Four-week pedometer-determined activity patterns in normal weight and overweight UK adults

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4-Week Pedometer Determined Activity Patterns in Normal Weight and Overweight UK Adults

Running title: Physical activity patterns in UK adults

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Abstract

Objective
To assess pedometer-determined physical activity levels, and activity patterns, in a sample of free-living normal weight and overweight UK adults.

Design
Pedometer based 4-week observational study.

Participants
122 healthy participants, recruited from two regions in the UK, classified as normal weight (33 females and 26 males) or overweight (31 females and 32 males), between the age range of 18 to 65 years, completed the study.

Measurements
Daily step counts were measured using a Yamax SW-200 pedometer, and were then recorded in an activity log. Comparisons were made between activity patterns occurring over different days of the week for the normal weight and overweight groups. Measurements of height, weight and percentage body fat, by bioelectrical impedance, were taken pre and post study.

Results
A consistent reduction in activity was observed on a Sunday in the overweight group, and mean daily step counts accumulated on Sundays were significantly lower, by an average of 2221 steps/day, when compared with all other days of the week (all $P<0.001$). In comparison, no day-of-the-week effect was observed in the normal weight group. Mean step counts reported on each day of the week did not differ significantly between the two groups, with the exception of Sunday when the overweight group reported significantly fewer steps than the normal weight participants (8093 versus 10538, $P<0.001$).

Conclusions
Activity levels dropped dramatically in the sample of overweight adults on a Sunday. Simple instructions to at-risk individuals, to increase their general activity levels on a Sunday, via general practitioners and public health messages could prove to be a subtle, but effective, strategy to tackle obesity.

Keywords
Physical activity, body mass index, pedometer, UK adults, Overweight, Obesity
**Introduction**

In the UK in 2004, approximately 67% of men and 59% of women were overweight (body mass index [BMI] $\geq 25$ kg/m$^2$), with just under 24% of both genders being classified as obese (BMI $\geq 30$ kg/m$^2$) (age range: 16 to 75+ years).\(^1\) Obesity represents a major public health problem, and strategies for its prevention and treatment are now a high public health priority.\(^2\)

In a survey of UK adults, approximately three-quarters of women and two-thirds of men failed to meet physical activity recommendations\(^1\) (undertaking a minimum of 30 minutes of at least moderate intensity activity, at least five times per week\(^1\)), with 44% reportedly leading sedentary lifestyles (reporting no moderate or vigorous physical activity lasting for at least 15 minutes over the previous 7 days).\(^3\) Research is therefore needed into the development of effective tools and interventions to help increase physical activity levels.\(^3\)

Pedometers provide an inexpensive, accurate and reliable, objective measure of physical activity by counting the number of steps taken per day. They enable the measurement of occupational, leisure time and household activity, along with that required for everyday transportation,\(^4\) and the use of these devices in both research and by members of the public is rapidly increasing.

The objective monitoring of physical activity using pedometers is still in its infancy and more is to be learnt about the wide sources of inter- and intra-individual variability common in the measurement of the number of steps taken per day (steps/day).\(^5\) The majority of research published investigating pedometer determined activity levels has been conducted on US adults, and with one exception,\(^6\) a popular monitoring frame has been seven days.\(^4\),\(^5\),\(^7\)-\(^9\) To date, little research has been published in the medical and scientific literature investigating pedometer-determined activity in healthy UK adults.\(^10\) With the growing problem of obesity worldwide it is essential to understand activity levels and patterns in different populations to aid in the formulation of appropriate public health messages.

The aim of the current study therefore was to assess pedometer determined physical activity in a sample of normal weight (BMI $< 25$) and overweight (BMI $> 25$) free-living UK adults. The study was conducted over a 4 week period as it was anticipated that an extended monitoring frame would both increase the likelihood of capturing participants’ habitual activity levels, and aid in the identification of any patterns of activity occurring over different days of the week, as has been observed in US adults.\(^6\)

**Methods**

**Participants**

Participants were recruited from two different counties in the United Kingdom – Leicestershire (n = 77) and Cornwall (n = 53) through advertisements placed in local media.

