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Body mass index, prudent diet score and social class across three generations: evidence from the Hertfordshire Intergenerational Study

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ABSTRACT

Background Studies describing body mass index (BMI) and prudent diet score have reported that they are associated between parents and children. The Hertfordshire Intergenerational Study, which contains BMI, diet and social class information across three generations, provides an opportunity to consider the influence of grandparental and parental BMI and prudent diet score across multiple generations, and the influence of grandparental and parental social class on child BMI.

Methods Linear regressions examining the tracking of adult BMI and prudent diet score across three generations (grandparent (F0), parent (F1) and child (F2)) were run from parent to child and from grandparent to grandchild. Linear mixed models investigated the influence of F0 and F1 BMI or prudent diet score on F2 BMI and prudent diet score. Linear regressions were run to determine whether social class and prudent diet score of parents and grandparents influenced the BMI of children and grandchildren.

Results BMI was significantly associated across each generational pair and from F0 to F1 in multilevel models. Prudent diet score was significantly positively associated between grandparents and grandchildren. Lower grandparental and parental social class had a significantly positive association with F2 BMI (F0 low social class: b=1.188 kg/m^2, 95% CI 0.060 to 2.315, p=0.039; F1 middle social class: b=2.477 kg/m^2, 95% CI 0.726 to 4.227, p=0.006).

Conclusion Adult BMI tracks across generations of the Hertfordshire Intergenerational Study, and child BMI is associated with parental and grandparental social class. The results presented here add to literature supporting behavioural and social factors in the transmission of BMI across generations.

What this paper adds

- Obesity and overweight have become increasing public health concerns in recent decades. Previous research has determined that body mass index (BMI) and diet are associated between parents and children and that there can be socioeconomic influences on BMI. A few studies, however, have extended intergenerational research investigating familial associations in BMI, prudent diet score and social class across three generations.
- This study reports that grandparent, parent and child BMI is associated across three generations of the Hertfordshire Intergenerational Study, and that grandparent and parent social class is significantly associated with child BMI. These results add to literature supporting the involvement of behavioural and social factors in the transmission of BMI across generations.

INTRODUCTION

Obesity and overweight have become an increasing public health concern in recent decades. Obesity has been associated with health conditions such as diabetes,[1] hypertension[2] and cancer,[3] and there is evidence that obesity is linked to socioeconomic inequalities.[4] Given the trend towards higher body mass index (BMI) in recent years, with its attendant public health burden, research has focused on how BMI may be associated across generations. Previous studies have reported that BMI can be associated between parents and children, and that these relationships are carried forward into offspring adulthood.[5–8] Evidence for the transmission of diet patterning, which may be a relevant explanatory factor, between parents and offspring has also been documented.[9 10] A few studies, however, have extended intergenerational research investigating familial associations in BMI and prudent diet score across three generations.

Previous studies have reported that the transmission of BMI between parents and children is due to an interplay between genetic and biological indicators and environmental explanations, such as parental diet or educational qualifications.[6 11–14] There is also evidence in the literature that parental social class is associated with offspring BMI and diet. Such studies have reported inverse relationships between parental social class and educational attainment and child BMI measurements, such that those parents with higher educational qualifications (or social class) had children with lower BMI measurements.[13 15–17]

While studies have examined the influence of grandparental social class on grandchild BMI,[1 2] there is a need for research examining the influence of parental and grandparental BMI and dietary patterning across multiple generations, particularly accounting for the social class of both the parents and grandparents. The Hertfordshire Intergenerational Study which contains socioeconomic, BMI and diet information across multiple generations, provides a uniquely placed cohort in which to conduct a study of BMI and prudent diet score across three familial generations. This paper aims to examine whether parental and grandparental BMI and prudent diet score are associated with child and grandchild BMI and prudent diet score, whether associations persist across three generations, and if these relationships can be explained by social class.

METHODS

The Hertfordshire Cohort Study (HCS) is a longitudinal cohort study, originally composed of 3225 males and females born in Hertfordshire County, UK between 1931 and 1939. This original HCS cohort was recruited in 1998 from birth records found in Hertfordshire health visitor ledgers. From 1998 to 2004, HCS cohort members were invited to take part in questionnaire data collection and clinical visits.[18] Survey data collected at this time included information about the cohort member's parents and childhood.[19] Of 1090 postal questionnaires sent to the offspring of HCS members, 746 were returned. Those 462 children and 284 grandchildren who were recruited into the HCS form the new intergenerational wave of data collection, and have completed lifestyle and health questionnaires. As this study aimed to explore the tracking of lifestyle across three generations, the sample was restricted to those participants for whom there were three generations of data present. Analyses presented here use data from 145 grandparents (F0 generation), 157 parents (F1 generation) and 211 children/grandchildren (F2 generation). Data for the F0 generation were collected from 1998 to 2004, during baseline HCS, when these participants were in middle age. Data for the younger generations were collected in 2017–2018, when the F1 generation were in middle age and the F2 generation were young adults.

