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Urban/rural differences in body weight: Evidence for social selection and causation hypotheses in Finland☆

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ABSTRACT

Average body weight differences between urban and rural areas have been reported in many countries, but it is unknown whether these are due to effects of social selection or social causation. We examined whether adolescent body mass index (BMI) predicted selective urban/rural migration over a 21-year period and whether urban/rural living over the same period predicted differences in BMI increase from adolescence to adulthood in Finland. The participants were from the prospective, population-based Cardiovascular Risk in Young Finns study ($n = 1787$) aged 12–18 years at baseline and 33–39 years at the final follow-up, with data collected at six follow-up phases. Supporting social selection, heavier adolescents were less likely to migrate to urban areas as adults: in obese adolescents the likelihood of living in an urban area at 33–39 years age was one third of that in normal weight adolescents. Supporting social causation, rural residence over the study period predicted a greater increase in BMI from adolescence to adulthood than urban residence did. These associations were independent of parental socioeconomic status and BMI, and of participants' own educational level, occupational class, marital status, and parenthood status. Together the findings suggest that the higher body weight of people living in rural areas of Finland may be due to both social selection and social causation mechanisms, i.e. heavier people tend to migrate to more rural areas where people tend to get heavier.

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Epidemiologic studies suggest regional differences in average body mass index (BMI) between urban and rural areas. Higher BMI has been observed in rural than in urban areas in Finland (Fogelholm et al., 2006; Leino, Raitakari, Porkka, Helenius, & Viikari, 2000; Pietinen, Vartiainen, & Männistö, 1996; Similä et al., 2005), the United States (Jackson, Doescher, Jerant, & Hart, 2005), Western part of Canada (Reeder, Chen, MacDonald, Angel, & Sweet, 1997), and Sweden (Rasmussen, Johansson, & Hansen, 1999) but not in all countries, e.g. in Brazil (Neutzling, Taddei, Rodrigues, & Sigulem, 2000) and Thailand (Aekplakorn et al., 2004). While life style factors may explain a large part of these urban/rural differences, selective migration associated with BMI might also be operating. The role of social selection and social causation in these differences remains poorly understood.

Fertility, mortality and migration are the three demographic processes that determine the dynamics and structure of populations (McFalls, 2003). High BMI has been shown to predict lower fertility, i.e. fewer number of children (Jokela et al., 2007; Jokela, Elovainio, & Kivimäki, 2008) and higher risk of mortality (McGee & Diverse Population Collaboration, 2005), but we are aware of only two studies examining the relationship between body weight and residential mobility. In the United States, Comstock, Kendrick, and Livesay (1966) found that obese individuals were less likely than their normal weight counterparts to move to a new location during a 15-year follow-up period. In Denmark, Halkjaer and Sørensen (2004) found no association between birth weight and selective migration. However, no prospective data have been available to

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determine whether adolescent body weight is associated with selective urban/rural migration.

Selective migration associated with body weight is related to broader themes of health-selective migration and neighborhood effects which have received increasing attention in social sciences (e.g. Brimblecombe, Dorling, & Shaw, 2000; Connolly, O'Reilly, & Rosato, 2007; Ek, Koiranen, Raatikka, Järvelin, & Taanila, 2008; Norman, Boyle, & Rees, 2005). If choices of residential locations are affected by health status, disease risk factors become unequally distributed across geographic regions and this may have implications for regional disease burden. The issue is particularly pertinent when less healthy individuals migrate to less wealthy areas, because this may create feedback loops in which selective migration and neighborhood effects end up reinforcing each other. It is therefore important to consider social selection together with social causation mechanisms.

In Finland – the setting of the present study – rural residents tend to have poorer health than urban dwellers (e.g. Blomgren, Martikainen, Mäkelä, & Valkonen, 2004; Fogelholm et al., 2006; Kujala, Remes, & Laitinen, 2006; Leino et al., 2000; Pesonen et al., 2001). Moreover, migration flows within Finland have been characterized by strong rural-to-urban migration since the 1960s and this trend was still ongoing at the time of this study (Koskinen et al., 2007). As people have been increasingly moving to urban centers and their surrounding suburban areas, the socioeconomic inequalities between urban and rural Finland have widened (Kainulainen, Rintala, & Heikkilä, 2001). Compared to urban areas, remote rural areas are characterized by lower socioeconomic status (SES), poorer health care, lower standards of living, and fewer opportunities of employment, among other factors (e.g. Kainulainen et al., 2001; Karvonen & Rintala, 2004). In the present sample, remote rural residence in adulthood was found to be associated with higher depressive symptoms and lower perceived social support (Jokela, Lehtimäki, & Keltikangas-Järvinen, 2007a). On the other hand, some social problems, such as crime, are most prevalent in urban centers (Kainulainen et al., 2001).

In this report from the longitudinal, population-based Cardiovascular Risk in Young Finns study (Åkerblom et al., 1991) we examined whether adolescent BMI predicted selective migration to urban areas over a 21-year period from adolescence to adulthood. In addition to analysis of social selection, data from six follow-up phases allowed us to test whether urban/rural residence over the life-course was associated with differences in BMI change from adolescence to adulthood, as would be expected if social causation was the driving force in urban/rural BMI differences. BMI has been shown to be associated with many sociodemographic predictors of migration, including education (e.g. Laitinen, Power, Ek, Sovio, & Järvelin, 2002), occupational class (e.g. Laitinen et al., 2002; Rahkonen, Lundberg, Lahelma, & Huuhka, 1998), and marital and parenthood status (e.g. Jokela et al., 2007; Jokela, Elovainio, & Kivimäki, 2008), so we assessed these factors as potential mediators in the association between BMI and urban migration. In addition, we examined whether this association was confounded by parental education and parental BMI.

