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Neighborhood socioeconomic status and adherence to dietary recommendations among Finnish adults: A retrospective follow-up study

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ABSTRACT

Neighborhood socioeconomic status (SES) is associated with dietary habits among the residents, but few studies have examined this association separately among long-term residents and movers. We calculated cumulative neighborhood SES score weighted by residential time in each address over 6 years for non-movers (n = 7704) and movers (n = 8818) using national grid database. Increase in average neighborhood SES was associated with higher adherence to dietary recommendations in both groups. Among the movers, an upward trajectory from low to high neighborhood SES was also associated with better adherence. Our findings suggest high SES areas might offer healthier food environments than low SES areas.

1. Introduction

Health inequalities are well demonstrated world-wide (WHO, 2014) and may be in part attributable to poorer health habits, including diet among individuals with lower socioeconomic status (SES) or education achievement (Galobardes et al., 2001; Giskes et al., 2006; Hulshof et al., 2003; Konttinen et al., 2012; Lallukka et al., 2007; Marmot, 2005). Recent studies suggest that consumption of food items such as fruits and vegetables may also vary by area of residence (Algren et al., 2015; Kivimäki et al., 2018), independently of individual level factors. Thus, it has been suggested that living in affluent neighborhoods may offer better possibilities to maintain healthy dietary habits than living in low-SES neighborhoods (Dubowitz et al., 2008; Wang et al., 2007).

The evidence supporting differing food consumption by area of residence is mixed (Algren et al., 2015). Some studies have reported higher fruit and vegetable intake (Ball et al., 2015), and higher healthy eating index score based on food frequency questionnaire (Drewnowski et al., 2016) among people living in high SES neighborhoods, whereas other studies have shown opposite trends for fruit and vegetable consumption among Western women living in deprived neighborhoods (Alves et al., 2013). Yet other studies have suggested that there is no clear association between neighborhood SES and vegetable consumption (Algren et al., 2015; Turrell et al., 2009). However, most of these studies focused only on specific components of the diet, for example fruit and vegetable consumption, which do not provide information about the whole diet. Another drawback is the reliance on a single-time measurement of residential address, which does not take into account residential mobility and therefore fails to capture long-term exposure or changes in residential environments.

Mechanisms underlying the associations between neighborhood SES and dietary habits are assumed to involve local food environments. This is supported by studies reporting clear differences in neighborhood food environments between low and high SES neighborhoods (Beaulac et al., 2009; Gordon-Larsen and Popkin, 2011; Morland et al., 2002; Morland and Filomena, 2007) with higher availability of fast-food restaurants, and energy-dense foods and food sources in lower-income and minority neighborhoods than in affluent neighborhoods (Hilmers et al., 2012; Jiao et al., 2016; Turrell et al., 2009). According to the Global Food Policy report (IFPRI, 2017), the most easily available and affordable diets for the urban poor are often unhealthy.

To address some of the above mentioned limitations, we investigated the association between neighborhood SES across a 6-year

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residential time window and participants' adherence to dietary recommendations taking diet into account more broadly than focusing on any single component of the diet. We performed these analyses separately for non-movers and movers, because average neighborhood conditions may have different associations than change in the conditions. In addition, we identified subgroups of movers following a similar trajectory in the neighborhood socioeconomic level and examined the association between these neighborhood SES trajectories and diet.

2. Methods

2.1. Study population

Health and Social Support (HeSSup) is a follow-up study commenced in 1998 (n = 25,901) representative of the Finnish Population in four age groups (20–24, 30–34, 40–44 and 50–54 years at baseline) (Suominen et al., 2012). We used self-reported consumption of selected food items and alcohol from a follow-up survey in 2003 (n = 19,629; response rate 76%). We excluded those who did not give us permission to perform data linkage (n = 729), or had missing information on home addresses between 1998 and 2003 (n = 71) or neighborhood SES (i.e. no information on the grid data base as they lived in sparsely inhabited areas with < 10 residents; n = 2256), or had not responded to the minimum of five food item questions (n = 42). Thus, the final study population for this study was 16,522.