Male and female adult 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, an equal number of participants were classified as either normal weight (BMI $< 25$) or overweight (BMI $> 25$), to reflect the 2001 prevalence of overweight in UK adults.\(^11\)
Responses on a health screen questionnaire 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. Participants were informed about the purpose of the study, they received written and oral information about the study protocol and provided written informed consent.

**Measurements of body weight and composition**

At the beginning of the study, height was measured without shoes using a wall-mounted stadiometer (Seca UK, Model: 206, Birmingham, Warwickshire, UK). Body weight, BMI and percentage body fat were measured using a Tanita Body Composition Analyser (Tanita UK Ltd, Model: BC-418 MA, Middlesex, UK) that measures body fat using 8-point bio-impedance analysis. Percent body fat measured using the Tanita BC-418 has been shown to correlate highly with the reference measure of dual-energy X-ray absorptiometry (DXA).12 As impedance fluctuates with the distribution of body fluid, to improve accuracy, participants were required to urinate before the measurement of percentage body fat was taken. Measurements of weight, BMI and body fat were repeated at the end of the study.

**Assessment of physical activity**

All participants were issued with a New Lifestyles Digi-Walker SW-200 pedometer (New Lifestyles, Inc., Lees Summit, MO) and an activity log. This brand of pedometer has been shown to accurately detect steps taken in both laboratory13-16 and free-living conditions.17 Participants were instructed to wear the pedometer throughout waking hours for a period of four weeks, only removing the pedometer when either bathing, showering or swimming. Each night before retiring participants recorded the number of steps displayed, in their activity log.

All participants were strongly encouraged not to make any changes to their typical daily routine of work and leisure activity. Upon completion of the study all completed a brief post study questionnaire enquiring whether they had suffered from any ill health 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 12. The normal and overweight participants were analysed as two separate groups. Mean daily step counts reported for each day of the week, over the four week period, were calculated to enable any activity patterns to be identified. Participants’ mean daily step counts were also calculated by averaging daily step counts reported over the four week study. Mean step counts reported on each specific day of the week were also calculated using the four sets of data available for each day. Using this data a repeated measures ANOVA was applied to test whether mean daily step counts differed with the day of the week, in the event of this test being statistically significant, post hoc comparisons, using paired samples t tests with a Bonferroni correction, were applied. Differences in mean daily step counts and demographic variables between the normal weight and overweight groups were analysed using independent samples t tests. Effect size of steps per day was calculated18 to ascertain the size of the difference in step counts between days of the week and between the normal and overweight groups. Differences in mean daily step counts between males and females, within each group, were analysed using independent samples t tests. Statistical significance was set at $P < 0.05$. 
Results

Participants
Of the 130 participants who started the study, four were lost at follow-up. Following their responses on the post study questionnaire, four further participants were excluded from the main analyses due to them reporting a major change to their daily routine occurring throughout the four week study. These changes included a change of job (n = 2), moving house (n = 1, this respondent reported extra activity because of packing, unpacking and moving large items), and suffering from a broken toe (n = 1). Results are reported for the remaining 122 participants.

Participants collected 3379 person-days of data, of a possible 3416 (99% compliance). There were no significant differences between the normal weight and overweight groups in terms of the number of days in which daily step counts were recorded (normal weight group = 27.6 days, overweight group = 27.8 days, t = 1.7, p > 0.05, independent samples t test) The entire sample (n = 122) had a mean daily step count of 10 617 (SD = 3302) steps/day.

The study was conducted throughout the Summer Solstice, with all data collected between the 21st June and 22nd September, 2005. Recruitment into the study took place over a 10 week period. There was no significant difference between the normal weight and overweight participants in terms of the week in which they were recruited into the study (t = 0.83, p > 0.05, independent samples t test).

