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1 Associations amongst sedentary and active behaviours, body fat and appetite
2 dysregulation: investigating the myth of physical inactivity and obesity.

3

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8

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22 **ABSTRACT**

23 **Background**

24 There is considerable disagreement about the association between free-living physical
25 activity and sedentary behaviour and obesity. Moreover studies frequently do not
26 include measures that could mediate between physical activity and adiposity. The
27 present study used a validated instrument for continuous tracking of sedentary and
28 active behaviours as part of habitual daily living, together with measures of energy
29 expenditure, body composition and appetite dysregulation. This cross-sectional study
30 tested the relationship between inactivity and obesity.

31 **Methods**

32 Seventy-one participants (81.7% women) aged 37.4 years (± 14) with a body mass
33 index (BMI) of 29.9 kg/m² (± 5.2) were continuously monitored for 6-7 days to track free-
34 living physical activity (light 1.5-3METs; moderate 3-6METs; and vigorous >6METs)
35 and sedentary behaviour (<1.5METs) with the SenseWear Armband. Additional
36 measures included body composition, waist circumference, cardiovascular fitness,
37 total and resting energy expenditure, and various health markers. Appetite control was
38 assessed by validated eating behaviour questionnaires.

39 **Results**

40 Sedentary behaviour (11.06 \pm 1.72 hours/day) was positively correlated with fat mass
41 ($r=0.50$, $p<0.001$) and waist circumference ($r=-0.65$, $p<0.001$). Moderate-to-vigorous
42 physical activity was negatively associated with fat mass ($r=-0.72$, $p<0.001$) and
43 remained significantly correlated with adiposity after controlling for sedentary
44 behaviour. Activity energy expenditure was positively associated with the level of PA
45 and negatively associated with fat mass. Disinhibition and Binge Eating behaviours
46 were positively associated with fat mass ($r=0.58$ and 0.47 , respectively, $p<0.001$).

47 **Conclusion**

48 This study demonstrated clear associations among objective measures of physical
49 activity (and sedentary behaviour), energy expenditure, adiposity and appetite control.
50 The data indicate strong links between physical inactivity and obesity. This relationship
51 is likely to be bi-directional.

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What are the new findings

- Habitual sedentary time was associated with higher adiposity.
- Moderate-to-vigorous physical activity (MVPA) was associated with lower adiposity.
- The strongest relationship was with MVPA.
- The relationship between physical (in)activity and adiposity is likely to be bidirectional and depends mainly on MVPA.

Impact on clinical practice

- Patients/clients should be encouraged to replace some sedentary and light activity with at least moderate PA such as brisk walking in order to optimise benefits.

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59 BACKGROUND

60 In recent years the relative contributions of overconsumption of food and the under-
61 expenditure of energy (physical inactivity) to obesity have been vigorously debated.
62 On one side it has been claimed that an increase in food availability (energy flux) was
63 more than sufficient to account for the increase in average body weight of US citizens
64 over a 20 year period.[1] This argument has recently been extended to a global
65 level.[2] In contrast it has been argued that the decline in work-related physical activity
66 (and therefore energy expenditure) over several decades has been sufficient to
67 account for a positive energy balance and the rise in obesity in the US.[3] In general it
68 seems that the excess food notion of obesity is more favourably received than the low
69 activity idea. This view has been promoted by the print media with headlines such as
70 'Why exercise makes you fat'.[4] These headlines have appeared despite evidence
71 from controlled trials demonstrating dose related effects of physical activity on weight
72 loss:[5] the more you do (duration or energy expended) the more weight is lost.
73 Additionally, although Cochrane systematic reviews have also reported beneficial
74 effects of exercise on weight loss independent of any dietary effect,[6] the view
75 persists that being active does not contribute to weight control. In a recent editorial
76 commentary in this journal, a headline title referred to '...the myth of physical inactivity
77 and obesity' and the text categorically stated that 'physical activity does not promote
78 weight loss'.[7] Strongly argued articles refuting these claims [8 9] have attempted to
79 prevent further damaging perceptions emanating from these claims.