2.2. Neighborhood socioeconomic status

Data on neighborhood factors were obtained from the Statistics Finland's grid database for the year 2000. This database contains information that is based on all Finnish residents on social and economic characteristics at the level of 250 m x 250 m grids (Statistics Finland, 2013). We combined information on household income (coded so that lower income gets higher values), unemployment rate, and the proportion of those aged > 18 years whose highest education level was elementary school (i.e. low level of education) to construct an index of neighborhood disadvantage (Halonen et al., 2012). For each of the three variables, we derived a standardized z score based on the total Finnish population (mean = 0, SD = 1). A score for neighborhood SES was then calculated by taking the mean value across the three z scores. We linked these data to the cohort participants' home addresses with dates of moves between 1998 and 2003 using the latitude and longitude coordinates. In total, the 16,522 participants had lived in 11,594 different neighborhoods during the follow-up. We identified those who were non-movers (the same residential address during the entire 6-year period) and movers (multiple residential addresses in the 6-year period; mean number of residential addresses was 3.2). For the non-movers and the movers, we calculated cumulative neighborhood disadvantage (CND) score weighted by residential time in each address (Halonen et al., 2015) using the formula:

$CND = \sum_{i=1}^{N} (T_i D_i) / \sum_{i=1}^{N} (T_i)$, where N = number of home addresses; T_i = residential time in address i; D_i = neighborhood disadvantage in address i

We divided the cumulative neighborhood disadvantage score into five categories of increasing neighborhood SES: very low (cumulative neighborhood disadvantage score > 1.0), low (0.5 to 1.0), intermediate (> -0.5 to < 0.5), high (-0.5 to -1.0) and very high (< -1.0) (Kivimäki et al., 2018). The proportion of Finnish adults with primary education only was 56% in areas of low and 18% in areas of high neighborhood SES, respectively. For these groups, average levels of annual household income were 12,832 euros and 38,483 euros, and unemployment rates 30% and 3%, respectively.

2.3. Dietary habits

The respondents reported their habitual frequency of eating or drinking selected dietary components in 2003. The question asked was: "How often have you consumed the following food items?" For each item there were seven response categories: 1 = 2 times a day or more often; 2 = once a day; 3 = on 3–6 days a week; 4 = on 4–10 days a month; 5 = on 1–2 days a month; 6 = rarely; and 7 = never. The portion size was not specified. The questionnaire included the following food items or groups: dark bread (fiber rich), white or brown bread, pastries and sweets, potato chips and similar snacks, fresh fruits and berries, vegetables, mushrooms, cheese, fat free milk, other milk, soured-milk products, tea, sausages, red meat (beef, pork, lamb), chicken or turkey, fish and eggs. The respondents reported also their habitual frequency and amount of beer, wine, and spirits intake, which was transformed into grams of alcohol per week. One unit of pure alcohol (12 g) was equal to a volume of 12 centiliter (cl) glass of wine, a 4 cl measure of spirits, or a 33 cl bottle of beer. Based on Nordic Nutrition Recommendations (NNR), the consumption of alcohol should be limited and not exceed 10 g alcohol per day for women and 20 g per day for men (Becker et al., 2004)

From the individual food items, we chose nine food items or groups [1) dark bread, 2) pastries and sweets, 3) fat free milk, 4) sausages, 5) red meat, 6) chicken or turkey, 7) fish, 8) fresh fruits and berries, and 9) vegetables] which together with alcohol use were used to form a dietary index to describe how well the person adheres to dietary recommendations (Table 1). The selected ten groups are in line with NNR 2004 (Becker et al., 2004). Each recommended choice provides one point for the index, so the overall score can vary from 0 to 10, the maximum indicating perfect adherence to recommendations. For the analyses, we multiplied the score by 10 to have a percentage scale ranging from 0 to 100.

To test the validity of the dietary index, we examined associations

Table 1
Dietary recommendations according to Nordic Nutrition Recommendation 2004 and proportions of the study participants following them.

Food item	Response alternative	N (%) following recommendation	Justification
Dark bread	≥ 2 / day	6001 (36.5)	Six portions whole grain products daily or at least ½ of daily used cereal products should be whole grain
Pastries and sweets	≤ 1–2 / week	8013 (48.7)	A limitation of the intake of refined sugars is necessary
Fat free milk	≥ 1 / day	6914 (42.1)	5–6 dl milk products and 2–3 slides cheese daily cover need of calcium Use fat free or low fat dairy products, and cheese not more than 17% fat.
Sausage	≤ 1–2 / week	9873 (60.6)	Limited use of processed meat (like sausages and cold cuts)
Red meat	≤ 1–2 / week	10,099 (61.7)	
Chicken or turkey	1 / day to ≤ 1–2 / week	13,207 (81.1)	Consumption of moderate amount of meat, preferably lean variates is part of balanced diet
Fish	≥ 1–2 / week	11,081 (67.7)	Fish 2–3 times a week, varied fish species
Fresh fruits and berries	≥ 2 / day	2512 (15.3)	Fruits, berries and/ or vegetable daily 5–6 portions
Vegetables	≥ 2 / day	2893 (17.6)	
Alcohol	< 10 g/day (women) < 20 g/day (men)	12,631 (76.6)	The consumption of alcohol should be limited

between adherence to dietary recommendations in 2003 and mortality among the participants. Information on all deaths were obtained from Statistics Finland. The participants were followed until the end 2013. During the mean follow-up of 10.1 (SD 0.8) years there were 437 deaths among the 16,522 participants. Cox proportional hazard model adjusted for age, sex and education showed that a 10-point increase in the dietary index score was associated with decreased hazard of death (HR 0.90, 95% CI 0.85–0.96; $p < 0.001$). This supports the validity of the index used by us to study neighborhood effects on adherence to dietary recommendations.

