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Educational inequality in the dietary approach to stop hypertension (DASH) diet in the UK: evaluating the mediating role of income

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Abstract

Apparent differences in the adoption of the Dietary Approach to Stop Hypertension (DASH) diet have been reported between less and more educated individuals. However, the mediating role of income has not been clarified. In this study, we aimed at quantifying the mediating effect of income on the relationship between education and the DASH score in the UK population. We analyzed data on 4864 subjects aged 18 years and older collected in three waves of the National Diet and Nutrition Survey (NDNS 2008-2016). The DASH score was calculated using sex-specific quintiles of DASH items. We carried out a counterfactual-based mediation analysis to decompose the total effect of education on DASH score into average direct effect (ADE) and average causal mediation effect (ACME) mediated by income. We found that the overall mediating effect of income on the relationship between education and the DASH score was only partial, with an estimated proportion mediated ranging between 6 to 9%. The mediating effect was higher among females (11.6%) and younger people (17.9%). Further research is needed to investigate which other factors may explain the socioeconomic inequality in the adoption of the DASH diet in UK.

Keywords: Dietary Approaches to Stop Hypertension, Diet quality, Socioeconomic inequalities, NDNS, Mediation analysis

Introduction

Cardiovascular disease (CVD) is the leading cause of mortality in the western societies. The UK is among the countries with the highest incidence of CVD in western Europe accounting for one in four premature deaths[1; 2] The role of socioeconomic position (SEP) on CVD has been recognized for a long time [3; 4]. Recent trends in the UK show that despite the overall decreasing CVD mortality rates, more favourable trends amongst the highest socioeconomic groups have widened relative inequality [5].

Diet is a key modifiable risk factor for CVD and is among the contributing factors to socioeconomic inequalities in CVD morbidity and mortality [1; 6]. A poorer diet has long been reported in low SEP individuals, consequently, improving the diet of people of low SEP is of utmost importance to reduce their burden of disease [7; 8; 9].

Compliance to the dietary approach to stop hypertension (DASH) has been proved effective in lowering blood pressure in patients with CVD as well as to prevent risk factors for CVD in the general population [10; 11; 12]. The DASH diet is high in fruits and vegetables, moderate in low-fat dairy products and low in animal protein but with a substantial amount of plant protein from legumes and nuts [13].

In previous work, using the same data, we showed that adherence to the DASH diet steadily falls with lowering levels of education and income [14]. Dietary costs are a constraint for healthy eating among people of low SEP [15; 16; 17] and the income-diet relationship is mediated by dietary cost and access to food [17; 18; 19]. However, the causal pathway between education and dietary choices has not been fully explained, and the role of income in dietary choices has not been clarified. In this study, we aimed to quantify the mediating effect of income on the relationship between education and the DASH score in the UK population.

Experimental methods

Data Source

In this analysis, we grouped three waves (2008-2012, 2013-2014, 2015-2016) of the UK National Diet and Nutrition Survey (NDNS). The NDNS is an annual ongoing cross-sectional survey carried out on behalf of Public Health England and the Food Standards Agency. It is designed to assess the diet, nutrient intake and nutritional status of a representative sample of UK adults and children. Households were randomly sampled from the U.K. Postcode Address File, with one adult and one child (18 months or older) or one child selected for inclusion. We included all subjects aged 18 years and older at the time of interview with available data on dietary records, education and income. We excluded subjects with total daily energy intakes below 500 kcal or above 5000 kcal per day as they are likely outliers [20]. Sociodemographic data, lifestyle behaviours, dietary habits, use of medications and dietary supplements were collected during a computer-assisted personal interview. Written informed consent was obtained from participants or their parents/guardians. The survey was conducted according to the Declaration of Helsinki guidelines. Ethical approval for the NDNS was obtained from the Oxfordshire A Research Ethics Committee and the Cambridge South NRES Committee (Ref. No. 13/EE/0016) [21; 22].

