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Article

Can socioeconomic factors explain geographic variation in overweight in Norway?



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ARTICLE INFO

Article history:

Received 28 October 2015

Received in revised form

1 February 2016

Accepted 28 April 2016

Keywords:

Overweight

Body mass index

Socioeconomic factors

Neighborhood

Multilevel modeling

Geographic factors

Norway

ABSTRACT

We explore if the geographic variation in excess body-mass in Norway can be explained by socioeconomic status, as this has consequences for public policy. The analysis was based on individual height and weight for 198,311 Norwegian youth in 2011, 2012 and 2013, stemming from a compulsory screening for military service, which covers the whole population aged seventeen. These data were merged with municipality-level socioeconomic status (SES) variables and we estimated both ecological models and two-level models with a random term at the municipality level. Overweight was negatively associated with income, education and occupation at municipality level. Furthermore, the municipality-level variance in overweight was reduced by 57% in females and 40% in males, when SES factors were taken into account. This suggests that successful interventions aimed at reducing socioeconomic variation in overweight will also contribute to reducing the geographic variation in overweight, especially in females.

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1. Introduction

Worldwide, the proportion of overweight adults has increased from 29% among men and 30% among women in 1980 to 37% and 38%, respectively, in 2013 (Ng et al., 2014). Every second type II diabetes case, every fifth ischemic heart disease case and more than every third of certain types of cancers are attributable to excess body weight (WHO, 2000). The rise in overweight is not only limited to developed countries; overweight is now a problem among all age groups in developing countries as well (Ng et al., 2014).

There are considerable geographic variations in overweight within many countries. In Norway, the share of youth considered overweight varied between 14.8% and 28.3% across the 19 counties in 2013 (Norwegian Institute of Public Health, 2015). Like the geographic variation in other health outcomes, such geographic variations in overweight has received considerable attention and puzzled researchers, politicians and policy makers (Bjerkedal & Brevik, 2001; Department of Health (UK), 2004; Jullumstro & Eide, 2013; Norwegian Ministry of Health and Care Services, 2012;

Smyth, 2015). Some countries have also introduced measures to reduce geographic variation in health. For example, in the UK the Government has set a Public Service Agreement target to address geographical inequalities in life expectancy, cancer, heart disease, stroke and related diseases (Department of Health, 2004). Also in Norway the municipalities, which are responsible for local public health, are obliged to keep an eye on geographical differences and suggest interventions when needed (Norwegian Ministry of Health and Care Services, 2012). However, an important question is whether steps could or should be taken to reduce the geographic variation in overweight, and the answer depends on the type of factors that contribute to it.

The aim of this paper is to contribute to this discussion by estimating how much of the geographic variation in overweight in Norway is explained by three indicators of socioeconomic resources (income, education, and occupational status), which in a number of studies have been associated with overweight. More specifically we estimate multilevel models with a random term at the municipality level and study how its variance is reduced when SES indicators are added. To our awareness such a study has not been carried out in any country earlier.

If socioeconomic factors contribute substantially to geographic variation in overweight, the implication is that reduction of SES variation in overweight – which is an important health policy goal in Norway and many other countries – will also reduce the geographic variation. For example, nationwide income

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supplementation to relatively poor people or general initiatives to reduce school dropout would also reduce the geographic variation. Conversely, if SES does not explain much of the geographic variation in overweight, it must be the result of other factors such as other individual characteristics (e.g. attitudes), neighborhood green space (Astell-Burt, Feng, & Kolt, 2014), or other aspects of the environment (unchangeable or man-made) not entirely determined by the SES of the population (e.g. fast food restaurants). Interventions to reduce the geographic differences would then have to be different from interventions aimed at reducing socioeconomic health inequalities.

We consider the socioeconomic resources in the municipality, indicated by average income, average education and occupational status. Information about corresponding individual level characteristics are not available. The associations between municipality-level socioeconomic resources and an individual's overweight will reflect two effects: first, own (or, for young people, parents') SES may have an impact on an individual's weight; second, there may be an effect of the SES in the municipality on individual weight. As explained below, separation of those two contributions would be of some value from a policy perspective, but the data available to us did not allow this.