The normal and overweight groups did not differ significantly in terms of age (Table 1). The overweight group reported a significantly lower overall mean daily step count in comparison with the normal weight group (P < 0.03) (Table 1).

Activity patterns over different days of the week
There was a consistent trend for the overweight participants to report a decrease in activity on a Sunday (Figure 1), and mean step counts reported on a Sunday were significantly lower than those reported on all other days of the week for this group (post hoc analyses with Bonferroni correction applied, all P < 0.001) (Table 2). In contrast, no significant day-of-the-week effect was observed in the normal weight group (Table 2). Because 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 (t = 4.95, P < 0.001) for the overweight participants. This resulted in an effect size of 0.53. In contrast, a similar analyses for the normal weight participants (t = 2.13, P < 0.05) resulted in a smaller effect size of 0.07.

Between group comparisons in daily step counts
Mean step counts reported on each day of the week did not differ significantly between the normal weight and overweight groups, with the exception of Sunday when the overweight group reported significantly fewer steps than the normal weight participants (Table 2).
effect size for the Sunday comparison of overweight versus normal weight participants was 0.11 compared to a smaller effect size of 0.02 for all other days of the week.

**Gender differences in mean daily step counts**
Within the normal and overweight groups there was a tendency for males to report a higher mean daily step count than their female counterparts (normal weight males = 12584 versus normal weight females = 10240 steps/day; overweight males = 10564 versus overweight females = 9422 steps/day) and this difference was statistically significant in the normal weight group (t = 2.93, *P* < 0.05), but not the overweight group (t = 1.39, *P* > 0.05).

**Comparisons of demographic variables taken pre and post study**
Comparisons of participant’s weight, BMI and percent body fat measures taken at the beginning and end of the study revealed no significant changes in the normal weight group (all *P* > 0.05, paired t tests). Similarly, no significant differences in pre and post study measures of weight and BMI were observed in the overweight group. A small (30.5% visit 1 versus 31.1% visit 2) but significant increase in percent body fat was observed however over the course of the study in the overweight group (t = 3.4, *P* < 0.001, paired t test).

**Discussion**
This study was the first of its kind to assess pedometer determined physical activity levels across the days of the week in a sample of normal weight and overweight UK adults. The results of the current study have shown that pedometer determined activity levels dropped significantly on a Sunday in a group of overweight individuals when compared with all other days of the week. No such day-of-the-week effect was observed in the normal weight group. When the two groups were compared, mean step counts reported on each day of the week did not differ significantly, with the exception of Sunday, when the overweight group reported significantly fewer steps than the normal weight participants.

Participants’ weights and percent body fats did not change significantly over the course of the study (with the exception of the overweight group who experienced a slight increase in body fat). All participants completed a post-study questionnaire upon completion of the trial and participants included in the analyses reported no changes to their normal routine, diet, or general activity levels during the study period. It therefore appears that we were successful in measuring normal daily pedometer-determined activity levels in a sample of free-living UK adults.

The reduction in activity on a Sunday seen in the overweight group is consistent with reports of activity patterns observed in US adults.6-8 For example, using the same pedometer, Tudor-Locke et al.5 reported that participants took significantly fewer steps (by approximately 1250 steps/day) on a Sunday in comparison with all other days of the week.

