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Title
Sitting patterns at work: objective measurement of adherence to current recommendations.

Running title
Sitting patterns at work.

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Abstract

Long uninterrupted sedentary periods, independent of total sedentary time, are risk factors for poor health. There is little objective data relating to workplace sedentary behavior and adherence to current recommendations. The sitting behaviour of office workers (n=83) was quantified objectively using body-worn accelerometers (activPAL™) over a working week. Adherence to three different recommendations (maximum length of a sitting event of: 20minutes, 30minutes and 55minutes) were assessed. Participants were seated at work for 5.3±1.0hours/day (Mean±1SD), equivalent to 66±12% of the working day, accrued in 27±7events/day individual sitting events. Dependent on the recommendation applied, 5-20% of sitting events and 25-67% of time was accumulated in sitting events longer than current guidelines. No participants met the 20 or 30minutes recommendations on every working day but seven (8%) participants met the 55minutes recommendation. In conclusion, office workers spend considerable period of their day sitting, accumulated in uninterrupted sitting events longer than current recommendations.

Key words
Sedentary; sitting; behaviour; adherence; activPAL™

Statement of relevance
Emerging evidence suggests prolonged sitting has negative health effects. In this study of office-workers 25-67% of time sitting was accumulated in events longer than minimum recommended durations. Adverse sitting behaviour is prevalent in the office making it an appropriate setting to target the reduction of this behaviour.
1. Introduction

Moderate to vigorous physical activity (MVPA) can have a beneficial effect on many health conditions such as cardiovascular disease, type II diabetes and obesity (Pate et al. 1995; Haskell et al. 2007). Very specific MVPA guidelines for adults exist, recommending 30 minutes of moderate intensity activity on most days of the week to be accumulated in bouts of 10 minutes or more (Haskell et al. 2007). It has been argued that many modern day occupations require too little MVPA and that strategies should be put in place to increase physical workloads in the workplace (Straker and Mathiassen 2009).

Sedentary behaviour can be defined as time spent sitting (Biddle 2007; Katzmarzyk et al. 2009; Owen et al. 2009) or sitting/supine (Chastin and Granat 2010; Jans et al. 2007). Recently, it has been shown that sedentary behaviour is a risk factor for many health conditions often independent of MVPA (Healy et al. 2008a; Katzmarzyk et al. 2009). Additionally, there is preliminary evidence that it is not just the total sedentary time which is relevant but the manner in which it is accumulated; longer sedentary events being associated with undesirable health markers (e.g. a large waist circumference) compared to shorter sedentary events (Healy et al. 2008b; Healy et al. 2011). Despite this, there are no official national guidelines for sedentary behaviour. The recommendations that do exist are few in number, vary in their advice, and appear to be based upon expert consensus rather than robust scientific evidence (Atlas and Deyo 2001; Chartered Society of Physiotherapy 2005; Owen et al. 2009).

Many occupations are computer-based, and this results in predominantly seated behaviour at work (Hill and Peters 1998; Smith et al. 1999). Data from a range of industrialised countries, including Sweden, U.S.A, Australia and New Zealand, suggests that increased sedentariness at work is an international phenomenon (Straker and Mathiassen 2009). While the biomechanical aspects of seating and sitting have been subject to extensive research (Corlett 2006; Page et al. 2009), behavioural aspects of sitting at work have not received the same level of attention. McCrady and Levine (2009) identified that workers in the USA were sedentary for approximately two hours more on working days compared to leisure days. Workers were classified as having jobs that were either “entirely sedentary” (chair bound most of the day) or “semi-sedentary” (intermittently standing and chair-bound but without substantial
walking or physical labour) (McCrady and Levine 2009). A recent report on the sitting behaviour of office-based workers in Australia found employees were sitting for 77% of their time at work (Thorpe et al. 2008). Thus the work place is a setting where sedentary behaviour is highly prevalent, and this presents an important location where strategies to reduce sedentary behaviour should be introduced (Hamilton et al. 2008; McCrady and Levine 2009). However, without clear evidence based guidelines targeted strategies are difficult to design and implement.