2.4. Covariates

Covariates were measured at the same time point than diet. Sociodemographic factors included age, sex, marital status and education. Education was categorized as: basic education, high school/vocational education, college, and university or higher education. Marital status was categorized as living alone (single, widowed, divorced) versus married/cohabiting. Other covariates, likely to associate both with area of residence and dietary habits, included chronic cardio-metabolic diseases noted by medical doctor (no/yes), severe financial difficulties (no/yes), death of spouse and/or divorce over the last five years, derived from the 2003 survey responses. To the chronic cardio-metabolic diseases included hypertension, diabetes, atrial fibrillation, ischemic heart disease and cerebrovascular disease. Information on death of spouse, divorce and severe financial difficulties was drawn from a list of 21 negative life event types (Vahtera et al., 2007). The response format included the following categories (yes/no): within the previous 6 months, within the previous 5 years, over 5 years ago or never. Events occurred within 6 months or 0.5–5 years of the survey, i.e. within the time window used for cumulative neighborhood SES, were identified. Urbanicity in the last residential neighborhood was assessed by population density within the 250 mx250 m neighborhood grid from the Statistics Finland's grid database.

2.5. Ethics

The HeSSup study was approved by the joint ethics committee of the University of Turku and the Turku University Central Hospital.

2.6. Statistical methods

Characteristics of the non-movers and movers according to the level of adherence to dietary recommendations were calculated and the significance of the group differences were tested with analysis of variance. To examine the association of neighborhood SES categories with individual food items/groups among the non-movers and movers, we used log-binomial regression analyses. The results are presented as prevalence with 95% confidence limits (CL) of participant's adherent to recommended amounts of individual food items. The association between cumulative neighborhood SES categories over the 6-year period and the dietary index among the non-movers and movers was assessed with general linear models. These results are presented as means and mean differences with 95% CL. All models were adjusted for sociodemographic factors (sex, age, marital status, and education), major life events (death of spouse, divorce, severe financial difficulties), chronic cardio-metabolic conditions, and urbanicity. Linear trend was tested using the level of neighborhood SES as a continuous variable. Difference in the trend between non-movers and movers was examined by including the interaction term 'moving status*neighborhood SES' to the regression model. Additionally, we examined whether the neighborhood SES – dietary index associations among non-movers and movers depended on sex-, age- or education by adding the corresponding interaction terms into each regression model. We did not further examine neighborhood effects in sex, age and education subgroups, because all P-values for the interactions were non-significant (> 0.13) among the two groups.

Because average neighborhood conditions and changes in these conditions are not necessarily similarly related to diet, we used latent class growth analysis with censored normal model to identify subgroups that are following a similar pattern of annual change in the neighborhood SES during the 6-year follow-up period. To determine optimum number of trajectories, we adopted an exploratory approach fitting two to six latent classes and focused only the movers as average neighborhood conditions and trajectories of neighborhood conditions are similar in non-movers. We specified a cubic growth term in all models, assuming that neighborhood SES can both decrease and increase with time. We compared the models using three selection criteria: (1) the Bayesian Information Criteria (BIC), where model with lower BIC values indicated well-fitting model (Kreuter and Muthén, 2008), (2) the average posterior probabilities of group membership for each class, where higher values (closer to 1) suggest that the trajectories correctly classify individuals with similar pattern of neighborhood SES, and discriminates between individuals with dissimilar neighborhood patterns (Andruff et al., 2009), and (3) the practical usefulness of the trajectories. To evaluate potential usefulness of the result, we examined both the distinctiveness and the sizes (proportions) of the trajectory groups (Nagin and Odgers, 2010). For the trajectory groups to serve a useful substantive purpose, they should be distinguishable in terms of their shapes and other explanatory characteristics. They should also be of reasonable sizes (at least five percent) to ensure precision (Andruff et al., 2009; Muthen and Muthen, 2000). Upon establishing the optimum number of trajectory classes, we then used general linear models to investigate the associations between each neighborhood SES trajectory and dietary index. All analyses were conducted using the SAS 9.4 Statistical Package (SAS Institute Inc., Cary, North Carolina).

3. Results

Percentages of participants ($n = 16,522$) adhering to recommendations of the single food items/groups are shown in Table 1. Consumption of dark bread was at the recommended level among 37% of the participants, and 49% of the participants consumed pastries and sweet as little as recommended. Over 40% of the participants used fat free milk according to the recommendation, at least once a day. The use of sausages, meat including lean meat and fish was in line with the recommendations among most participants (the percentages varied between 61 and 81). Less than 20% of the participants consumed vegetables as well as fruits and berries as recommended and 77% limited alcohol consumption to the recommended level (Table 1).