Dietary Records

Respondents were asked to complete a dietary record for four chosen consecutive days (including weekends and weekdays), giving a detailed description of each item consumed, the time of consumption and amount, using household measures and photographs. Participants recorded brand names for foods wherever possible and were asked to collect the food label information/wrappers for any unusual foods and ready meals consumed to help coders identify or clarify items. For homemade dishes participants were asked to record on a separate page in the diary the individual ingredients and quantities for the whole dish along with a brief description of the cooking method and how much of the dish the participant had consumed. Information on missing food items was collected on repeat visits by interviewers. Trained diet coders then entered the food intake data from completed recordings using an in-house dietary assessment system DINO (Diet In Nutrients Out). The food composition data used was the Department of Health's NDNS Nutrient Databank. Coders attempted to match each food or drink item with a food code and a portion code from DINO. Where the coder could not resolve the food or portion consumed, the entry was flagged as a query for action by an editor who had greater nutrition knowledge and experience. For a random 10% of all diaries the editors also undertook a further 100% check of all food and portion code entries [21; 22].

Outcomes

The primary outcome of the study was the DASH score, while average daily intakes of fruit and vegetables were considered as secondary outcomes. The DASH score was computed according to the method described in Fung et al., where points (from 1 to 5) were assigned based on sex-specific quintiles of intake in order of most consumption for fruit; vegetables (excluding potatoes); whole grains; low-fat dairy products; nuts, seeds and legumes [(13)]. Quintiles for red and processed meats, free sugar and sodium were assigned 1-5 points in order of least consumption. According to this algorithm the overall DASH score ranged between 8 (lowest compliance) and 40 points (highest compliance) [(13)]. To compute the DASH score, we retrieved variables from the NDNS food and nutrient database, which included nutrient and granular food level information for each subject. Using disaggregated foods from the database, we derived the intakes of whole grains, low fat dairy products, nuts, seeds and legumes as well red and processed meats. Collectively, this information was then used to compute the DASH score.

Exposure variable

The highest level of attained education was the exposure of this study. We reclassified the eight original categories for the highest educational qualification into the following four categories: Degree or equivalent [1], Higher educational, below degree level [2], General Certificate of Secondary Education (GCSE) [3-5] and No qualification [7]. The original categories 3 to 5 were merged in the same category (GCSE) since these categories correspond to academic school-leaving qualifications typically completed between 16-18 years or vocational courses of equivalent level. We excluded: "foreign or other qualifications" [6] since this category included individuals with different levels of education, full-time students [8] (i.e. they had not completed their education program), and individuals with missing values.

Mediator

Total disposable household income includes income contributions from earnings, state support, pensions and investment income over the previous 12 months and is net of tax. It was equivalised to adjust for the presence of other adults and children in the household, in order to allow comparisons across households of different size and composition [(23)]. Each household member was given a standard weight (0.67 for the first adult, 0.33 for other adults, 0.20 for each additional child aged less than 14 years and 0.33 for each additional child aged 14 and over) [(23)]. Then, household income was divided by the sum of the standard weights. Equivalised household income below or above £ 304 per week over the previous 12 months (i.e. 15,850 £ per year) was considered as a mediator of the relationship between education and adherence to the DASH diet.

Statistical Analysis

We compared sociodemographic characteristics and outcome measures across educational levels using χ^2 test for categorical variables or Wilcoxon rank sum test for continuous variables. When the overall tests gave significant results, we compared the highest level of education with each other level applying the Bonferroni correction for multiple comparisons (i.e. the differences between groups were considered significant at α = 0.017, 0.05/3 comparisons). We carried out a counterfactual-based mediation analysis to decompose the total effect of education on DASH score into average direct effect (ADE) and average causal mediation effect (ACME) mediated by income [24]. **Figure 1** shows the causal relationship hypothesized in the mediation analysis. We performed the mediation analysis also on the secondary outcomes (i.e., fruit and vegetables intake).

