

Time spent in sedentary posture is associated with waist circumference and cardiovascular risk

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31 **Abstract**

32 **Background**

33 The relationship between metabolic risk and time spent sitting, standing and stepping has not
34 been well established. The present study aimed to determine associations of objectively measured
35 time spent sitting, standing and stepping, with coronary heart disease (CHD) risk.

36 **Methods**

37 A cross-sectional study of healthy non-smoking Glasgow postal workers, n=111 (55 office-
38 workers, 5 women, and 56 walking/delivery-workers, 10 women), who wore activPAL physical
39 activity monitors for seven days. Cardiovascular risks were assessed by metabolic syndrome
40 categorisation and 10-y PROCAM risk.

41 **Results**

42 Mean(SD) age was 40(8) years, BMI 26.9(3.9)kg/m² and waist circumference 95.4(11.9)cm.
43 Mean(SD) HDL-cholesterol 1.33(0.31), LDL-cholesterol 3.11(0.87), triglycerides
44 1.23(0.64)mmol/l and 10-y PROCAM risk 1.8(1.7)%. Participants spent mean(SD) 9.1(1.8)h/d
45 sedentary, 7.6(1.2)h/d sleeping, 3.9(1.1)h/d standing and 3.3(0.9)h/d stepping, accumulating
46 14,708(4,984)steps/d in 61(25) sit-to-stand transitions per day. In univariate regressions -
47 adjusting for age, sex, family history of CHD, shift worked, job type and socio-economic status -
48 waist circumference (p=0.005), fasting triglycerides (p=0.002), HDL-cholesterol (p=0.001) and
49 PROCAM-risk (p=0.047) were detrimentally associated with sedentary time. These associations
50 remained significant after further adjustment for sleep, standing and stepping in stepwise
51 regression models. However, after further adjustment for waist circumference, the associations

52 were not significant. Compared to those without the metabolic syndrome, participants with the
53 metabolic syndrome were significantly less active – fewer steps, shorter stepping duration and
54 longer time sitting. Those with no metabolic syndrome features walked >15,000 steps/day, or
55 spent >7h/day upright.

56 **Conclusion**

57 Longer time spent in sedentary posture is significantly associated with higher CHD risk and
58 larger waist circumference.

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61 **Introduction**

62 Sedentary occupation and overall behaviour is now the norm in modern societies. Technological
63 advancements in Western economies have reduced the energy requirements of daily living, with
64 populations spending more hours sitting, at work, in transport and during leisure-time.¹ There is
65 little evidence to suggest that reduced occupational physical activity leads to compensatory
66 increases during leisure-time, or *vice versa*.²⁻⁵ Studies from Europe, US and Australia find that
67 adults spend half of work days sitting (average 4.2 h/d) and about 2.9 h/d of leisure-time sitting.⁶⁻

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71 An increasing body of literature suggests that sitting time, independent of physical activity levels,
72 promotes cardiovascular disease.^{9,10} Both self-report and objective data have shown that time
73 spent sedentary has an independent detrimental association with coronary and diabetes-related
74 metabolic risk factors, such as waist circumference, blood glucose, insulin and triglycerides and
75 HDL-cholesterol.¹¹⁻¹⁶ Healy et al.¹⁵ found that accelerometer-determined time spent inactive was
76 significantly associated with waist circumference, blood lipid and glucose profiles. Another
77 recent study found that while physical activity log and recall methods failed to show any clear
78 relationship, accelerometer-measured objective activity was directly related to 10-y Framingham
79 coronary risk.¹⁷

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82 There is a paucity of evidence on the relationship between objectively measured sedentary
83 behaviour patterns, such as sitting/lying and upright postures, and cardiovascular risk. In a Dutch
84 cross-sectional study van der Berg et al.¹⁸ found that, an additional hour of time spent sedentary
85 posture was associated with a 22% greater odds for type 2 diabetes and a 39% greater odds for
86 the metabolic syndrome. Other studies have used accelerometer counts as a proxy^{14,15} but low
87 acceleration counts also include periods of quiet standing or standing still which is metabolically
88 different from sitting. In both animal and human studies, sitting, unlike standing, is associated
89 with reduced skeletal muscle lipoprotein lipase activity and detrimental changes in lipid profile.¹⁻
90 ²¹ The present study examined the associations between CHD risk and time spent in objectively-
91 measured postures (sitting, lying and standing) and of stepping.

