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1 **Office workers objectively measured sedentary behaviour and physical activity during**
2 **and outside working hours**

3

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27

28

29 **Abstract** (135 words)

30

31 **Objective:** To examine objectively-determined sedentary behaviour and physical activity
32 (PA) during and outside working hours in full-time office workers.

33 **Methods:** 170 participants wore an ActiGraph GT1M accelerometer for 7-days. Time spent
34 sedentary (<100 counts/minute), in light PA (100–1951 counts/minute), and moderate-
35 vigorous PA (\geq 1952 counts/minute) were calculated for workdays (including working hours
36 and non-working hours) and non-workdays.

37 **Results:** Participants accumulated significantly higher levels of sedentary behaviour (68%
38 versus 60%) and lower levels of light activity (28% versus 36%) on workdays in comparison
39 to non-workdays. 71% of working hours were spent sedentary. Individuals who were most
40 sedentary at work were also more sedentary outside work.

41 **Conclusions:** Those who are most sedentary at work do not compensate by increasing their
42 PA or reducing their sedentary time outside work. Occupational interventions should address
43 workplace and leisure-time sedentary behaviour.

44

45 **Keywords:** sitting time, light intensity physical activity, workplace, occupational health,
46 leisure-time

47 **Introduction**

48 Sedentary behaviour, defined as “any waking behaviour characterised by an energy
49 expenditure ≤ 1.5 METs while in a sitting or reclining posture” (page 540),¹ is an independent
50 risk factor for a number of adverse health outcomes. For example, greater sitting time (the
51 terms sitting and sedentary behaviour are used interchangeably herein) has been associated
52 with increased risk of overweight, obesity and weight gain,^{2,3} cancer,^{4,5} type 2 diabetes and
53 the metabolic syndrome,^{2,6} all-cause mortality and cardiovascular disease mortality,^{7,8}
54 independent of moderate-to-vigorous physical activity. There is a growing consensus that
55 sedentary behaviour represents a unique aspect of human behaviour and that it should not
56 be viewed as simply the absence of physical activity.^{7,9}

57

58 Adults typically spend time sitting in three domains: the workplace, during leisure and for
59 transport.¹⁰ Economic advances and industrial innovation have resulted in large numbers of
60 people employed within sedentary occupations, and data from Australian workers have
61 shown that half of their total daily self-reported sitting time takes place at work.^{11,12}

62 Accelerometer data from Australian office workers has shown that between 66 and 82% of
63 their working day is spent sedentary.¹³⁻¹⁵ Of concern, it has been observed in some studies
64 that those who are sedentary for a large proportion of their working day do not compensate
65 by increasing their physical activity levels and/or reducing their sedentary behaviour during
66 leisure time.^{12,14,16,17}

67

68 Our understanding of the prevalence of sedentary behaviour in UK adults is currently limited,
69 and has largely been restricted to the study of leisure time screen-based sedentary
70 behaviours¹⁸ or to specific occupational groups, such as postal workers.¹⁷ It is important to
71 measure sedentary behaviour and physical activity across a range of domains, particularly
72 the workplace, if we are to truly understand patterns and determinants of these behaviours in
73 adults, in order to inform behaviour change interventions.¹⁹ To date, limited research has
74 examined objectively measured sedentary time during and outside working hours.^{13,14}

75 Increasing our understanding of the potential impact of sedentary behaviour during work, on
76 sedentary behaviour and physical activity outside of work has been highlighted as a
77 research priority.¹³ The aim of the current study therefore was to examine objectively-
78 determined sedentary behaviour and physical activity occurring during and outside working
79 hours in a sample of full-time office workers from the UK. A secondary aim was to build on
80 our understanding of the links between sedentary behaviour accumulated during and outside
81 of working hours by investigating whether those who are sedentary for a large proportion of
82 their working hours compensate by decreasing their sedentary behaviour, or increasing their
83 physical activity, during non-working hours.

84

85 **Methods**

86 ***Participants***

87 A convenience sample of 210 office workers were recruited from Loughborough University
88 and local businesses within the East Midlands region of the UK. The study inclusion criteria
89 ensured that all participants were aged between 18-65 years and in full-time office-based
90 work. Responses on a health screen questionnaire completed at the outset confirmed that
91 participants were all in good general health with no reported physical illnesses or disabilities
92 that may affect their normal daily routine. The sample consisted of individuals employed
93 within administrative roles, and all participants described themselves as having a
94 predominately sedentary occupation. The standard working hours of the organisations
95 involved were 9am to 5pm on Mondays to Fridays. The study received ethical approval from
96 the Loughborough University Ethical Advisory Committee, and participants provided written
97 informed consent.