2. Data and methods

2.1. Data

Our study was based upon individual-level (but anonymized) data on height and weight of the Norwegian youth in 2011, 2012 and 2013. Height and weight was self-reported and supplied in an internet based military muster from the Norwegian Armed Forces. Since 2010 it has been compulsory for Norwegian citizens to provide this information, as part of a large questionnaire during the year they turn 17 (Fauske, 2011). Hence, the response rate is as high as 97%¹. Individuals who become Norwegian citizens after the age of 17 years and individuals who do not finish school on time can fill out the form at an older age. We excluded all individuals who were over the age of 18 when answering the questions about height and weight (1.3% of females and 3.5% of males). Our study population comprised 90,568 females and 107,743 males². We also have access to information about the individual's municipality of residence.

2.2. Variables

The dependent variable was overweight, defined as the body mass index (BMI, weight in kilograms divided by height in meters squared) being above 25 in adults. This limit accords with World Health Organization guidelines (World Health Organization, 1995). However, body mass changes substantially with age and our population consisted of individuals aged 16–18. Hence, we used age- and sex-specific overweight cut-off values to account for changing interpretation of BMI by age and sex in younger age groups (Cole, Bellizzi, Flegal, & Dietz, 2000).

The level of aggregation was the Norwegian municipalities, as defined the 1st of January 2014, and the analysis encompassed all 428 municipalities in the country. As recommended by

Galobardes, Lynch, and Smith (2007), we included three aggregate measures to reflect the socioeconomic conditions in the area. These are median gross income in 2012, the share of the population above the age of 16 with college or university education in 2012, and the share of the population aged 15–74 who were in leading positions³ in 2012. A number of previous studies have demonstrated that the associations between income and health behaviors are non-linear (Ecob & Smith, 1999; Ettner, 1996), so we grouped the income variable into five categories.

As covariates we also include the share of the population aged 16–66 and the square root of the population size⁴. The reason for including population size is that it is a reasonable indicator of the degree of urbanity, which is positively associated with income. Living in an urban area has also been found to be negatively associated with the prevalence of overweight (Biehl et al., 2013). The age structure may affect the share of the population who are employed, and thus the average income in the population. Additionally, BMI tends to vary by age (Flegal, Carroll, Kuczmarski, & Johnson, 1998), which then again may have an impact on our sample through peer-effects (Trogon, Nonnemaker, & Pais, 2008).

It is likely that the effects of socioeconomic factors on overweight may vary across the sexes. The possibility of such variation has rarely been analyzed from a multilevel perspective (Wen & Maloney, 2014). A few studies have indicated that women, on the whole, may be more influenced by area-level contexts than men (King, Kavanagh, Jolley, Turrell, & Crawford, 2006). However, other studies have found stronger associations between composite measures of neighborhood disadvantage and mortality among men than among women (Kravdal, 2010). We ran a Chow test based on a logit model and found that the coefficients (both at the individual- and area-level) varied significantly by sex. This further supports sex-stratified analyses.

Finally, we controlled for 1-year age groups at the individual level and response year.

2.3. Statistical analysis

In the first step, we generated descriptive graphs of the associations between overweight prevalence in the municipality and the three socioeconomic variables, based on locally weighted regressions with a bandwidth of 0.8 to place less emphasis on the outliers.

In the second step, we estimated two-level logistic models, where the dependent variable was the binary overweight variable at the individual level. The models were of the form:

$$\text{Logit}(y_{i,j}) = \alpha_0 + \alpha_1 A_{i,j} + \alpha_2 T_{i,j} + \alpha_3 X_j + \zeta_j \quad (1)$$

where i indexes the individuals, j indexes the 428 municipalities, y is the overweight status for individual i in municipality j , A is the age group, and T response year. X is a vector of the municipality-level variables. ζ_j is a random intercept which is assumed to be independent across municipalities' j and independent of the other covariates in the models. The variance of this random term is a measure of the between-municipality variation in the dependent variable, which is not explained by the variables included in the model. We estimate the proportional change in the variance (PCV) by the formula (Merlo et al., 2006):

¹ This number was obtained from personal communication with staff at the Norwegian Armed Forces.