80 For over two decades we have investigated the interactions between energy
81 expenditure and energy intake.[10] We have demonstrated in several published
82 studies that a programme of supervised and measured exercise in obese individuals
83 leads to a significant reduction in body fat and a maintenance or increase in lean mass
84 (fat-free mass) in both men and women.[11-13] These studies indicate that physical
85 activity has the capacity to influence body fat in obese people. Recently we have used
86 a sensitive validated wearable device (BodyMedia SenseWear armband (SWA)) to
87 directly measure the amount of time people spend in sedentary behaviour and in light,
88 moderate and vigorous activity.[14] We have quantified the amount of time (and
89 energy expended) in sedentary and active behaviours, and related this to measures
90 of body adiposity and validated traits reflecting dysregulated appetite control. We have

91 used this methodology to directly test the myth of physical inactivity and body fatness
92 (obesity). The study was designed to provide accurate and objective measures of the
93 quantity of sedentary and active behaviours in habitual daily life, and to examine the
94 relationships with measures of adiposity, energy expenditure, fitness and markers of
95 health; and with psychological measures of the loss of control over appetite.

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109 **METHODS**

110 **Participants**

111 Seventy-one participants (81.7% women) aged 37.4 years (± 14) with a body mass
112 index (BMI) of 29.9 kg/m² (± 5.2) were recruited from the University of Leeds, UK, and
113 surrounding area for this cross-sectional study. Sixty-eight of the 71 participants had
114 valid SWA data (95.8% compliance) and all participants had valid body composition
115 and appetite dysregulation data. Participants were males and females aged >18 years
116 with no contraindications to exercise and not taking medication known to effect
117 metabolism or appetite. All participants provided written informed consent before
118 taking part in the study, and ethical approval was granted by the School of Psychology
119 Ethics Board (14-0091).

120 **Study design**

121 Participants attended the research unit twice over the course of one week. Free-living
122 PA and sedentary behaviour were measured continuously for a minimum of 7 days for
123 >22 hours/day. Participants were fasted for a minimum of 12 hours and had abstained
124 from exercise and alcohol for at least 24 hours before both laboratory visits.

125 On the morning of day one the following measures were taken: height, weight, waist
126 and hip circumference, body composition and resting metabolism. Health markers
127 including, fasting blood glucose diastolic and systolic blood pressure (BP) and resting
128 heart rate (HR) were taken, along with measures of appetite dysregulation (Three-
129 Factor Eating Questionnaire, Binge Eating Scale). Participants were provided with a
130 PA diary and fitted with a SenseWear Mini Armband (BodyMedia, Inc., Pittsburgh, PA).

131 *Anthropometrics*

132 Height was measured using a stadiometer (Leicester height measure, SECA) and
133 body composition was measured using air plethysmography (Bodpod, Concord, CA).
134 Body weight was obtained from the BodPod whilst participants were wearing minimal
135 clothing. BMI was calculated as weight in kg / height in m². Waist circumference was

136 measured horizontally in line with the umbilicus and hip circumference was measured
137 horizontally at the maximum circumference of the hip. Three measures were taken for
138 each and averaged. The same researcher completed all measurements.

139 *Resting metabolic rate and health markers*

140 Resting metabolic rate (RMR) was measured using indirect calorimetry (GEM, NutrEn
141 Technology Ltd, Cheshire, UK). Participants were instructed to remain awake but
142 motionless in a supine position for 40 minutes, with RMR calculated from respiratory
143 data averaged during the last 30 minutes of assessment. BP and resting HR were
144 measured using an automatic sphygmomanometer (Omron) immediately after
145 completion of the RMR procedure. Fasting glucose was obtained from a finger prick
146 blood sample analyzed using a blood glucose analyzer (YSI 2300 STAT PLUS
147 Glucose and Lactate Analyzer).

