b}	9070 (3335) ^b	8035 (3416) ^a	<0.001	9277 (4044)
Sunday	9271 (4265) ^{a, b}	7282 (3539) ^b	6342 (3036) ^a	<0.001	7681 (3851)
Within group differences	0.001*	<0.001**	<0.001**		<0.001**

* within group differences, mean daily step counts reported on a Sunday were significantly lower than those reported on Tuesday and Wednesday in the normal weight group, following post hoc analyses (both $p < 0.002$).

** within group differences, mean daily step counts reported on a Sunday were significantly lower than those reported on all other days of the week in the overweight and obese groups, and for the sample as a whole, following post hoc analyses (all $p < 0.001$)

^{a, b} between group differences, step counts with the same superscript letter were significantly different from one another, following Bonferroni corrected post hoc analyses (all $p < 0.05$).

Table 3

Mean (SD) daily step counts calculated over the four week study for normal weight, overweight and obese participants stratified by age group (along with the means for the complete sample) from the East Midlands, assessed in winter 2006.

	Normal weight (n = 86)		Overweight (n = 91)		Obese (n = 75)		Between group differences (p value)	All (n = 252)	
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)		n	Mean (SD)
18 – 29 years	42	10281 (3316) ^a	23	9462 (2934)	14	8430 (2041) ^a	0.05	79	9715 (3064)
30 – 45 years	26	10817 (2404) ^a	33	9518 (2996)	33	8917 (3523) ^a	0.03	92	9669 (3114)
46 – 65 years	18	9341 (3810) ^a	35	8455 (2886) ^b	28	6977 (2016) ^{a, b}	0.02	81	8141 (2973)
Within group differences		NS		NS		0.03*			<0.001**

* within the obese group, the 46 - 65 year olds took significantly fewer steps than the 30 - 45 year olds, following post hoc analyses ($p = 0.03$)

** within the whole sample, the 46 - 65 year olds took significantly fewer steps than both the 18 - 29 year olds and the 30-45 year olds, following post hoc analyses (both $p < 0.01$)

^{a, b} between group differences, step counts with the same superscript letter were significantly different from one another, following post hoc analyses (all $p < 0.05$).

Figure 1