A literature search identified three different recommendations which specified maximum sitting time; 20 minutes (Chartered Society of Physiotherapy 2005), 30 minutes (Atlas and Deyo 2001), and a five minute break every hour (Owen et al. 2009). The 20 minute recommendation was taken from the Chartered Society for Physiotherapy, Fit-for-work initiative (Chartered Society of Physiotherapy 2005) and the 30 minute recommendation was based upon information given to individuals with acute low back pain (Atlas and Deyo 2001). The development of both of these recommendations was rooted in musculoskeletal medicine. In contrast, the five minute breaks every hour recommendation, was developed with a focus on metabolic health, and was based upon the potential clinical implications of normative objectively measured sitting data (Owen et al. 2009). However, all three of these recommendations appear to be based upon authors’ professional judgment rather than robust scientific rationale.

A first step towards developing more evidence based guidelines should be to collect objective normative data of sitting behaviour in the work place and assess adherence to current recommendations. Whilst recent research has objectively quantified total sitting time at work (Thorpe et al. 2008; McCrady and Levine 2009), this data has been collected using accelerometer counts as a proxy for sitting times rather than using devices that directly measure sitting. Additionally, there has been no published data on sitting patterns such as the length of individual sitting events. Such information may help develop an understanding of what type of sitting recommendations may be practical to achieve and guide future interventions to reduce sedentary behaviour. The aim of this study was to objectively quantify patterns of sitting behaviour in an office setting and to assess adherence to current sitting recommendations.
2. Materials and methods

2.1 Design
In this observational study, which is a reanalysis of data collected for another study, the sitting behaviour of office-based employees during working hours over a one-week period was recorded using activity monitoring. The total sitting time accumulated and the patterns of sitting behaviour were quantified and compared to current sitting recommendations within the literature.

2.2 Participants
Participants for this study were selected from a database of free-living physical activity profiles of healthy adults. Participants were recruited onto the data-base using recruitment emails circulated to staff and postgraduate students of Glasgow Caledonian University. Participants were included on the data base if they were aged ≥18 years, lived in the community, had no mobility problems and were not expecting to experience any unusual activity in the monitoring week (e.g. on vacation). Participants from the database were selected if they worked in an office-based occupation, classified as entirely sedentary (chair bound most of the day) or semi-sedentary (intermittently standing and chair-bound but without substantial walking or physical labour) as defined by McCrady and Levine (2009). For individuals that did not provide clear indication of which days were working and non-working, weekdays were considered to be working days. Any individual who worked part-time but did not indicate which days they worked were excluded from the data set. Participants were also excluded from the data set if the number of working days recorded was less than three days. Ethical approval was received from the Glasgow Caledonian School of Health and Social Care research and ethics committee. All participants provided written informed consent.

2.3 Procedure
Sedentary activity was measured over a seven day period between October 2007 and October 2009 in Glasgow, Scotland. A time frame of 9:00am to 5:00pm on working days was selected to represent time at work. This time frame was selected to represent the usual working hours of Glasgow Caledonian University staff. Sitting events which
crossed this time boundary were also included if more than half of that event was within the 9:00-5:00pm time frame.

2.4 Physical activity monitor

Physical activity was measured using the activPAL™ physical activity monitor. The activPAL™ is an accelerometer based device which is worn on the thigh. The monitor produces a signal which is related to the inclination and movement of the thigh. From this signal it can directly identify time spent in the postures of sitting/lying, standing and walking on a second by second basis. The monitor has been shown to be a valid (>99% sensitivity and specificity) and reliable (ICC >0.99) measure of sitting posture (Grant et al. 2006). The activPAL™ is small and unobtrusive requiring little input from the wearer. These issues of accuracy and low burden are important when measuring exposure to risk factors in an office environment (Van Eerd et al. 2009).