The ADE represents the expected difference in the potential value of DASH score when the level of education is changed but income is held constant at the value that would take if education equals the exposed category. The ACME represents the expected difference in the potential value of DASH score when income takes the value that would take under the exposed education category as opposed to the reference category, while education is held constant. The two quantities add up to the estimated total effect of education on DASH score. The proportion of total effect mediated by income was also computed as the ratio between ACME and total effect. Confidence intervals (CI) at 95% level were obtained by bootstrap with 1000 replications.
The estimate of these quantities requires a system of equations with two different regression models: a model for the outcome and a model for the mediator. For the primary outcome, we used a linear regression, while for the secondary outcomes we modeled the median values using quantile regression models to account for the skewed distribution of fruit and vegetable intakes. For the mediator, we fitted a binomial regression model with probit link function. The model for the mediator included terms for education, sex, age (as linear and quadratic term to account for nonlinear relationship between age and income or DASH score), ethnic group (white or others) and area of residence as dependent variables, while the model for the outcome included the same set of predictors plus income.

We also tested the interaction between income and education, and since it did not yield statistically significant results, we did not include it in the models. In addition, we tested if the magnitude of ACME differed among sexes, age-groups (individuals aged less than 65 years *vs* 65 and over) and areas of residence by performing a moderated mediation analysis. To perform the moderated mediation analysis, we fit the mediator and the outcome models including the moderator and its interaction terms with respect to education and income. To run the mediation analysis, we used the R package "mediation", and to test the difference between the mediation effects among moderator strata, we used the "test.modmed" function [25]. All tests were two-sided with a threshold for significance set at 0.05.

Results

Table 1 shows the distribution of sociodemographic characteristics of the study population by educational level. We included 4864 subjects (2055 males and 2809 females). Graduated compared to not qualified individuals were younger (median age: 43 vs 63 years), more likely non-whites (12.7% *vs* 3.2%) and had a higher household income (median income: 41.100 *vs* 17.500 ₤ per year).

Table 2 shows the mean values of DASH score and the median values of fruit and vegetable intake across the educational levels. The mean values of DASH score were 25.6 in the group of graduated individuals, 23.6 in those with a high education below the degree, and around 23 in the lower education levels. Fruit and vegetables consumption increased with increasing of education levels.

The regression models used for the mediation analysis are reported in the **Supplements**, **Table S1**. Education was directly related to income and it was also directly related to DASH score, fruit and vegetables intakes, after controlling for income. Income, in turn, was also directly associated with higher values of the DASH score, fruit and vegetable intakes.

Table 3 gives the results of the mediation analysis. Being in the "higher education below degree level", GCSE level and "no qualification" categories showed average differences in DASH score (i.e., total effect) of -1.81 (95% CI: -2.21 to -1.45), -2.81 (95% CI: -3.20 to -2.34) and -3.58 (95% CI: -4.03 to -3.16), respectively, as compared to "degree or equivalent". The proportion of these differences mediated by income were 6.1%, 8.3% and 8.8%, respectively. Similar patterns, though with greater proportion mediated, emerged for total fruit and vegetables intake. The proportion mediated on total fruit intake was 6.5% for "higher education below degree level", 9.6% for GCSE level, and 9.2% for "no qualification". Corresponding figures for total vegetable intake were 7.4% for "higher education below degree level", 10.8% for GCSE level, and 10.5% for "no qualification".

Figure 2 shows the results of the moderation analysis of the mediated effect of income on the relationship between education and adherence on DASH score, according to sex, age and area of residence. The mediating effect were significantly different among strata of sex and age group (*P*= 0.042 and *P*= 0.018, respectively). The proportions mediated were greater for females (11.6%) compared to males (5.4%), and for individuals aged below 65 years (17.9%) compared to older ones (6.3%). A greater mediating effect was observed in Scotland and Northern Ireland as compared to England, however the differences were not significant (*P*= 0.42 and *P*= 0.11, respectively).

Discussion

In our study, we found that the mediating effect of income on the relationship between education and the DASH score was small, with an estimated proportion mediated ranging between 6 to 9%.

Our findings are in line with a recent study which reported that dietary cost explained between 2- 7% of the association between educational level and diet quality measures [26]. This data suggests that other unmeasured factors are in place in determining socioeconomic inequalities in a healthy diet, such as one's ability to use dietary knowledge and attitudes to achieve better diet quality within a given food budget [7; 19]. There is additional supporting evidence indicating that high SEP is associated with nutrition and health literacy and other psychosocial resources which may explain the low mediating effect we found in our study [7; 19]. The education-diet relationship is mediated by knowledge about food and attitudes towards healthy eating which in turn affect behavior and make the individual more receptive to health education measures [27; 28]. Interestingly, people of low SEP are less able to make decisions that favour long-term health benefits [7]. People living in lower socio-economic groups already have difficult trade-offs to make about household expenditure which in turn, makes healthy food choices more difficult [29]. Moreover, in the UK as well as in other high-income countries, the amount of money spent by people on food as a proportion of their overall income is relatively low, though it is higher amongst poor households [30].