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94 **Methods**

95 A cross-sectional study of postal workers was undertaken to relate time spent sedentary (sitting/
96 lying) and stepping to CHD risk factors in apparently healthy individuals. The study aimed to
97 include a range of different physical activity profiles, involving both mainly sedentary office-
98 bound postal workers and more active delivery staff.

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101 **Study Participants**

102 Recruitment was carried out by local advertisement, with no incentives offered, from the Royal
103 Mail Group in Greater Glasgow, Scotland. The employees (n = 5,335; 90.2% men) worked in

104 four shifts: full-day (9am to 5pm), early (5am to 1pm) and late (1pm to 9 pm) and night (9pm to
105 5am) with two days off work, including Sunday, each week. Only apparently healthy, non-
106 smokers, with no personal history of myocardial infarction, stroke, CHD, hypertension or
107 diabetes mellitus were included. None of the participants was on any lipid, blood pressure or
108 glucose lowering medication. All volunteers, 59 delivery (5 women) and 59 office staff (10
109 women) aged 22 to 60 years, were invited to the study and data collection took place between
110 September 2006 and September 2007.

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113 **Protocol**

114 Participants wore a physical activity monitor (activPAL, PAL Technologies Ltd, Glasgow, UK)
115 for seven days, had weight, height and blood pressure measured, and provided fasting blood
116 samples. Seven participants (3 male delivery and 4 male office workers) refused to provide blood
117 samples, thus the final sample for analysis was 111, 56 delivery workers (5 women) and 55 office
118 workers (10 women). The study aims and protocol were explained and informed written consent
119 obtained, following approval from the Ethics Committee of Glasgow Caledonian University.

120 Socio-demographic data, including age, home address postcode and family history of CHD, were
121 obtained. From postcodes, national tables²² were used to provide the Scottish Index of Multiple
122 Deprivation (SIMD) score for each participant, as a measure of socioeconomic status, rated from
123 1 (least deprived) to 5 (most deprived). Weight, height and waist circumference were measured
124 according to the WHO protocol²³. Fasting serum concentrations were measured of glucose (by
125 hexokinase method), adiponectin (R&D Elisa) and lipids namely, triglycerides, total cholesterol,

126 LDL cholesterol and HDL cholesterol (by automated analyser) in quality controlled NHS
127 laboratory.

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130 Coronary risk was assessed using the PROCAM.²⁴ This risk calculator generates 10-year CHD
131 risk, for men aged 35-65y and women aged 45-65y, based on sex, age, family history of CHD,
132 cigarette smoking, systolic blood pressure, fasting HDL-cholesterol, LDL-cholesterol,
133 triglycerides and fasting glucose concentration. The ages of 67 men and 6 women fell within the
134 ranges appropriate for this risk calculator. As a second indication of CHD risk and of diabetes
135 risk, participants were classified as having metabolic syndrome, or not, using both the NCEP
136 criteria²⁵ and IDF criteria²⁶: fasting serum triglycerides ≥ 1.7 mmol/l, glucose ≥ 5.6 mmol/l, HDL-
137 cholesterol ≤ 1.03 mmol/l for men or ≤ 1.30 mmol/l for women, waist circumference ≥ 102 cm for
138 men or ≥ 88 cm for women, and blood pressure $\geq 130/85$ mmHg.

