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ARTICLE

Epidemiology and Population Health

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

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Abstract

Background This study aimed to use compositional data analysis to: (1) investigate the prospective associations between changes in daily movement behaviours and adiposity among elderly women; and (2) to examine how the reallocation of time between movement behaviours was associated with longitudinal changes in adiposity.

Subjects/methods This is a 7-year longitudinal study in Central European older women ($n = 158$, baseline age 63.9 ± 4.4 years). At baseline and follow-up, light-intensity physical activity (LIPA), moderate-to-vigorous physical activity (MVPA) and sedentary behaviour were measured by accelerometer and body adiposity (body mass index [BMI], body fat percentage [%BF]) was assessed from measured height and weight and bioelectrical impedance analyser. Compositional regression with robust estimators and compositional longitudinal isotemporal substitution analysis explored if, and how, changes in movement behaviours were associated with adiposity.

Results Over 7 years, the prevalence of obesity in the sample increased by 10.1% and 14.6% according to BMI and %BF, respectively, and time spent in sedentary behaviour increased by 14%, while time spent in LIPA and MVPA decreased by 14% and 21%, respectively. The increase in sedentary behaviour at the expense of LIPA and MVPA during the 7-year period was associated with higher BMI and %BF at follow-up (both $p < 0.01$). The increase in LIPA or MVPA at the expense of sedentary behaviour was associated with reduced BMI and %BF at follow-up. In our sample, the largest change in BMI (0.75 kg/m^2; 95% confidence interval [CI]: 0.37–1.13) and %BF (1.28 U; 95% CI: 0.48–2.09) was associated with longitudinal reallocation of 30 min from MVPA to sedentary behaviour.

Conclusions We found an association between longitudinal changes in daily movement behaviours and adiposity among elderly women in Central Europe. Our findings support public health programmes to increase or maintain time spent in higher-intensity physical activity among elderly women.

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)

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[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 h 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 h 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 the influence of all behaviours to be considered relative to each other, i.e. a time-use epidemiology approach [11]. This shift has been facilitated by the development of new analytical models based on compositional data analysis [5, 8, 12].

Studies using a compositional approach to explore the associations between movement behaviours and adiposity among older adults have, to our knowledge, all been cross-sectional [1, 3, 13]. They suggest that older adults who spend more time in moderate-to-vigorous physical activity (MVPA) and less time in sedentary behaviour have better body composition. One study estimated body mass index (BMI) to decrease by 0.7 U when 15 min were reallocated from sedentary behaviour to MVPA [13]. Unexpectedly, this study reported the same estimated improvement (0.7 U) in BMI when 15 min of light-intensity physical activity (LIPA) were reallocated to MVPA. This suggests that in relation to adiposity there is no benefit of LIPA over sedentary behaviour. However, cross-sectional reallocation or isotemporal substitution studies do not provide evidence on how within-person changes in behaviour over time are associated with health outcomes. As such, their findings should be considered cautiously when planning interventions and advising policy. Studies with longitudinal exposures are required to provide evidence on how changes in time use, specifically how reallocating time between movement behaviours, are associated with outcomes.

This study aimed to use an integrated time-use approach to: (1) investigate the prospective associations between changes in daily movement behaviours and adiposity among elderly women; and (2) to examine how the reallocation of time between movement behaviours was associated with longitudinal changes in adiposity.

Subjects and methods

Design and participants

This was a longitudinal study with baseline data collected during 2009–2011 in three university cities in Central Europe with very similar weather, cultural and economic conditions; namely, Olomouc in Czech republic, Katowice in Poland and Prešov in Slovakia. Older women were recruited from within University of Third Age programmes to participate in physical activity and body composition measurements. The exclusion criteria for baseline study involvement were inability to walk without any prosthetic aids and being under the age 60. Follow-up data collection was conducted during 2016–2018. So that data in 2009–2011, and 7 years later in 2016–2018 were collected in the same month, the exact date of follow-up data collection was individually tailored. The follow-up stage implemented the same assessment methods, device settings, process and measurement conditions (measurement protocol) that were used at the baseline stage.

At baseline, valid data were available from 325 older women. After 7 years, all women were approached and invited to get involved in the follow-up assessment. Out of 325 baseline participants: 36 died before follow-up; 57 were not able to continue participating in the study due to serious illness; and 65 did not agree to complete all parts of the measurements. Thus, the follow-up sample consisted of 167 women. Of these, 158 women had valid baseline and follow-up data, and were included in the ensuing analyses.