Methods

Participants

The participants were 1787 women ($n = 923$) and men ($n = 864$) participating in the ongoing population-based Cardiovascular Risk in Young Finns study (Åkerblom et al., 1991; Raitakari et al., 2008). The original sample consists of 3596 Finnish healthy children and adolescents derived from six birth cohorts, aged 3, 6, 9, 12, 15, and 18 years at the baseline. In order to select participants who were broadly representative of Finnish children and adolescents in terms of living conditions and socioeconomic and demographic background, Finland was divided into five areas according to the location of the university cities with a medical school (Helsinki, Kuopio, Oulu, Tampere and Turku). In each area, urban and rural boys and girls were randomly selected on the basis of their personal social security number from the Social Insurance Institution's population register, which covers the whole population of Finland. All participants gave written informed consent, and the study was approved by local ethics committees.

The study began in 1980 and the participants have been followed subsequently in six follow-up phases 3, 6, 9, 12, 17, and 21 years after the baseline. For the present analyses we included three oldest cohorts, who were adolescents (i.e. 12, 15 and 18 years of age) at the baseline and adults (i.e. 33, 36 and 39 years of age) in the most recent follow-up phase in year 2001. We used data from all study phases except from Year 17 when information on place of residence was not collected. The number of participants varied between 616 and 1787 depending on the analysis and included variables.

Body mass index

Adolescent height and weight were measured at the baseline when the participants were 12, 15, and 18 years of age. Measurements were taken in a medical examination with a Seca weight scale and anthropometer. Body mass index (BMI) was calculated as BMI = weight in kilograms/(height in meters)^2. Adulthood height and weight were measured in a medical examination in the same way in Year 21, when the participants were 33, 36, and 39 years of age.

In order to illustrate the results of selective migration, the participants were categorized into groups of underweight, normal weight, overweight, and obese on the basis of their adolescent BMI. For the age-specific overweight and obese groups we used the international cut-off values provided by Cole, Bellizzi, Flegal, and Dietz (2000), i.e. overweight above 21.7, 23.9, and 25.0 for women 12, 15, and 18 years of age, and 21.2, 23.3, and 25.0 for men of the same age, and obesity over 26.7, 29.1, 30.0, for women and 26.0, 28.3, and 30.0 for men. Based on these cut-offs 7.2% of women and 8.7% of men were categorized as overweight and 0.9% of women and 1.4% of men were categorized as obese in adolescence. In the absence of established cut-off values for adolescent underweight, we categorized individuals with BMI in the lowest 5.0% into this group. This categorizing was carried out within gender and age cohort, and yielded the cut-off values of 14.8, 16.6, and 17.6 for women 12, 15, and 18 years of age, and the corresponding values of 15.2, 17.0, and 18.3 for men.

Urban/rural residence

Urban/rural residence was determined on the basis of two separate indicators: self-reported place of residence and population density statistics of home municipality. *Place of residence* was reported by the participants (or their parents) on a four-point scale (1 = remote rural, 2 = rural, 3 = suburban, 4 = urban) at each follow-up in Years 0, 3, 6, 9, 12, and 21. For the social causation analysis, we created an index of life-course rural residence by summing together the 4-point scores of place of residence in Years 0, 3, 6, 9, 12, and 21. Thus, an individual who had always lived in remote rural areas was assigned a score of 6 and an individual who had always lived in urban areas had a score of 24. The sum score was categorized into quintiles and this categorical variable was used in the analyses.

Population density of the participant's home municipality was expressed as the number of inhabitants per square kilometer of land

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for which data were obtained from governmental database (Statistics of Finland). Between 1980 and 2001 Finland was governmentally divided into 448–464 municipalities, the varying number reflecting municipality mergers. Of these, 84–109 were cities and the rest were towns and rural municipalities. In 2001, approximately 70% of the 5.2 million Finns lived in cities. The municipalities' physical size ranged from 6 to 15,173 km^2 of land (Median = 423), the number of inhabitants ranged from 128 to 559,718 (Median = 5097), and population densities ranged from 0.2 to 3034 inhabitants per km^2 of land (Median = 11). In Years 0, 3, 6, 9, 12, and 21 the participants of the present study were living in 17, 57, 83, 136, 155, 175, and 178 different municipalities around Finland.

When comparing the analyses with these two measures of urban/rural residence, it should be noted that the self-reported measure reflects a more local indicator of residence than population density. Different kinds of residential areas may coexist within a given municipality, e.g. a city within an otherwise sparsely populated rural region. Cross-sectional rank-order correlations between population density and self-reported residence at the follow-ups were in the range of $r = 0.55$–0.67 ($p < 0.001$), implying that the two measures were clearly related but not redundant measures of urban/rural residency.