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141 **Physical activity recording**
142 Physical activity and sedentary behaviour were recorded for seven consecutive days using the
143 activPAL monitor to provide time spent stepping, standing and sitting/lying as well as steps,
144 mean stepping rate and number of sit-to-stand transitions per day. In addition, though the
145 activPAL does not differentiate sleeping (lying posture) from sitting posture, time spent sleeping
146 was extracted from the activPAL raw output. This was defined as prolonged periods (>2 hours)
147 of continuous inactivity during sleeping hours. Sleeping hours were simply night hours for those
148 who worked day shifts and day hours for the two participants who worked night shifts. Sleep

149 duration was subtracted from total sedentary time to obtain waking hours' sedentary time,
150 referred to as sedentary time in this manuscript. Both short and long sleep durations have been
151 reported to be associated with higher risk of CHD.²⁷

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154 The activPAL was worn on the mid anterior thigh using adhesive tape according to the
155 manufacturer's guidance and throughout seven days except during activities that risk it being in
156 contact with water, e.g. bathing or swimming. Participants were asked to note down any non-
157 wear periods in the food diary that they also completed as part of the wider study (not relevant to
158 the current study) and these were checked with each participant at the debrief session. The inter-
159 device reliability (ICC = 0.99) and accuracy (95.9% agreement with direct observation) of the
160 activPAL for reporting time spent sedentary, standing and walking have been reported
161 previously.²⁸ The inter-device reliability (0.99) and accuracy ($\geq 98.99\%$, depending on walking
162 speed) for step count and stepping rate have also been reported.²⁹ Stepping rate (cadence) is
163 reported by the activPAL as number of steps per minute during stepping time. Data were
164 accepted for inclusion with a minimum of three 24-hour periods, including a non-work day, as
165 recommended by others.³⁰

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168 **Data analyses**

169 Age, SIMD values (1 to 5), family history of CHD, job type (delivery or office worker) and
170 work-shifts were obtained. Outcome variables for physical activity were daily time (h) spent
171 sedentary, standing and stepping, step count, average stepping rate and daily sit-to-stand

172 transitions. The outcome measures included BMI, waist circumference, systolic and diastolic
173 pressure, fasting lipids (triglycerides, total cholesterol, LDL, HDL cholesterol), fasting glucose,
174 and adiponectin. The 10-year PROCAM CHD risk score was generated from age, blood pressure,
175 fasting HDL and LDL cholesterol, triglycerides and glucose.²⁴ The presence of the metabolic
176 syndrome (derived from levels of fasting glucose, triglycerides, HDL cholesterol, blood pressure
177 and waist circumference) was also obtained.

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180 The data were tested for normality and summary data were produced using SPSS version 18.0.
181 Univariate associations were explored and multivariable linear regressions undertaken to model
182 the relationship between sedentary time and CHD risk. Adjustment for age, sex, SIMD, family
183 history of CHD, job type and shift (model 1). Job type was considered because self-selection into
184 job type cannot be ruled out. Similarly, as shift patterns may affect sleep patterns, this was
185 included in the model. In addition, further stepwise adjustments were made for sleep duration
186 (model 2), then standing (model 3), stepping in replacing standing (model 4), both standing and
187 stepping (model 5). These stepwise adjustments showed that including stepping time in model 5
188 did lead to improvement in the R^2 value for any of five outcome variable but rather a drop in R^2
189 was observed in model 4. We believe this was due to the observed strong correlation between
190 sitting, standing and stepping $r = 0.34-0.61$, $p < 0.001$). One approach would have been to employ
191 compositional data analysis. However, rather than fitting compositional data that are not
192 clinically meaningful, stepping time was excluded in the final model (model 6) where additional
193 adjustments were also made for waist circumference. It is thought that body size may have
194 bidirectional relationship with sedentary behaviour, and thereby predict the behaviour.³¹

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197 Adjusting for the same variables as above, binary logistic regression was modelled to determine
198 the odds of the metabolic syndrome from the physical activity parameters. The associations were
199 explored in the whole sample and for the 67 men only. Separate analyses were not undertaken for
200 the 15 women.