2.5 Data analysis

Three sitting activity outcome measures were calculated for the whole group and for occupational subgroups; 1) the total number of sitting events/day 2) the total times sitting/day and 3) the mean of the longest sitting periods for each participant. Adherence to sedentary recommendations was then assessed. Adherence to three separate recommendations were used in this study; a maximum sitting time of 20 minutes (Chartered Society of Physiotherapy, 2005), a maximum sitting time of 30 minutes (Atlas and Deyo, 2001), and a five minute break every hour (Owen et al. 2009). The latter recommendation was operationalised as a maximum sitting time of 55 minutes.

The activPAL™ software (version: 5.9.1.1) classified the acceleration signal into sit/lie, stand and walk. In-house purpose built software (written in visual basic for applications, to run in excel), was used to present data by event and to select data between 9 and 5pm on work days. Visual inspection of the day was used to identify workdays and check whether the first and last periods should be included. A number of different outcome measures were calculated from the sitting data. For the whole sample, total sitting time, total number of events and total time and number of events longer than 20 minutes, 30 minutes and 55 minutes were derived. An event is defined
as a single uninterrupted sitting period. These were calculated from cumulative frequency graphs of sitting activity as a proportion of number of events and total time. For each participant, the longest sitting event was reported. In addition, the number of sitting events greater than 20, 30, and 55 minutes in each day was calculated. From this, the number of days in which the sitting recommendations were met for each individual was identified. Individuals were deemed to have met the guidelines if they met the criteria for each working day assessed.

Different subgroups of office-based worker, based on self-reported job description, e.g. lecturer, technician were identified. Differences between subgroups for basic demographics and the key sitting outcome measures were compared using a one-way ANOVA with the Statistical Package SPSS (Version 18.0).

3. Results

From a physical activity database of 121 individuals, data from 83 participants were included in this study. The remaining 38 participants were excluded as; they were not office-based, there was insufficient information to allow classification as an office-based employee or to identify their work days, or there were less than three working days recorded. Of the 83 participants included, four occupational subgroups were identified; 27 lecturers, 27 researchers (desk-based), 7 technicians and 22 administrators. One way ANOVA revealed significant differences between occupational subgroups for age (lecturers were statistically older than researchers and administrators) and BMI (no significant post-hoc differences); there were no statistically significant differences in descriptive characteristics between the subgroups. Participant characteristics are shown in Table 1. Data were available over five working days for the majority of participants (n=60). The minimum number of working days recorded was three (n=6) and the maximum was six (n=1).

Insert Table 1 here

3.1 Sitting time

For the group as a whole, 66±12% [range 31-90%] (mean±1SD [range]) of time at work was spent sitting. The total time spent sitting by participants during 388 working
days was 2,042 hours (5.3±1.0 hours/working day [range 2.5-7.2]), which was achieved in a total of 9,918 (27±7 events/working day [range 13-48]) individual sitting events. The mean of the longest sitting event of each participant was 98±34 minutes [range 43-201]. There was no statistically significant difference between the four occupational subgroups for total sitting time or the number of sitting events, though there was a trend for the technicians to spend less time sitting and accumulate more sitting events (Figure 1). There was a statistically significant difference between the occupational subgroups for the mean longest sitting period (p<0.01). The technicians’ mean longest sitting period was shorter than for the researchers (Figure 1).

Insert Figure 1 here

3.2 20 minutes recommendation

Figures 2 and 3 show a cumulative frequency graph of the duration of sitting as a proportion to the cumulative number of sitting events (figure 2) and the cumulative sitting time (figure 3) standardised to the number of working days. The horizontal lines identify how sitting behaviour relates to the 20, 30 and 55 minute sitting duration recommendations.

Of the total sitting time, 20% of events and 67% of time was in single duration sitting events that lasted longer than 20 minutes (figure 2 & 3; Table 2). The most sitting events taken by a participant which were longer than the recommended duration of 20 minutes in a single working day was 11 (from a maximum possible of 23 events). Five (6%) participants met the recommendation on at least one of the days observed and none of the participants met the recommendation for sitting in periods of no longer than 20 minutes for every working day assessed.

