Are longitudinal reallocations of time between movement behaviours associated with adiposity among elderly women? A compositional isotemporal substitution analysis

1   **Are longitudinal reallocations of time between movement behaviours**

2   **associated with adiposity among elderly women?**

3   **A compositional isotemporal substitution analysis**

4

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16   *Running title:* Longitudinal reallocations between movement behaviours

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26   **ABSTRACT**

27   **Background:** This study aimed to use compositional data analysis to: 1) investigate the prospective

28   associations between changes in daily movement behaviours and adiposity among elderly women; and

29   2) to examine how the reallocation of time between movement behaviours was associated with

30   longitudinal changes in adiposity.

31   **Subjects/Methods:** This is a 7-year longitudinal study in Central European older women (n=158,

32   baseline age 63.9±4.4 years). At baseline and follow-up, light-intensity physical activity (LIPA),

33   moderate-to-vigorous physical activity (MVPA) and sedentary behaviour were measured by

34   accelerometer and body adiposity (body mass index [BMI], body fat percentage [%BF]) was assessed

35   from measured height and weight and bioelectrical impedance analyser. Compositional regression

36   with robust estimators and compositional longitudinal isotemporal substitution analysis explored if,

37   and how, changes in movement behaviours were associated with adiposity.

38   **Results:** Over 7 years, the prevalence of obesity in the sample increased by 10.1% and 14.6% according

39   to BMI and %BF, respectively, and time spent in sedentary behaviour increased by 14%, while time

40   spent in LIPA and MVPA decreased by 14% and 21%, respectively. The increase in sedentary behaviour

41   at the expense of LIPA and MVPA during the seven-year period was associated with higher BMI and

42   %BF at follow-up (both p<0.01). The increase in LIPA or MVPA at the expense of sedentary behaviour

43   was associated with reduced BMI and %BF at follow-up. In our sample, the largest change in BMI (0.75

44   kg/m^2; 95% % confidence interval [CI]: 0.37-1.13) and %BF (1.28 units; 95% CI: 0.48-2.09) was

45   associated with longitudinal reallocation of 30 min from MVPA to sedentary behaviour.

46   **Conclusion:** We found an association between longitudinal changes in daily movement behaviours and

47   adiposity among elderly women in Central Europe. Our findings support public health programs to

48   increase or maintain time spent in higher intensity physical activity among elderly women.

49

INTRODUCTION

How people spend their time in movement-related behaviours throughout the day may influence their body composition.[1] It is well accepted that spending more time in physical activity is related to healthier body composition (i.e., the reduction of fat mass and increase of fat-free mass),[2] and that spending more time in sedentary behaviour is related to less healthy body composition.[3]Yet few studies have explored these relationships among elderly people, and even fewer have used device-based, longitudinal measures of movement behaviours. As studies that apply the compositional methodology specifically to older people are scarce, there is a lack of evidence to underpin obesity interventions and public health policy for older people based on reallocations of time between movement behaviours. More evidence is required, as robust interventions for improved time use may lead to better health and alleviate future economic costs amid an ageing population.

Most previous studies have considered movement behaviours such as physical activity and sedentary behaviour to be independent predictors of obesity.[4] However, movement behaviours are not independent of each other – they are co-dependent.[4-6] This is because movement behaviours take place in time, and available time in a day is finite. Each day, we have 24 hours on disposal. To increase the time spent in one behaviour, we must take this time from one or more other behaviours within that same day.[6-8] This means it does not make sense to explore the health associations of one behaviour independently of the other behaviours. Instead, movement behaviours should be considered relative to each other. This holds also for any subset of daily behaviours, e.g., waking behaviours.[9,10] Although waking behaviours do not necessarily sum to the same duration for every participant (as with the 24-hour day), the data are nonetheless compositional when conceptualised as scale invariant, i.e., we are interested in the relative proportions (or time shares) of behaviours rather than absolute amounts. Thus, when considering the impact of changing one behaviour, we simultaneously consider the impact of other behaviour(s) which are changed to compensate. Accordingly, there has been a recent conceptual shift in behavioural epidemiology which moves away from exploring movement behaviours as independent risk factors, towards an approach which allows

76 the influence of all behaviours to be considered relative to each other, i.e., a time-use epidemiology

77 approach.[11] This shift has been facilitated by the development of new analytical models based on

78 compositional data analysis.[5,8,12]