148 *Appetite dysregulation*

149 Participants completed the Three Factor Eating Questionnaire, a 51 item
150 questionnaire measuring restraint, disinhibition and hunger[15] and the Binge Eating
151 Scale, a 16 item questionnaire measuring binge eating behaviour and cognitions
152 indicative of eating disorders.[16]

153 *Free living PA and EE*

154 Free-living physical activity and sedentary behaviour was measured objectively using
155 the SWA. Participants wore the armband on the posterior surface of their upper non-
156 dominant arm for a minimum of 22 hours per day for 7-8 days (except for the time
157 spent showering, bathing or swimming). This data collection allowed for the calculation
158 of daily averages for each activity category. The SWA measures motion (triaxial
159 accelerometer), galvanic skin response, skin temperature and heat flux. Proprietary
160 algorithms available in the accompanying software calculate energy expenditure (EE)
161 and classify the intensity of activity. Sedentary behaviour was classified as <1.5 METs,
162 light 1.6-2.9 METs, moderate 3-5.9 METs and vigorous >6 METs.[17] Sedentary
163 behaviour and PA variables were calculated as a percentage of total awake time over

164 the wear period of 6-7 days, for example, total sedentary minutes were divided by total
165 awake minutes to give the proportion of awake time spent sedentary over the total
166 wear period. Moderate and vigorous PA was grouped together to form one MVPA
167 category to correspond with the guidelines for PA.[18] The SWA has been shown to
168 accurately estimate time in MVPA and EE at rest and during free-living light and
169 moderate intensity PA.[19-22] For the SWA data to be valid >22 hours of data per day
170 had to be recorded and at least six 24 hour periods (midnight to midnight) including 2
171 weekend days. Participants completed a physical activity diary to coincide with the PA
172 monitoring period detailing the intensity, duration and type of activity performed along
173 with details on removal of the SWA

174 Participants returned to the lab on day 7 or 8 to return the activity monitors and
175 completed PA diary. Cardiovascular fitness was also measured.

176 *Maximal aerobic capacity*

177 Maximal aerobic capacity ($\dot{V}O_2\text{max}$) was measured during an incremental treadmill
178 test with expired air (Sensormedics Vmax29, Yorba Linda, USA) and heart rate (Polar
179 RS400, Polar, Kempele, Finland) measured continuously. Attainment of true $\dot{V}O_2\text{max}$
180 was determined by a plateau in $\dot{V}O_2$ with an increase in workload, a respiratory
181 quotient (RQ) of >1 and a HR within 20 beats of age predicted maximum HR (220-
182 age).

183 **Statistical analysis**

184 Data are reported as mean \pm SD throughout. Statistical analysis was performed using
185 IBM SPSS for Windows (Chicago, Illinois, Version 21). For reasons of scientific rigour
186 and to reduce the likelihood of false positives, we only regarded relationship as
187 meaningful with a p value < 0.01. Characteristics of the study population were
188 summarised using descriptive statistics. Pearson correlations were performed to
189 examine the associations amongst sedentary and active behaviour, body composition
190 and appetite dysregulation. In addition partial correlations were also carried out to
191 separate the effects of a third variable acting concurrently on two variables; this

192 involved controlling for body fat percentage, sedentary behaviour and MVPA in
193 different analyses.

194

195 **RESULTS**

196 **Participant Characteristics**

197 Study sample characteristics are displayed in table 1. Of the 71 participants who took
198 part in the study 68 provided ≥ 6 days of valid armband data. Average wear time of the
199 armband was 23.55 ± 0.26 hours/day ($98 \pm 1.2\%$). Participants were sedentary for an
200 average of 11.06 ± 1.72 hours/day (excluding sleep) and recorded 3.26 ± 1.03 hours/day
201 in light PA and 2.10 ± 1.40 hours/day in MVPA (see figure 1). Participants mean age
202 was 37.35 ± 14.01 and their average total energy expenditure was 2708.07 ± 421.81
203 kcal/d.