The current study first uses questionnaire data from F0, F1 and F2 generations of the HCS to examine relationships between adult BMI and prudent diet score in generational pairs across three generations.

Adult BMI was measured on a continuous scale. Prudent diet score is an assessment of diet quality in which diets including whole cereals, fatty fish, vegetables and fruits are given high scores, and diets with more sugar, dairy, chips and white carbohydrates are given low scores. The calculation of the HCS prudent diet score has been discussed in previous literature.[20] In brief, Food-Frequency Questionnaire (FFQ) data were used in principal component analyses to identify the most 'prudent' diet components. Individual prudent diet scores were then calculated based on their association to these components (more compliance to the prudent diet yielded higher scores, and less compliance produced lower scores). In this study, prudent diet components were drawn from the FFQ answers of the F0 generation, and these components were used to calculate prudent diet scores for F0, F1 and F2 participants individually based on the diet information they reported via questionnaire.

Previous research into associations between socioeconomic status (SES) and health outcomes suggests using several SES measures, such as income, social class and educational attainment.[21] As the Hertfordshire Intergenerational Study contains detailed National Statistics Socioeconomic Classification (NSSEC) social class information for each generation, and in an effort to compare similarly collected data across the three generations, NSSEC was the only SES measure examined. For married women in the F0 generation, NSSEC social class measurements capture their husband's occupational status. In the younger two generations, social class measurements reflect the participant's own occupational status, regardless of marital status. As the following analyses treat parent to child relationships individually, the social class measurements of mothers and fathers are linked independently to the social class data of their children or grandchildren. Eight NSSEC social class categories ranging from 'Larger employers and higher managerial' to 'Routine' were organised into high, middle and low social class for these analyses.

Linear regressions examining parental or grandparental BMI and child or grandchild BMI, and parental or grandparental prudent diet score and child or grandchild prudent diet score, were run from parent to child (F0–F1 and F1–F2) and from grandparent to grandchild (F0–F2). These analyses compared BMI to BMI and prudent diet score to prudent diet score across generational pairs, in effort to determine whether BMI and prudent diet score track across generations. Next, linear mixed models investigating the influence of parent or grandparent BMI or prudent diet score on F2 BMI and prudent diet score were run to assess relationships between grandparents and grandchildren while accounting for the influence of parents. These models considered both fixed and random effects, and were adjusted for the sex of the participant in each generation. Finally, linear regressions were run to determine whether lifestyle indicators (social class and prudent diet score) of parents and grandparents influenced the BMI of children and grandchildren.

Results are reported as regression coefficients, followed by 95% CIs and p values. Normal variables were summarised using means and SD. Sample sizes vary across models presented in this study as data were assumed to

Table 1 Demographics of F0, F1 and F2 generations

	F0			F1			F2		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Age (years)	145	66.1	2.9	157	55.4	3.9	211	25.2	5.8
BMI (kg/m^2)	145	26.5	3.5	154	25.8	4.5	198	23.7	3.9
Prudent diet score	145	0.2	1.1	143	1.6	1.2	193	1.4	1.6
	N	%		N	%		N	%	
Sex									
Male	76	52.4		40	25.5		105	49.8	
Female	69	47.6		117	74.5		106	50.2	
Social class									
High	83	57.6		98	72.6		104	69.3	
Middle	17	11.8		13	9.6		18	12.0	
Low	44	30.6		24	17.8		28	18.7	

BMI, body mass index.

be missing completely at random, and therefore, all available data were included within models. All analyses were run using the statistical software package STATA V.16.0.

RESULTS

Demographic data for the F0, F1 and F2 generations is displayed in table 1. Questionnaire data were collected for F0 and F1 generation participants in midlife (F0 mean age: 66.1 years; F1 mean age: 55.4 years) and in young adulthood for the F2 generation (F2 mean age: 25.2 years). On average, F2 participants had the lowest BMI measurements (F0: 26.5 kg/m^2; F1: 25.8 kg/m^2; F2: 23.7 kg/m^2) and had higher prudent diet scores than F0 participants (F0: 0.2; F1: 1.6; F2: 1.4).

There were a greater percentage of male participants than female participants in the F0 generation (male: 52.4%; female: 47.6%), but there were more female than male participants in the F1 (male: 25.5%; female: 74.5%) and F2 (male: 49.8%; female: 50.2%) generations. F0 participants reported the highest percentage of low social class (30.6%), while their children, the F1 participants, reported the highest percentage of high social class (72.6%).