The reduction in step counts reported on a Sunday seen in our overweight group is larger (2221 steps/day) than that reported in the study by Tudor-Locke et al.5 A possible explanation for this is Tudor-Locke et al.’s5 sample were not categorised into different BMI groups. It is therefore possible that their normal weight individuals may have masked a larger ‘Sunday effect’ present in their overweight participants. Our complete sample took on average 1560 steps/day less on a Sunday in comparison with the number of steps taken during the rest of the week, a reduction similar to that observed by Tudor-Locke et al.5
As previously observed in a sample of Swiss adults\textsuperscript{19}, mean daily step counts measured in our sample (the complete sample took an average of 10 617 ± 3302 steps/day) are higher, by approximately 3000 to 4000 steps per day, than those observed in US adults\textsuperscript{5, 8, 20, 21}. The step counts observed in the current study are also similar to those observed in a recent study using Finish adults\textsuperscript{22}, in which a control group, continuing with their normal daily routine, reported a mean daily step count of approximately 9500 steps/day\textsuperscript{22}. Using data from the National Health and Nutrition Examination Survey (NHANES), in 2002 the prevalence of obesity in the US was reported to be 30.6\textsuperscript{23}, in comparison with the 24\% obesity prevalence seen in UK adults in 2004\textsuperscript{1}. Differences in step counts may therefore help to explain differences in the prevalence of obesity between UK and US adults.

Like other studies investigating reported physical activity levels in UK adults, this study found that overweight individuals were less active than those classified as normal weight.\textsuperscript{1, 3} While mean daily step counts did not differ significantly between the two study groups on Monday through to Saturday, there was a tendency for the overweight group to have a lower step count on each of these days. Overall, the overweight group had a significantly lower mean daily step count in comparison with the normal weight group, by an average of 1271 steps/day. This difference, of approximately 1000 steps/day between the two groups, could have important consequences in terms of body weight regulation. 1000 steps is the equivalent of expending approximately 50 kcal of energy,\textsuperscript{24} and Hill et al.\textsuperscript{24} have estimated that the gradual weight gain seen in the US over the past 15 years could have resulted from a consistent, sustained, positive energy balance of approximately 50 kcal/day.

The reduction in activity seen on a Sunday in the overweight participants is of particular concern considering the numerous studies published documenting that energy intake actually increases over the weekend period.\textsuperscript{25-31} The reported increase in energy intake that occurs over the weekend coupled with the reduction in physical activity reported on a Sunday in the overweight participants suggests that weekends are a time of positive energy balance in this at-risk group. It would be useful for future studies to compare daily energy intakes with daily step counts.

It is interesting to consider why such a decrease in activity on a Sunday was seen in the overweight group, but not in the normal weight group. From reports of any sporting or recreational physical activity undertaken each day, recorded in participants’ activity log, it was observed that the normal weight group were more likely to participate in sporting or recreational physical activity on a Sunday, in comparison with the overweight participants. Sunday was actually the day when the normal weight group reported the most number of minutes engaged in recreational physical activity or sport (mean = 25 minutes/day), in comparison with the other days of the week. In contrast, the overweight group reportedly undertook an average of 11 minutes of physical activity on a Sunday, and this figure was similar to the number of minutes reported on all other days of the week. The difference in the number of minutes reportedly engaged in sporting/recreational physical activity on a Sunday was statistically significant between the normal weight and overweight groups (t = 2.0, p = 0.04).

Despite the overweight participants accumulating, on average, the recommended 10 000 steps/day\textsuperscript{32} on Monday through to Saturday, it could be speculated that due to a potential positive energy balance, as suggested by research investigating patterns in energy intake over different days of the week,\textsuperscript{25-31} coupled with the decrease in activity observed in this group on
a Sunday, accumulating 10 000 steps/day on six days per week is not sufficient to prevent unhealthy fat accretion.

The current study, like other studies investigating reported physical activity levels in UK adults, found that males were generally more active than females. It appears that the gender differences in mean daily step counts, reported in the normal weight group, were due to differences in the number of minutes reportedly engaged in sport or recreational physical activity. From the activity log, it is possible to ascertain that normal weight males reported significantly more minutes undertaking sport/recreational physical activity per day in comparison with their female counterparts (males = 28 minutes/day, females = 10 minutes/day, t = 3.2, p < 0.01). In contrast, within the overweight group there were no gender differences in the mean number of minutes reportedly spent undertaking sport/recreational physical activity per day (males = 13 minutes/day, females = 6 minutes/day, t = 1.95, p > 0.05).