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203 **Results**

204 All 111 participants completed the full 7d study. Fifteen participants worked full day shifts, 92
205 early shift, three late shift and only one worked night shift. A third (32 men; 4 women) had first-
206 degree family histories of CHD. The distribution of the participants by SIMD was as follows: n =
207 13, 20, 17, 23 and 38 for SIMD 1, 2, 3, 4 and 5 respectively. During the study, the shift patterns
208 of the participants were full-day (n = 15), early (n = 92), late (n = 4). The summary statistics of
209 the study participants are shown in Table 1. For the 73 participants aged between 35-65y (men,
210 n=67) and 45-65y (women, n=6), among whom PROCAM could be applied, 10y PROCAM risk
211 ranged from 0.1-12.0%, mean 1.9(SD 1.7)%.

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214 In exploratory univariate analyses, waist circumference (correlation coefficient, $r = 0.28$, p
215 $=0.002$), fasting triglycerides ($r = 0.30$, $p = 0.002$), HDL cholesterol ($r = -0.38$, $p < 0.0001$) and
216 10-y PROCAM risk ($r = 0.33$, $p = 0.004$) were significantly and adversely associated with

217 sedentary. Waist circumference ($r = -0.23$, $p = 0.014$), fasting triglycerides ($r = -0.22$, $p = 0.018$),
218 HDL cholesterol ($r = 0.24$, $p < 0.01$) and 10-y PROCAM risk ($r = -0.37$, $p = 0.001$) were
219 significantly and favourably associated with stepping time. In these non-adjusted correlations, 10-
220 y PROCAM risk showed an inverse significant ($r = -0.25$, $p = 0.031$) association with daily step
221 count, and serum adiponectin levels showed an inverse significant association with sedentary
222 time ($r = -0.24$, $p = 0.012$) and a positive significant association with standing time ($r = 0.93$, $p =$
223 0.002). Standing time also had a significant positive association with HDL cholesterol ($r = 0.36$,
224 $p = 0.0001$) and a significant inverse association with waist circumference ($r = 0.20$, $p = 0.033$).
225 Physical activity and sedentary behaviour were not significantly associated with BMI, blood
226 pressure, serum glucose or LDL cholesterol. None of the risk factors was significantly associated
227 with stepping rate or number of sit-to-stand transitions.

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230 After adjusting for age, sex, SIMD, family history of CHD, job type and shift worked, greater
231 waist circumference, higher serum triglycerides and lower HDL cholesterol were significantly
232 ($p < 0.05$) associated with longer time spent sedentary (model 1 in table 2). These associations
233 remained significant after adjustments were made for sleep (model 2), then standing (model 3),
234 stepping (model 4) and then both standing and stepping in addition to sleep (model 5). After
235 further adjustment for waist circumference (model 6), the associations of sedentary time with
236 triglycerides and HDL cholesterol were no longer significant. Sedentary time appears to be
237 better predictor of waist circumference, serum triglycerides and HDL cholesterol than stepping,
238 standing and sleeping durations (models 3 and 4). However, this association was no longer
239 significant after further adjusting for waist circumference (model 6). No significant association

240 was observed between physical activity behaviour and serum adiponectin in the adjusted
241 analyses. The variables together explained (R^2) 18.5% of variance in serum triglycerides, 30%
242 for HDL cholesterol, 23% for adiponectin, 22% for waist circumference and 48% for 10-year
243 PROCAM risk (model 5 in table 2). Sleep duration was a strong positive predictor of serum
244 HDL cholesterol, even after adjusting for waist circumference. No significant associations were
245 found between physical activity behaviour and BMI or LDL cholesterol. Analysis for men alone
246 did not change the overall findings.