98

99 ***Procedure***

100 At the beginning of the study participants either attended a laboratory at Loughborough
101 University or were visited by research staff at their place of work. During this meeting
102 participant's body mass (kg) and height (cm) were directly measured without shoes using

103 electronic weighing scales (Tanita UK Ltd) and a wall-mounted stadiometer (Seca UK). BMI
104 was calculated as kg/m^2 , and general demographic information (age, gender, nature of
105 employment, job title) recorded. Participants were issued with an ActiGraph accelerometer
106 and shown the correct wearing position. Participants were instructed to begin wearing the
107 device upon waking up the following day. During the seven day monitoring period,
108 participants were requested to continue with their normal daily routine. Upon completion of
109 the monitoring period participants met with a researcher to return the accelerometer. During
110 this meeting they were asked to confirm if they had experienced a typical working week
111 whilst wearing the device and any days in which participants reported missing work through
112 either illness or leave days were recorded.

113

114 ***Sedentary behaviour and physical activity measurement and data processing***

115 Participants wore an ActiGraph GT1M accelerometer (ActiGraph, Pensacola, FL) throughout
116 waking hours for seven consecutive days, except during water based activities. The
117 accelerometer was worn around the waist, above the midline of the thigh. The accelerometer
118 was set to record at 1-minute epochs. Accelerometer data were downloaded using ActiLife
119 version 5 and processed using KineSoft version 3.3.75. Accelerometer data were considered
120 valid if there were more than 600 minutes of monitoring per day (excluding continuous
121 strings of zero counts for 60 minutes or longer) recorded on at least three weekdays and one
122 weekend day.²⁰ The widely used <100 counts/minute (cpm) cut-point was employed to
123 estimate sedentary time (i.e. estimated time spent sitting),²¹ whilst the Freedson cut-points
124 were used to estimate time spent in light intensity (100 – 1951 cpm) (such as slow walking)
125 and moderate to vigorous intensity (such as brisk walking or jogging/running) physical
126 activity (MVPA) (≥ 1952 cpm).²²

127

128 As preliminary analyses revealed that no significant differences occurred between the time
129 spent in sedentary behaviour and physical activity across Monday to Friday (data not
130 shown), time spent in sedentary behaviour, light intensity activity and MVPA were

131 summarised for workdays (Monday to Friday in the present sample) and non-workdays
132 (Saturday and Sunday). On workdays, time spent in each behaviour were also summarised
133 during working hours (9am to 4.59 pm) and during non-working hours (before 9am and after
134 5pm).

135

136 ***Statistical analyses***

137 Statistical analyses were conducted using IBM SPSS Statistics for Windows version 21.
138 Time spent in sedentary behaviour, light intensity activity and MVPA, along with the
139 proportion of time spent in each behaviour (accounting for accelerometer wear time), on
140 workdays, non-workdays, during working hours and non-working hours on workdays were
141 checked for normality using the one-sample Kolmogorov-Smirnov test, which showed that all
142 data were not normally distributed. Non-parametric analyses were therefore undertaken and
143 the median and inter-quartile ranges (IQR) are presented as descriptors throughout. To
144 account for differences in accelerometer wear time during and outside working hours,
145 comparisons were undertaken using the proportion of wear time spent in each behaviour
146 (sedentary, light activity, MVPA) as opposed to the absolute minute data. Specifically, the
147 proportions of time spent in each behaviour were compared between workdays and non-
148 workdays, and between working hours and non-working hours on workdays using Wilcoxon-
149 signed ranks tests.

150

151 To address the secondary aim of this study, participants were grouped into tertiles based on
152 the proportion of time spent sedentary during working hours. Tertile 1 (lowest working hours
153 sedentary behaviour) consisted of individuals who spent less than 68% of their working
154 hours sedentary (n = 55). Tertile 2 (medium working hours sedentary behaviour) consisted
155 of individuals who spent between 68 and 74% of their working hours sedentary (n = 54), and
156 tertile 3 (highest working hours sedentary behaviour) consisted of individuals who were
157 sedentary during working hours for equal to or above 75% of the time (n = 61). The three
158 groups were compared in terms of the proportion of accelerometer wear time spent in

159 sedentary behaviour, light activity and MVPA on non-workdays and during non-working
160 hours on workdays using Kruskal-Wallis tests with Bonferroni-corrected post hoc
161 comparisons. Age and BMI were also compared between the three groups using Kruskal-
162 Wallis tests with Bonferroni-corrected post hoc comparisons. To further explore any links
163 between sedentary behaviour accumulated during and outside of working hours, Spearman
164 correlations examined whether there were any associations between sedentary behaviour
165 measured during working hours and sedentary behaviour accumulated on non-workdays,
166 and during non-working hours on workdays. Statistical significance was set at $p < 0.05$ for all
167 analyses unless otherwise stated.