Insert Table 2 here
Insert figures 2 and 3 here

3.3 30 minutes recommendation
Of the total sitting time, 12% of events and 52% of time was in single duration sitting events that lasted longer than 30 minutes (figure 2 & 3; table 2). The most sitting events taken by a participant which were longer than the recommended duration of 30 minutes in a single working day was 7 (from a maximum possible of 15 events). Fifteen (18%) participants met the recommendation on at least one of the days observed. None of the participants met the recommendation for sitting in periods of no longer than 30 minutes for every working day assessed.

3.4 55 minutes recommendation
Of the total sitting time, 5% of events and 25% of time was in single duration sitting events that lasted longer than 55 minutes (figure 2 & 3; table 2). In a single working day, the maximum number of seated events recorded which were longer than 55 minutes was four (out of a maximum of seven possible sitting events). Sixty-one (73%) of participants met the recommendation on at least one of the days observed. Seven (8%) of the participants met the recommendations for sitting in periods of no longer than 55 minutes for every working day assessed. It is worth noting that a greater percentage of technicians (43% [n=3]) achieved the 55 minute recommendations on all working days compared to the other occupation categories. However, small subgroup numbers prevent more in-depth statistical analysis.

4. Discussion
This study adds to the small amount of objective data available which reports the total time spent sitting in an office-based environment. Additionally, this is the first study to objectively quantify the sitting patterns of office-based individuals in the workplace environment, and it is the first to investigate adherence to current subjective recommendations on sitting behaviour. Total sitting time was approximately 66% of the total time spent working, of which 5-20% of events, and 25-67% of time was in single duration events that lasted longer than the recommended minimum duration, depending upon which recommendations were applied. None of the participants met the recommendation for sitting in events of less than 20 and 30 minutes duration on every day of the week. But 7 (8%) of participants did meet the 55 minutes recommendations on every day of the week and 61 (73%) on at least one day a week.
The reasons for such poor adherence to recommendations are unclear. Current recommendations are not well publicised. As such, it is difficult for individuals to comply with recommendations of which they are likely unaware. It may be that recommendations are not well advertised because there exists little or no consensus on what is appropriate. Current recommendations for sitting appear to be based on expert consensus rather than strong scientific evidence (Atlas and Deyo 2001; Chartered Society of Physiotherapy 2005; Owen et al. 2009). There is a need for more robust basic data to be collected to facilitate the development of comprehensive sedentary behaviour guidelines (Healy et al. 2008b). Previous research on other health behaviours has identified the importance of using clear messages to facilitate uptake of effective behaviour change strategies (Pechmann and Reibling 2000). Similarly, clearer recommendations on sitting duration would likely increase adherence to sitting guidelines.

Poor adherence may also be the result of current recommendations being unachievable in today’s workplace and future guidelines need to be sensitive to this. If a health goal is to be motivating it should be achievable so that the individual can experience some success which can be used as a platform to encourage further behavioural change (Klein et al. 2004), otherwise it may have a negative or demotivating effect resulting in even poorer adherence. This provides some support for the use of the 55 minute recommendation as they are clearly achievable. They were the only current recommendations where any participants achieved the recommendations every working day assessed and considerably more participants achieved the recommendations on at least one day (73%) compared to the other recommendations used in this study. However, simply because the recommendation is more achievable should not be the only reason for adopting a certain sitting recommendation at work. More research is required to quantify the appropriate length of sitting periods for health and wellbeing before firm recommendations are made.

The data presented here could be used to develop future recommendations. For example, depending on the recommendation applied, the mean number of events lasting longer than recommended ranged from 1-5 events per day. This is a relatively small number of events which need to be targeted. Such targeting could involve simple workplace restructuring to interrupt these longer sitting events e.g. placing printers away from the PC. The National Institute for Health and Clinical Excellence
(NICE) highlights how architects, designers and facility managers should engage with such simple workplace environment organisation to maximise physical activity e.g. ensuring staircases are well signposted and appropriately positioned to make them more attractive to use (NICE 2008). However, the evidence to support such strategies is lacking (Dugdill et al. 2008). There is a need for future research to investigate if adverse sitting behaviour could be reduced in the workplace using simple environmental interventions.