Half of the participants had lived in the same address the whole 6-year period, while another half were movers (Table 2). Among both non-movers and movers, over half of the participants were women and cohabiting. A majority of the participants had higher, i.e. college or university education. Compared to the non-movers, the movers were much younger (Table 2). Among both non-movers and movers, half of the all 10 food items/groups were consumed as recommended, as indicated by a mean dietary score of 51.6 (SD 17.2) and 49.3 (SD 16.2), respectively (Table 2). Those having good adherence to dietary recommendations were characterized by female gender, older age, higher education, and living in neighborhoods with high population density while severe financial difficulties and divorce were associated with worse adherence, among both non-movers and movers.

3.1. Cumulative neighborhood SES and single food items

The adherence to the recommendations of single food items/groups and alcohol consumption by the level of cumulative neighborhood SES among the non-movers and movers are presented in Table 3. Among both groups, there was a linear positive association between increasing cumulative neighborhood SES and the likelihood to conform to the recommendations regarding sausages, read meat, chicken/turkey, fish

Table 2
Descriptive characteristics of the study participants and mean adherence with standard deviation (SD) to dietary recommendations. Statistical differences were tested with Analysis of Variance.

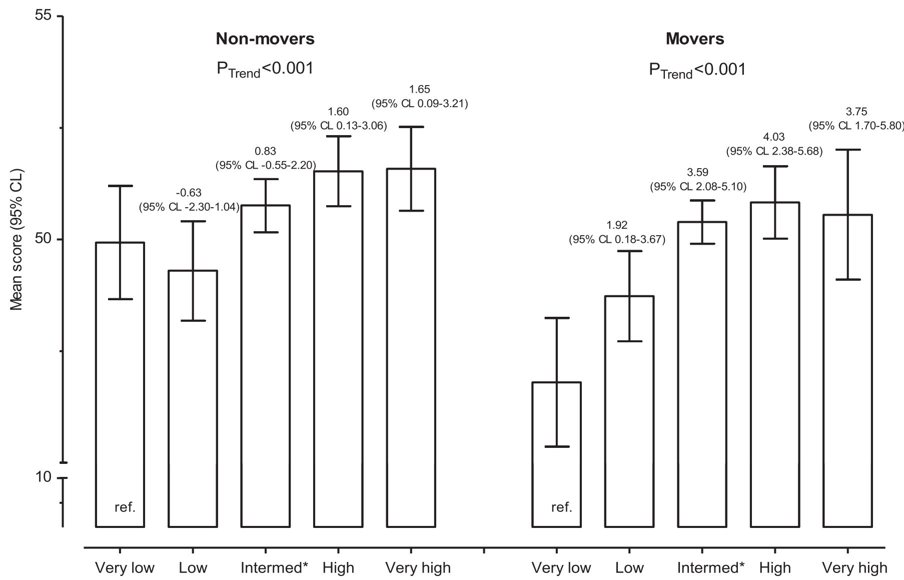
Variables		Adherence to dietary recommendations[a]					
		Non-movers			Movers		
		N (%)	Mean (SD)	P	N (%)	Mean (SD)	P
All		7704 (47)	51.6 (17.2)		8818 (53)	49.3 (16.2)	
Sex	Men	3133 (41)	46.6 (16.0)	< 0.001	3184 (36)	45.3 (15.6)	< 0.001
	Women	4571 (59)	55.1 (17.2)		5634 (64)	51.5 (16.1)	
Marital status	Single	1707 (22)	50.1 (17.6)	0.03	2625 (30)	49.6 (16.6)	0.32
	Cohabiting	5972 (78)	51.9 (17.1)		6153 (70)	49.2 (16.0)	
Age group	25–29	341 (4)	48.3 (15.4)	< 0.001	4057 (46)	48.7 (15.5)	< 0.001
	35–39	1270 (16)	48.9 (16.1)		2439 (28)	48.8 (15.9)	
	45–49	2645 (34)	51.2 (16.6)		1131 (15)	50.3 (16.9)	
	55–59	3448 (45)	53.3 (18.0)		1009 (11)	51.4 (18.4)	
Level of education	Basic	1074 (14)	48.9 (17.4)	< 0.001	869 (10)	47.5 (16.8)	< 0.001
	High school[b]	2476 (32)	49.6 (17.3)		2350 (27)	46.5 (16.5)	
	College	2520 (32)	53.3 (17.4)		2410 (27)	49.8 (16.1)	
	University	1591 (21)	54.1 (16.0)		3150 (36)	51.5 (15.5)	
Cardio-metabolic diseases	No	6140 (80)	51.5 (17.2)	0.31	7967 (91)	49.2 (16.1)	0.30
	Yes	1516 (20)	52.1 (17.3)		820 (9)	49.8 (17.1)	
Financial difficulties[c]	No	6681 (87)	52.0 (17.4)	< 0.001	6986 (79)	49.7 (16.2)	< 0.001
	Yes	975 (13)	49.1 (16.2)		1802 (21)	47.7 (15.9)	
Death of a spouse[c]	No	7568 (99)	51.7 (17.2)	0.18	8731 (99)	49.3 (16.2)	0.93
	Yes	88 (1)	49.2 (18.1)		57 (1)	49.5 (17.9)	
Divorse[c]	No	7310 (95)	51.8 (17.2)	0.03	7051 (80)	49.6 (16.2)	0.001
	Yes	346 (5)	49.7 (16.9)		1737 (20)	48.1 (16.0)	
Population density[d]	< 50	2470 (32)	50.6 (17.3)	0.001	2143 (25)	47.9 (16.3)	< 0.001
	50–100	1830 (24)	51.5 (17.0)		1551 (18)	48.4 (15.9)	
	101–200	1467 (19)	52.6 (17.3)		1717 (20)	49.7 (16.2)	
	> 200	1935 (25)	52.2 (17.1)		3258 (38)	50.4 (16.2)	