² A few individuals answered the question about height and weight twice (at 17 and 18). However, we do not have the opportunity to correct for this in our data. To check whether or not this has an impact on our results we reran the analysis, excluding those who are 18. It does not alter the findings and we kept the 18-year olds in our analyses.

³ Leading positions are here defined according to the Norwegian Standard for Classification of Occupations (STYRK). All codes that start with the number 1 are leading positions or politicians.

⁴ Some of the data used in this publication are based on the Norwegian Social Science Data Services Municipality Database. The Norwegian Social Science Data Services is not responsible for data analysis or interpretation done here.

$$PCV = \frac{(V_A - V_B)}{V_B} \times 100$$

where V_A is the variance of the random term in the initial model and V_B is the corresponding variance in the expanded model. The PCV expresses how much of the variation in overweight across municipalities that can be explained by the additional covariates included in the expanded model.

We report marginal effects (ME) based on each regression. These were calculated for each variable fixing the other variables at their whole sample mean values. Furthermore, the municipality-level random effects were all set to zero, i.e. the MEs for each variable were calculated for an average municipality.

3. Results

Overweight was more common among males than among females (Table 1). The mean number of respondents per municipality was lower among the overweight compared with non-overweight; however, no difference was found by age. In both females and males, the overweight prevalence was higher in 2013 than in 2011 and 2012. Those who were overweight generally came from municipalities with lower income, lower education and fewer in leading positions. In addition, overweight was more common in municipalities with smaller populations.

Fig. 1 displays the smoothed value from the locally weighted regressions of the associations between percent overweight at the municipality level and each of the SES variables. Fig. 1 also displays bubble-plots where the size of the bubbles correspond with the population size in the municipality.

We observe first that there were negative associations between the share of the population who were overweight and the median income at the municipality level, the share of the population with a university degree, and the share of the population in leading positions (Fig. 1). Furthermore, the municipalities with the largest populations (the largest circles) were also the populations with the highest incomes, most educated populations and greatest share in leading positions. Correspondingly, the inhabitants in the municipalities with the largest populations were also less overweight, both among males and females at the age of 16–18. Finally, we observe that the patterns in each figure were similar in females and males, i.e. those municipalities that had low prevalence of overweight in females also had low prevalence in males, and vice versa.

In model 1 – adjusted for individual age, age structure in the municipality and population size- the variance of the municipality random term was 0.038 in females and 0.042 in males (Table 2). Two-thirds of the observations in a normal distribution are between one standard deviation below and one standard deviation above the average. These results therefore mean that 1/3 of the population live in municipalities where the log odds of overweight was more than about $\sqrt{0.04}$ below or above the average, i.e. where the overweight probability was more than about 20% below or above the average.

When SES variables were added (alone) in model 2, 3 and 4, the municipality random term decreased for both sexes. In females the “share in leading positions” had the largest impact on the variation in overweight across municipalities, by reducing the variation with 53%. In males, the “share with high education” was most important as it reduced variation in overweight by 32%. In both females and males, median income was the least important variable in terms of explaining geographic variation in overweight in Norway. The three SES variables were included jointly in model 5 (Table 2). Fifty-seven percent of the variance in overweight across municipalities -among females- could be explained by the three SES

Table 1
Summary statistics of the estimation sample.

	Females		Males	
	Non-OW	OW	Non-OW	OW
BMI groups				
Number	73,323	17,245	81,728	26,015
%	80.96	19.04	75.85	24.15
Mean number of respondents per municipality	3164.2	2451.5	3116.3	2439.5
Age (mean)	16.8	16.8	17.0	17.0
Response year by BMI group (%)				
2011	81.8	18.2	76.0	24.0
2012	80.8	19.2	77.4	22.6
2013	80.2	19.8	74.4	25.6
Municipality level variables				
Share of the population aged 16–66	0.677	0.673	0.677	0.673
Median income	342,696	337,355	342,353	337,640
Share of the population with high education	0.072	0.062	0.071	0.062
Share of the population in leading positions	0.077	0.074	0.077	0.074
Mean municipality population	98,782	74,091	97,179	73,865

OW: overweight.

variables. In males the corresponding proportion was 40%.