Linear regression analyses determined that there are significant associations between individual prudent diet score and social class in the F0 (b=–0.204, 95% CI –0.365 to –0.042, p=0.014), F1 (b=–0.271, 95% CI –0.486 to –0.055, p=0.014) and F2 (b=–0.462, 95% CI –0.771 to–0.153, p=0.004) generations. However, there were no significant associations between prudent diet score and social class across generational pairs.

As presented in table 2, in models by generational pair, patterns of association differ for prudent diet score and BMI. While there are significant positive BMI associations across all three generations, the only prudent diet score relationship is between grandparent and grandchildren prudent diet score (b=0.409, 0.210, 0.607, p<0.001). In this pair, the prudent diet score of a grandparent was significantly positively associated with the diet score of a grandchild, such that a unit increase in grandparental prudent diet score is associated with a 0.409 increase in the prudent diet score of the grandchild.

Multilevel models examining lifestyle associations across three generations reported significant relationships in prudent diet and BMI across family triads. The results of these models, which examine the effect of both F0 and F1 prudent diet scores on F2 diet scores and the effect of both F0 and F1 BMI on F2 BMI, are presented in table 3. Prudent diet results echo those reported in table 2, as F0 and F2 prudent diet scores remain significantly positively associated (b=0.350, 0.121, 0.579, p=0.003). The significant associations between F0 and F2 BMI reported in table 2 are attenuated in table 3 after controlling for F1 (parent) BMI (b=0.239, 0.112, 0.367, p<0.001). In both multilevel models, more estimated variance was explained by the F1 generation (prudent diet variance (SE): 1.511 (0.297); BMI: 4.013 (1.565)) than by the F0 generation (prudent diet: <0.001

Table 2 Linear regressions examining associations between parental prudent diet or BMI and child prudent diet or BMI

	Parent to child											
	F0–F1				F1–F2				F0–F2			
	N	β	95% CI	P value	N	Β	95% CI	P value	N	β	95% CI	P value
Prudent diet	156	0.128	–0.058 to 0.314	0.175	180	0.101	–0.092 to 0.295	0.303	212	0.409	0.210 to 0.607	<0.001
BMI (kg/m^2)	167	0.374	0.180 to 0.568	<0.001	199	0.243	0.123 to 0.362	<0.001	219	0.177	0.039 to 0.316	0.012

Adjusted for age and sex of F0, F1 and F2.
BMI, body mass index.

Table 3 Mlm examining effect of F0 and F1 prudent diet or BMI on F2 prudent diet or BMI

	Prudent diet				BMI (kg/m^2)			
	N	β	95% CI	P value	N	β	95% CI	P value
F0	145	0.350	0.121 to 0.579	0.003	158	0.102	−0.048 to 0.253	0.183
F1	134	0.122	−0.084 to 0.328	0.246	145	0.239	0.112 0.367	<0.001

Adjusted for sex of F0, F1, and F2.
BMI, body mass index.

(<0.001); BMI: <0.001 (<0.001)). The variance at the F0 level is very small.

Table 4 reports results of models examining whether parental or grandparental social class and prudent diet score are determinants of child or grandchild BMI. There are no significant associations between F0 lifestyle indicators and F1 BMI or between F0 and F1 prudent diet score and F2 BMI. There are, however, significant positive relationships between grandparent and parent social class and child BMI. Grandchildren of F0 participants with low social class were more likely to have high BMIs than grandchildren of F0 participants with high social class (low social class: b=1.188, 0.060, 2.315, p=0.039). Similarly, children of F1 participants reporting middle social class had greater BMIs than those children with parents reporting high social class (middle social class: b=2.477, 0.726, 4.227, p=0.006).

DISCUSSION

This study reports that BMI tracks across three generations of the Hertfordshire Intergenerational Study, such that greater parental and grandparental BMI are associated with greater child and grandchild BMI. These results reflect those in previous studies that have examined these relationships between two generations, in which the parent-to-child adiposity associations observed in children were maintained until mid-adulthood,[14] and they build on previous research by extending these associations beyond parents and children to grandparents and grandchildren. While prudent diet score was only significantly positively associated from F0 to F2, significant positive BMI associations were reported in each generational pair model, and generational associations in BMI remained significant in multilevel models.