168

169 To understand the pattern of sedentary behaviour and physical activity occurring throughout
170 the day, line graphs were constructed depicting the mean minutes per hour spent in
171 sedentary behaviour, light intensity activity and MVPA across the typical wear period (7am –
172 11.59pm) for workdays and non-workdays. The line graphs only contain data from valid days
173 (>10 hours) and hours (all 60 minutes) in which the accelerometer was worn by each
174 participant. Separate graphs were created for the three tertiles for working hours sedentary
175 behaviour described above in order for any differences in patterns between the groups to be
176 identified.

177

178 **Results**

179 Of the 210 participants who commenced the study, 170 (30% male, mean age 40.1 ± 12.7
180 years; mean BMI $24.5 \pm 3.8 \text{ kg/m}^2$) provided valid data and were included in the analyses.

181 There were no significant differences between those who provided valid data and those who
182 did not in terms of age, BMI or gender proportion ($p > 0.05$). Males and females did not differ
183 significantly in terms of the proportion of wear time spent in sedentary behaviour and light
184 intensity physical activity during working and non-working hours on workdays (all $p > 0.05$).

185 Overall on workdays, males spent a significantly greater proportion of time and minutes in
186 MVPA in comparison to females ($4 \pm 3\%$ versus $3 \pm 3\%$, $p = 0.01$, [median \pm IQR]; 38 mins/day

187 versus 30 mins/day, $p = 0.01$). There were no significant differences in the proportion of time
188 spent in sedentary behaviour, or in light intensity activity and MVPA between males and
189 females on non-workdays (all $p > 0.05$, data not shown). Given the limited differences in the
190 proportion of time spent in each behaviour during and outside working hours between males
191 and females, the analyses presented below focus on the sample as a whole.

192

193 Median accelerometer wear time was 874 ± 103 mins/day on workdays and 767 ± 113
194 mins/day on non-workdays days ($p < 0.001$), the sample provided valid accelerometer data
195 (wear time ≥ 10 hours/day) on 7 days/person (median value). Given the significant
196 differences in wear time between the days (and between working hours and non-working
197 hours on workdays, Table 1), the proportions of wear time spent in each behaviour
198 (sedentary, light intensity activity and MVPA) were compared during and outside working
199 hours as opposed to the absolute minutes. On workdays participants spent a significantly
200 greater proportion of time in sedentary behaviours, and significantly less time in light
201 intensity physical activity in comparison to non-workdays (Table 1). There were no significant
202 differences between workdays and non-workdays in terms of the proportion of time spent in
203 MVPA.

204

205 On workdays only, participants spent a greater proportion of time in sedentary behaviour
206 during working hours, and less time in light intensity physical activity in comparison to non-
207 working hours (Table 1). Overall, sedentary behaviour accumulated during working hours
208 accounted for 57% of total daily sedentary time on workdays. There were no significant
209 differences in the proportion of time spent in MVPA during working and non-working hours
210 on workdays.

211

212

Insert Table 1 about here

213

214 When grouped into tertiles according to the proportion of working hours spent sedentary,
215 significant differences in sedentary behaviour and light intensity physical activity were
216 observed between the groups during non-working hours (Table 2). Participants in the lowest
217 tertile for sedentary behaviour at work spent significantly less time in sedentary behaviour
218 and more time in light intensity physical activity than those in the medium and high tertiles on
219 non-work days (post hoc analyses, all $p < 0.01$). The three groups did not differ significantly in
220 terms of the proportion of time spent in MVPA on non-workdays (weekend days in the
221 present sample). Similarly, during non-working hours on workdays, participants in the lowest
222 tertile for sedentary behaviour at work spent significantly less time in sedentary behaviour
223 and more time in light intensity physical activity than those in the medium and high tertiles
224 (post hoc analyses, all $p < 0.01$). Like non-work days, there were no significant differences
225 between the groups in terms of the proportion of time spent in MVPA during non-working
226 hours on workdays (Table 2). There were no significant differences in BMI between
227 participants in the three tertiles ($p > 0.05$). However, participants in the lowest tertile for
228 sedentary behaviour at work were significantly older (46 ± 13 years) than those in the medium
229 (38 ± 12 years) and high (36 ± 11 years) tertiles ($p < 0.01$).

230

231 For the sample as a whole, there were significant associations between the proportion of
232 time spent sedentary during working hours and the proportion of time spent sedentary on
233 non-workdays ($r = 0.25$, $p < 0.001$), and during non-working hours on workdays ($r = 0.36$,
234 $p < 0.001$).