[a] Mean score for adherence to Nordic Nutrition Recommendation 2004; total points based on 10 individual food items/groups for the dietary index scaled so that score can range from 0 to 100.
[b] Including vocational school.
[c] Over the last five years.
[d] Adult population density within the 250 m × 250 m neighborhood as proxy of urbanicity.

Table 3
Adjusted[a] prevalence (%) of participants (95% CI) adherent to recommended amounts of individual food items by level of and changes in cumulative neighborhood SES.

Food items/groups	Non-movers					
	Very low (n = 654)	Low (n = 843)	Intermediate (n = 3242)	High (n = 1759)	Very high (n = 1206)	P_{trend}
Dark bread *≥ 2 / day*	38 (35–41)	37 (34–40)	38 (36–39)	37 (35–39)	32 (30–35)	0.003
Pastries, sweets *≤ 1–2 / week*	47 (43–51)	46 (42–49)	46 (44–48)	48 (45–50)	52 (49–52)	0.008
Fat free milk *≥ 1 / day*	41 (37–45)	41 (38–45)	43 (41–44)	42 (39–44)	41 (39–44)	0.99
Sausage *≤ 1–2 / week*	56 (52–60)	52 (49–56)	59 (57–61)	60 (58–62)	65 (62–68)	< 0.001
Red meat *≤ 1–2 / week*	58 (55–62)	58 (55–61)	61 (60–63)	63 (61–65)	63 (60–66)	0.002
Chicken, turkey *1 / day to ≤ 1–2 / week*	79 (75–82)	80 (77–83)	80 (79–82)	82 (80–84)	84 (82–36)	< 0.01
Fish *≥ 1–2 / week*	64 (61–68)	68 (65–71)	68 (66–69)	70 (68–72)	71 (68–73)	0.001
Fresh fruits, berries *≥ 2 / day*	13 (11–15)	13 (11–15)	14 (12–15)	14 (13–16)	14 (12–15)	0.43
Vegetables *≥ 2 / day*	15 (13–18)	15 (13–18)	16 (14–17)	18 (16–19)	17 (15–19)	0.04
Alcohol *(women < 10 g/day; men < 20 g/day)*	80 (77–83)	75 (73–78)	78 (77–80)	76 (74–78)	73 (70–76)	< 0.01
	Movers					
	Very low (n = 496)	Low (n = 1026)	Intermediate (n = 5168)	High (n = 1625)	Very high (n = 503)	P_{trend}
Dark bread *≥ 2 / day*	36 (32–41)	35 (32–39)	34 (33–35)	31 (29–34)	30 (26–35)	0.005
Pastries, sweets *≤ 1–2 / week*	49 (45–54)	49 (42–52)	49 (48–51)	51 (49–54)	48 (444–53)	0.54
Fat free milk *≥ 1 / day*	40 (36–45)	39 (37–43)	43 (41–44)	41 (38–43)	44 (40–49)	0.29
Sausage *≤ 1–2 / week*	51 (47–56)	57 (55–60)	61 (59–62)	62 (60–64)	63 (59–67)	< 0.001
Red meat *≤ 1–2 / week*	58 (53–62)	57 (54–60)	62 (61–64)	63 (61–65)	59 (55–64)	0.03
Chicken, turkey *1 / day to ≤ 1–2 / week*	71 (67–76)	76 (74–79)	81 (80–82)	83 (82–85)	85 (83–88)	< 0.001
Fish *≥ 1–2 / week*	60 (56–65)	64 (61–67)	66 (65–68)	68 (66–71)	71 (67–75)	< 0.001
Fresh fruits, berries *≥ 2 / day*	12 (10–16)	13 (11–15)	12 (11–13)	12 (11–14)	11 (9–14)	0.50
Vegetables *≥ 2 / day*	14 (11–17)	14 (12–17)	15 (14–16)	17 (15–19)	18 (15–22)	0.01
Alcohol *(women < 10 g/day; men < 20 g/day)*	76 (72–79)	78 (76–780	77 (75–78)	74 (72–76)	70 (66–74)	0.002