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249 Higher 10-year PROCAM risk was significantly ($p < 0.05$) associated with sedentary time,
250 adjusting for age, sex, SIMD, family history of CHD, job type and shift worked (model 1 in
251 table 2). This association remained significant after further adjustment for sleep (model 2) but
252 not after adjusting for standing, stepping or waist circumference (models 3-6). Sedentary time
253 explains (R^2 change) 2% of the variance in 10-year PROCAM risk, 2% in waist circumference,
254 1% in serum HDL and 4% in serum triglycerides (table 2). The association of sedentary time
255 with PROCAM risk (Figure 1) appears to be curvilinear, such that greater deterioration of risk
256 is associated with longer time spent sedentary. However, the introduction of a quadratic term
257 (square of sedentary time) in the model did not yield a significant association ($R^2 = 0.01$, 95%
258 CI: -0.01 - 0.03). One additional hour per day sitting was associated with 0.18% (95% CI 0.01–
259 0.36%) greater 10-year PROCAM risk.

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262 Thirteen study participants had the metabolic syndrome, as defined by NCEP.³² Compared to
263 those without the metabolic syndrome, participants with the metabolic syndrome were
264 significantly less active, with lower step count, slower stepping rate, shorter stepping duration
265 and longer time spent sedentary (table 3). Twenty participants satisfied the IDF consensus criteria
266 for metabolic syndrome.²⁶ These participants similarly spent more time in a sedentary posture
267 and walked less than those without metabolic syndrome (table 3). Those participants with no
268 metabolic syndrome features walked ≥ 3.5 hour/day, $>15,000$ steps/day, or spent >7 h/day upright.

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271 The logistic regression model was used to explore the association between physical activity time
272 and the development of the metabolic syndrome. After adjusting for age, sex, family history of
273 CHD, job type, shift worked, socioeconomic status and shift worked, no significant association
274 was found between time in posture and activity with the development of the metabolic syndrome.

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277 **Discussion**

278 The present study set out to relate objectively measured time spent in sedentary posture, standing
279 and stepping to a comprehensive list of cardiovascular and diabetes-related risk factors. The data
280 indicate that sedentary behaviour is associated with coronary and diabetes risk as reflected by
281 metabolic syndrome, with elevated waist circumference, elevated serum triglycerides, and
282 lowered serum HDL cholesterol. After adjusting for socio-demographic variables, sleep and
283 physical activity (stepping and standing), time spent sedentary was positively associated with

284 coronary risk, as determined by PROCAM. This association has been quantified to demonstrate
285 the level of risk (the β coefficient or odds ratio) associated with sedentary behaviour.

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288 These findings, if proven to be a causal relationship, may offer support for a health promotion
289 intervention in the workplace, to reduce sitting and increase time spent in an upright posture.

290 Animal studies have shown that preventing ambulatory activity of the hind limb over 24 hours
291 could lead to a reduction in plasma HDL-cholesterol by 22% and lipoprotein lipase activity (the
292 hormone responsible for triglyceride catabolism) by 90% to 95%.^{19,33} LPL activity in limb

293 muscles is dependent on local contractile activity. Sedentary behaviour therefore promotes CHD
294 independently from lack of moderate-vigorous physical activity, and as demonstrated

295 previously⁴, adults do not necessarily compensate sedentary posture at work with upright posture

296 after work. Reducing sedentary behaviour by spending more time upright, thereby engaging limb
297 and trunk muscles, is a simple protective mechanism to reduce CVD. The metabolic cost of

298 upright posture is approximately 33-40% higher than that of sitting posture.^{34,35} It is recognised

299 that one recent small study³⁶ of energy expenditure of some activities (lasting \leq 15min duration)

300 found no significant difference in energy expenditure between sitting and standing. Mansoubi et
301 al.³⁷, on the other hand, suggest reclassifying some sitting-based activities as non-sedentary

302 because they may involve energy expenditures $>$ 1.5 METs, the cut-off for sedentary behaviour
303 by definition.³⁸ It is our view that participation in such activities are not a common occurrence. It

304 is rather unusual to engage in sitting activities that expend more energy than standing activities.