Covariates

Parental SES and BMI

At baseline the parents of the participants reported their years of completed education (Mothers' mean = 9.2, standard deviation = 3.0; Fathers' mean = 8.9, SD = 3.5), and household income ($M = 4.8$, SD = 2.0 on an 8-point scale). Following a method used previously in the present sample (Jokela, Lehtimäki, & Keltikangas-Järvinen, 2007b), *parental SES* indicator was created by calculating first the mean of the years of education of the mother and the father and then standardizing this mean into a Z score ($M = 0$, SD = 1; for single-parent households parental education was determined by the years of education of the single parent). Next, the annual income of the household was standardized into a Z score, and then the Z scores of education and income were summed and the resulting sum score was standardized ($M = 0$, SD = 1) and used as an indicator of parental SES. High values indicated high parental SES. *Father's and mother's BMI* was calculated on the basis of their self-reported height and weight at baseline.

Adulthood sociodemographic covariates

Education was coded as primary (mandatory schooling up to age 15 or less), secondary (high school or equivalent, usually between ages 15 and 18), and tertiary (college or equivalent) completed education. *Occupation* was coded using a four-category categorization (0 = manual worker, 1 = blue collar, 2 = white collar, 3 = student/other). Dichotomous indicators were created for *marital status* (0 = does not live with a partner, 1 = married/cohabiting) and *parenthood status* (0 = does not have children, 1 = has children). All adulthood sociodemographic covariates were created as time-variant, i.e. they were assessed at each follow-up phase. Data on occupation, marital status, and parenthood status were not collected in Years 0 and 3, when the participants were 12–21 years of age, so at these follow-ups occupational class was assigned as 'student/other', marital status as 'no partner', and parenthood status as 'no children'.

Statistical analysis

Analysis of social selection

As a preliminary analysis, we fitted six separate ordinal regression models to predict residence in Years 0, 3, 6, 9, 12, and 21 with Year 0 adolescent BMI. In the first model examining the cross-sectional association between BMI and residence in Year 0, age and gender were entered as covariates. The five regression models predicting residence from Year 3 to Year 21 by Year 0 BMI were additionally adjusted for Year 0 residence.

In the main analysis of selective migration, we applied random-intercept multilevel ordinal regression modeling to assess the migration trajectories of individuals over the 21 year study period in a single model using GLLAMM statistical software (Rabe-Hesketh, Skrondal, & Pickles, 2002; Rabe-Hesketh, Skrondal, & Pickles, 2004; www.gllamm.org). Continuous outcome measures (i.e. population density) were assessed with linear multilevel regression models. We hypothesized that there is a nonlinear migration trajectory from adolescence to adulthood, such that people tend to move to more urban areas in young adulthood but then to more rural areas in adulthood (Nilsson, 2003), so we fitted a quadratic term of time (i.e. time^2) to test if this provided better fit than a linear model. The indicators of time were centered on Year 21, so that the intercept coefficients indicated the association between covariates and place of residence in Year 21.

In addition to including main effects, we tested interaction effects between covariates and time in order to assess whether the association between place of residence and covariates changed over time. Multilevel modeling can take advantage of all available data, so these analyses included all participants who had data on adolescent BMI and place of residence at least from one follow-up phase. An average participant provided data for 4 of the 6 possible follow-up phases. The coefficients of the multilevel ordinal regression models were expressed as odds ratios (OR).

Analysis of social causation

The association between life-course urban/rural residence and adulthood BMI was assessed with linear regression analysis with Year 21 BMI as the dependent variable, categorical life-course residence as the independent variable, and Year 0 BMI, gender, and age at baseline as covariates. We fitted this model first for participants who had full data at each follow-up ($n = 618$). Given that this analysis excluded a substantial proportion of participants, we also fitted the model using a sum score in which missing values of residence were imputed using regression method with age, gender, education, occupation, marital and parenthood status, and the available values of residence at all other measurement points ($n = 1286$).

Sensitivity analyses

In addition to the main analyses described above, we carried out several sensitivity and supplementary analyses to assess the robustness of the findings. These included assessing selective migration with objectively assessed population density rather than self-reported residence, examining whether the association between BMI and urban migration was explained by general migration propensity rather than selective migration, whether the association was due to adolescent height rather than BMI, and whether the results were confounded by selective attrition. These analyses supported the conclusions of the main analyses and they are described in detail in the Results section.

Results

Selective migration

Descriptive statistics of the sample are shown in Table 1. Across the 21-year follow-up, there was an overall migration trend characterized by increasing proportion of urban and suburban residence and decreasing rural residence up to Year 9 after which the

Table 1
Descriptive statistics.