Table 3 shows the marginal effects (ME), which were calculated based on the two-level logit model. The ME for the categorical variables (i.e. age, response year, median income) shows the discrete change from base level (reference category). The ME for the continuous variables (i.e. population age, population (squared), share with high income and share in leading positions) shows the change when the continuous variables change by one unit.

Age was significantly and negatively associated with the probability of individual overweight in females and males in each model 1–5 (Table 3). In both females and males those who responded in 2013 were significantly more likely to be overweight than those who responded in 2011. Median income was significantly and negatively associated with overweight (Model 2; Table 3). Overweight was also significantly associated with education and share in leading positions at the municipality level (Model 3–4; Table 3). When all SES variables were included in Model 5 both the share with high education and the share in leading positions remained significant.

To explore the robustness of the findings we repeated our analysis with a few modifications. First, in the multilevel approach larger municipalities contributes more to the estimated variance compared with the smaller municipalities. To explore whether or not our findings were strongly influenced by the large municipalities, we omitted the five largest municipalities and reran the models. The variation explained by SES -in the model including all SES variables (model 5)- was 48% in females and 37% in males. Second, we ran models with share living in urban areas as a control variable instead of population size. This did not alter our findings. Third, we grouped the education variable and the occupational status variable to allow for non-linear effects, which had little or no impact on the estimated variances. Fourth, we entered a number of additional SES variables like unemployment rate, mean income and education stratified by sex. More of the random term was explained when more SES variables were included. However, these models also suffered from multicollinearity (resulting in wide confidence intervals and big changes in the values and signs of the coefficients when additional variables were entered into the model), which made the interpretation of the coefficients difficult.

Finally, gestation and early infancy are critical periods for health and overweight development in adolescence and adulthood (Currie & Almond, 2011; Dietz, 1994). To explore this association we ran models controlling for median income and mean education