Table 1. Descriptive statistics of study sample

Variable	Mean (SD)	Range
Age (years)*	37.35 (14.01)	18.00 – 72.00
Height (m)*	1.66 (0.09)	1.49 – 1.91
Body mass (kg)*	82.24 (15.26)	44.90 – 113.90
BMI (kg/m²)*	29.94 (5.24)	19.10 – 39.90
Fat mass (kg)*	31.79 (13.37)	5.00 – 60.40
Lean mass (kg)*	50.44 (9.28)	32.10 – 81.40
Waist circumference (cm)*	100.23 (12.83)	69.00 – 133.70
Systolic blood pressure (mm Hg)*	118.17 (14.12)	87.00 – 162.00

Diastolic blood pressure (mm Hg)*	77.80 (10.25)	61.00 – 77.80
Resting heart rate (bpm)*	58.56 (9.71)	37.00 – 84.00
Blood glucose (mmol/L)**	4.73 (0.69)	1.98 – 6.70
Resting metabolic rate (kcal/d)†	1698.54 (296.86)	1070.90 – 2451.90
Total energy expenditure (kcal/d)∧	2708.07 (421.81)	1827.30 – 4256.60
Cardiovascular fitness (ml/kg/min)∧	40.99 (7.88)	29.60 – 54.93
SWA wear time (hours/d)∧	23.55 (0.26)	22.47 – 23.95
Sedentary behaviour (hours/d)∧	11.06 (1.72)	6.01 – 15.40
Light PA (hours/d)∧	3.26 (1.03)	1.35 – 6.05
MVPA (hours/d)∧	2.10 (1.40)	0.48 – 6.74
Restraint*	8.21 (3.82)	0.00 – 17.00
Disinhibition*	8.85 (3.88)	0.00 – 15.00
Hunger*	6.00 (3.16)	0.00 – 13.00
Binge Eating*	13.23 (7.31)	1.00 – 34.00

SWA, SenseWear armband; MVPA, moderate-to-vigorous physical activity; * n=71; ** n=69; † n=70; ∧ n=68

204

Figure 1 near here

205

206 **Association between sedentary behaviour and different categories of physical**
 207 **activity**

208 Sedentary behaviour was negatively associated with light ($r(66)=-0.39$, $p=0.001$),
 209 moderate ($r(66)=-0.76$, $p<0.001$) and vigorous ($r(66)=-0.44$, $p<0.001$) PA. Light PA
 210 was also negatively associated with vigorous PA ($r(66)=-0.33$, $p<0.01$). Moderate and
 211 vigorous PA were positively correlated ($r(66)=0.65$, $p<0.001$).

212 **Associations between sedentary behaviour, physical activity and body**
213 **composition**

214 Sedentary behaviour was positively correlated with multiple indices of adiposity
215 including body mass ($r(66)=0.44$, $p<0.001$), BMI ($r(66)=0.50$, $p<0.001$), fat mass
216 ($r(66)=0.50$, $p<0.001$) and waist circumference ($r(66)=0.45$, $p<0.001$) as shown in
217 Table 2. On the other hand, MVPA was negatively associated with body mass ($r(66)=-$
218 0.55 , $p<0.001$), BMI ($r(66)=-0.71$, $p<0.001$), fat mass ($r(66)=-0.72$, $p<0.001$) and waist
219 circumference ($r(66)=0.45$, $p<0.001$).