235

236 *Insert Table 2 about here*

237

238 An hour by hour breakdown of the time (in minutes) spent in sedentary behaviour, light
239 intensity activity and MVPA on workdays and non-workdays are shown in Figures 1 and 2,
240 respectively for participants grouped into tertiles according to the proportion of time spent
241 sedentary during working hours. On workdays the three groups displayed a similar pattern

242 in terms of the accumulation of sedentary behaviour and light intensity physical activity
243 across the day, however, as to be expected based on how the groups were defined
244 (sedentary behaviour during working hours), the differences between sedentary behaviour
245 and light activity over working hours becomes more pronounced across the groups. During
246 working hours (9am to 4.59pm) sedentary behaviour was the most prominent behaviour
247 across all groups. All groups exhibited a small dip in this behaviour around lunch time
248 followed by another dip immediately after working hours which is then followed by a steady
249 increase in sedentary behaviour as the evening progresses. It is evident from Figure 1 that
250 on workdays, the pattern of light intensity activity displays a mirror image of the pattern of
251 sedentary behaviour for all groups, suggesting that light intensity activities offset sedentary
252 behaviours. For all groups, MVPA displays a distinct pattern, showing small increases prior
253 to working hours (7 – 8.59am), around lunch time (1 – 1.59pm) and after work into the early
254 evening (5 – 7.59pm).

255

256 The pattern of sedentary behaviour and physical activity accumulated hour by hour on non-
257 workdays (Figure 2) differs to that seen for workdays (Figure 1) for all groups. Through until
258 mid-afternoon (8am – 3.59pm), the proportion of sedentary behaviour and light intensity
259 activity is relatively equal for participants in the lowest tertile for working hours sedentary
260 behaviour. From 4pm onwards sedentary behaviour gradually increases throughout the
261 evening as light intensity activity decreases. A similar pattern can be observed in the
262 medium tertile group, however throughout the day sedentary behaviour is the predominant
263 behaviour, with the steady increase in sedentary behaviour and the decline in light activities
264 starting earlier in the day (1pm onwards). On non-workdays sedentary behaviour is the most
265 prominent behaviour throughout the day for participants grouped in the highest tertile for
266 working hours sedentary behaviour. The pattern of MVPA on non-workdays appears to be
267 similar across the groups, with MVPA being higher during the day, and decreasing from 7pm
268 onwards.

269

270 *Insert Figures 1 and 2 about here*

271

272 **Discussion**

273 The present study examined sedentary behaviour and physical activity accumulated during
274 and outside working hours in a sample of full-time office workers from the UK. On both
275 workdays and non-workdays sedentary behaviour was the most prevalent behaviour
276 exhibited by the sample, accounting for 68% and 60% of accelerometer wear time
277 respectively. On workdays, participants were highly sedentary during working hours, with
278 71% of working hours spent in sedentary behaviour. Overall, sedentary behaviour
279 accumulated during working hours accounted for 57% of total daily sedentary time on
280 workdays.

281

282 The present findings add to the growing evidence highlighting the workplace as an important
283 setting for the accumulation of high volumes of sedentary behaviour.¹³ The proportion of
284 working hours spent sedentary in the current sample is similar to that observed in Australian
285 office workers, using objective measures.¹³⁻¹⁵ Given the workplace is the major contributor
286 to total daily sedentary time on work days, worksite interventions designed to reduce, or
287 break up, sedentary behaviour are urgently needed in UK office workers. Indeed, research in
288 Australian and Swedish workers has started to investigate the effectiveness of sit-to-stand
289 workstations for reducing sedentary time at work.^{23,24} If successful, the incorporation of sit-to-
290 stand workstations in offices of sedentary workers within the UK workforce could be an
291 effective strategy for reducing sedentary behaviour during working hours.

292

293 It was observed in the present study that sedentary behaviour accumulated during working
294 hours was positively associated with sedentary behaviour measured on non-workdays, and
295 during non-working hours on workdays. Furthermore, when split into tertiles according to the
296 proportion of working hours spent sedentary, participants in the highest tertile for working
297 hours sedentary behaviour spent a significantly greater proportion of time in sedentary

298 behaviour during non-working hours on workdays and less time in light intensity activity in
299 comparison to participants in the lowest tertile for working hours sedentary behaviour. The
300 same finding was also observed on non-work days. The observation that those who were
301 most sedentary during working hours were also the most sedentary out of working hours is
302 similar to that reported in Dutch¹⁶ and Australian¹⁴ workers. In the present study, there were
303 no significant differences between the groups in terms of the proportion of time spent in
304 MVPA either during non-working hours on workdays, or on non-workdays. This suggests
305 that, in the present sample, those who are sedentary for a large proportion of their working
306 day do not compensate by increasing their physical activity levels outside of working hours.
307 This finding is in contrast to that reported by Chau et al.¹² who observed in Australian
308 workers that individuals with jobs which involve mostly sitting were more likely to report
309 being physically active during their leisure-time than individuals in more active jobs. The
310 differences in study findings may be attributable to differences in lifestyles between these
311 Australian and British samples, further highlighting the importance of understanding these
312 lifestyle behaviours in different populations. Whilst participants in the three tertiles for
313 working hours sedentary behaviour did not differ in terms of job role, those in the lowest
314 tertile were older than those in the medium and high tertiles, indicating that sedentary
315 behaviour levels and patterns may vary across age groups. This warrants further study in
316 larger samples.