	Year 0	Year 3	Year 6	Year 9	Year 12	Year 21
Age range	12–18	15–21	18–24	21–27	24–30	33–39
Age[a]	14.8 (2.4)	17.5 (2.4)	20.8 (2.4)	23.8 (2.4)	26.8 (2.5)	35.8 (2.4)
Gender						
Women	51.8	53.1	55.1	56.7	56.9	55.1
Men	48.2	46.9	44.9	43.3	43.1	44.9
Place of residence						
Urban	10.9	12.8	17.8	18.7	16.7	14.7
Suburban	37.5	37.2	45.7	48.3	45.2	45.7
Rural	25.9	27.6	17.4	19.5	22.5	19.2
Remote rural	25.8	22.4	19.0	13.5	15.7	20.5
Population density[b]	61.0	68.3	71.8	73.0	75.1	79.3
log (population density)[a]	4.1 (1.9)	4.2 (1.8)	4.5 (1.9)	4.7 (1.9)	4.6 (1.9)	4.7 (1.9)
Education						
Primary	56.4	41.4	38.6	22.2	20.5	9.6
Secondary	43.6	58.6	52.6	63.6	62.9	70.2
Tertiary	0.0	0.0	8.8	14.2	16.6	20.2
Occupation						
Manual	0.0	0.0	31.8	32.2	31.1	30.4
Blue collar	0.0	0.0	23.6	34.9	43.2	48.1
White collar	0.0	0.0	1.8	6.6	11.0	21.2
Student/Other	100.0	100.0	42.8	26.3	14.6	0.4
Lives with a partner	0.0	0.0	27.6	49.6	62.7	77.2
Has children	0.0	0.0	8.0	20.5	34.1	74.2
Participant's BMI[a,c]	19.7 (3.0)					25.4 (4.2)
Parental SES[a,d]	0.0 (1.0)					
Mother's BMI[a,d]	24.9 (3.8)					
Father's BMI[a,d]	25.9 (3.0)					
n	1787	1351	1245	1264	1060	1300

Note: Values are percentages of participants unless otherwise indicated.
Data on occupation, marital status, and parenthood status were not collected in years 0 and 3.

[a] Values are means (and standard deviations).

[b] Values are median of persons/km^2 of land.

[c] $n = 1286$.

[d] $n = 1343$.

trend was reversed somewhat (Table 1). A preliminary analysis indicated that Year 0 BMI was not associated with residence in Year 0 (OR = 0.99, SE = 0.02, $p = 0.42$), Year 3 (OR = 1.01, SE = 0.02, $p = 0.65$) and Year 6 (OR = 0.99, SE = 0.02, $p = 0.67$), but Year 0 BMI did predict residence in Year 9 (OR = 0.95, SE = 0.02, $p = 0.02$), Year 12 (OR = 0.93, SE = 0.02, $p = 0.002$), and Year 21 (OR = 0.93, SE = 0.02, $p < 0.001$), so that high BMI decreased the probability of living in urban areas. We also tested whether there was a nonlinear association between BMI and residence, but none of the quadratic effects of BMI were significant (all p values > 0.12). There were no BMI × gender interaction effects in any of the regression models (p values > 0.24) indicating no gender differences.

In the multilevel modeling we first fitted unconditional means and growth models without covariates (data not shown). The model intraclass correlation was $\rho = 0.56$, indicating that 56% of the variance in residence over time was due to within-participant effects and 44% due to between-participant effects. A quadratic trajectory fitted the data significantly better than a linear trajectory ($\chi^2 = 197.94$, df = 1, $p < 0.001$), so linear and quadratic terms of time were included in all subsequent models.

Covariates were entered in three steps. First, we included participants' BMI and its significant interaction effects with Time (Table 2, model 1). High BMI predicted lower probability of urban migration which became apparent with time, as indicated by the interaction effect between BMI and time. These results are illustrated in Fig. 1 in which the predicted probabilities of living in urban, suburban, rural, and remote rural areas are plotted against time by BMI groups. The four panels of Fig. 1 demonstrate that overweight and obese adolescents were less likely than normal weight adolescents to move to urban and suburban areas and more likely to migrate into more rural areas. The opposite pattern was observed in underweight adolescents, although this difference was not as strong as for the overweight and, in particular, obese adolescents.

In the second step we assessed whether the association between BMI and selective migration was affected by adjustment for baseline parental SES and parental BMI (Table 2, model 2). High parental SES predicted increased probability of urban migration whereas parental BMI was associated with rural residence but not with selective migration over time, as indicated by the lack of interaction effects between parental BMI and time. The association between adolescent BMI and selective migration remained statistically significant even after adjustment for these covariates.

In the third step, we assessed whether the BMI-migration association was explained by adulthood sociodemographic factors by including time-variant adulthood sociodemographic covariates and their statistically significant interaction effects with time (Table 2, model 3). Urban residence was associated with higher education, having no children, high and student/other occupational class categories, and having no partner. Occupational class and having no partner became more strongly associated with urban residence over time, as indicated by their interaction effects with time. Adjusted for adulthood sociodemographic covariates, adolescent BMI still predicted decreased probability of urban migration. Although the data on sociodemographic factors in Years 0 and 3 were incomplete, this was unlikely to bias the adjustment with respect to the BMI-migration association because this association emerged only later in adulthood when more complete data on sociodemographic covariates were available.

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Table 2
Predicting selective urban migration over 21 years from adolescence to adulthood by adolescent BMI and sociodemographic covariates.