Previous studies investigating the extent of mediating factors such as availability and accessibility found substantively different results across various contexts (i.e. 4-76%). In addition, none of these evaluations have accommodated the possibility that the mediated effect of affordability, availability and accessibility may require the joint operation of exposure and mediator [31; 32]. Acceptability of foods for example, may also explain the observed sex differences seen in dietary quality in our results as well as in previous research [33]. In our study, women had a higher DASH score and the mediated effect of income was greater in females than in males. This is likely the consequence of the different attitudes of women towards healthy food choices. In fact, females tend to express greater health concerns, are more motivated to control their weight, spend more on healthier food and more likely to be responsible for meal preparation [34; 35]. Conversely, a male's diet may reflect his spouse's/partners food choices more than his own preferences [36]. However, this difference could also reflect a more accurate completion of dietary reports among women who are more likely involved in the preparation of meals [37].

When looking at age differences, the mediating effect of income was higher amongst young people in comparison to older people. Previous studies have shown that healthy eating and also knowledge on nutrient recommendations increases with age [38; 39; 40]. For younger people identity is inextricably linked with health behaviors and additional knowledge may not necessarily have an impact on dietary choices made [38]. Other factors that may contribute to the higher mediating effect within younger adults include a lack of motivation and apathy to eat healthily (particularly in males), the preference for unhealthy food, emotional responses to eating, a lack of the skills to plan for, shop, prepare and cook healthy foods [41]. Some researchers have also suggested that young people may not possess the cognitive maturity or development to rationally attribute their current dietary choices/behaviour [40; 42]. In addition, other studies suggest that SEP indicators such as income and education may have different interactions and impact across the life course. For example, education is achieved during early adulthood, whereas income and occupational position describe SEP during later adulthood [28]. For younger adults, the association with education may also be related to the parents' nutrition education or perhaps to their knowledge of health and chronic diseases [38 ; 40; 42].

A recent population-based study in the UK demonstrated that the likelihood of consuming a DASH-style diet was dependent on economic factors and geographical location [17]. Within the UK, geographical differences have been shown to affect differing foods changes. Our results also suggest that in Scotland and Northern Ireland income has a greater mediating effect than in England. Although the precision of estimates is low and no firm conclusions can be made, our findings, like previous literature, suggest that race, tradition and perceived acceptability of energy-dense foods celebrated and marketed as part of culture heritage also influence food choice [39; 41] .

The study has also some limitations. Firstly, we cannot rule out that unmeasured confounders such as early life socioeconomic conditions which may have affected income and eating behaviours independently from individual education [43]. Children born in low socioeconomic conditions are likely to have fewer opportunities both within their education and within their career. In addition, they are more likely to emulate the unhealthy eating behaviours which they may have been exposed to in their homes and communities [7]. Secondly, as in most nationwide population surveys, the most deprived groups may be under-represented (i.e. homeless, unemployed or migrants not speaking English) as they are less likely to participate in the survey [44]. However, measures were taken by the NDNS team to reduce the effect of potential non-response bias [21; 22]. Finally, food diaries are self-reported and are then subject to recall bias and misreporting [20].

This study has also important strengths. Firstly, this is the first study to explore the mediating effect of income on the relationship between education and the DASH score in the UK. Secondly, the analysis was based on the NDNS data, a high quality, representative, up-to-date UK data source. Finally, food and nutrient data were gathered from a self-reported four-day diary, which measures actual intake and is less prone to recall bias than food frequency questionnaires, commonly used in epidemiological studies.

In conclusion, within the UK population, the association between education and DASH diet is only by a minor part mediated by income. Further research is needed to investigate which other factors may explain the socioeconomic inequality in the adoption of the DASH diet.