220 Partial correlations were performed to identify the independent effects of sedentary
221 behaviour (controlled for MVPA), light PA (controlled for MVPA and sedentary
222 behaviour, separately) and MVPA (controlled for sedentary behaviour) on body
223 composition. After controlling for MVPA the magnitude of the correlation between
224 sedentary behaviour and adiposity were markedly weakened. However, when the
225 correlations between MVPA and adiposity were adjusted for sedentary behaviour all
226 correlations remained significant (body mass ($r(65)=-0.38$, $p=0.001$), BMI ($r(65)=-0.57$,
227 $p<0.001$) fat mass ($r(65)=-0.63$, $p<0.001$) and waist circumference ($r(65)=-0.55$,
228 $p<0.001$)). Controlling the correlation between body composition and light PA for
229 sedentary behaviour resulted in significant positive correlation for body mass, BMI, fat
230 mass, body fat percentage and waist circumference.

231 The graphical relationships between fat mass and the percentage time spent
232 sedentary and in MVPA categories are shown in Figure 2.

233

234 Figure 2 near here

235

236 It is noticeable in Figure 2a that four participants have low amounts of sedentary
237 behaviour and it was possible that these values were unduly influencing the
238 correlation. When the statistical test was repeated excluding these subjects the
239 correlation remained positive and significant ($r(62)=0.31$, $p=0.01$).

Table 2. Correlation between sedentary and active behaviours and body composition

	Body mass	BMI	Fat mass	Waist circumference	Lean mass
Sedentary behaviour	0.44**	0.50**	0.50**	0.45**	-0.01
Light PA	0.06	0.18	0.19	0.17	-0.18
MVPA	-0.55**	-0.71**	-0.72**	-0.65**	0.14
Sedentary behaviour¹	-0.001	-0.14	-0.16	-0.13	0.18
Light PA¹	0.01	0.16	0.18	0.15	-0.16
Light PA²	0.32†	0.54**	0.52**	0.45**	-0.19
MVPA²	-0.38**	-0.57**	-0.63**	-0.55**	0.24

n=68; Data are Pearson correlation (r). ¹ Controlled for MVPA (minutes); ² Controlled for sedentary behaviour (minutes). ** p<0.001; † p<0.01. BMI, body mass index.

240

241 **Associations between sedentary behaviour, physical activity and markers of**
242 **appetite dysregulation**

243 There were no significant correlations between sedentary behaviour and any of the
244 indices of appetite dysregulation; Restraint (r(66)=-0.13, p=0.30), Disinhibition
245 (r(66)=0.16, p=0.19), Hunger (r(66)=-0.02, p=0.88), and Binge Eating (r(66)=0.14,
246 p=0.25).

247 However, light PA and MVPA showed some relationship to the questionnaire scores,
248 but these were no longer apparent when partial correlations were performed
249 controlling for the amount of body fat (see Table 3).

250

Table 3. Correlations between sedentary and active behaviours and appetite dysregulation

	Sedentary behaviour	Light PA	MVPA	Sedentary behaviour ¹	Light PA ¹	MVPA ¹
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Restraint	-0.13	0.14	0.05	-0.15	0.15	0.08
Disinhibition	0.16	0.36†	-0.44**	-0.13	0.25	-0.06
Hunger	-0.02	0.24	-0.15	-0.05	0.23	-0.16
Binge Eating	0.14	0.24*	-0.34†	-0.05	0.15	-0.07

n=68; Data are Pearson correlation (r). ¹ Controlled for body fat percentage. ** p<0.001; † p<0.01. MVPA, moderate-to-vigorous physical activity.

251 **Associations among physical activity, sedentary behaviour and energy**
252 **expenditure**

253 In order to investigate whether the relationship between behaviour and adiposity was
254 accounted for by energy expenditure, Activity Energy Expenditure (AEE) was
255 calculated as the difference between Total EE (Armband) and RMR (directly measured
256 by indirect calorimetry). The AEE was positively correlated with MVPA (r(66)=0.48,
257 p<0.0001) and negatively related to time spent in sedentary behaviour (r(66)=0.57, p
258 <0.0001).