	Model 1 ($n = 1787$)	Model 2 ($n = 1343$)	Model 3 ($n = 1787$)
Time	1.34*** (0.034)	1.37*** (0.041)	1.16** (0.056)
Time^2	0.99*** (0.001)	0.99*** (0.001)	1.00 (0.001)
Gender			
Women	(reference)	(reference)	(reference)
Men	0.90 (0.101)	0.88 (0.109)	0.95 (0.109)
Age at baseline	1.07** (0.028)	1.10*** (0.032)	1.06* (0.029)
Adolescent BMI	0.88*** (0.023)	0.89*** (0.028)	0.89*** (0.025)
Adolescent BMI × Time	0.99*** (0.001)	0.99*** (0.001)	0.99*** (0.001)
Parental SES		2.06*** (0.178)	
Parental SES × Time		0.98*** (0.004)	
Mother's BMI		0.96* (0.017)	
Father's BMI		0.96 (0.021)	
Education			
Primary			(reference)
Secondary			1.07 (0.077)
Tertiary			2.48*** (0.352)
Occupation			
Manual			(reference)
Blue collar			1.15 (0.180)
White collar			1.39 (0.282)
Student/Other			3.52** (1.484)
Occupation × Time			
Manual			(reference)
Blue collar			1.00 (0.015)
White collar			1.04* (0.023)
Student/Other			1.08* (0.033)
Has a partner			0.37*** (0.061)
Has a partner × Time			0.90*** (0.013)
Has children			0.60*** (0.062)

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. The coefficients are odds ratios (and standard errors) of a multilevel ordinal regression model with a 4-point outcome (1 = Remote rural 2 = Rural 3 = Suburban 4 = Urban). Time was centered at the end of the follow-up. Only statistically significant interaction effects with Time were included in the model.

Sensitivity analyses for selective migration

We then repeated the above analyses with population density rather than self-reported residence as the dependent variable. The results showed significant effects of Year 0 BMI ($B = -0.06$, $SE = 0.02$, $p < 0.001$) and its interaction effect with Time ($B = -0.003$, $SE = 0.001$, $p < 0.001$) suggesting that higher BMI predicted decreased probability of urban migration, a finding corresponding to those obtained with self-reported urban/rural residence measure. The results are illustrated in Fig. 2 in which logged population density is plotted against time by BMI groups. Adjusting for parental covariates or participants' own sociodemographic did not alter the association between BMI and selective migration in this analysis (data not shown).

Given that there was a general trend of urban migration in the sample, it is possible that the lower probability of urban migration associated with high BMI reflected lower migration probability in general rather than urban migration in particular. We assessed this possibility by examining whether adolescent BMI predicted the probability of moving from one municipality to another, regardless of the population density of the municipality. We created 14 new dichotomous dependent variables indicating whether or not the home municipality of the participant was the same at two different follow-up phases, covering all the possible combinations of the 6 follow-up pairs. Of the 14 separate logistic regression models predicting these probabilities by adolescent BMI, gender, and age at baseline, none were statistically significant ($p < 0.05$), suggesting that adolescent BMI did not predict general propensity of between-municipalities migration and that the association between BMI and selective urban migration was therefore not due to differences in migration probability.

Height is naturally associated with BMI ($r = 0.42$, $p < 0.001$), so we assessed whether the selective migration effect was due to adolescent body height rather than BMI. Height predicted migration when residence was assessed with self-reported residence (Height: standardized $OR = 1.08$, $SE = 0.10$, $p = 0.38$; Height × Time: standardized $OR = 0.99$, $SE = 0.003$, $p < 0.001$). The migration patterns associated with height, however, were different from those associated with BMI. While BMI was not associated with baseline residence but predicted widening residential differences over time (Figs. 1 and 2), urban residence was associated with taller baseline height but these residential differences decreased rather than increased over time. We illustrated this by plotting the probabilities of suburban and remote rural residence against time by height group (Fig. 3; short = below 1SD of birth-cohort mean, average = within 1SD of birth-cohort mean, tall = above 1SD of birth-cohort mean; in the interest of clarity, the trajectories of urban and rural residence were omitted from Fig. 3, as they exhibited similar patterns to suburban and remote rural trajectories, respectively). This converging pattern was similar albeit weaker with population density as the dependent variable (Height: $B = 1.66$, $SE = 0.54$, $p = 0.002$; Height × Time: $B = -0.03$, $SE = 0.02$, $p = 0.04$). Adolescent height was associated with more densely populated residence in Year 0 (difference between short and tall groups = 0.61) and predicted more urban residence also in Year 21 (difference between short and tall group = 0.43) although not as strongly as in Year 0. As might be expected from these results, adjusting for height did not substantially alter the association between BMI and migration (data not shown).

The above analyses of selective migration were concerned with how place of residence changes as a function of time and adolescent BMI. The consequences of selective migration can also be assessed in another way by examining how mean adolescent BMI changes as a function of time and place of residence. This analysis allows one to estimate how selective migration produces BMI differences between residential areas independently of any effects place of residence may have on BMI because adolescent BMI is assessed only once at baseline. To this end, we fitted a linear multilevel model similar to model 1 of Table 2 but with adolescent BMI as the dependent variable and place of residence as the independent variable (data not shown). As shown in Fig. 4, during the follow-up period the average adolescent BMI in urban and suburban areas decreased by 0.62 and 0.03 units, respectively, while average BMI in rural and remote rural areas increased by 0.13 and 0.40 units, respectively. If transformed first into standard deviations and then into units of adulthood BMI (i.e. $\chi = \mathrm{BMI}/3.0 \times 4.2$), these differences can be interpreted to equal to 0.87 and 0.05 adulthood BMI unit decrease for urban and suburban areas and 0.19 and 0.56 adulthood BMI unit increase for rural and remote rural areas. At the end of the follow-up period, the average adolescent BMI difference between urban and remote rural areas was 0.96 adolescent BMI units, equaling to 1.35 adulthood BMI units.