[a] Adjusted for sex, age, marital status, education, chronic cardio-metabolic diseases, severe financial difficulties, death of spouse, divorse and urbanicity.



	Very low	Low	Intermed*	High	Very high	Very low	Low	Intermed*	High	Very high
Number of participans:	654	843	3242	1759	1206	496	1026	5168	1625	503
Observed means:	49.5	49.7	51.7	52.5	52.6	44.7	47.6	49.6	50.4	50.5
Adjusted means:	49.9	49.3	50.8	51.5	51.9	46.8	48.7	50.4	50.8	50.6

Fig. 1. Adherence to dietary recommendation by neighborhood SES among non-movers and movers stratified to participants with very low, low, intermediate, high and very high cumulative neighborhood SES. Mean scores and mean differences (above the columns) and their 95% confidence limits adjusted for sex, age, marital status, education, chronic cardiometabolic diseases, severe financial difficulties, death of spouse, divorce and urbanicity. *Intermediate.

and vegetables, while this association reversed in the likelihood to conform to recommendations about dark bread and alcohol consumption. A corresponding positive association was also observed in relation to the recommendations regarding pastries and sweets, but only among non-movers. The consumption of fat free milk or fruits and berries did not associate with neighborhood SES.

3.2. Cumulative neighborhood SES and dietary index

In the total population with non-movers and movers combined, each 1-SD increase in the original continuous cumulative neighborhood SES was associated with 1.68 (95% CL 1.32–2.02) points higher dietary score. As shown in Fig. 1, those living in low SES neighborhoods had lowest dietary index mean scores within the non-movers and movers. In both groups a higher cumulative neighborhood SES was associated with a higher dietary index score. These associations were linear ($p < 0.001$), with no evidence of a trend difference (test of interaction $P = 0.14$). Among non-movers, those who had lived in a very high SES neighborhood had 1.65 (95% CL 0.09–3.21) points higher mean dietary score compared to those living in the lowest SES neighborhood when adjusted for the covariates. Among the movers, the corresponding mean difference was 3.75 (95% CL 1.70–5.80) points.

3.3. Neighborhood SES trajectories and dietary index

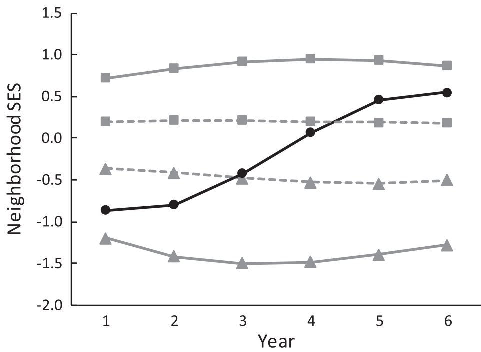
The trajectory analyses suggested five types of trajectories as the optimal solution to characterize the movers over the 6-year period (supplemental Table 1). As shown in Fig. 2, the 5-class trajectory included four groups that maintained a similar neighborhood SES level throughout the follow-up period: stable high (21% of participants), stable intermediate (42%), stable low (25%) and stable very low (6%). In addition, an upward trajectory (7%) was identified, characterized by a low initial neighborhood SES level which gradually improved over time. Fig. 2 shows the lowest dietary score, 46.2, for stable very low trajectory and slightly higher score, 48.5, for participants in the stable low trajectory. Higher scores - 49.8–50.0 – were observed for stable intermediate, stable high and upward trajectories. Mean difference in dietary score between upward and stable very low was similar to that between stable high and stable very low.

4. Discussion

The present study is, to our knowledge, one of the first to assess the relationship between stable and changed neighborhood socioeconomic status and adherence to dietary recommendations. In this study of nearly 17,000 Finnish adults, we found that those living in the highest SES neighborhoods had better adherence to dietary recommendations than those who lived in the lowest SES neighborhoods. Moving into a higher SES neighborhood was also associated with better adherence to dietary recommendations, whereas the trajectory analysis did not identify a group who would have moved into lower SES neighborhoods.