79 Studies using a compositional approach to explore the associations between movement behaviours

80 and adiposity among older adults have, to our knowledge, all been cross-sectional.[1,3,13] They suggest

81 that older adults who spend more time in moderate-to-vigorous physical activity (MVPA) and less time

82 in sedentary behaviour have better body composition. One study estimated body mass index (BMI) to

83 decrease by 0.7 units when 15 minutes were reallocated from sedentary behaviour to MVPA.[13]

84 Unexpectedly, this study reported the same estimated improvement (0.7 units) in BMI when 15

85 minutes of light physical activity (LIPA) were reallocated to MVPA. This suggests that in relation to

86 adiposity there is no benefit of LIPA over sedentary behaviour. However, cross-sectional reallocation

87 or isotemporal substitution studies do not provide evidence on how within-person changes in

88 behaviour over time are associated with health outcomes. As such, their findings should be considered

89 cautiously when planning interventions and advising policy. Studies with longitudinal exposures are

90 required to provide evidence on how changes in time use, specifically how reallocating time between

91 movement behaviours, are associated with outcomes.

92 This study aimed to use an integrated time-use approach to: 1) investigate the prospective associations

93 between changes in daily movement behaviours and adiposity among elderly women; and 2) to

94 examine how the reallocation of time between movement behaviours was associated with longitudinal

95 changes in adiposity.

96

97 **SUBJECTS AND METHODS**

98 **Design and participants**

99 This was a longitudinal study with baseline data collected during 2009–2011 in three university cities

100 in Central Europe with very similar weather, cultural and economic conditions; namely, Olomouc in

101 Czech republic, Katowice in Poland, and Prešov in Slovakia. Older women were recruited from within

102 University of Third Age programs to participate in physical activity and body composition

103 measurements. The exclusion criteria for baseline study involvement were inability to walk without

104 any prosthetic aids and being under the age 60. Follow-up data collection was conducted during 2016–

105 2018. So that data in 2009–2011, and 7 years later in 2016–2018 were collected in the same month,

106 the exact date of follow-up data collection was individually tailored. The follow-up stage implemented

107 the same assessment methods, device settings, process and measurement conditions (measurement

108 protocol) that were used at the baseline stage.

109 At baseline, valid data were available from 325 older women. After seven years, all women were

110 approached and invited to get involved in the follow-up assessment. Out of 325 baseline participants:

111 36 died before follow-up; 57 were not able to continue participating in the study due to serious illness;

112 and 65 did not agree to complete all parts of the measurements. Thus, the follow-up sample consisted

113 of 167 women. Of these, 158 women had valid baseline and follow-up data, and were included in the

114 ensuing analyses.

115 Participation in the study was voluntary and women could withdraw from the study at any time. For

116 both baseline and follow-up measurements, all participants provided their written informed consent.

117 The study was carried out in accordance with the Declaration of Helsinki and was approved by the

118 institutional scientific ethics committee.

119

120 **Measurements**

121 *Movement behaviors: physical activity and sedentary behavior*

122 Physical activity and sedentary behavior were measured at baseline and follow-up using a uniaxial

123 ActiGraph GT1M accelerometer device (Manufacturing Technology Inc., FL, USA). The research staff

124 personally checked the fastening of the device at the right hip. The participants were instructed to

125 wear the accelerometer for eight consecutive days during waking hours with exception of bathing and

126 swimming. The accelerometer sampling interval was set at 1-minute epochs. Non-wear time was

127 defined by an interval of 60 consecutive minutes of zero counts per minute (cpm), allowing for 2

128   minutes of non-zero count interruptions. This algorithm is provided in the manufacture's software

129   (ActiGraph, LLC., Pensacola, FL, USA). For the assessment of accelerometer-derived movement

130   behaviours, a 'valid day' was defined as the one in which the participant had ≥10 h of wear time. To be

131   included in the analyses, the participants had to have valid data for at least 4 days (3 workdays and 1

132   weekend day) in both baseline and follow-up measurements.[14] Amount of time spent in sedentary

133   behavior, LIPA and MVPA was derived for each valid day. For sedentary behavior, the cut-point of 100

134   counts/min was used as the commonly used threshold for senior populations.[15] LIPA and MVPA levels

135   were defined according to Freedson cut-off points.[16]

136

137   *Body adiposity*

138   Body height was measured barefooted using a P-375 portable anthropometer to the nearest 0.1 cm

139   (Trystom, Olomouc, Czech Republic). Body weight (to the nearest 0.1 kg) and body fat percentage