Participation in the study was voluntary and women could withdraw from the study at any time. For both baseline and follow-up measurements, all participants provided their written informed consent. The study was carried out in accordance with the Declaration of Helsinki and was approved by the institutional scientific ethics committee.

Measurements

Movement behaviours: physical activity and sedentary behaviour

Physical activity and sedentary behaviour were measured at baseline and follow-up using a uniaxial ActiGraph GT1M accelerometer device (Manufacturing Technology Inc., FL, USA). The research staff personally checked the fastening of the device at the right hip. The participants were instructed to wear the accelerometer for 8 consecutive days during waking hours with exception of bathing and swimming. The accelerometer sampling interval was set at 1 min epochs. Non-wear time was defined by an interval of 60 consecutive minutes of zero counts per minute (cpm), allowing for 2 min of non-zero count interruptions. This algorithm is provided in the manufacture's software (ActiGraph, LLC., Pensacola, FL, USA). For the assessment of accelerometer-derived movement behaviours, a 'valid day' was defined as the one, in which the participant had ≥10 h of wear time. To be included in the analyses, the participants had to have valid data for at least 4 days (3 workdays and 1 weekend day) in both baseline and follow-up measurements [14]. Amount of time spent in sedentary behaviour, LIPA and MVPA was derived for each valid day. For sedentary behaviour, the cut-point of 100 counts/min was used as the commonly used threshold for senior populations [15]. LIPA and MVPA levels were defined according to Freedson cut-off points [16].

Body adiposity

Body height was measured barefooted using a P-375 portable anthropometer to the nearest 0.1 cm (Trystom, Olomouc, Czech Republic). Body weight (to the nearest 0.1 kg) and body fat percentage (%BF) were assessed using the InBody 720 multi-frequency bioelectrical impedance analyser (Biospace Co., Ltd., Seoul, Korea). All the women were required fast for at least 4 h, hydrate properly for 24 h preceding the measurement. BMI was calculated as weight/height^2 (kg/m^2) and categorised as 'normal' weight (<25 kg/m^2), overweight (25–29.9 kg/m^2) and obesity (≥30 kg/m^2). Body fat percentage (%BF) was classified as 'normal' (≤35%) and obesity (>35%). Regardless of body weight and physical activity level, multi-frequency bioelectrical impedance analysis has been suggested as a valid method for body composition assessment in older women [17].

Statistical analyses

Statistical analyses were performed using SPSS 22.0 software (SPSS Inc., an IBM Company, Chicago, IL, USA) and R 3.4.2 software (R Foundation for Statistical Computing, Vienna, Austria). For baseline and follow-up, the daily composition consisted of three parts of waking movement behaviour (sedentary behaviour, LIPA and MVPA) and was closed to 16 h (assuming 8 h of sleep a day) for the purpose of isotemporal substitution modelling. We assumed 8 h of daily sleep based on previous reports of sleep duration in this age group [18], and the average non-wear time observed in this sample which included sleep and potentially other activities, such as bathing, and lying awake in bed (14.1 ± 1.2 h and 13.6 ± 1.2 h, at baseline and follow-up, respectively). The composition for isotemporal substitution modelling could be also closed to the mean wake/wear time (if such data are available). The statistical analyses took the relative nature of movement behaviour data into consideration. This means that not absolute values of movement behaviours but rather ratios between them formed the source of relevant information [10]. After ensuring there were no zero values in any compositional parts, the compositions were expressed as pivot coordinates [19], being a special case of isometric log ratios (ILRs). Accordingly, the ILRs were constructed in a specific way so that the first pivot coordinate included all relative information regarding one dominant activity (numerator), versus the geometric mean of the remaining activities (denominator). This first pivot coordinate can also be expressed as the (scaled) sum of log-ratios; this is reflected by the schematic notation in Table 2. Three sets of pivot coordinates were constructed, with each set treating a different activity (sedentary behaviour, LIPA and MVPA) as the dominant activity.

The prospective associations between changes in daily movement behaviours and adiposity were investigated via robust compositional regression models (with the MM-estimator of regression parameters) [10] in order to avoid possible influence of outlying observations [12], with the follow-up adiposity parameter as the dependent variable and differences between follow-up and baseline movement behaviours (in terms of pivot coordinates) as the explanatory variables. To capture the differences between follow-up and baseline for the aggregated relative effect of each compositional part (sedentary behaviour, LIPA and MVPA) with respect to contributions of the remaining parts, three models (one for each set of differences between the respective pivot coordinates) were conducted for each adiposity parameter (BMI and %BF). Age, country, respective baseline adiposity parameter and pivot coordinate representations of baseline movement behaviour composition were included as covariates in each model.