317

318 The finding that those who were most sedentary during working hours, were also the most
319 sedentary during non-working hours, coupled with the observation that there appears to be
320 no compensatory increases in physical activity outside of work, is a major concern. The
321 'highest working hours sedentary behaviour' group spent over 10 hours per day in sedentary
322 behaviour on workdays, suggesting that these individuals are at an increased risk of
323 numerous chronic conditions associated with high volumes of sedentary behaviour.⁸ In
324 addition to an increased risk of chronic disease, evidence suggests that these individuals
325 may also be at an increased risk of musculoskeletal disorders²⁵ and impaired work

326 performance.¹⁵ Based on the present findings, and others,¹⁴⁻¹⁶ it is suggested that worksite
327 sedentary behaviour interventions also target sedentary behaviour outside of working hours.
328
329 The hour by hour breakdown of time spent in each behaviour for the three groups on
330 workdays highlights working hours (9am – 4.59 pm) and the evening (8pm onwards) as
331 critical periods during the day when sedentary behaviour is most prevalent. Whilst the overall
332 pattern of behaviour is similar on workdays across the three groups, the difference between
333 light intensity activity and sedentary behaviour becomes more pronounced between the
334 groups. Participants in the lowest tertile for working hours sedentary behaviour exhibited
335 less time in sedentary behaviour and a greater proportion of time in light intensity activity in
336 the hours before work, in comparison to the remaining groups. This difference could be
337 down to differences in commuting behaviour between the groups, however as participants
338 did not report their mode of transport to or from work in the present study, this cannot be
339 confirmed. For all groups on workdays (and non-workdays), the pattern of light intensity
340 physical activity is the inverse to that of sedentary behaviour suggesting that light intensity
341 activities offset sedentary behaviours. Given the apparent strong link between sedentary
342 behaviour and light intensity physical activity, workplace interventions promoting increases in
343 light intensity activity should be effective in reducing sedentary time. Given recent evidence
344 suggesting that light intensity physical activity is beneficial to health,²⁶ future worksite
345 interventions targeting sedentary behaviour should incorporate the promotion of light
346 intensity physical activity where feasible, such as encouraging the use of pooled
347 printers/copiers, centrally placed water coolers, restricting email and telephone contact for
348 employees in the same building etc. Emerging experimental evidence has shown that
349 breaking up sedentary behaviour every 20 minutes with 2 minutes of light walking
350 significantly improves glucose and insulin regulation.²⁷ A strategy such as this could be
351 implemented in future worksite interventions.

352

353 A small dip in sedentary behaviour and increases in light activity and MVPA were observed
354 around the lunch period on workdays, suggesting that this period could be a suitable time for
355 encouraging longer breaks in sedentary behaviour and increases in physical activity. Indeed,
356 previous research has demonstrated the effectiveness of instructor-led lunchtime walking
357 groups for promoting physical activity in sedentary workers.²⁸ In addition, recent research
358 has shown that light intensity physical activity during lunch time was associated with reduced
359 work performance impairment in office workers.¹⁵

360

361 This study provides novel information on how sedentary behaviour and physical activity is
362 accumulated during and outside working hours in a sample of office workers from the UK.
363 The objective measurement of sedentary behaviour and physical activity is a strength of the
364 present study as it likely overcomes the limitations of bias and recall common with self-report
365 measures. The study is not without its limitations however. Whilst the ActiGraph
366 accelerometer has been widely used as an objective measure of sedentary behaviour, this
367 waist-worn device is not capable of distinguishing between standing and sitting/lying
368 postures. Therefore, some periods of standing still may have been misclassified as
369 sedentary behaviour. Furthermore, in the present study we applied the commonly used <100
370 cpm cut-point to estimate sedentary behaviour. Despite its wide use, this cut-point was not
371 empirically derived and recent contradictory evidence has questioned the validity of this
372 particular cut-point.^{29,30} For example, Kozey-Keadle²⁹ suggested a cut-point of 150 cpm may
373 be more accurate at defining sedentary time, while Hart et al.³⁰ have reported that a cut-point
374 of <50 cpm may be more appropriate. Further research would benefit from the use of an
375 inclinometer, as used elsewhere,¹⁷ which is capable of distinguishing between different
376 postures. A further limitation of our study is participants did not record their start and finish
377 work times in a daily diary, the working hours (9am – 5pm) assigned in the present study
378 were based on our knowledge of the standard working hours applied in the organisations in
379 which participants were based. It is possible therefore that some of our participants may
380 have been at work for longer or shorter periods than these assigned hours on some days of