Social causation

Social causation analyses examined whether urban/rural residence over the 21-year follow period predicted adulthood BMI in Year 21 when adjusted for Year 0 BMI, gender, and age at baseline. Linear regression models in participants with no missing data showed that life-course rural residence predicted higher adulthood BMI than urban residence with a fairly linear dose–response pattern (Fig. 5, dark bars; B for trend $= -0.26$, $SE = 0.10$, $p = 0.01$). On average, BMI of participants in the most rural group was 0.9 kg/m^2 higher than BMI of those in the most urban group.

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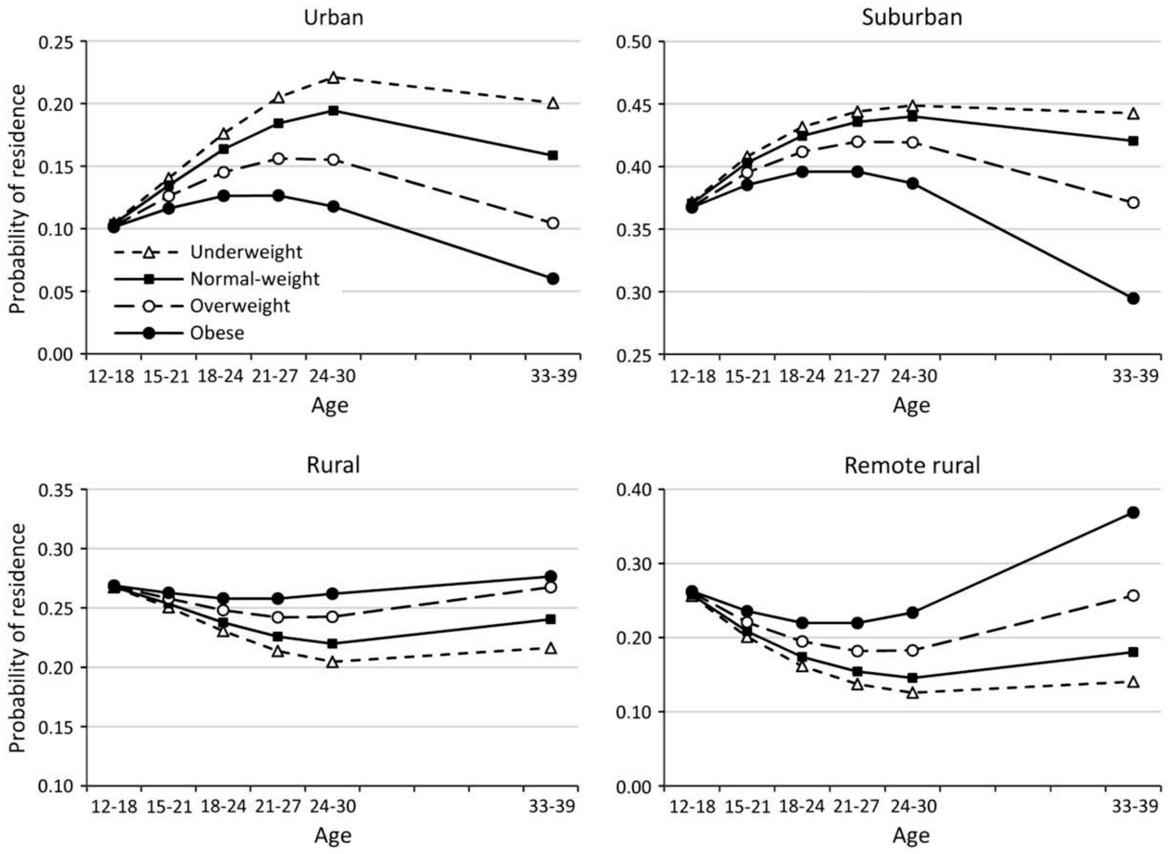

Fig. 1. Predicted probability of living in urban, suburban, rural, and remote rural area as a function of age and adolescent BMI group, adjusted for gender and age at baseline. Note the different y-axis scales in the panels.

Adjusting for Year 21 education, occupation, marital status, and parenthood status did not substantially change this association ($B = -0.21$, $SE = 0.11$, $p = 0.06$; BMI difference between the extreme groups of urban/rural residence = 0.8 kg/m^2). The association between urban/rural residence and adulthood BMI was similar when imputed data of residence were used (Fig. 5, gray bars).

Attrition analysis

We estimated potential bias caused by selective attrition in two ways. An attrition analysis indicated that adolescent BMI did not predict the probability of participation at any particular follow-up phase or the number of participated follow-ups in a linear or quadratic fashion (all p values > 0.26). These results suggest that adolescent BMI was not associated with selective attrition. In addition, we refitted the multilevel model (Table 2, model 1) of selective migration by including only participants who had full data of all 6 follow-up phases ($n = 631$). In this subsample, BMI ($OR = 0.85$, $SE = 0.04$, $p = 0.001$) and its interaction effect with time ($B = 0.99$, $SE = 0.002$, $p = 0.001$) predicted migration in a similar