Dietary guidelines for individual food items used by us are based on research evidence indicating that diets with plenty of vegetarian foods, fish, and low-fat dairy products are associated with a lower risk of most chronic diseases, whereas diets high in red and processed meats are associated with adverse health effects (Wirfält et al., 2013). We found that participants living in high SES neighborhoods had better adherence to dietary recommendations regarding fish and vegetable consumption. Prior studies have mostly focused only on vegetable and fruit consumption with mixed findings (Ball et al., 2015). Some studies have not found any association between area SES and variety in vegetable consumption (Algren et al., 2015; Turrell et al., 2009), or only small or modest associations regarding consumption of fruits and vegetables (Alves et al., 2013; Ball et al., 2015), whereas others have observed strong positive associations (Dubowitz et al., 2008; Kivimäki et al., 2018). It is possible that these associations are dependent on other factors typically not measured in those studies, such as living close to supermarkets, convenience stores, fast-food restaurants (Fleischhacker et al., 2011; Morland and Filomena, 2007; Rahmanian et al., 2014; Rummo et al., 2017). Availability of fruits and vegetables has also been linked to their consumption (Li et al., 2017; Morland and Filomena, 2007). We found a linear association between higher neighborhood SES and higher vegetable consumption, but no association with consumption of fresh fruits and berries. The reasons for this difference are unclear. Rural areas often have a lower neighborhood SES, but offer good possibilities to pick up and preserve berries for own use, potentially masking an association between neighborhood SES and consumption of berries. However, this is an unlikely explanation for our findings as urbanicity was taken into account in the analysis.

Studies examining broader dietary habits are scarce. In one prior



Trajectory	N	%	Dietary score Mean (95% CL)	Mean difference (95% CL)
Stable high	1825	21	50.0 (49.3-50.8)	3.8 (2.2-5.4)
Upward	621	7	50.0 (48.8-51.3)	3.8 (1.9-5.7)
Stable intermediate	3672	42	49.8 (49.3-50.3)	3.6 (2.1-5.1)
Stable low	2200	25	48.5 (47.8-49.1)	2.3 (0.7-3.8)
Stable very low	500	6	46.2 (44.8-47.6)	0 (ref.)

Fig. 2. Trajectories of annual neighborhood SES over the six-year study period, the group sizes and the associations with dietary score. Mean scores and mean differences for adherence to dietary recommendation (95% confidence limits) adjusted for sex, age, marital status, education, chronic cardio-metabolic diseases, severe financial difficulties, death of spouse, divorce and urbanicity.

study, higher residential property values (as a measure of neighborhood SES) were associated with higher healthy eating index scores (Drewnowski et al., 2016). Our finding of an association between high cumulative and increased neighborhood SES and adherence to dietary recommendations was similar in spite of the differences in the indicator of neighborhood SES and dietary indices. To our knowledge, no prior study has examined how trajectories of neighborhood SES are linked to dietary habits. We observed that upward trajectory was associated with as high dietary index scores as stable high trajectory. This finding suggests that high SES areas might offer healthier food environments than low SES areas, leading to improvement of dietary habits among those who move from low to high SES areas. Some studies, however, have suggested that an individual's own socio-economic status play a more important role in shaping the diet than the area-level socio-economic status: a Dutch study did not report any independent influence of area-level socioeconomic status on diet, such as food choice, breakfast consumption and fruit intake (Giskes et al., 2006). However, the neighborhood SES in that study was not based on the characteristics of the total population of the residential areas, but on that of the GLOBE study participants, and their study sample was much smaller (n = 1339).

Reasons for the associations between neighborhood SES and dietary habits can be related to the local food environments. Previous studies have reported disparities in neighborhood food environment in low and high SES neighborhoods, which may result in differences in overall dietary habits (Beaulac et al., 2009; Gordon-Larsen and Popkin, 2011; Morland et al., 2002; Morland and Filomena, 2007). For example, the availability of fast-food restaurants, and energy-dense foods and food sources is often greater in lower-income and minority neighborhoods than in affluent neighborhoods (Hilmers et al., 2012; Jiao et al., 2016; Turrell et al., 2009).

Some research also suggests that neighborhood residents who have better access to supermarkets with a large variety of healthy foods and limited access to small food stores or fast-food restaurants tend to have healthier diets and even lower level of obesity (Black et al., 2014; Larson et al., 2009; Maguire et al., 2015; Wang et al., 2007). On the other hand, a higher number of food destinations within 400 m of home, regardless of the food destination type, has also been associated with better diet quality in adults (McInerney et al., 2016). In addition to the availability of food, differences in food consumption can be explained by the cost of the food products. It has been shown that the higher cost of more nutritious diets may contribute to socioeconomic disparities in health (Monsivais et al., 2012). It should be kept in mind, though, that a majority of the food environment studies are from the US where the relationships between socioeconomic factors and health may be more observable than in other countries (Cummins and Macintyre, 2006). Thus, more research on the mechanisms between neighborhood SES and diet are needed. However, even if the gradient related to neighborhood SES could be attenuated by external measures, the adherence to dietary recommendations was overall rather low, especially regarding consumption of fresh fruits and berries. Thus, improving the general adherence to dietary recommendation remains a challenge of its own.