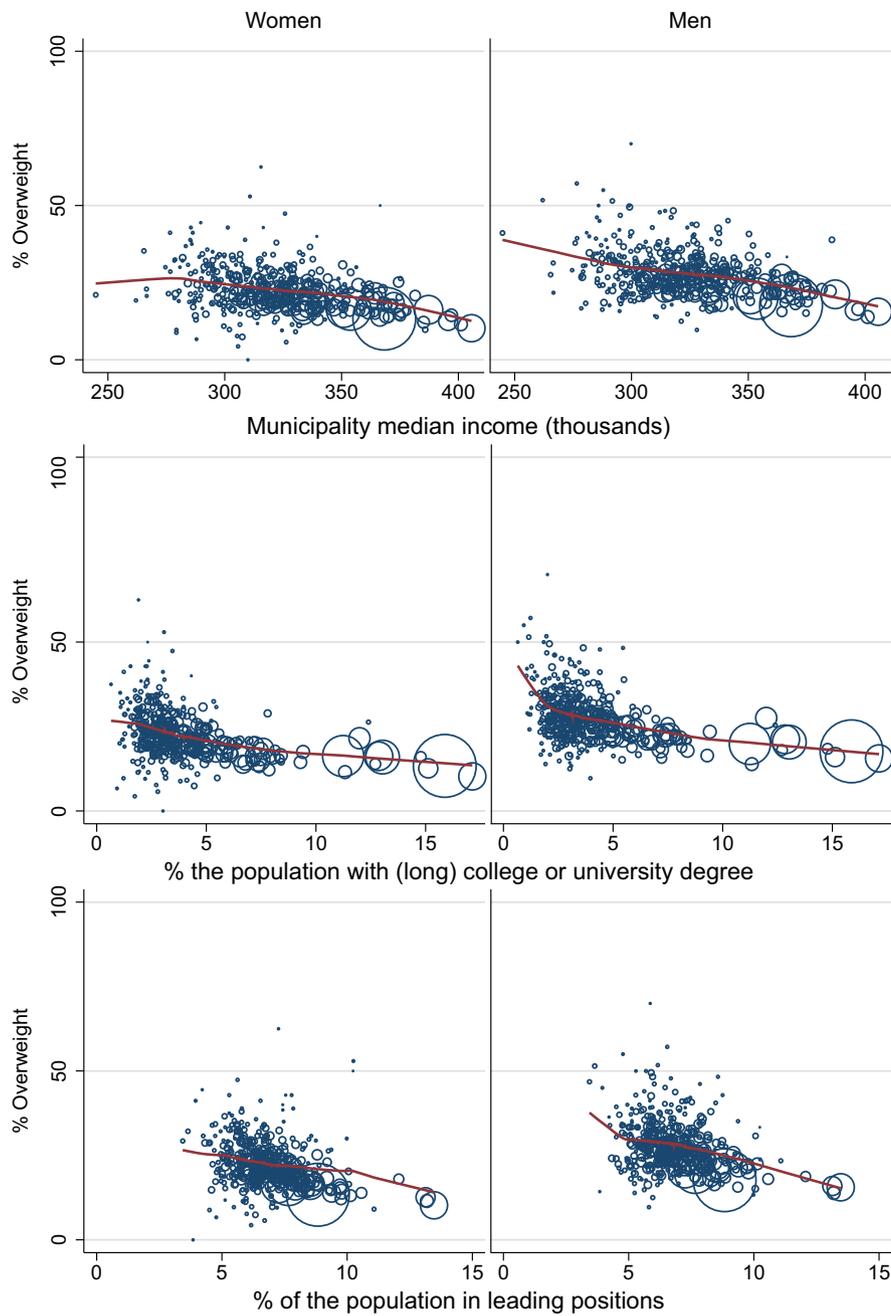


Fig. 1. municipality-level overweight on municipality-level characteristics from locally weighted regressions.

Table 2
Variance of the municipality-level random term from two-stage regressions in females and males.

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Variance	p-Value								
Females										
Variance of the municipality level random term	0.03765	< 0.001	0.02764	< 0.001	0.02485	< 0.001	0.01756	< 0.001	0.01636	< 0.001
Proportional change in variance (PCV)			26.59%		34.00%		53.37%		56.56%	
Males										
Variance of the municipality level random term	0.04174	< 0.001	0.03281	< 0.001	0.02844	< 0.001	0.02934	< 0.001	0.02509	< 0.001
Proportional change in variance (PCV)			21.40%		31.87%		29.72%		39.88%	

Model 1 covariates: age, response year, share of the population aged 16-66, and population (squared).

Model 2 covariates: age, response year, share of the population aged 16-66, population (squared), and median income.

Model 3 covariates: age, response year, share of the population aged 16-66, population (squared), and share of the population with high education.

Model 4 covariates: age, response year, share of the population aged 16-66, population (squared), and share of the population in leading positions.

Model 5 covariates: age, response year, share of the population aged 16-66, population (squared), median income, share of the population with high education, and share of the population in leading positions.

Table 3
Marginal effects of the individual level and municipality-level characteristics from two-stage regressions in females and males.