259 **Associations between markers of appetite dysregulation and body composition**

260 TFEQ Disinhibition and Binge Eating were positively associated with body mass
261 (r(69)=0.51 and r(69)=0.49, respectively, p<0.001), BMI (r(69)=0.59 and r(69)=0.45,
262 respectively, p<0.001), fat mass (r(69)=0.58 and r(69)=0.47, respectively, p<0.001)
263 and waist circumference (r(69)=0.56 and r(69)=0.48, respectively, p<0.001). Fat free
264 mass was not significantly associated with any of the measures of appetite
265 dysregulation nor were there any associations between any of the measures of body
266 composition and Restraint or Hunger (see table 4).

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Table 4. Correlations between body composition and appetite dysregulation

	Body mass	BMI	Fat mass	Waist circumference	Lean mass
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Restraint	-0.20	-0.05	-0.07	-0.14	-0.23
Disinhibition	0.51**	0.59**	0.58**	0.56**	0.00
Hunger	0.18	0.12	0.10	0.12	0.15
Binge Eating	0.49**	0.45**	0.47**	0.48**	0.12

n=71; Data are Pearson correlation (r). ** p<0.001. BMI, body mass index.

268

269

270 **DISCUSSION**

271

272 The aim of the present study was to examine the associations amongst objectively
 273 measured free-living sedentary and active behaviours, body composition and appetite
 274 dysregulation, and to throw light upon the potential link between physical (in)activity
 275 and obesity.

276

277 **Free-living sedentary and active behaviour and adiposity**

278 Our data show sedentary behaviour and light PA was associated with higher adiposity.
 279 However, after controlling for MVPA the magnitude of the correlation between
 280 sedentary behaviour and body fat percentage was weakened and the correlation
 281 between light PA and body fat percentage was strengthened. Previous research
 282 assessing the relationship between sedentary behaviour and adiposity has yielded
 283 mixed results. Lynch et al,[23] reported an association between sedentary time and
 284 waist circumference and BMI in breast cancer survivors, furthermore after controlling
 285 for MVPA the associations were attenuated. Similarly, when lean and obese
 286 individuals were compared the obese group spent around 2 hours/day longer in
 287 sedentary behaviours.[24 25] Longitudinal studies have also demonstrated an
 288 association between sedentary behaviour and adiposity. Ekelund et al.[26] found that
 289 those who gained weight over a 5 to 6 year period performed significantly more
 290 sedentary behaviour than those who lost weight at follow-up.

291 The relationship between sedentary behaviour, light PA and adiposity has important
 292 implications given that sedentary behaviour and light PA accounts for the majority of

293 the waking day.[27] In the current sample participants spent just over 11 hours of their
294 waking day in sedentary activities and over 3 hours in light PA. Similar values have
295 been observed in previous studies,[28 29] however, some studies report less
296 sedentary time and more light intensity PA perhaps due to variations in measurement
297 techniques.[30 31] Important to note are the correlations between light intensity PA
298 and all markers of adiposity after controlling for sedentary behaviour. Under these
299 circumstances light PA is associated with increased body mass, BMI, fat mass, body
300 fat percentage and waist circumference and becomes a marker for sedentary
301 behaviour. We have noted the inverse association between light and vigorous PA this
302 means that the protective effect of exercise on adiposity is threshold based, and needs
303 to be at least moderate intensity to produce any benefit.

304 Our data confirm the association between MVPA and adiposity previously
305 demonstrated.[23 31-34] MVPA was inversely associated with body mass, BMI, fat
306 mass, body fat percentage and waist circumference independent of sedentary
307 behaviour. The positive association between MVPA and total energy expenditure
308 observed in our data (data not presented) provides one possible explanation for the
309 relationship with adiposity; PA results in increased energy expenditure. Healy et al,[34]
310 also demonstrated an inverse association between MVPA and adiposity independent
311 of sedentary behaviour. After controlling for MVPA only body fat percentage remained
312 significantly correlated with sedentary behaviour but all correlations remained
313 significant between MVPA and indices of adiposity when controlled for sedentary
314 behaviour. This suggests that the absence of MVPA could be more important than the
315 presence of sedentary behaviour in the accumulation of fat mass. Recommendation
316 to displace sedentary time with light PA may not be sufficient for weight management
317 and to accrue any benefit PA must be at least moderate intensity in line with current
318 PA guidelines.[35]