140   (%BF) were assessed using the InBody 720 multi-frequency bioelectrical impedance analyser (Biospace

141   Co., Ltd., Seoul, Korea). All the women were required fast for at least 4 h, hydrate properly for 24 h

142   preceding the measurement. BMI was calculated as weight/height^2 (kg/m^2) and categorised as

143   'normal' weight (<25 kg/m^2), overweight (25–29.9 kg/m^2), and obesity (≥30 kg/m^2). Body fat

144   percentage (%BF) was classified as 'normal' (≤35%) and obesity (>35%). Regardless of body weight and

145   physical activity level, multi-frequency bioelectrical impedance analysis has been suggested as a valid

146   method for body composition assessment in older women.[17]

147

148   *Statistical analyses*

149   Statistical analyses were performed using SPSS 22.0 software (SPSS Inc., an IBM Company, Chicago, IL,

150   USA) and R 3.4.2 software (R Foundation for Statistical Computing, Vienna, Austria). For baseline and

151   follow-up, the daily composition consisted of three parts of waking movement behaviour (sedentary

152   behaviour, LIPA and MVPA) and was closed to 16 h (assuming 8 h of sleep a day) for the purpose of

153   isotemporal substitution modelling. We assumed 8 h of daily sleep based on previous reports of sleep

154   duration in this age group,[18] and the average non-wear time observed in this sample which included

155   sleep and potentially other activities, such as bathing, and lying awake in bed (14.1±1.2 h and 13.6±1.2

156   h, at baseline and follow-up, respectively). The composition for isotemporal substitution modelling

157   could be also closed to the mean wake/wear time (if such data are available). The statistical analyses

158   took the relative nature of movement behaviour data into consideration. This means that not absolute

159   values of movement behaviours but rather ratios between them formed the source of relevant

160   information.[10] After ensuring there were no zero values in any composiitonal parts, the compositions

161   were expressed as pivot coordinates,[19] being a special case of isometric log ratios (ILRs). Accordingly,

162   the ILRs were constructed in a specific way so that the first pivot coordinate included all relative

163   information regarding one dominant activity (numerator), versus the geometric mean of the remaining

164   activities (denominator). This first pivot coordinate can also be expressed as the (scaled) sum of log-

165   ratios; this is reflected by the schematic notation in Table 2. Three sets of pivot coordinates were

166   constructed, with each set treating a different activity (sedentary behaviour, LIPA and MVPA) as the

167   dominant activity.

168   The prospective associations between changes in daily movement behaviours and adiposity were

169   investigated via robust compositional regression models (with the MM-estimator of regression

170   parameters)[10] in order to avoid possible influence of outlying observations,[12] with the follow-up

171   adiposity parameter as the dependent variable and differences between follow-up and baseline

172   movement behaviours (in terms of pivot coordinates) as the explanatory variables. To capture the

173   differences between follow-up and baseline for the aggregated relative effect of each compositional

174   part (sedentary behaviour, LIPA and MVPA) with respect to contributions of the remaining parts, three

175   models (one for each set of differences between the respective pivot coordinates) were conducted for

176   each adiposity parameter (BMI and %BF). Age, country, respective baseline adiposity parameter and

177   pivot coordinate representations of baseline movement behaviour composition were included as

178   covariates in each model.

179 To quantify how longitudinal reallocations of time between movement behaviours were associated

180 with changes in adiposity, the above-mentioned models were used for prediction purposes.

181 Differences between pivot coordinate representations of the hypothetical follow-up and mean

182 baseline movement behaviour compositions (that were linearly adjusted to sum to 16 hours) were

183 calculated to estimate BMI and %BF changes associated with one-to-one reallocations.[8] The estimated

184 differences for BMI and BF, respectively, were calculated for time reallocations of 5, 15 and 30 minutes

185 and 95% confidence intervals (CI) were obtained. Significance level was set a $p<0.05$. When the 95% CI

186 did not cover zero, the change was considered as significant.

187 A comprehensive explanation of the compositional analysis is included in Additional file.

188

189 **RESULTS**

190 Baseline and follow-up characteristics of the study sample are presented in Table 1. At baseline, the

191 average age was 63.9 years, the majority of participants were non-smokers (93%) and retired (87.3%)

192 with high prevalence (53.2%) of secondary or higher education. Over 7 years, the prevalence of obesity

193 in the sample increased by 10.1% and 14.6% according to BMI and %BF, respectively. The relative

194 difference between baseline and follow-up compositional means was 1.14, 0.86, and 0.79 which means

195 that time spent in sedentary behaviour increased by 14%, while time spent in LIPA decreased by 14%

196 and time spent in MVPA decreased by 21%.