305 However, fitting more upright time into busy workdays on a habitual basis is an easy message,

306 and is potentially acceptable. Encouraging leisure time physical activity is of course valuable, but

307 tends to result in erratic and poorly sustained improvements.³⁹⁻⁴¹ Efforts to increase participation
308 in moderate-to-vigorous physical activity are complementary with that of reducing sedentary
309 behaviour.

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312 Previous research using pedometers has related step counts to risks. In the present study, using
313 the activPAL which is more accurate and reliable than pedometers in measuring steps²⁹, we found
314 that waist circumference and 10-y PROCAM risk were associated with step count in unadjusted
315 data, but not after adjustments. The presence of the metabolic syndrome was significantly
316 associated with daily step count. Though the number of cases of the metabolic syndrome was
317 relatively small, the findings corroborate previous results. Schofield et al.⁴² reported that
318 Australian adolescent girls who achieved less than 10,000 steps/day were significantly more
319 likely to have two or more CHD risk factors. We have further shown that CHD risk has stronger
320 associations with time spent stepping and in sedentary posture than with step count.

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323 A previous cross-sectional study involving 168 subjects reported that greater number of breaks in
324 sedentary time (i.e. 'transitions' to standing posture) had beneficial associations with waist
325 circumference, BMI, triglycerides and 2-hour postprandial glucose.⁴³ That pattern was not
326 confirmed in the present study; in neither the unadjusted nor the adjusted analyses were sit-to-
327 stand transitions associated with coronary risk. However, unlike this previous study, ours did not
328 include 2-hour postprandial glucose but rather fasting blood glucose only, and this may explain
329 the difference in findings. Importantly, the differences in the findings - in particular the

330 association with waist circumference, BMI and triglycerides - may also lie in data quality: in the
331 previous study, sedentary time was estimated by actiGraph, setting an arbitrary cut-off (≤ 100
332 counts/minute) as a proxy for sedentary time, while actiGraph counts rising above this value were
333 considered transitions out of sedentary behaviour. Secondly, the actiGraph does not differentiate
334 standing still from sitting and lying, and will therefore misclassify a change from standing still to
335 stepping as a break in sedentary time⁴⁴. Standing still is different from sitting in that the former is
336 known to elicit cardio-protective metabolic changes in skeletal muscles.^{20,21} The activPAL, used
337 in the present study accurately measures sit-to-stand transitions²⁷, so our data are likely to be
338 more reliable.

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341 We found no demonstrable relationship between physical activity or sedentary behaviour and
342 blood pressure, the latter being within the normal ranges, although previous studies reported
343 higher blood pressure with longer television watching time⁴⁵ and lower energy expenditure.⁴⁶
344 Furthermore, no significant association was found between fasting glucose and the physical
345 activity parameters despite earlier reports of independent association of objectively measured
346 light-intensity physical activity with 2-hour postprandial glucose in other non-diabetic
347 subjects.^{45,47} The differences may be due to the differences in the measurement of sedentary
348 behaviour: television watching time, accelerometer counts and heart rate in the previous studies
349 versus time spent sitting and lying in the present study. The difference may also be due the
350 differences in outcome measures: fasting glucose versus 2-hour postprandial glucose. A more
351 recent large study involving 2,497 participants wearing the same activity monitor as in the
352 present study (the activPAL) found higher odds for type 2 diabetes with sedentary behaviour.¹⁸

353 The present study adds significant new information to the recent studies and reviews⁴⁴⁻⁵⁰ which
354 call for valid and reliable quantitative assessment of sedentary behaviour and its relationship with
355 CVD and diabetes. Future studies should endeavour to use similar assessment methods for both
356 sedentary behaviour and the outcome variables.