381 the study. However, participants were asked upon completion of the study to report whether
382 they had had a typical week during the monitoring period, and any days where the
383 participant had reported taking additional days off work through sickness or illness were
384 removed ahead of the analyses. The study's cross-sectional design prevents us from
385 making conclusions about causality, it is therefore not possible to determine whether being
386 sedentary at work leads to an individual being more sedentary out of working hours. Further
387 longitudinal research is required to understand the long term relationships between
388 sedentary behaviour accumulated during and outside working hours. Limited demographic
389 information was collected from participants in the present study; further research with larger
390 samples should explore patterns of sedentary behaviour occurring across different age
391 groups, educational groups and employment sectors for example, in order to enhance the
392 development of tailored interventions for reducing sedentary time.

393

394 **Conclusions**

395 The present study extends our knowledge on the patterns of sedentary behaviour and
396 physical activity on workdays and non-workdays in office workers living in the UK. The
397 sample as a whole spent a large proportion of time in sedentary behaviour on both workdays
398 and non-workdays. Of concern, it was observed in the present study that those who are
399 sedentary for a large proportion of their working hours also accumulate a high proportion of
400 time in sedentary behaviour during non-working hours. There was no evidence to suggest
401 that those with high volumes of sedentary behaviour during working hours compensated for
402 this by increasing their time in light intensity activity or MVPA out of working hours. Given the
403 high volume of sedentary behaviour seen in the current study, and others, workplace
404 interventions are urgently needed to reduce sedentary time in adults to reduce the risk of
405 numerous chronic diseases associated with sedentary behaviour. Interventions should focus
406 on reducing both workplace sedentary behaviour and leisure-time sedentary behaviour in
407 sedentary office workers.

408

409 **References**

- 410 1. Sedentary Behaviour Research Network. Standardized use of the terms “sedentary”
411 and “sedentary behaviours”. *Appl Physiol Nutr Metab.* 2012;37:540–542.
- 412 2. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television watching and other
413 sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in
414 women. *JAMA.* 2003;289:1785-1791.
- 415 3. Brown WJ, Williams L, Ford JH, Ball K, Dobson AJ. Identifying the energy gap:
416 magnitude and determinants of 5-year weight gain in midage women. *Obes Res.*
417 2005;13:1431-1441.
- 418 4. Gierach GL, Chang SC, Brinton LA, et al. Physical activity, sedentary behavior, and
419 endometrial cancer risk in the NIH-AARP Diet and Health Study. *Int J Cancer.*
420 2009;124:2139-2147.
- 421 5. Lynch BM. Sedentary behavior and cancer: a systematic review of the literature and
422 proposed biological mechanisms. *Cancer epidemiology, biomarkers & prevention : a*
423 *publication of the American Association for Cancer Research.* 2010;19:2691-2709.
- 424 6. Edwardson CL, Gorely T, Davies MJ, et al. Association of sedentary behaviour with
425 metabolic syndrome: a meta-analysis. *PloS one.* 2012;7:e34916.
- 426 7. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all
427 causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc.* 2009;41:998-
428 1005.
- 429 8. Wilmot EG, Edwardson CL, Achana FA, et al. Sedentary time in adults and the
430 association with diabetes, cardiovascular disease and death: systematic review and
431 meta-analysis. *Diabetologia.* 2012;55:2895-2905.
- 432 9. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in
433 obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes.*
434 2007;56:2655-2667.
- 435 10. Chau JY, der Ploeg HP, van Uffelen JG, et al. Are workplace interventions to reduce
436 sitting effective? A systematic review. *Prev Med.* 2010;51:352-6.