197 The results displayed in Table 2 (Model 1, Row 1, $\beta=1.34$ for BMI and 3.15 for %BF) indicate that the

198 increase in sedentary behaviour at the expense of LIPA and MVPA during the seven-year period was

199 associated with higher BMI and %BF at follow-up. The increase in LIPA (Model 2, Row 1) or MVPA

200 (Model 3, Row 1) at the expense of the other two behaviours was associated with reduced BMI and

201 %BF at follow-up. The aggregated relative increase of LIPA was not significant for BMI ($\beta=-0.65$,

202 $p=0.110$), however this is not surprising because the respective pivot coordinate amalgamates log-

203 ratios with contradictory associations (see Model 1, Row 2 and Model 3, Row 2).

204   Table 3 and Figures 1 show the estimated changes in BMI and BF% associated with the change in

205   movement behaviour composition, i.e., with isotemporal substitutions between behaviours. By change

206   in movement behaviour composition we mean that 0 to 30 min are reallocated from one behaviour in

207   the mean baseline composition to another behaviour in the mean follow-up composition (NB the mean

208   compositions are calculated as the geometric means of the behaviours, linearly adjusted to sum to the

209   total assumed waking time of 16 h). At significance level $p<0.05$, the estimated changes in adiposity

210   parameters were significant for all reallocation cases apart for the change in %BF for reallocation from

211   LIPA to MVPA. The largest effect was observed when the change in movement pattern was

212   characterized by replacing the time spent in MVPA by the time spent in sedentary behaviour. We can

213   expect that a 30-min exchange from MVPA to sedentary behaviour would predict on average a

214   0.75 kg/m^2 increase in BMI and a 1.28 unit increase in %BF. We can also assume that the reverse

215   exchange of time between these behaviours would result in a 0.37 kg/m^2 decrease in BMI and a

216   0.65 unit decrease in %BF.

217

218   **DISCUSSION**

219   This longitudinal study among older women revealed that reallocations of time from a higher-intensity

220   to a lower-intensity movement behaviour were associated with higher adiposity. It also seems that

221   reallocations of the same amount of time in the opposite direction (i.e. from a lower-intensity to a

222   higher-intensity movement behaviour) may be associated with smaller reductions in adiposity.

223   Our findings of decreases in physical activity and increases in sedentary behaviour over time generally

224   align with longitudinal findings previously reported among older populations.[20,21] This may be due to

225   increasing physical impairment, co-morbidities, and changes in work, family and social commitments

226   as people age. We are unaware of any previous studies prospectively linking changes in device-

227   measured movement behaviours with adiposity in older adults; however, the findings of this study

228   partially concur with cross-sectional evidence.[1,13] Less time spent in MVPA in favour of other

229   movement behaviours of lower intensity (LIPA and sedentary behaviour) has consistently emerged as

230 the most detrimental factor in the association with adiposity among not only older adults, but across

231 the lifespan. This is not surprising, as MVPA requires higher energy expenditure than LIPA and

232 sedentary behaviour. Thus, replacing MVPA with LIPA and sedentary behaviour may lead to an

233 imbalance between energy intake and energy expenditure, and subsequent gain of excess fat.

234 However, our study does not provide evidence on the direction of causation. Reverse causation is also

235 plausible – as adiposity increases, time spent in MVPA is replaced by behaviours requiring lower energy

236 expenditure. It is also possible that the relationship is bidirectional. A previous study suggested that

237 obesity may lead to a subsequent increase in sedentary behaviour among middle-aged and older

238 adults.[22] However, this study did not conceptualise sedentary behaviour as a part of the time-use

239 composition and examine reallocations of time between different behaviours.

240 Contrary to previous cross-sectional studies,[3] we found beneficial associations of adiposity status with

241 reallocations of time from sedentary behaviour to LIPA. However, these associations were weak. The

242 reallocation of 30 minutes from sedentary behaviour to LIPA was associated with –0.10 and –0.27 units

243 change in BMI and %BF, respectively. By comparison, the reallocation of 30 minutes from sedentary

244 behaviour to MVPA was associated with a much larger change in BMI (–0.37 units; –1.4%) and %BF (–

245 0.65 units; –1.9%). However, increasing MVPA by 30 minutes represents an increase of 75% from

246 baseline daily MVPA. This may not be an achievable intervention goal, particularly among older adults.