To quantify how longitudinal reallocations of time between movement behaviours were associated with changes in adiposity, the above-mentioned models were used for prediction purposes. Differences between pivot coordinate representations of the hypothetical follow-up and mean baseline movement behaviour compositions (that were linearly adjusted to sum to 16 h) were calculated to estimate BMI and %BF changes associated with one-to-one reallocations [8]. The estimated differences for BMI and BF, respectively, were calculated for time reallocations of 5, 15 and 30 min and 95% confidence intervals (CI) were obtained. Significance level was set a $p < 0.05$. When the 95% CI did not cover zero, the change was considered as significant.

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

Results

Baseline and follow-up characteristics of the study sample are presented in Table 1. At baseline, the average age was 63.9 years, the majority of participants were non-smokers (93%) and retired (87.3%) with high prevalence (53.2%) of secondary or higher education. Over 7 years, the prevalence of obesity in the sample increased by 10.1% and 14.6% according to BMI and %BF, respectively. The relative difference between baseline and follow-up compositional means was 1.14, 0.86 and 0.79, which means that time spent in sedentary behaviour increased by 14%, while time spent in LIPA decreased by 14% and time spent in MVPA decreased by 21%.

The results displayed in Table 2 (Model 1, Row 1, $\beta =$ 1.34 for BMI and 3.15 for %BF) indicate that the increase in sedentary behaviour at the expense of LIPA and MVPA during the 7-year period was associated with higher BMI and %BF at follow-up. The increase in LIPA (Model 2, Row 1) or MVPA (Model 3, Row 1) at the expense of the other two behaviours was associated with reduced BMI and %BF at follow-up. The aggregated relative increase of LIPA

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

	Baseline Mean (SD)	Follow-up 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/m^2)	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/m^2)	60 (38)	75 (47.5)
Overweight (25–29.9 kg/m^2)	69 (43.7)	38 (24.0)
Obesity (≥30 kg/m^2)	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-intensity physical activity, *MVPA* moderate-to-vigorous physical activity, *BMI* body mass index, *%BF* body fat percentage

[a]Composition closed to 16 h

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

	Body mass index (kg/m^2)		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

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-intensity 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/m^2)			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

was not significant for BMI ($\beta = -0.65$, $p = 0.110$), however this is not surprising because the respective pivot coordinate amalgamates log-ratios with contradictory associations (see Model 1, Row 2 and Model 3, Row 2).

Table 3 and Fig. 1 show the estimated changes in BMI and %BF associated with the change in movement behaviour composition, i.e. with isotemporal substitutions between behaviours. By change in movement behaviour composition we mean that 0–30 min are reallocated from one behaviour in the mean baseline composition to another behaviour in the mean follow-up composition (NB the mean compositions are calculated as the geometric means of the behaviours, linearly adjusted to sum to the total assumed waking time of 16 h). At significance level $p < 0.05$, the estimated changes in adiposity parameters were significant for all reallocation cases apart for the change in %BF for reallocation from LIPA to MVPA. The largest effect was observed when the change in movement pattern was characterised by replacing the time spent in MVPA by the time spent in sedentary behaviour. We can expect that a 30 min exchange from MVPA to sedentary behaviour would predict on average a 0.75 kg/m^2 increase in BMI and a 1.28 U increase in %BF. We can also assume that the reverse exchange of time between these behaviours would result in a 0.37 kg/m^2 decrease in BMI and a 0.65 U decrease in %BF.

Discussion

This longitudinal study among older women revealed that reallocations of time from a higher-intensity to a lower-intensity movement behaviour were associated with higher adiposity. It also seems that reallocations of the same amount of time in the opposite direction (i.e. from a lower-intensity to a higher-intensity movement behaviour) may be associated with smaller reductions in adiposity.