- 437 11. Miller R, Brown W. Steps and sitting in a working population. *Int J Behav Med.*
438 2004;11:219-224.
- 439 12. Chau JY, van der Ploeg HP, Merom D, Chey T, Bauman AE. Cross-sectional
440 associations between occupational and leisure-time sitting, physical activity and
441 obesity in working adults. *Prev Med.* 2012;54:195-200.
- 442 13. Thorp AA, Healy GN, Winkler E, et al. Prolonged sedentary time and physical activity
443 in workplace and non-work contexts: a cross-sectional study of office, customer
444 service and call centre employees. *Int J Behav Nutr Phys Act.* 2012;9:128.
- 445 14. Parry S, Straker L. The contribution of office work to sedentary behaviour associated
446 risk. *BMC Public Health.* 2013;13:296.
- 447 15. Brown HE, Ryde GC, Gilson ND, Burton NW, Brown WJ. Objectively measured
448 sedentary behavior and physical activity in office employees: relationships with
449 presenteeism. *J Occup Environ Med.* 2013;55:945-953.
- 450 16. Jans MP, Proper KI, Hildebrandt VH. Sedentary behavior in Dutch workers:
451 differences between occupations and business sectors. *Am J Prev Med.*
452 2007;33:450-454.
- 453 17. Tigbe WW, Lean ME, Granat MH. A physically active occupation does not result in
454 compensatory inactivity during out-of-work hours. *Prev Med.* 2011;53:48-52.
- 455 18. Stamatakis E, Hamer M, Dunstan DW. Screen-based entertainment time, all-cause
456 mortality, and cardiovascular events: population-based study with ongoing mortality
457 and hospital events follow-up. *J Am Coll Cardiol.* 2011;57:292-299.
- 458 19. Clemes SA, David BM, Zhao Y, Han X, Brown W. Validity of two self-report
459 measures of sitting time. *J Phys Act Health.* 2012;9:533-539.
- 460 20. Matthews CE, Ainsworth BE, Thompson RW, Bassett DR, Jr. Sources of variance in
461 daily physical activity levels as measured by an accelerometer. *Med Sci Sports*
462 *Exerc.* 2002;34:1376-1381.
- 463 21. Atkin AJ, Gorely T, Clemes SA, et al. Methods of Measurement in epidemiology:
464 sedentary Behaviour. *Int J Epidemiology.* 2012;41:1460-1471.

- 465 22. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and
466 Applications, Inc. accelerometer. *Med Sci Sports Exerc.* 1998;30:777-781.
- 467 23. Healy GN, Eakin EG, Lamontagne AD, et al. Reducing sitting time in office workers:
468 Short-term efficacy of a multicomponent intervention. *Prev Med.* 2013;57:43-48.
- 469 24. Straker L, Abbott RA, Heiden M, Mathiassen SE, Toomingas A. Sit-stand desks in
470 call centres: associations of use and ergonomics awareness with sedentary behavior.
471 *Applied ergonomics.* 2013;44:517-522.
- 472 25. Gerr F, Marcus M, Ensor C, et al. A prospective study of computer users: I. Study
473 design and incidence of musculoskeletal symptoms and disorders. *American Journal*
474 *of Industrial Medicine.* 2002;41:221-235.
- 475 26. Healy GN, Dunstan DW, Salmon J, et al. Objectively measured light-intensity
476 physical activity is independently associated with 2-h plasma glucose. *Diabetes Care.*
477 2007;30:1384-1389.
- 478 27. Dunstan DW, Kingwell BA, Larsen R, et al. Breaking up prolonged sitting reduces
479 postprandial glucose and insulin responses. *Diabetes Care.* 2012;35:976-983.
- 480 28. Chan CB, Ryan DA, Tudor-Locke C. Health benefits of a pedometer-based physical
481 activity intervention in sedentary workers. *Prev Med.* 2004;39:1215-1222.
- 482 29. Kozey-Keadle S, Libertine A, Lyden K, Staudenmayer J, Freedson PS. Validation of
483 wearable monitors for assessing sedentary behavior. *Med Sci Sports Exerc.*
484 2011;43:1561-1567.
- 485 30. Hart TL, McClain JJ, Tudor-Locke C. Controlled and free-living evaluation of
486 objective measures of sedentary and active behaviors. *J Phys Act Health.*
487 2011;8:848-857.

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492 **Figure legends**

493 **Figure 1.** Minutes spent in sedentary behaviour, light intensity physical activity and MVPA
494 during each hour of the working day for participants grouped into tertiles based on the
495 proportion of time spent sedentary during working hours.

496

497 **Figure 2.** Minutes spent in sedentary behaviour, light intensity physical activity and MVPA
498 during each hour of the non-working day for participants grouped into tertiles based on the
499 proportion of time spent sedentary during working hours.

500

501 **Table 1.** Sedentary behaviour and physical activity (PA) measured during and outside
 502 working hours in 170 office workers. Data represents the median and inter-quartile ranges
 503 (IQR).