The major strength of our study is the utilization a high resolution 250 m x 250 m grid database linked to data to all home addresses of the participants over a 6-year time window prior to the assessment of adherence to healthy diet. The chronological order of the exposure and outcome, as well as the possibility to examine associations separately for non-movers and movers controlling for individual-level socio-demographic factors add to the validity of our findings.

This study has also some limitations. Measurement of dietary index at one time point only is a major limitation, although dietary patterns are quite consistent from childhood to adulthood (Kivimäki et al., 2018; Mikkilä et al., 2005). Thus, we cannot rule out selection (i.e. dietary preferences in selecting living environments) as an alternative explanation for our findings. Second, we did not take into account clustering of similar observations at the neighborhood level in the analyses. However, the population sample was not drawn from specific neighborhoods and the exposure was based on 6-year residential history that was used to calculate average level of and temporal trends in neighborhood SES. As there are > 50,000 neighborhoods with at least 10 residents in the Statistics Finland's grid database, clustering at the neighborhood-level is highly unlikely. Third, because our neighborhood data was from the Statistics Finland's grid database for the year 2000, we could not take into account changes in neighborhoods in non-movers over time. However, relative differences between neighborhoods change slowly (Halonen et al., 2016; Kivimäki et al., 2018). Indeed, the correlation of relative neighborhood SES in 2000 with that in 2009 grid database is 0.78 suggesting that our findings are still valid. Fourth, we had no information about the reasons for moving from one neighborhood to another. If the same reason influenced dietary choices, then they could introduce bias to our results. In multivariable adjusted analyses, we could control for a number of such factors including chronic illnesses like cardiovascular diseases and diabetes that may require diet modification, as well as severe financial difficulties, divorce and spousal bereavement. Fifth, use of self-reported dietary data may have resulted in bias, as respondents may have systematically under- or over-reported the consumption of individual food items (social desirability). An additional limitation relates to the use of a brief food frequency questionnaire that was used to characterize the individual dietary patterns in general. Food frequency questionnaires may not adequately assess absolute intakes, but they are useful for ranking persons according to relative consumption within a study population (Hu et al., 1999). We included to our healthy eating index all those food groups for which the justification for the recommendation was obtained (Becker et al., 2004). For example, milk and milk products provide several nutrients, but also a lot of saturated fat, which is why use of low-fat variants is recommended. We included fat free milk as that was the only low-fat variant in our questionnaire. In addition, consumption of moderate amount of lean meat was recommended, for which we used consumption of chicken and turkey requested in our questionnaire. Supporting the validity of our dietary index, we found that the higher the scores of the index, the lower the risk of death among participants was. As poor diet is a leading risk factor for non-communicable diseases (GBD 2016 and Collaborators, 2017), our index assessing adherence to dietary recommendations obviously identify meaningful differences in dietary habits by neighborhood SES.

Our large population-based sample consisted mainly of individuals of European origin living in a welfare society, thus, the generalizability of our findings to other populations and cultures needs to be confirmed in other studies. Generalizability to Finns is likely to be good as the overall consumption levels of the individual food items in this study population were in line with another population based study that assessed food consumption in Finland (Helldán et al., 2013). Also a rather good generalizability of the results to more affluent Western societies can be anticipated being fairly good.

5. Conclusion

To our knowledge, this study is the first one to investigate the link between long-term and changed neighborhood SES and adherence to dietary recommendations within a large population cohort controlling for individual level socioeconomic factors. Our study suggests that the overall diet quality is dependent on neighborhood SES so that those living in or moving into the high SES neighborhoods have better adherence to dietary recommendations than those living in the lowest SES neighborhoods. It is possible, for example, that high SES areas might offer healthier food environments than low SES areas, leading to improvement of dietary habits among those who move from low to high SES areas. Public health efforts to improve dietary habits may benefit from identification of community level determinants of dietary preferences.

Conflict of interest

HL participated as an advisory board member, consultant, and speaker for Nestlé Nutrition Institute and Nestlé Finland.

Authorship

All authors are responsible for reported research and all authors have participated in the concept and design of the study, analysis and interpretation of data and drafting the manuscript. All the authors have had sufficient access to the data to verify the manuscript's scientific integrity and they approved the final manuscript as submitted and agree to be accountable for all aspects of work.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.healthplace.2018.10.007.

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