Chapter 2.4.1 Does the importance of dietary costs for fruit and vegetable intake vary by socioeconomic position?

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Based on ‘Mackenbach et al. Does the importance of dietary costs for fruit and vegetable intake vary by socioeconomic position? British Journal of Nutrition 2015, 114: 1464-1470’.

Abstract

Evidence suggests that diets meeting recommendations for fruit and vegetable (F&V) intake are more costly. Dietary costs may be a greater constraint on the diet quality of people of lower socioeconomic position (SEP). The aim of this study was to examine whether dietary costs are more strongly associated with F&V intake in lower-SEP groups than in higher-SEP groups. Data on individual participants’ education and income was available from a population based, cross-sectional study of 10,020 British adults. F&V intake and dietary costs (GBP/day) were derived from a semi-quantitative Food Frequency Questionnaire. Dietary cost estimates were based on UK food prices. General linear models were used to assess associations between SEP, quartiles of dietary costs, and F&V intake. Effect modification of SEP gradients by dietary costs was examined with interaction terms. Analysis demonstrated that individuals with lowest quartile dietary costs, low income and low education consumed less F&V than individuals with higher dietary costs, high income or education. Significant interaction between SEP and dietary costs indicated that the association between dietary costs and F&V intake was stronger for less-educated and lower income groups. That is, socioeconomic differences in F&V intake were magnified among individuals who consumed lowest-cost diets. Such amplification of socioeconomic inequalities in diet among those consuming low-cost diets indicates the need to address food costs in strategies to promote healthy diets. Additionally, the absence of socioeconomic inequalities for individuals with high dietary costs suggests that high dietary costs can compensate for lack of other material, or psychosocial resources.
Introduction

Consumption of a healthy diet is a priority for reducing obesity and its associated chronic diseases.[1] People who do not meet dietary guidelines such as for fruit and vegetable (F&V) intake, are at increased risk of cardiovascular disease[2] and all-cause mortality.[3] However, a study in a representative sample of UK adults showed that diets meeting fruit and vegetable recommendations were more costly.[4] This is concordant with a line of research in the US showing that adherence to a healthy diet (lower energy-density, higher intake of vitamins, potassium and dietary fiber) is more costly than adherence to a less healthy diet (e.g. [5–7]).

Economic factors such as food price, cost of healthy diets, personal or household income or the amount of money available to purchase food may be important for dietary quality.[5,6,8–12] Studies have shown that constraining food budgets can lower the nutritional adequacy of the diet[13,14] and that economic uncertainty may adversely affect people’s food choices.[15] Dietary costs may therefore be a barrier for the uptake and maintenance of healthy diets.[16,17]

Dietary costs as a constraint on diet quality could be especially crucial for less-educated groups, who tend to prioritise low-cost in food choices[18] and may lack other resources that motivate healthy eating.[19–24] Socioeconomic disparities in health and nutrition are well documented.[25–31] There is some evidence suggesting that dietary costs are in the causal pathway between socioeconomic position (SEP) and diet.[8,9,30,31] On the other hand, one study reported that the association between income, diet cost and diet quality was stronger in less-educated individuals than in more-educated individuals.[9] This suggests that SEP can act as a moderator in the relation between dietary cost and diet. Yet, it remains to be evaluated whether dietary costs are equally important for diet quality across socioeconomic groups.

In a UK population-based cross-sectional study with data on socioeconomic position (defined as education and income), individual dietary costs and diet quality, we sought to describe whether the association between dietary costs and fruit and vegetable (F&V) intake varied across socioeconomic groups. We hypothesised that SEP, dietary costs and F&V intake would be interrelated, and more specifically, that dietary costs would be more strongly associated with F&V intake for people of low SEP than people of high SEP.