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Coef.	p-Value								
Females										
Age										
16	Base group									
17	-0.00688	0.025	-0.00702	0.023	-0.00690	0.025	-0.00694	0.025	-0.00700	0.024
18	0.02480	< 0.001	0.02477	< 0.001	0.02467	< 0.001	0.02473	< 0.001	0.02465	< 0.001
Response year										
2011	Base group									
2012	0.01074	0.001	0.01073	0.001	0.01078	0.001	0.01089	0.001	0.01085	0.001
2013	0.01692	< 0.001	0.01693	< 0.001	0.01694	< 0.001	0.01707	< 0.001	0.01702	< 0.001
Municipality level variables										
Share of the population aged 16–66	-0.30903	0.011	-0.06000	0.632	-0.15204	0.183	-0.15028	0.163	-0.03723	0.748
Population (squared)	-0.00019	< 0.001	-0.00014	< 0.001	-0.00002	0.504	-0.00012	< 0.001	-0.00007	0.034
Median income										
Low			Base group						Base group	
Medium low			-0.01067	0.077					-0.00655	0.214
Medium			-0.02194	0.001					-0.01244	0.030
Medium high			-0.02734	0.002					-0.01113	0.171
High			-0.05547	< 0.001					-0.01993	0.035
Share of the population with high educ.					-0.81747	< 0.001			-0.29239	0.034
Share of the population in leading pos.							-1.33920	< 0.001	-0.88939	< 0.001
Males										
Age										
16	Base group									
17	-0.02982	< 0.001	-0.02992	< 0.001	-0.02997	< 0.001	-0.03006	< 0.001	-0.03007	< 0.001
18	-0.00127	0.777	-0.00140	0.757	-0.00165	0.714	-0.00174	0.700	-0.00179	0.692
Response year										
2011	Base group									
2012	-0.01187	< 0.001	-0.01191	< 0.001	-0.01188	< 0.001	-0.01183	< 0.001	-0.01188	< 0.001
2013	0.01740	< 0.001	0.01745	< 0.001	0.01750	< 0.001	0.01760	< 0.001	0.01757	< 0.001
Municipality level variables										
Share of the population aged 16–66	-0.14477	0.285	0.13447	0.337	0.03110	0.806	0.00328	0.980	0.15655	0.240
Population (squared)	-0.00024	< 0.001	-0.00019	< 0.001	-0.00004	0.344	-0.00018	< 0.001	-0.00007	0.069
Median income										
Low			Base group						Base group	
Medium low			-0.00354	0.600					0.00010	0.987
Medium			-0.01773	0.014					-0.00815	0.228
Medium high			-0.03735	< 0.001					-0.01861	0.053
High			-0.05578	< 0.001					-0.01840	0.112
Share of the population with high educ.					-0.98829	< 0.001			-0.58650	0.001
Share of the population in leading pos.							-1.21166	< 0.001	-0.52766	0.022

in the municipality at the time when each individual was born⁵. We did not have information corresponding about occupational status at birth. In females, inclusion of income at birth reduced the variance in overweight with 27%, which was almost identical to the reduction observed when income in 2012 was added. Inclusion of education at birth reduced the variance in overweight in females with 32%, compared with 34% when education in 2012 was added. In men, the corresponding numbers were 26% at birth and 21% in 2012, 29% for education at birth and 32% for education at in 2012. Finally, we ran models including all SES variables at the time of birth and in 2012. In females, 59% of the variance was explained, compared with 57% in the models including SES in 2012 only. In men, the comparable numbers were 41% and 40%, respectively.

4. Discussion

We found negative and significant associations between overweight and education at the municipality level in Norway among

both females and males. Similar negative associations were found for occupation and median income at the municipality level. The study also showed that these three socioeconomic variables in total could explain 57% and 40% of the variation in overweight across municipalities in females and males, respectively.

The association between individual body mass index and area-level socio-economic resources supports findings reported in previous studies. A number of these studies have used composite indicators of SES (Adams et al., 2009; Chen & Truong, 2012; Do et al., 2007; Feng & Wilson, 2015; Sundquist, Malmström, & Johansson, 1999; Wen & Maloney, 2014), while other studies have looked specifically at area-level income (Cetateanu & Jones, 2014; King et al., 2006), area-level education (Harrington & Elliott, 2009) or area-level occupational status (Cetateanu & Jones, 2014). A Canadian study, which included school-aged children, used individual-level SES variables in addition to area-level income, occupation and education. This study found that both individual- and area-level SES variables were negatively associated with individual BMI (Janssen, Boyce, Simpson, & Pickett, 2006). However, the mentioned studies explore the associations between high BMI and area-level SES; they do not estimate how much of the geographic variation in high BMI that could be explained by SES. To our awareness, our study provides the first estimates of this.