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359 In man, adiponectin appears to reflect insulin sensitivity but may not be a powerful upstream
360 determinant.⁵¹ We found no significant relationship between adiponectin and physical activity
361 measures, in keeping with prior studies which have yielded differing results.⁵²⁻⁵⁴ Adiponectin
362 levels were, however, significantly associated with waist circumference, reflecting the well-
363 known relationship between insulin sensitivity and obesity.

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366 **Strengths and Limitations**

367 Our study has strengths, but also limitations. We used a more intensive measured assessment,
368 which provides more reliable data than conventional step-counters, but this inevitably restricts
369 study numbers and power. We used appropriate statistical methods to avoid over-reporting
370 positive findings, and have not made assertions that invoke beta errors, which could arise from
371 low power. The sample was of white Caucasians, not balanced between the sexes, so conclusions
372 cannot be drawn for other races or for women alone. The main conclusions are based on data
373 adjusted for sex, but while we have no *a priori* reason to suspect sex differences, we have
374 confirmed in sensitivity analyses that the main findings remain for men alone. Though the
375 activPAL does not differentiate sleeping (lying posture) from sitting posture, it was possible to

376 identify sleep from the raw output, as prolonged periods (>2 hours) of continuous inactivity
377 during sleep hours. Sedentary time is usually reported as a single measure, including sleeping
378 time. Adjusting for sleep as best as we could is therefore a strength of the study.

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381 The study could have benefited from body composition data but due to lack of facilities for these
382 measures. Waist circumference, adjusted for sex and age, is a more robust predictor than BMI of
383 body fat measured by densitometry, and where the range of body fat is narrow a greater waist
384 circumference is a marker of elevated visceral fat mass.⁵⁵ In the present study, waist
385 circumference was shown to have significant positive association with sedentary behaviour - the
386 latter explaining 3% of the variance in waist circumference (table 2). After adjusting for waist
387 circumference, the association between sedentary time and 10-year PROCAM risk and with HDL
388 cholesterol were no longer significant, but the association with triglycerides remained significant.
389 It is possible that any effects of sedentary behaviour on CHD risk act through an elevated waist
390 circumference and dyslipidaemia.

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393 The present study reports results from cross-sectional data of healthy participants with relatively
394 low PROCAM-determined CHD risk. Although our data are cross-sectional, our subjects were
395 selected as healthy, so we feel reverse-causality would be improbable. There is ample existing
396 evidence for coronary risk reduction with greater physical activity, but health promotion does not
397 achieve activity targets sustainably for large numbers, so it will be important to test,
398 prospectively, the proposal that CHD risk might be reduced by increasing time spent in a vertical

399 posture. It will also be valuable to include a range of ethnic and racial groups and more women in
400 any future studies.

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402

403 **Conclusion**

404 Longer time spent in sedentary posture is significantly associated with higher CHD risk,
405 including larger waist circumference, higher triglycerides and lower HDL cholesterol. Future
406 prospective research is required to ascertain if new targets for sitting, lying, standing and
407 stepping, to avoid metabolic risk, can be proposed. The levels associated with zero risk factors in
408 the present study, >15,000 steps/day or >7 hours per day spent upright, would be challenging and
409 difficult to sustain unless incorporated into occupations.

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Conflict of Interest

This research was funded by Glasgow Caledonian University as part of a PhD project. Although Professor Malcolm Granat is a director of PAL Technologies Ltd, this research is not intended in any way to promote the activPAL monitor or the company. Professor Naveed Sattar's research is supported by the British Heart Foundation and Diabetes UK. Professor Mike Lean's research is supported by Diabetes UK and by Counterweight Ltd. The other authors have no conflict of interest to declare.

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Figure Legends

Figure 1: Associations of predicted cardiovascular risk with time spent in sedentary posture. The regression line and the 95% confidence interval of prediction are shown. Adjustments were made for sex, age, job type, shift worked, family history of CHD, waist circumference (where waist circumference is not the dependent variable), and time spent sleeping and time in upright posture.