Methods

Study sample

The Fenland Study is a population-based cohort study of adults born between 1950 and 1975 and registered with general practices in Cambridgeshire, UK, conducted by the Medical Research Council Epidemiology Unit.[32] The study aimed to include at least 10,000 adults. Recruitment started in 2005 and included attendance to one of three clinical sites in Cambridgeshire for a highly detailed in-person assessment with numerous anthropometric, biological and clinical measurements. At the time of the present analysis, complete data from 10,452 participants were available (collected between 2005 and 2013). Exclusion criteria of the Fenland Study included pregnancy, previously diagnosed diabetes, inability to walk unaided, psychosis, or terminal illness. We excluded participants with extreme values
for energy intake based on sex-specific cut-offs suggested by Willett.[33] Additionally, we excluded participants with no data on energy intake. This resulted in an analytic sample of 9,911 participants.

Ethical approvals
The study was approved by the NRES Committee – East of England Cambridge Central and performed in accordance with the Declaration of Helsinki. All participants provided written informed consent to participate in the study.

Demographics and socioeconomic position
Self-reported data on gender, age and household size (for analysis with income as SEP) were obtained from the Fenland questionnaire. For each participant, self-reported highest educational qualification and annual household income were used as indicators of SEP. Education was measured in four categories: ‘no qualifications’, ‘compulsory education’ (O-levels or GSCEs), ‘further education’ (A-levels and vocational equivalents) and ‘higher education’ (degree level). Educational attainment was stratified into ‘11 years of education or less’ (included no qualifications and general certificate of secondary education), ‘12-13 years of education’ (A-levels) and ‘13+ years of education’ (included university degree or equivalent and beyond). Household income was measured in three strata: <£20,000, £20,000–40,000 and ≥£40,000 per year. Participants self-reported smoking status as ‘current’, ‘former’ or ‘never’.

Dietary assessment
Participants recorded the frequency and portions of consumption of foods and beverages by completing a 130-item, semi-quantitative food frequency questionnaire (FFQ) to assess habitual consumption of food. This FFQ has been used in the UK EPIC studies and has been shown to generate reproducible and valid food intake assessments.[34] Nutrition composition analyses of dietary intake data yielded grams of daily intake of fruit and vegetables, which we used as primary outcome variables. Fruit included 11 items from the FFQ including fresh, dried and tinned varieties, but excluded fruit juice. Vegetables included 26 items from the FFQ including fresh, frozen and tinned varieties, but not potatoes. A variable on alcohol intake was derived based on 4 items in the FFQ. Participants reported on their weekly intake of units ‘wine’, ‘beer, lager or cider’, ‘port, sherry, vermouth, liquors’ and ‘spirits’. Weekly unit intake was transformed into grams of alcohol intake per day (1 unit = 8 grams ethanol).

Dietary costs
We used established techniques to derive the monetary costs of diets.[35,36] Individual dietary costs (the monetary value attached to consumed diets) were estimated by merging a food price variable with the FFQ nutrient composition database.[35] Retail prices for each of the foods in the FFQ were obtained in June 2012 from five key supermarket chains using MySupermarket.com, a website for comparing supermarket food prices nationwide in the UK. These five nationwide retailers (Tesco, Sainsbury’s, Asda, Waitrose and Ocado) together had a 68% market share in 2012.[37] The lowest, non-promotion price from the five retailers was selected. For packaged goods including most fresh produce, the medium package size was typically selected. Prices were adjusted for preparation and waste[36] to yield an adjusted food price for each 100 grams edible portion.[38] Combining this new variable with the Fenland food and nutrient database allowed the derivation of the monetary value of
each participant’s diet. The variable obtained for each respondent was dietary costs per day (£/day – crude diet cost). Three dietary cost variables were used for analysis: 1) crude dietary cost, 2) dietary cost per 8.4 mega Joules (MJ) and 3) energy-adjusted dietary costs. The dietary cost per 8.4 MJ (2000 kcal) reflects a daily energy ration for many adults and has been used widely in the literature (e.g.[13,39,40]). The energy-adjusted dietary costs variable was created by energy-adjusting daily (crude) diet costs on the method of residuals and then categorised into quartiles,[41] a standard energy adjustment and stratification technique in epidemiological studies.[35]