There have been a number of articles which have objectively assessed adherence to MVPA guidelines, and only a small percentage (<5%) of individuals met current American College of Sports Medicine physical activity guidelines (Troiano et al. 2008; Chastin et al. 2009). The current study is the first to specifically investigate adherence to sedentary recommendations. The results of this study suggest a similar low level of adherence (0-8%) highlighting the need to address adherence issues for this behaviour.

A small number of studies have attempted to objectively quantify free-living sedentary behaviour (Levine et al. 2005; Thorpe et al. 2008; Matthews et al. 2008; McCrady and Levine 2009). Matthews et al. (2008) identified that Americans spend 54.9% (7.7 hours/day) of their waking day sedentary. The reason for the difference in total sedentary time for the current study and that of Matthews et al. (2008) is likely due to differing methodology. Matthews et al. (2008) looked at individuals in America >6 years-old during their waking day, whilst the current study looked at adults UK workers during their 9:00–5:00am working day. A recent report on the sitting behaviour of office-based workers in Australia, found 77% of employees time at work was spent seated (Thorpe et al. 2008). Discrepancies between the current study and Thorpe et al. (2008) could be related to differences in methodology, but the information available for the Thorpe et al. (2008) study was limited, making comparison difficult. For example, it was not identified what type of accelerometer was used to quantify sedentary behaviour. The current study differs from all previous research which have objectively measured sitting behaviour at work as it quantified the pattern in which the sedentary behaviour was accumulated, which is itself an independent risk factor for cardiovascular ill health (Healy et al. 2008b; Healy et al. 2011) and is directly linked to the achievement (or not) of current recommendations.
The sub-group analysis found a trend for the technician group to spend less time sitting and have more sitting events compared to the other groups. Additionally the mean longest sitting period was significantly shorted for the technicians compared to the researchers. This suggests that technicians had less adverse sedentary patterns than the other subgroups. It also suggests that the mean longest sitting period may be a more sensitive measure of sedentary patterns than the other measures used. Overall however, the difference in sitting behaviour between groups was relatively small and may simply reflect the natural variation of sitting behaviour for different sedentary office-based occupations. This arguably makes the study more reflective of real life office work rather than looking at a very narrow office-based occupational group such as administrative staff only. Alternatively, the different sitting behaviour between groups may reflect differences in demographic characteristics between the occupational subgroups.

This study had a number of limitations. A convenience sample of office-based workers was used. Different office-based occupations may vary in their seating behaviours, thus the findings may not be generalisable to all office-based workers. Precise data on work hours were not available for each individual and so work time was arbitrarily chosen to match the predominant prevailing work hours of the occupations represented. As there was a lack of identifiable sedentary guidelines in the literature, there were no strong criteria against which to assess adherence. The recommendations identified were taken from relatively anecdotal suggestions and may not be appropriate for guidelines. However, this limitation is a consequence of the sparse literature in the area and identifying this lack of evidence provides a useful starting point for the development and assessment of guidelines and adherence in the area of sitting behaviour. A strength of this paper was the use of a direct measure of sitting behaviour compared to some other studies which have indirectly measured sedentary behaviour using low levels of accelerometer counts (Healy et al. 2008a; Healy et al. 2008b; Matthews et al. 2008).

5. Conclusion
This study found that within the office-based working environment complete adherence to current sitting recommendations ranged from 0-8%. 5-20% of sitting events, and 25-67% of time sitting was accumulated in events that lasted longer than
the recommended minimum duration. This data reinforces previous research that the work place is an environment in which exposure to adverse sedentary behaviour is high and indicates that the workplace is a highly appropriate setting in which to target the reduction of this behaviour.