Our findings of decreases in physical activity and increases in sedentary behaviour over time generally align with longitudinal findings previously reported among older populations [20, 21]. This may be due to increasing physical impairment, co-morbidities and changes in work, family and social commitments as people age. We are unaware of any previous studies prospectively linking changes in device-measured movement behaviours with adiposity in older adults; however, the findings of this study partially concur with cross-sectional evidence [1, 13]. Less time spent in MVPA in favour of other movement behaviours of lower intensity (LIPA and sedentary behaviour) has consistently emerged as the most detrimental factor in the association with adiposity among not only older adults, but across the lifespan. This is not surprising, as MVPA requires higher energy expenditure than LIPA and sedentary behaviour. Thus, replacing MVPA with LIPA and sedentary behaviour may lead to an imbalance

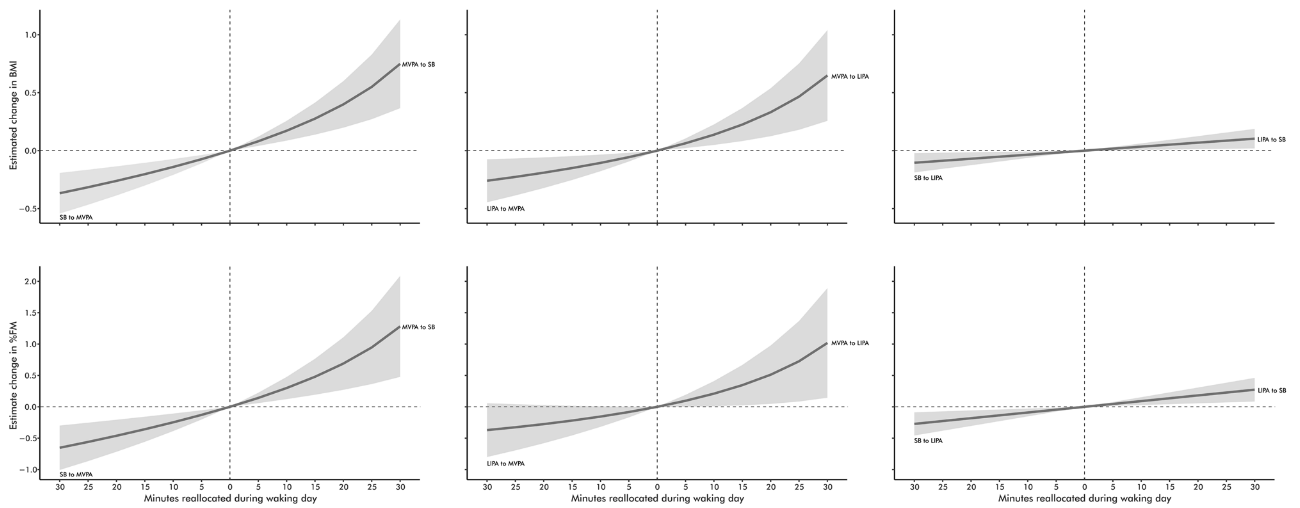

Fig. 1 Estimated changes in follow-up body mass index and body fat percentage associated with time reallocation between baseline and follow-up movement behaviour composition. *BMI* body mass index, *%BF* body fat percentage, *SB* sedentary behaviour, *LIPA* light-intensity physical activity, *MVPA* moderate-to-vigorous physical activity.

between energy intake and energy expenditure, and subsequent gain of excess fat. However, our study does not provide evidence on the direction of causation. Reverse causation is also plausible—as adiposity increases, time spent in MVPA is replaced by behaviours requiring lower energy expenditure. It is also possible that the relationship is bidirectional. A previous study suggested that obesity may lead to a subsequent increase in sedentary behaviour among middle-aged and older adults [22]. However, this study did not conceptualise sedentary behaviour as a part of the time-use composition and examine reallocations of time between different behaviours.

Contrary to previous cross-sectional studies [3], we found beneficial associations of adiposity status with reallocations of time from sedentary behaviour to LIPA. However, these associations were weak. The reallocation of 30 min from sedentary behaviour to LIPA was associated with −0.10 and −0.27 U change in BMI and %BF, respectively. By comparison, the reallocation of 30 min from sedentary behaviour to MVPA was associated with a much larger change in BMI (−0.37 U; −1.4%) and %BF (−0.65 U; −1.9%). However, increasing MVPA by 30 min represents an increase of 75% from baseline daily MVPA. This may not be an achievable intervention goal, particularly among older adults. However, the reallocation of 30 min from sedentary behaviour to LIPA requires a comparatively small behavioural change (only a 7% increase from baseline daily LIPA). To obtain the same difference in BMI units (−0.37 U) estimated for reallocating 30 min from sedentary behaviour to MVPA, 104 min could be reallocated from sedentary behaviour to LIPA. This suggests that, in this particular context, each minute of MVPA is worth around 3.5 min of LIPA. Similarly for %BF, the reallocation of 71 min from sedentary behaviour to LIPA would be needed to get the same estimated difference (−0.65 U). Such a reallocation strategy may be more feasible for older adults, as LIPA is incidental to daily living and can be accumulated by simple modifications to daily activities, such as slow walking to visit friends rather than driving.