The significant positive influence of parental and grandparental social class on F2 BMI reported in this cohort echoes studies indicating gene–environment interactions in the transmission of BMI,[13 15–17] and support findings reported by previous studies of parental SES and child BMI in adulthood. Okasha *et al* reported that in the Glasgow Alumni Study, the social class of a father was significantly associated with the BMI of his child,[22] and in a study of three British cohorts, Bann *et al* found inequalities in BMI by childhood social class position, with lower childhood social class being associated with higher adult BMI.[23] In the present study, children and grandchildren of parents and grandparents reporting low or middle social class were more likely to have high BMI measurements than children and grandchildren of parents and grandparents of higher social class. The results presented here add to the literature describing associations between socioeconomic indicators and obesity across generations. These intergenerational BMI and social class results also suggest potential epigenetic explanations for BMI associations

Table 4 Regression analyses examining the influence of parental and grandparental social class and prudent diet score on BMI of F1 and F2 participants

	F1 BMI				F2 BMI			
	N	β	95% CI	P value	N	β	95% CI	P value
F0 associations								
F0 prudent diet score	167	−0.289	−0.963 to 0.384	0.397	219	−0.125	−0.581 to 0.332	0.591
F0 social class								
High	166				218			
Middle		1.023	1.186 to 3.233	0.362		1.557	−0.076 to 3.189	0.061
Low		0.811	0.696 to 2.318	0.289		1.188	0.060 to 2.315	0.039
F1 associations								
F1 prudent diet score					185	−0.076	−0.541 to 0.388	0.746
F1 social class								
High					178			
Middle						2.477	0.726 to 4.227	0.006
Low						−0.468	−1.983 to 1.047	0.543

Adjusted for age and sex of F0, F1 and F2.
BMI, body mass index.

across generations, which may help untangle mechanisms through which genetics and environment act on familial health.[3] Further study into the association between BMI and DNA methylation in this cohort is indicated.

Previous literature has reported that the diets and energy intakes of parents and children are associated.[24] Results presented in this study are more equivocal about the relationship of prudent diet score across generations. This may be due in part to the use of prudent diet score as the diet quality measure, as it is a composite measure of diet using F0 prudent diet components to create prudent diet scores for all three generations. It is possible that this made it difficult to compare prudent diets across generations. The lack of diet associations across generations may also be due to sample stratification. Previously published studies have examined diet quality between two and three generations in samples stratified by sex,[25 26] with intergenerational diet relationships found between grandmothers, mothers, and daughters. While sample size restrictions limited sample stratification in the present study, future research should extend this work in larger cohorts.

The significant association of individual prudent diet score and social class for the F0 and F1 generations further indicates that social class may influence dietary patterns. However, as there were no significant associations between prudent diet score and social class across generations in the HCS, the intergenerational relationship between dietary patterning and social class is an avenue for future research.

It is also possible that food purchasing behaviours, food consumption and foods available have changed substantively between the generations examined here,[27] making it difficult to parse out relationships. Future research into the associations between parental social class and child BMI and prudent diet scores as more modern cohorts age is indicated.

STRENGTHS AND LIMITATIONS

The results reported here are strengthened by the use of data from a large intergenerational cohort study containing information from families originating from one county in the UK. As the grandparents in this study were all born in the same local area around the same time, it is likely they began life eating similar foods, therefore making them an important cohort for the study of diet and its consistency and implications over time. Additionally, the study benefits from having detailed socioeconomic, health and social class information from across three generations, rather than two, which is much more common.

Conversely, a limitation faced by this study is the differences in the ages at which data was collected across the generations. Analyses of the influence of grandparental and parental social class on the diet and BMI of F2 generation participants may have been restricted by the fact that the F2 data were collected at a different stage of life than the data available for the F0 and F1 participants. Additionally, there was limited data on socioeconomic status: no income information was collected, and in the F0 generation, educational attainment was reported as the age at which the participant left education, not as qualifications obtained, as it is for the F1 and F2 generations, meaning that NSSEC was the only comparable SES variable available. Future studies would benefit from the use of educational attainment and income as additional social class indicators.

Previously published work using HCS data has determined that the baseline HCS cohort was similar to participants in the Health Survey for England participants in 1996 and 1998,[1] which suggests that the HCS was nationally representative at baseline. While it is likely that healthy responder bias is present in the HCS, which may have influenced which intergenerational participants agreed to return a postal questionnaire, this bias is unlikely to have impacted the BMI and prudent diet scores reported here.

CONCLUSIONS

This study reports that grandparent, parent and child BMI is associated across three generations of the HCS, and that grandparent and parent social class is significantly associated with child BMI. These results add to literature supporting the involvement of behavioural and social factors in the transmission of BMI across generations. Differential social inequalities over the lifecourse and changes in diet quality over generations may be explanations for why significant associations were present between parental and grandparental social class in the youngest generation, but absent in the middle generation. Further research is needed to examine the relationship between social class and BMI and diet across generations in more recent cohorts.

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Data availability statement Data are available on reasonable request. Access to Hertfordshire Intergenerational Study data is controlled by the cohort steering committee. Enquiries regarding data access may be made using the contact tab on the cohort website: https://www.mrc.soton.ac.uk/herts.

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