319

320 **Free-living sedentary and active behaviour, appetite dysregulation and** 321 **adiposity**

322 There were no correlations between sedentary behaviour and any of the measures of
323 appetite dysregulation. MVPA was associated with higher Disinhibition and Binge
324 Eating but these relationships were no longer significant after controlling for body fat

325 percentage. Our analysis has shown a strong relationship between measures of
326 adiposity and questionnaire measures of eating that imply a loss of control over
327 appetite in the environment. This association is supported by many studies in the
328 literature.[36 37] This outcome suggests that any observed relationship between
329 sedentary behaviour and trait measures of poor appetite control may be mediated
330 indirectly via mechanisms involved in adipose tissue dynamics.

331

332 **Conclusion**

333 This study has examined the relationship between objective measures of physical
334 activity (from sedentary to vigorous) and measures of adiposity under conditions of
335 daily habitual living. The outcome has shown that the level of physical activity is
336 associated with body fatness and is likely to be relevant for obesity.

337 The outcome measures were based on systematic measures taken under natural
338 conditions without any specific intervention. The analysis was derived from
339 correlations (and partial correlations) and the interpretation informed by logic and
340 plausibility. We are aware that correlations are not proof of causation, but they
341 certainly do not rule out the possibility of causal relationships. This study has shown
342 strong and statistically significant links between bodily activity and adiposity; this
343 provides presumptive evidence that sedentary behaviour itself and a low level of
344 physical activity is relevant for obesity. Our interpretation is that bidirectional causality
345 can account for this link. Therefore, low levels of physical activity involving low energy
346 expenditure will lead to a positive energy balance and favour the gain of body fat. In
347 turn a greater degree of adiposity (caused by low activity or by high energy intake) will
348 serve as a disincentive to perform physical activity and will favour a positive energy
349 balance. However, these comments are one interpretation of the data and should be
350 clarified with further investigation.

351 Importantly, the relevance of physical activity for obesity is corroborated by
352 intervention studies. It has been demonstrated that taking people from an inactive to
353 an active state by means of a regime of supervised daily exercise leads to a significant
354 loss of fat tissue and a gain (or maintenance) of lean mass.[11 13] In contrast when
355 people are shifted from an active to a sedentary state, there is no down-regulation of
356 food intake thereby resulting in a positive energy balance and the potential for weight

357 gain.[38] It is important to recognise that evidence and arguments indicating the
358 importance of low physical activity in adiposity, does not deny the contribution of food
359 intake to obesity. Indeed there is abundant evidence that overconsumption of food is
360 a major cause of a positive energy balance and increased body fatness.[39]
361 Interestingly the dynamic effects of fatness itself exacerbate the energy imbalance;
362 while increasing adiposity serves as a disincentive to perform physical activity, it does
363 not deter food consumption.

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388

389 **CONTRIBUTION**

390 AM, CG, GF and JB designed research; AM conducted research; AM, CG, GF and
391 JB analysed data; AM, CG, GF and JB wrote manuscript. All authors discussed
392 results/interpretation and approved the final manuscript. No authors declare a
393 conflict of interest.

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395 **TWITTER**

396 https://twitter.com/aceb_leeds

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536 **LEGENDS**

537 Figure 1. The proportion of waking time spent sedentary, in light PA and MVPA. Data
538 presented as percentage of awake time and total minutes.

539 Figure 2. Correlation between proportion of awake time spent sedentary and in MVPA
540 and fat mass.

541 Figure 3. Correlation between fat mass and binge eating.