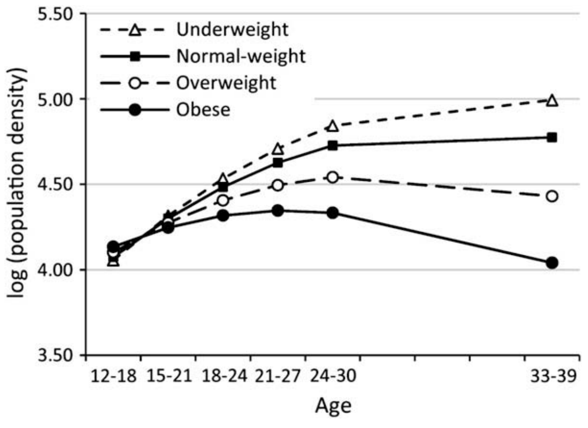

Fig. 2. Predicted mean population density of home municipality as a function of age and adolescent BMI group, adjusted for gender and age at baseline.

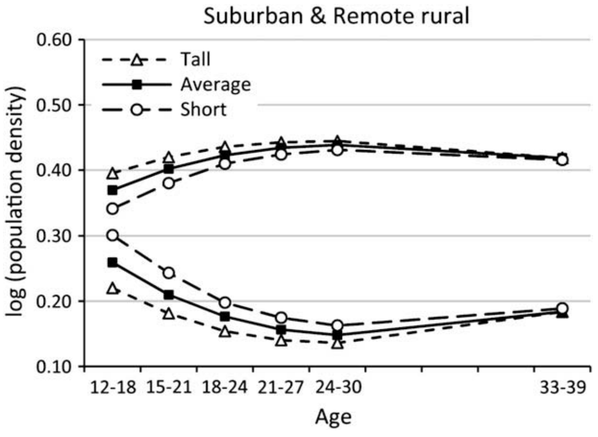

Fig. 3. Predicted probability of living in suburban (three uppermost lines) and remote rural (three lowermost lines) area as a function of age and adolescent height group (short = below 1SD of mean, average = within 1SD of mean, tall = above 1SD of mean), adjusted for gender and age at baseline.

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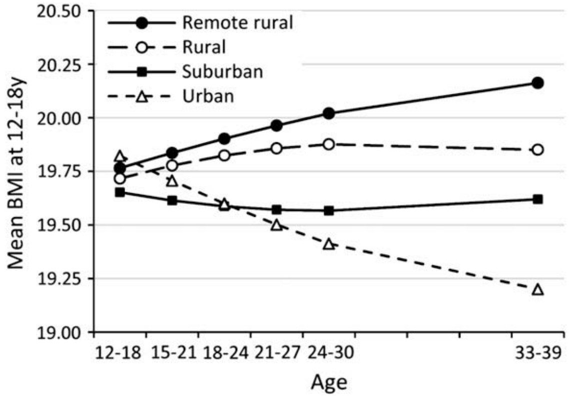

Fig. 4. Average adolescent BMI assessed at 12–18 years of age as a function of age and place of residence, adjusted for gender and age at baseline.

fashion as in the total sample ($n = 1787$), suggesting that our results were unlikely to be affected by attrition in any substantial way.

Discussion

The present findings suggest that the higher body mass index (BMI) observed in people living in rural areas of Finland (e.g. Fogelholm et al., 2006; Leino et al., 2000; Pietinen et al., 1996; Similä et al., 2005) may be due to both social selection and social causation mechanisms. Supporting social selection, adolescent BMI predicted selective urban/rural migration trajectories over a 21-year follow-up period from adolescence to adulthood independently of education, occupational class, marital status, and parenthood status. Compared to adolescents of normal weight, overweight and obese adolescents were less likely to migrate to urban areas and more likely to migrate to more rural areas, whereas underweight adolescents were slightly more likely to migrate to more urban areas. Supporting social causation, rural residence over time predicted higher adulthood BMI than urban residence did.

Adolescent BMI was not associated with adolescent place of residence but predicted migration in adulthood. This is probably because adolescents' residence is mainly determined by their parents' residential choices, while the importance of personal characteristics and preferences in decision making increases with age. The consequences of BMI being associated with selective migration were quite substantial. Compared to adolescents of normal weight, obese adolescents were about two times more likely to live in a remote rural area and three times less likely to live in an urban area at 33–39 years of age. However, it should be noted that only ~1% of the participants belonged to the obese group and ~8% to the overweight group in adolescence.

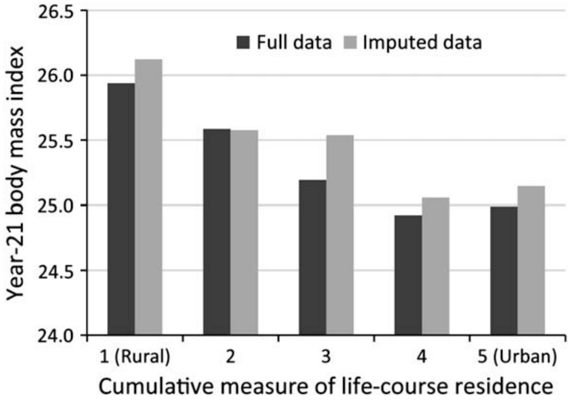

Fig. 5. Adulthood BMI as a function of life-course cumulative measure of rural/urban residence and adulthood BMI (full data n = 618, imputed data n = 1286), adjusted for gender and age at baseline.