Consistent with other studies using compositional data analysis [6, 13], we found asymmetrical responses in adiposity depending on whether MVPA was increased or decreased. In our sample, the average benefits estimated for the reallocation of a set duration of time to MVPA were not as large as the estimated worsening of the adiposity status when the same duration was reallocated away from MVPA. This asymptotic dose–response relationships between PA and health outcomes are a common finding in the literature [23]. For example, the relationship between physical activity dosage and all-cause mortality has consistently been found to be asymptotic [24]. Some studies have found an asymptotic relationship also between exercise dosage and weight loss [25, 26]. It should be noted, however, that most of these studies did not use compositional data analysis and account for co-dependence between time-use components [1, 4]. The asymmetry of estimated responses can be observed in Fig. 1 and suggests that the relative benefits obtained from avoiding a quantum fall in current levels of MVPA are greater than the relative benefits accrued by an increase of the same quantum. This would suggest that the maintenance of MVPA is an important intervention goal, particularly as people age and their MVPA levels tend to decline. It should be noted, however, that the confidence intervals for absolute values of the estimated changes in adiposity for reallocations to and from MVPA were overlapping, which means that we cannot generalise about the asymmetry beyond our study sample.

Our study provided evidence to suggest that interventions enabling elderly women to shift time from lower to higher-intensity behaviours have the potential to decrease adiposity. Replacing sedentary behaviour with MVPA appears to be the best strategy, but larger replacements of sedentary behaviour with LIPA may achieve similar gains. If increasing time spent in MVPA is not feasible, our study suggests that it may be worthwhile to support elderly people to maintain their current MVPA levels. Programmes to create safe environments and opportunities for MVPA may be warranted. A previous study suggested the role of LIPA should be an important focus for future studies [27]. Our findings support the recommendation in the context of obesity research. These findings are particularly relevant from a public health perspective, because Central Europe has an aging population, consistent with most other European countries, as life expectancy is increasing. However, unlike in other European regions, the overall population in Central Europe is predicted to decline [28] due to low birth rates, a strong emigration drive and restrictive immigration policies. Evidence to inform healthier daily movement behaviours among older people is, therefore, becoming increasingly important, especially among Central Europeans, who are already lagging behind other countries in terms of their obesity status and overall health [29].

The strengths of this study include the repeated measures of movement behaviours spanning 7 years, using identical measurement procedures, and using accelerometers. Longitudinal data of older adults' movement behaviours are scarce and rarely reported. However, we only had two points of data measurement, meaning patterns of change may not have been detected. Adiposity indicators were measured using standardised procedures and analyses were conducted using statistical models that are appropriate for the relative nature of movement behaviour data. The generalisability of the study is limited due to its non-probability convenience sample with very few smokers, high prevalence of higher education and participation in organised PA (57% participating one or more times/week). In addition, our sample only included women, meaning results cannot be extrapolated to men without caution. It is possible that our findings are confounded by unmeasured factors such as dietary changes and smoking habits. In addition, although we used the most common cut-points in accelerometry data analyses [15], different cut-points can substantially impact the classification of the proportion of time spent in different movement behaviours in a sample of older women. It should be considered that our measurement protocol did not include examination of sleep duration, which may have confounded findings as sleep is co-dependent with movement behaviours and longer sleep appears to be beneficially associated with adiposity [30]. It is possible that the exclusion of sleep has led to overestimation of the benefits of MVPA or LIPA and conservative estimates for the unfavourable influence of sedentary behaviour. In addition, for analytical purposes and interpretability of estimates, we linearly adjusted the waking-day compositions to sum to 16 h when average wear times were between 14.1 ± 1.2 and 13.6 ± 1.2 h. This implies that the composition of behaviours during the unmeasured period of waking time is the same as during the measured period, which may not necessarily be the case.

In conclusion, we found an association between changes in daily movement behaviours and adiposity among elderly women in Central Europe. Increases in MVPA and LIPA, and decreases in sedentary behaviour were beneficially associated with adiposity indicators. Our findings support public health programmes to increase or maintain time spent in higher-intensity physical activity among elderly women.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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