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Conflicts of interest: None

Authors' Contributions: Gianfranco Alicandro conceptualised the study, Paola Bertuccio, Gianfranco Alicandro and Linia Patel designed the study, Gianfranco Alicandro and Paola Bertuccio performed the data analysis, Linia Patel, Gianfranco Alicandro and Paola Bertuccio wrote the original draft and all authors reviewed and edited drafts. Carlo La Vecchia was responsible for overall supervision. All authors read and approved the final manuscript.

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Figure legends

Figure 1. Directed acyclic graph showing the relationship between education and adherence to the dietary approach to stop hypertension (DASH). Arrow A displays the average direct effect (ADE) of education on adherence to DASH, while path B + C displays the average causal mediation effect (ACME) mediated by low income. The sum of ADE and ACME gives the total effect. The last three arrows display the confounding variables.

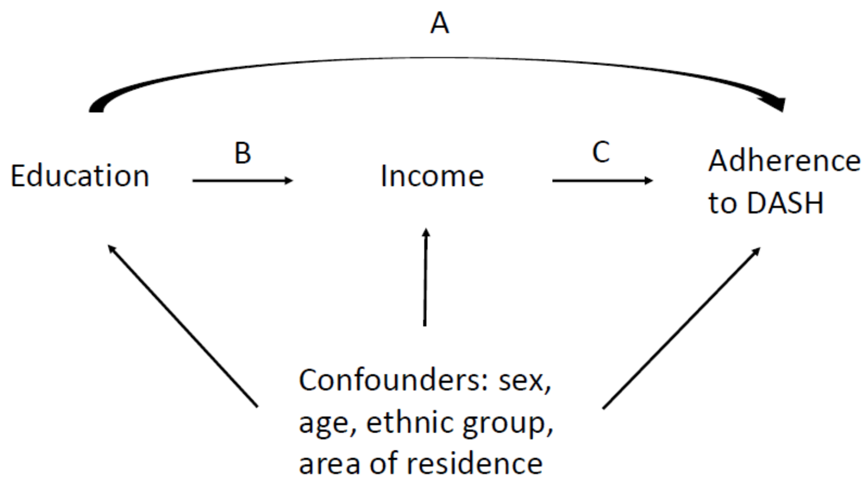

Figure 2. Moderated mediation effect of income on the relationship between education and DASH score by sex, age, and region of residence. The figure shows the total effect of education on DASH score, the average direct effect (ADE), the average causal mediation effect (ACME) and the proportion mediated (%) by income in strata of sex, age and region of residence.