The study was based on an extensive register data source,

⁵ The birth year varied across the sample. To avoid that these variables were affected by changes across time in relative level of education and income, we included the income and education in 1995 for all individuals. This was the median birth year in the sample.

which provided information on height and weight among women and men in 428 Norwegian municipalities. However, there are limitations that need to be taken into consideration when interpreting the findings. First, our measure of overweight was based on BMI, which has been criticized because it does not incorporate measures of body fat, which is an independent predictor of ill health (Burkhauser & Cawley, 2008). Second, and related to this, there may be measurement errors: if BMI is mis-measured (as it was based on self-reported height and weight), and if the level of mis-measurement is associated with SES, our coefficients might be biased. Finally, there may be reverse causality and omitted variables, either at the individual- or area-level, and the implications of this are discussed in more detail below.

4.1. Potential mechanisms explaining the findings

It is reasonable to assume that the environmental factors linking SES and overweight largely reflect differences in diet⁶ and physical activity⁷ (Janssen et al., 2006). The possible pathways are reviewed below, with attention both to the effects of individual (parental) SES and those of area-level SES (net of individual SES). As mentioned, we pick up both types of effects when municipality-level SES is included alone.

4.1.1. Effect of individual (parents) level SES

A number of studies considering the importance of individual-level SES have found high-BMI to be associated with income, education and occupation (Biehl et al., 2013; Elstad, 2013; Kinge, Strand, Vollset, & Skirbekk, 2015; McLaren, 2007). Income could affect BMI, for example by affecting resources available to buy certain types of food and to participate in leisure-time physical activities. Furthermore, a number of studies have suggested that education enables people to integrate healthy behaviors into their daily routine, which may give them better health outcomes, and educated people are also more likely to pass on healthy habits to their children (Atella & Kopinska, 2014; Laitinen, Räsänen, Viikari, & Åkerblom, 1995; Mirowsky & Ross, 1998). Also occupation has been argued to influence body mass, as low status jobs are often associated with lack of autonomy, which might for example make it difficult to manage time effectively to adopt a healthy lifestyle (Wardle, Waller, & Jarvis, 2002). This may further contribute to different ideals for body weight depending on occupational status (McLaren, 2007).

4.1.2. Effect of area-level SES

A number of studies on dietary choices and physical activity suggest that there is an effect of area-level SES variables net of individual characteristics. Area-level SES may have an impact on individual behavior by setting the social norm for health behaviors and then influence all individuals in the area. In addition, area-level SES may have implications for the built and institutional environment, which then again influence the behavior of most individuals in an area.

One such factor might be decreased neighborhood opportunities for physical activity in low-SES areas (Black & Macinko,

2008; Kavanagh et al., 2005), (Gordon-Larsen, Nelson, Page, & Popkin, 2006), (Wilson, Kirtland, Ainsworth, & Addy, 2004). A number of studies have also found diet, e.g. consumption of sweets and soft drinks, to be influenced by area SES. (Janssen et al., 2006), (Shohaimi et al., 2004; Turrell, Blakely, Patterson, & Oldenburg, 2004), (Diez-Roux et al., 1999).

More of the geographic variation could be explained by SES among women than men (according to a comparison of point estimates). This supports studies which suggest a stronger connection between neighborhood socioeconomic capital for women than for men (Do et al., 2007). Moreover, some researchers have hypothesized that the neighborhood environment may be generally more important for women than for men (King et al. 2006), as women traditionally spent more time in the home and were thus more exposed to the neighborhood (Robert, 1999). Such effects might be less relevant in our case, and when it comes to neighborhood SES in particular, findings have been mixed. Indeed, some authors have concluded that effects on mortality may be strongest among men (Kravdal 2010). Thus, it was not obvious what one should expect to find with respect to the importance of municipality SES for overweight, and with a focus on proportion explained (compared to other factors that include other types of community characteristics), predictions would be even harder to make.

4.2. Implications and suggestions for further research

Our findings suggest that SES contribute much to the geographic variation in overweight. Leaving aside the possibility of endogeneity problems,⁸ this means that socioeconomic resources are important determinants of overweight and are distributed unevenly across the country. Hence, successful attempts to reduce the socioeconomic variation will also reduce the geographic variation.