**Acknowledgments**

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**Conflict of Interest Statement**

One of the authors is a co-inventor of the activPAL™ physical activity monitor and a director of PALtechnologies Ltd. The remaining authors declare no competing interests.

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Figure legends

**Fig 1**: Mean and standard deviation of (a) number of sitting events, (b) total daily sitting time and (c) duration of longest sitting event; by occupational subgroup.

**Fig 2**: Cumulative frequency graph of the duration of sitting as a proportion to the cumulative number of sitting events standardised to the number of working days. The horizontal lines identify how sitting behaviour relates to the 20, 30 and 55 minute sitting duration recommendations.

**Fig 3**: Cumulative frequency graph of the duration of sitting as a proportion to the cumulative sitting time standardised to the number of working days. The horizontal lines identify how sitting behaviour relates to the 20, 30 and 55 minute sitting duration recommendations.
Table 1: Participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>Total Group (n= 83)</th>
<th>Lecturers (n=27)</th>
<th>Researchers (n=27)</th>
<th>Technicians (n=7)</th>
<th>Administrators (n=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender (male)</strong></td>
<td>25 (30%)</td>
<td>6 (22%)</td>
<td>10 (37%)</td>
<td>4 (57%)</td>
<td>5 (24%)</td>
</tr>
<tr>
<td><strong>Age (yrs)</strong></td>
<td>40±10</td>
<td>48±8</td>
<td>34±8</td>
<td>42±9</td>
<td>39±9</td>
</tr>
<tr>
<td><strong>Height (m)</strong></td>
<td>1.70±0.08</td>
<td>1.69±0.07</td>
<td>1.71±0.09</td>
<td>1.73±0.08</td>
<td>1.69±0.09</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>72±13</td>
<td>70±12</td>
<td>71±11</td>
<td>71±12</td>
<td>77±17</td>
</tr>
<tr>
<td><strong>BMI (kg.m²)</strong></td>
<td>24.9±3.8</td>
<td>24.5±3.5</td>
<td>24.1±3.1</td>
<td>23.5±2.4</td>
<td>27.0±4.9</td>
</tr>
</tbody>
</table>

Table 1: Participant characteristics for total sample and its sub groups. Data are presented as means ± standard deviation.
Table 2: Participant adherence to guidelines

<table>
<thead>
<tr>
<th></th>
<th>20 minutes</th>
<th>30 minutes</th>
<th>55 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of sitting events longer than recommendations (number/day)</strong></td>
<td>5.0±1.5</td>
<td>3.1±1.1</td>
<td>1.0±0.6</td>
</tr>
<tr>
<td><strong>% of sitting events longer than recommendations (%)</strong></td>
<td>20±6</td>
<td>12±4</td>
<td>4±2</td>
</tr>
<tr>
<td><strong>Sitting time longer than recommendations (hrs/day)</strong></td>
<td>3.6±1.2</td>
<td>2.8±1.1</td>
<td>1.8±0.9</td>
</tr>
<tr>
<td><strong>% of sitting time longer than recommendations (%)</strong></td>
<td>64±14</td>
<td>51±14</td>
<td>31±15</td>
</tr>
<tr>
<td><strong>Maximum sitting events in one day longer than recommendations (number)</strong></td>
<td>11 (max 23)</td>
<td>7 (max 15)</td>
<td>4 (max 7)</td>
</tr>
<tr>
<td><strong>Participants meeting recommendations every day (number)</strong></td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>7 (8%)</td>
</tr>
<tr>
<td><strong>Participants meeting recommendations on any day (number)</strong></td>
<td>5 (6%)</td>
<td>15 (18%)</td>
<td>61 (73%)</td>
</tr>
</tbody>
</table>

Table 2: This table shows participants adherence to the three different guidelines Data presented as mean ± standard deviation, number (max), or number (%).

Footnote; max = maximum; this relates to the maximum number of sitting events in one day which were longer than the recommendations e.g. at least one individual had 11 sitting events in one day longer than 20 minutes out of a possible 23 events.