	All days (median \pm IQR)			Work days only (median \pm IQR)		
	Work days	Non-work days	Differences * (p value)	During working hours	Non-working hours	Differences * (p value)
Number of valid days**	781	303		781	781	
Wear time (mins/day)	874 \pm 103	767 \pm 113	<0.001	477 \pm 15	406 \pm 79	<0.001
% of wear time spent sedentary	68 \pm 9	60 \pm 14	<0.001	71 \pm 12	63 \pm 12	<0.001
Time in sedentary behaviour (mins/day)	580 \pm 101	460 \pm 105		333 \pm 61	254 \pm 72	
% of wear time spent in light PA	28 \pm 9	36 \pm 14	<0.001	25 \pm 11	33 \pm 10	<0.001
Time in light PA (mins/day)	246 \pm 90	278 \pm 126		117 \pm 55	130 \pm 48	
% of wear time spent in MVPA	4 \pm 3	4 \pm 4	0.40	4 \pm 4	3 \pm 5	0.82
Time in MVPA (mins/day)	32 \pm 26	28 \pm 33		17 \pm 17	13 \pm 17	

504 *Comparisons undertaken using Wilcoxon-signed ranks tests. As significant differences in
 505 accelerometer wear time were observed between workdays and non-workdays, and
 506 between working hours and non-working hours, comparisons were undertaken between the
 507 proportion of accelerometer wear time spent in each behaviour. Minutes spent in each
 508 behaviour are also included in the table for comparison purposes.

509 **The number of valid days (wear time \geq 10 hours/day) included in the analyses.

510 **Table 2.** Sedentary behaviour and physical activity measured during and outside working hours in office workers grouped into tertiles according
 511 to the proportion of working hours spent sedentary. Data represents the median and inter-quartile ranges (IQR).

	All days (median ± IQR)							
	Workdays				Non-workdays			
	Tertile 1 (n = 55)	Tertile 2 (n = 54)	Tertile 3 (n = 61)	Between group differences (p value)*	Tertile 1 (n = 55)	Tertile 2 (n = 54)	Tertile 3 (n = 61)	Between group differences (p value)*
Number of valid days**	260	251	270		97	95	111	
Wear time (mins/day)	888 ± 112	884 ± 87	850 ± 77	0.02	775 ± 120	764 ± 84	744 ± 135	0.16
% of wear time spent sedentary	59 ± 9	69 ± 5	72 ± 6	<0.001	54 ± 18	61 ± 11	64 ± 13	<0.001
Time in sedentary behaviour (mins/day)	508 ± 102	594 ± 79	609 ± 76		427 ± 149	479 ± 114	468 ± 79	
% of wear time spent in light PA	37 ± 8	28 ± 4	23 ± 7	<0.001	41 ± 15	36 ± 10	31 ± 12	<0.001
Time in light PA (mins/day)	325 ± 87	246 ± 41	198 ± 74		311 ± 106	274 ± 117	230 ± 104	
% of wear time spent in MVPA	4 ± 4	3 ± 2	3 ± 3	0.21	4 ± 4	3 ± 4	4 ± 5	0.53
Time in MVPA (mins/day)	35 ± 36	30 ± 18	31 ± 26		28 ± 32	26 ± 33	30 ± 33	
	Work days only (median ± IQR)							
	During working hours				Non-work hours			
	Tertile 1 (n = 55)	Tertile 2 (n = 54)	Tertile 3 (n = 61)	Between group differences (p value)*	Tertile 1 (n = 55)	Tertile 2 (n = 54)	Tertile 3 (n = 61)	Between group differences (p value)*
Number of valid days**	260	251	270		260	251	270	
Wear time (mins/day)	478 ± 13	478 ± 13	474 ± 17	0.26	420 ± 86	418 ± 55	387 ± 64	<0.01
% of wear time spent sedentary	60 ± 14	71 ± 3	78 ± 4	<0.001	60 ± 12	65 ± 10	66 ± 13	<0.001
Time in sedentary behaviour (mins/day)	286 ± 68	335 ± 17	365 ± 26		247 ± 80	263 ± 64	243 ± 63	
% of wear time spent in light PA	35 ± 12	25 ± 3	19 ± 5	<0.001	37 ± 10	32 ± 7	29 ± 10	<0.001
Time in light PA (mins/day)	163 ± 52	118 ± 19	88 ± 24		150 ± 56	128 ± 41	117 ± 53	
% of wear time spent in MVPA	4 ± 4	4 ± 3	3 ± 3	<0.001	4 ± 5	3 ± 3	4 ± 5	0.14
Time in MVPA (mins/day)	20 ± 19	17 ± 13	13 ± 13		13 ± 25	13 ± 14	16 ± 18	

512 *Between group comparisons undertaken using Kruskal-Wallis tests with Bonferroni-corrected post hoc comparisons. To account for differences
 513 in accelerometer wear time between groups, comparisons were undertaken between the proportion of accelerometer wear time spent in each
 514 behaviour. Minutes spent in each behaviour are also included in the table for comparison purposes.

515 **The number of valid days (wear time ≥10 hours/day) included in the analyses for each tertile group.