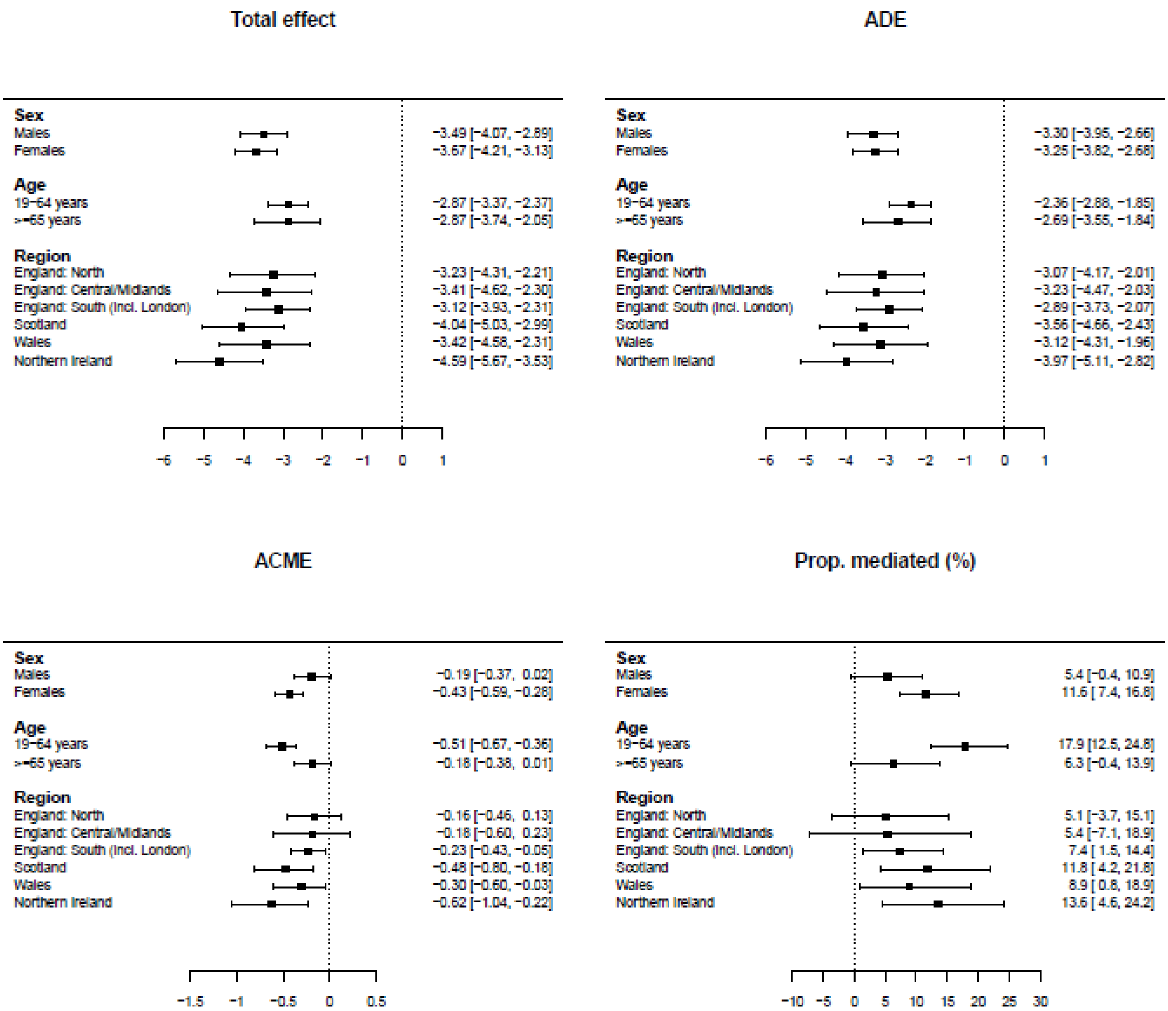

Table 1. Sociodemographic characteristics of the study population by educational level.

	Degree or equivalent N = 1295	Higher education, below degree level N = 1334	GCSE N = 1094	No qualification N = 1141	All levels N = 4864	*P* value [a]
Sex						0.78
Males	536 (41.4)	566 (42.4)	458 (41.9)	495 (43.4)	2055 (42.2)	
Females	759 (58.6)	768 (57.6)	636 (58.1)	646 (56.6)	2809 (57.8)	
Age						
Median (IQR)	43 (34-55)	45 (34-56)	46 (36-58)	63 (49-73)	48 (36-62)	<0.001[c,d]
Ethnic group						<0.001[b,c,d]
White	1129 (87.3)	1265 (95.0)	1047 (95.9)	1105 (96.8)	4546 (93.5)	
Other	164 (12.7)	67 (5.0)	45 (4.1)	36 (3.2)	312 (6.4)	
Area of residence						
England: North	213 (16.4)	221 (16.6)	212 (19.4)	185 (16.2)	831 (17.1)	<0.001[b,c,d]
England: Central/Midlands	170 (13.1)	165 (12.4)	130 (11.9)	129 (11.3)	594 (12.2)	
England: South (incl. London)	444 (34.3)	375 (28.1)	311 (28.4)	230 (20.2)	1360 (28.0)	
Scotland	188 (14.5)	237 (17.8)	147 (13.4)	195 (17.1)	767 (15.8)	
Wales	137 (10.6)	177 (13.3)	161 (14.7)	194 (17.0)	669 (13.8)	
Northern Ireland	143 (11.0)	159 (11.9)	133 (12.2)	208 (18.2)	643 (13.2)	
Income (£ per year, thousands)						
Median (IQR)	41.1 (27.5-61.6)	28.7 (17.5-40.6)	22.2 (12.9-32.5)	17.5 (12.3-28.7)	27.5 (16.4-42.5)	<0.001[b,c,d]
Low (< 15.85)	109 (8.4)	254 (19.0)	337 (30.8)	443 (38.8)	1143 (23.5)	
High (≥ 15.85)	1186 (91.6)	1080 (81.0)	757 (69.2)	698 (61.2)	3721 (76.5)	