The findings also provide evidence for the social causation hypothesis of rural residence and high BMI. Living in a rural area predicted a greater increase of BMI from adolescence to adulthood than urban living did. This may be due to regional differences in health behaviors and lifestyles (Similä et al., 2005), and may reflect differences in muscle mass as well as body fat. The influence of rural versus urban living over the 21 years created a difference of approximately 0.9 BMI units between the extremes of life-course urban and rural residents. Thus, the effect sizes of social selection and causation were of a similar magnitude, as selective migration was estimated to create a difference of 1.4 adulthood BMI units between urban and remote rural areas over the same follow-up period. In combination these findings imply that the selection and causation mechanisms may act to strengthen each other. That is, heavier people tend to migrate to more rural areas where people tend to get heavier.

Underlying mechanisms

At present, the observed association between BMI and selective migration lacks a strong theoretical explanation. Most demographic studies of migration have concentrated on economic incentives (e.g. the availability of jobs) and social transitions (e.g. marriage, having children) as catalysts of residential mobility (Edlund, 2005; McFalls, 2003; Rodgers & Rodgers, 1997; Rye, 2006). High BMI is known to be related to multiple psychological, social, and health outcomes, such as mental health (e.g. Simon et al., 2006), economic and marital success (e.g. Jokela et al., 2007; Jokela, Elovainio, & Kivimäki, 2008; Rahkonen et al., 1998), and morbidity and mortality (Haslam & James, 2005; McGee & Diverse Populations Collaboration, 2005). Although sociodemographic factors predicted urban migration in the expected way in the present sample, they did not account for any substantial portion of the BMI-migration association.

Two explanations for the association between BMI and selective urban/rural migration seem plausible. First, low BMI may be correlated with life style factors or psychological characteristics that predict migration to urban areas (cf. Jokela, Elovainio, Kivimäki, & Keltikangas-Järvinen, 2008; Rentfrow, Gosling, & Potter, 2008) and this way BMI may become correlated with urban/rural migration. Second, it is possible that BMI is more directly related to selection of residential locations. Body weight may be differently related to psychological and social consequences in urban and in rural areas, and this may explain differences in residential choices. Perhaps rural areas provide more favorable social environments for individuals with high BMI or, more likely, urban and rural locations may be perceived differently by individuals with different body weights – whether or not these locations actually have different implications for their well-being. Currently there is no evidence for either of these hypotheses, but they are both empirically testable.

The lower probability of urban migration in obese adolescents may have implications for understanding the social consequences of obesity. Urban environments provide more economic opportunities than rural communities do, and rural-to-urban migrants have been shown to achieve higher socioeconomic status than their counterparts staying in rural areas (Rodgers & Rodgers, 1997; Rye, 2006). If obese people are less likely to migrate to cities, they may have less opportunities and resources for achieving socioeconomic goals. This might partly account for the previously reported adverse socioeconomic correlates of obesity (e.g. Laitinen et al., 2002; Rahkonen et al., 1998; Sarlio-Lähteenkorva & Lahelma, 1999). Rural

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residence may also increase the health risks of obesity, as health care resources tend to be fewer in rural than in urban areas (Kainulainen et al., 2001). On the other hand, rural residence may attenuate some of the adverse social outcomes of obesity, e.g. decreased marriage probability, if such outcomes are more common in rural than in urban areas.

Height exhibited the opposite pattern of urban/rural migration to BMI. Adolescent height was associated with urban residence in adolescence but this association attenuated or even disappeared completely over time in adulthood. This suggests that environmental circumstances in urban areas may induce faster physical growth in childhood and adolescence, but that these urban/rural height differences dilute as individuals migrate across rural and urban areas. In other words, adulthood urban/rural height differences may reflect the long-term effects of early developmental environments, i.e. social causation, rather than selective migration.

We assessed regional differences on the basis of urban/rural residence, but other dimensions of geographic variance should merit attention in future biodemographic studies of migration and residence. There are, for example, health differences between residents of Eastern and Western Finland (Juonala et al., 2004; Juonala et al., 2005). Furthermore, frequent residential mobility has been related to poor health (Larson, Bell, & Young, 2004). Future research should seek to integrate these diverse findings by assessing the causal relations of BMI, health, and different dimensions of residence together. The present findings suggest that it may be useful to examine health-related selective migration with specific measures of individual characteristics rather than with overall measures of health.

Concluding remarks

Our main finding that both social selection and social causation may be acting in creating urban/rural differences in average body weight is based on a study design with several methodological strengths. The prospective study design with a population-based sample allowed us to assess the bidirectional association of body weight and urban/rural residence in Finland. Height and weight were measured in a medical examination, and the results of self-reported residence were replicated with objectively measured population density of home municipality, so reporting bias could not explain the results. The follow-up period spanned from adolescence to adulthood, which is an important developmental period for making long-lasting life decisions, including residential choices (Arnett, 2000). On the other hand, residential differences between BMI groups emerged only in adulthood, and all the participants were still under 40 years old at the final follow-up phase. Further data are needed to assess whether and how BMI influences migration in later adulthood. Finally, as migration patterns and urban/rural differences in body weight vary by country, it may be expected that the role of BMI in migration patterns differs by study population. This suggests promising avenues for comparative research in understanding how physical characteristics affect complex social behavior such as migration.

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