247 However, the reallocation of 30 minutes from sedentary behaviour to LIPA requires a comparatively

248 small behavioural change (only a 7% increase from baseline daily LIPA). To obtain the same difference

249 in BMI units (–0.37 units) estimated for reallocating 30 minutes from sedentary behaviour to MVPA,

250 104 minutes could be reallocated from sedentary behaviour to LIPA. This suggests that, in this

251 particular context, each minute of MVPA is worth around 3.5 minutes of LIPA. Similarly for %BF, the

252 reallocation of 71 minutes from sedentary behaviour to LIPA would be needed to get the same

253 estimated difference (–0.65 units). Such a reallocation strategy may be more feasible for older adults,

254 as LIPA is incidental to daily living and can be accumulated by simple modifications to daily activities,

255 such as slow walking to visit friends rather than driving.

256 Consistent with other studies using compositional data analysis,[6,13] we found asymmetrical responses

257 in adiposity depending on whether MVPA was increased or decreased. In our sample, the average

258 benefits estimated for the reallocation of a set duration of time to MVPA were not as large as the

259 estimated worsening of the adiposity status when the same duration was reallocated away from

260 MVPA. This asymptotic dose-response relationships between PA and health outcomes are a common

261 finding in the literature.[23] For example, the relationship between physical activity dosage and all-cause

262 mortality has consistently been found to be asymptotic.[24] Some studies have found an asymptotic

263 relationship also between exercise dosage and weight loss.[25,26] It should be noted, however, that most

264 of these studies did not use compositional data analysis and account for co-dependence between time-

265 use components.[1,4] The asymmetry of estimated responses can be observed in Figures 1 and suggests

266 that the relative benefits obtained from avoiding a quantum fall in current levels of MVPA are greater

267 than the relative benefits accrued by an increase of the same quantum. This would suggest that the

268 maintenance of MVPA is an important intervention goal, particularly as people age and their MVPA

269 levels tend to decline. It should be noted, however, that the confidence intervals for absolute values

270 of the estimated changes in adiposity for reallocations to and from MVPA were overlapping, which

271 means that we cannot generalise about the asymmetry beyond our study sample.

272 Our study provided evidence to suggest that interventions enabling elderly women to shift time from

273 lower to higher intensity behaviours have the potential to decrease adiposity. Replacing sedentary

274 behaviour with MVPA appears to be the best strategy, but larger replacements of sedentary behaviour

275 with LIPA may achieve similar gains. If increasing time spent in MVPA is not feasible, our study suggests

276 that it may be worthwhile to support elderly people to maintain their current MVPA levels. Programs

277 to create safe environments and opportunities for MVPA may be warranted. A previous study

278 suggested the role of LIPA should be an important focus for future studies.[27] Our findings support the

279 recommendation in the context of obesity research. These findings are particularly relevant from a

280 public health perspective, because Central Europe has an aging population, consistent with most other

281 European countries, as life expectancy is increasing. However, unlike in other European regions, the

282 overall population in Central Europe is predicted to decline[28] due to low birth rates, a strong emigration

283 drive, and restrictive immigration policies. Evidence to inform healthier daily movement behaviours

284 among older people is, therefore, becoming increasingly important, especially among Central

285 Europeans, who are already lagging behind other countries in terms of their obesity status and overall

286 health.[29]

287 The strengths of this study include the repeated measures of movement behaviours spanning 7 years,

288 using identical measurement procedures, and using accelerometers. Longitudinal data of older adults'

289 movement behaviours are scarce and rarely reported. However, we only had two points of data

290 measurement, meaning patterns of change may not have been detected. Adiposity indicators were

291 measured using standardised procedures and analyses were conducted using statistical models that

292 are appropriate for the relative nature of movement behaviour data. The generalizability of the study

293 is limited due to its non-probability convenience sample with very few smokers, high prevalence of

294 higher education and participation in organized PA (57 % participating one or more times/week). In

295 addition, our sample only included women, meaning results cannot be extrapolated to men without

296 caution. It is possible that our findings are confounded by unmeasured factors such as dietary changes

297 and smoking habits. Additionally, although we used the most common cut-points in accelerometry