If it is a goal to reduce the social variation in overweight, and if low individual income and education are important determinants of overweight, interventions to prevent high-school drop-out or move people out of poverty – regardless of geographic location – may be effective measures. One could also try to reduce the effect of having low education or income, for example by providing certain health-promoting goods to individuals in low SES groups. Successful interventions of these two types will necessarily have a larger impact on overweight rates in areas where incomes and educational levels tend to be low and overweight therefore most common. In other words, the geographic variation will automatically be reduced.

The motive behind such attempts to reduce socioeconomic variation in overweight, through general interventions that are not specially targeted towards low-SES areas, would be that the returns to interventions would be just as good in the less disadvantaged areas. Stated differently, by helping the same number of people with the same low education and income in high SES areas, one could achieve as much in terms of less overweight. However, this argument would not hold if more people could be helped for the same amount of money in the most disadvantaged areas, for example because of scale advantages in poverty reduction. In that case, it would make good sense to steer some of the efforts to reduce social variation specifically towards low-SES areas, and if that is done, the geographic variation would be even more strongly reduced than if the efforts to reduce the social variation are not geographically targeted in this way.

Similarly, if overweight instead is influenced by the socioeconomic resources in the community rather than of the

⁶ Strict definitions of diets that contribute to overweight are hard to find, though there is much knowledge about dietary choices that increase the likelihood of weight gain. For example, the consumption of energy-dense and high-fat diets, beverages containing high amounts of sugar, large portion sizes and fast food have been associated with high BMI (Black & Macinko, 2008; The Norwegian Directorate of Health, 2015)

⁷ Physical activity is the only way to increase caloric expenditure that can be modified through behavior (Black & Macinko, 2008). National authorities encourage individuals to engage in regular physical activity at least 30 minutes per day. However, to maintain a healthy weight after weight reduction the advice is 60–90 min per day (The Norwegian Directorate of Health, 2015).

⁸ Caused by, for example, factors that affect both SES and BMI.

individual, it would be sound from a social equality perspective to direct interventions towards the low-SES areas in particular. The reduction in overweight might be as good if similar initiatives were taken elsewhere, but one would then support people that were not in quite as bad situation at the outset. Our data did not allow us to assess the importance of individual- versus community-level effects.⁹

To summarize, successful attempts to reduce social inequalities in high body mass would also lead to smaller geographic variation, especially if the interventions to some extent are targeted towards low-SES areas.

This argument hinges on the assumption that the estimates reflect causal effects of SES and not that some factors influence both SES and overweight. Though it would be valid, in theory, also if a change in SES for some reason is accompanied by corresponding changes in these factors. We control for population size and age structure, however there are potential omitted variables that could explain our findings. These are first, individual factors such as chronic conditions or discount rate (the rate of time preference) (Komlos, Smith, & Bogin, 2004; Morris, 2007), which may both affect the BMI of individuals and also their employment status. And second, omitted area variables such as the local schools, which may influence children's diet and body mass in addition to later life SES (Eide & Showalter, 1998; Jaime & Lock, 2009; Simon, Kwan, Angelescu, Shih, & Fielding, 2008). Hence, a challenge for further research could be to exogenously identify variation in the socioeconomic factors to explore its impact on overweight across and within areas.

The other main message from this study is that roughly half of the geographic variation in Norway could *not* be explained by income, education and occupation. The unexplained part could be a result of other population characteristics, such as attitudes, and marital status, operating either at the individual- or aggregate level. In addition, it could be explained by the built environment (not entirely determined by the socioeconomic resources) like the availability of parks and bike lanes. Finally, it could be explained by the unchangeable physical environment (Kravdal et al., 2015), latitude and distance from the sea (affecting e.g. local food traditions) being examples. Hence, to fully understand geographic variation in overweight, more research needs to be done to explore the consequences of including other variables than SES in these models.

To conclude, income, education and occupation were important variables for explaining geographic variation in overweight (among women in particular). This is important from a health policy perspective, as it means that interventions to reduce social inequalities in overweight most likely also will help to reduce the geographic inequalities.

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⁹ Even if information on individual socioeconomic resources were available, separation of these two types of effects would be difficult not least because of unobserved individual characteristics affecting the chance of moving to or remaining in low-SES areas, and because the resources in the community have implications in the longer run for the individual resources.

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