[a] Chi-squared test for categorical variables; Wilcoxon rank sum test for continuous variables.
[b,c,d] denote the significant results of the comparisons across levels of education after applying the Bonferroni correction for multiple comparisons: b) "Higher education, below degree level" significantly differs from "Degree or equivalent" c) GCSE significantly differs from "Degree or equivalent", d) "No qualification" significantly differs from "Degree or equivalent".
GCSE: General Certificate of Secondary Education; IQR: Interquartile Range.

Table 2. DASH score, fruit and vegetable consumption according to educational level.

	Degree or equivalent	Higher education, below degree level	GCSE	No qualification	*P* value [a]
DASH score, mean (SD)	25.6 (5.2)	23.6 (5.4)	22.8 (5.8)	23.2 (5.2)	<0.001[b,c,d]
Fruit (g), median (IQR)	110 (45-184)	75 (20-148)	54 (5-134)	50 (4-120)	<0.001[b,c,d]
Vegetables (g), median (IQR)	197 (138-269)	161 (106-229)	147 (94-214)	134 (85-195)	<0.001[b,c,d]

[a] Wilcoxon rank sum test for continuous variables.
[b,c,d] denote the significant results of the comparisons across levels of education after applying the Bonferroni correction for multiple comparisons: b) "Higher education, below degree level" significantly differs from "Degree or equivalent" c) GCSE significantly differs from "Degree or equivalent", d) "No qualification" significantly differs from "Degree or equivalent".
DASH: Dietary approach to stop hypertension; GCSE: General Certificate of Secondary Education; IQR: Interquartile Range; SD: Standard Deviation.

Table 3. Decomposition of the total effect of education on adherence to DASH diet, fruit and vegetable consumption into direct and indirect effect mediated through income and corresponding 95% confidence intervals. Reference category: degree or equivalent.

	Higher education, below degree level	GCSE	No qualification
DASH score			
ACME	-0.11 (-0.16; -0.07)	-0.23 (-0.32; -0.14)	-0.31 (-0.45; -0.21)
ADE	-1.70 (-2.10; -1.33)	-2.58 (-2.98; -2.09)	-3.27 (-3.72; -2.83)
Total effect	-1.81 (-2.21; -1.45)	-2.81 (-3.20; -2.34)	-3.58 (-4.03; -3.16)
Proportion mediated	6.1 (3.6; 9.0)	8.3 (5.0; 12.0)	8.8 (5.6; 13.0)
Total fruit			
ACME	-2.2 (-3.4; -1.5)	-4.9 (-6.7; -3.6)	-6.9 (-9.7; -5.1)
ADE	-31.1 (-38.9; -20.8)	-46.6 (-54.3; -35.2)	-68.0 (-75.8; -56.0)
Total effect	-33.3 (-41.4; -23.2)	-51.6 (-59.3; -40.2)	-74.9 (-82.3; -64.1)
Proportion mediated	6.5 (4.5; 12.0)	9.6 (6.8; 14.0)	9.2 (6.7; 14.0)
Total vegetables			
ACME	-2.5 (-3.8; -1.4)	-5.0 (-6.7; -3.3)	-6.8 (-9.3; -4.6)
ADE	-31.0 (-39.2; -22.3)	-40.8 (-50.1; -32.8)	-57.8 (-67.2; -48.7)
Total effect	-33.5 (-41.5; -24.7)	-45.8 (-55.1; -37.5)	-64.6 (-74.6; -55.2)
Proportion mediated	7.4 (4.1; 11.0)	10.8 (6.9; 15.0)	10.5 (7.1; 15.0)

ACME: Average causal mediation effect; ADE: Average direct effect; DASH: Dietary approach to stop hypertension; GCSE: General Certificate of Secondary Education.