298 data analyses,[15] different cut-points can substantially impact the classification of the proportion of

299 time spent in different movement behaviours in a sample of older women. It should be considered

300 that our measurement protocol did not include examination of sleep duration, which may have

301 confounded findings as sleep is co-dependent with movement behaviours and longer sleep appears to

302 be beneficially associated with adiposity.[30] It is possible that the exclusion of sleep has led to

303 overestimation of the benefits of MVPA or LIPA and conservative estimates for the unfavourable

304 influence of sedentary behaviour. Additionally, for analytical purposes and interpretability of

305 estimates, we linearly adjusted the waking-day compositions to sum to 16 hours when average wear

306 times were between 14.1±1.2 and 13.6±1.2 hours. This implies that the composition of behaviours

307 during the unmeasured period of waking time is the same as during the measured period, which may

308 not necessarily be the case.

309 In conclusion, we found an association between changes in daily movement behaviours and adiposity

310 among elderly women in Central Europe. Increases in MVPA and LIPA, and decreases in sedentary

311 behaviour were beneficially associated with adiposity indicators. Our findings support public health

312 programs to increase or maintain time spent in higher intensity physical activity among elderly women.

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317

318 **CONFLICTS OF INTEREST**

319 The authors declare no conflict of interest.

320

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Table 1. Baseline and follow-up characteristics of the study sample

	Baseline	Follow-up
	Mean (SD)	Mean (SD)
Age and nationality		
Age (years)	63.9 (4.4)	
Czech, Polish, Slovak (n (%))	63 (39.9), 62 (39.2), 33 (20.9)	
Anthropometrics		
Body height (cm)	160.1 (6.8)	159.7 (6.9)
Body weight (kg)	68.4 (10.7)	69.6 (11.6)
Body mass index (kg/m²)	26.5 (4.1)	27.3 (4.3)
Body fat percentage (%)	34.3 (6.9)	36.7 (6.8)
Wear time and activity composition		
Wear time (h)	14.1 (1.2)	13.6 (1.2)
Compositional mean of SB, LIPA, MVPA (min)[a]	505, 415, 40	573.5, 354.9, 31.6
Compositional mean of SB, LIPA, MVPA (%)	52.6, 43.2, 4.2	59.7, 37, 3.3
Weight status according to BMI, n (% of n)		
'Normal' weight (<25 kg/m²)	60 (38)	75 (47.5)
Overweight (25–29.9 kg/m²)	69 (43.7)	38 (24.0)
Obesity (≥30 kg/m²)	29 (18.3)	45 (28.5)
Obesity status according to %BF, n (% of n)		
'Normal' (≤35%)	87 (55.1)	64 (40.5)
Obesity (>35%)	71 (44.9)	94 (59.5)

SD = standard deviation; SB = sedentary behaviour; LIPA = light physical activity; MVPA = moderate-to-vigorous physical activity; BMI = body mass index; %BF = body fat percentage.
[a] composition closed to 16 hours.

Table 2. Pivot coordinate compositional MM-regression estimates for models with the follow-up adiposity measures as response variables.