A limitation of the current study is the sample size. Using BMI, participants were categorised as either normal weight or overweight, within the overweight group (n = 63) only 21 participants were considered obese (BMI ≥ 30kg/m²). This resulted in it not being possible to further consider activity patterns of obese versus overweight and normal weight participants. In addition, data was collected from only two areas in the UK and participants were self selected to take part, although there is no reason to suppose that normal and overweight individuals would self select differently into the study. It would be interesting to repeat the current study using participants recruited from other areas within the UK. It would also be recommended that a larger sample of overweight and obese (BMI > 30) individuals be sampled to enable comparisons to be made between these groups. A further limitation, common to pedometers is the fact that they do not measure physical activity using only upper body movements, such as washing the dishes or ironing, they also do not measure the activity involved in weight training. Therefore, in this study we are only measuring day-to-day ambulatory activity.

In conclusion, nutritional intake and physical activity levels are factors that need to be effectively manipulated in the successful prevention, and treatment, of obesity. However, the current energy imbalance that is thought to lead to weight gain is small, for example, Hill et al. estimate that 90% of the US population are gaining weight due to a positive energy balance of ≤ 100 kcal/day. Therefore, simple instructions to at-risk individuals, to increase their general activity levels on a Sunday, via general practitioners and public health messages could prove to be a subtle, but effective, strategy in tackling obesity in UK adults.

**Acknowledgment**
The authors gratefully acknowledge the help of Carole Clemes for organising and overseeing participant recruitment in Cornwall.
References


Table 1. Demographic data from the two participant groups

<table>
<thead>
<tr>
<th></th>
<th>Normal weight (n = 59)</th>
<th>Overweight (n = 63)</th>
<th>Between group differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>33 Females, 26 Males</td>
<td>31 Females, 32 Males</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>t-value</td>
</tr>
<tr>
<td></td>
<td>38.8 (11.9)</td>
<td>42.3 (12.3)</td>
<td>1.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.9 (10.1)</td>
<td>169.4 (9.6)</td>
<td>0.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.5 (9.6)</td>
<td>84.4 (11.6)</td>
<td>10.3</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.3 (2.0)</td>
<td>29.5 (4.4)</td>
<td>11.6</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>21.6 (8.0)</td>
<td>30.5 (9.4)</td>
<td>5.5</td>
</tr>
<tr>
<td>Mean daily step count</td>
<td>11273 (2262)</td>
<td>10002 (3245)</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Figure 1

Table 2. Mean daily step counts calculated for each day of the week for the two study groups, along with the means for the complete sample

<table>
<thead>
<tr>
<th></th>
<th>Normal weight (n = 59)</th>
<th>Overweight (n = 63)</th>
<th>Between group differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>33 Females, 26 Males</td>
<td>31 Females, 32 Males</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>t-value</td>
</tr>
<tr>
<td>Monday</td>
<td>10648 (5678)</td>
<td>16582 (4118)</td>
<td>0.4</td>
</tr>
<tr>
<td>Tuesday</td>
<td>11280 (7681)</td>
<td>10177 (4146)</td>
<td>1.7</td>
</tr>
<tr>
<td>Wednesday</td>
<td>11535 (4907)</td>
<td>10595 (4211)</td>
<td>1.3</td>
</tr>
<tr>
<td>Thursday</td>
<td>11325 (3718)</td>
<td>10038 (4102)</td>
<td>1.6</td>
</tr>
<tr>
<td>Friday</td>
<td>11531 (3909)</td>
<td>10278 (4043)</td>
<td>1.7</td>
</tr>
<tr>
<td>Saturday</td>
<td>11630 (4308)</td>
<td>10149 (4516)</td>
<td>1.8</td>
</tr>
<tr>
<td>Sunday</td>
<td>10538 (4019)</td>
<td>8095 (3055)</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within group</td>
<td>differences (steps/day)</td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Note: a 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 group (p < 0.001).