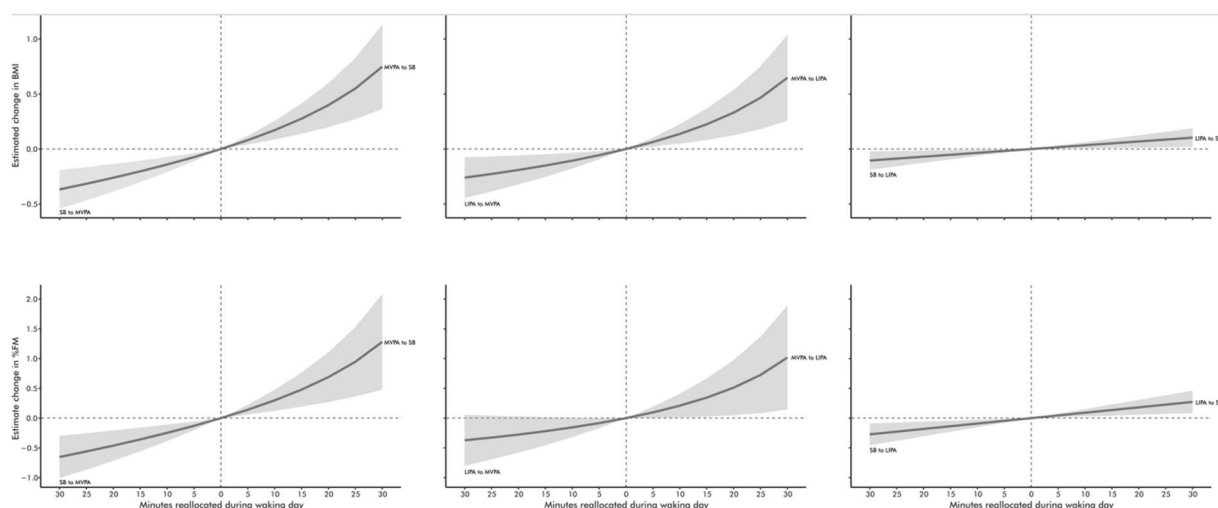|	Body mass index (kg/m²)		Body fat (%)	
	β_{ilr} (SE)	p-value	β_{ilr} (SE)	p-value
Model 1				
SB/LIPA+SB/MVPA) difference	1.34 (0.40)	< 0.001	3.15 (0.82)	<0.001
(LIPA/MVPA) difference	0.02 (0.29)	0.940	−0.50 (0.71)	0.480
Model 2				
(LIPA/SB+LIPA/MVPA) difference	−0.65 (0.41)	0.110	−2.01 (0.96)	0.040
(SB/MVPA) difference	1.17 (0.27)	<0.001	2.48 (0.50)	<0.001
Model 3				
(MVPA/SB+MVPA/LIPA) difference	−0.69 (0.19)	<0.001	−1.14 (0.41)	0.006
(SB/LIPA) difference	1.15 (0.45)	0.010	2.98 (1.00)	0.003

Note: All models were adjusted for age, country, and movement behaviour compositions at baseline. The first pivot coordinate has been expressed as the sum of individual log-ratios for ease of interpretation (a comprehensive explanation of the compositional analysis is included in Additional file).
BMI = body mass index; BF% = body fat percentage; β = unstandardised regression coefficient; SE = standard error; SB = sedentary behaviour; LIPA = light physical activity; MVPA = moderate-to-vigorous physical activity

Table 3. Estimated changes (and their 95% confidence intervals) in follow-up BMI and %BF associated with time reallocation between baseline and follow-up movement behaviour composition.

Reallocation	Body mass index (kg/m²)			Body fat (%)		
	5 min	15 min	30 min	5 min	15 min	30 min
SB to LIPA	−0.02 (−0.03, -0.00)	−0.05 (-0.09, −0.01)	−0.10 (−0.19, −0.02)	−0.05 (−0.08, −0.01)	−0.14 (−0.23, −0.04)	−0.27 (−0.46, −0.09)
SB to MVPA	−0.07 (−0.11, −0.04)	−0.20 (−0.30, −0.10)	−0.37 (−0.54, −0.19)	−0.13 (−0.20, −0.06)	−0.36 (−0.56, −0.16)	−0.65 (−1.01, −0.30)
LIPA to SB	0.02 (0.00, 0.03)	0.05 (0.01, 0.09)	0.10 (0.02, 0.19)	0.05 (0.01, 0.08)	0.14 (0.04, 0.23)	0.27 (0.08, 0.46)
LIPA to MVPA	−0.06 (−0.09, −0.02)	−0.15 (−0.25, 0.05)	−0.26 (−0.45, 0.07)	−0.08 (−0.17, 0.00)	−0.22 (−0.46, 0.02)	−0.37 (−0.80, 0.06)
MVPA to SB	0.08 (0.04, 0.12)	0.28 (0.14, 0.41)	0.75 (0.37, 1.13)	0.14 (0.06, 0.22)	0.48 (0.19, 0.77)	1.28 (0.48, 2.09)
MVPA to LIPA	0.06 (0.02, 0.11)	0.23 (0.08, 0.37)	0.65 (0.26, 1.04)	0.10 (0.00, 0.19)	0.35 (0.02, 0.67)	1.02 (0.14, 1.89)

BMI = body mass index; %BF = body fat percentage; SB = sedentary behaviour; LIPA = light-intensity physical activity; MVPA = moderate-to-vigorous physical activity

Figure 1. Estimated changes in follow-up body mass index and body fat percentage associated with time reallocation between baseline and follow-up movement behaviour composition.

BMI = body mass index; %BF = body fat percentage; SB = sedentary behaviour; LIPA = light-intensity physical activity; MVPA = moderate-to-vigorous physical activity