Analytical approach
First, general linear model (GLM) analysis was applied to describe the socioeconomic gradient in combined F&V intake and dietary costs as continuous variables, using both education and income as socioeconomic predictors. The addition of covariates into the models was theoretically informed a priori and included: age, gender, energy intake (for analysis with crude dietary costs as outcome) and household size (for analysis with income as socioeconomic indicator). Smoking and alcohol intake variables were tested as additional confounders but were left out of the models as they did not change the coefficients by more than 10%. Both daily (crude) dietary costs and dietary cost per 8.4 MJ were examined as dependent variables. Second, we examined dietary costs as an independent variable by stratifying energy-adjusted dietary costs into quartiles and presenting participant characteristics across quartiles. Quartiles were based on the entire sample, so all quartiles of dietary costs were equal. Finally, we examined the joint associations between combined F&V intake by (energy adjusted) dietary cost quartiles and SEP. A cross product term of dietary cost quartiles and SEP was added to the adjusted model to test for effect modification by SEP. As sensitivity analysis, we additionally adjusted the models with interactions between dietary cost quartiles and education for income, and the models with interactions between dietary cost quartiles and income for education.

Given the low prevalence of missing data we conducted complete case analysis. A two-sided alpha level of 0.05 was used to test for statistical significance. All analyses were conducted using IBM SPSS Statistics 22.0.

Results
Mean age (SD) of the participants was 47.8 years (7.4) and 46.1% were men. Half of the sample had household incomes over £40,000 per year and 14% had household income less than £20,000 per year. Nearly one-third of the sample had a university degree or higher and 45% had further education. Women reported lower calorie intake than men (7.7 MJ/day versus 8.8 MJ/day), but a higher intake of F&V (585 grams/day versus 474 grams/day) than men. The average estimated dietary costs were £4.26 per day and £4.46 per 8.4 MJ.

Table 2.4.1.1 shows the mean fruit and vegetable intake (grams/day) by demographic strata. Adjusted for sex, F&V intake and dietary costs both increased with age. Adjusted for age, women reported eating more F&V. Relative to people with highest educational attainment, those with lowest level of education had a 10% lower mean F&V intake after adjustment for sex and age (501 vs. 553 grams for
lowest and highest education, respectively). Similarly, relative to people with highest incomes, those with lowest incomes had a 6% lower mean F&V intake after adjustment for sex and age (511 vs. 545 grams). These trends were all statistically significant.

Both income and educational attainment were positively associated with higher mean dietary costs per day and higher mean dietary costs per 8.4 MJ. Whereas education was more strongly related to F&V intake, income was more strongly related to diet cost. The difference in daily dietary costs between those with lowest versus highest incomes was approximately 7%, while the difference between those with lowest versus highest educational attainment was approximately 3%. Results for dietary costs per 8.4 MJ were similar, with a 9% difference by income and 3% difference by education.
Table 2.4.1.1. Mean daily fruit and vegetable intake and dietary costs by demographic and socio-demographic strata among UK adults – The Fenland Study

<table>
<thead>
<tr>
<th></th>
<th>Mean F&amp;V intake (grams per day, 95%CI)</th>
<th>Mean diet cost (£ per day, 95%CI)</th>
<th>Mean diet cost (£ per 8.4 MJ, 95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9,911</td>
<td>528 (522, 533)</td>
<td>4.22 (4.20, 4.25)</td>
</tr>
<tr>
<td>Age-Group**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29-39</td>
<td>1,427</td>
<td>498 (483, 512)</td>
<td>4.14 (4.08, 4.21)</td>
</tr>
<tr>
<td>40-49</td>
<td>3,932</td>
<td>510 (502, 519)</td>
<td>4.21 (4.17, 4.25)</td>
</tr>
<tr>
<td>50-59</td>
<td>4,003</td>
<td>541 (532, 549)</td>
<td>4.26 (4.22, 4.30)</td>
</tr>
<tr>
<td>≥60</td>
<td>549</td>
<td>557 (534, 581)</td>
<td>4.28 (4.18, 4.39)</td>
</tr>
<tr>
<td>P-trend</td>
<td></td>
<td>&lt;0.001</td>
<td>0.015</td>
</tr>
<tr>
<td>Gender†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>4,551</td>
<td>472 (462, 482)</td>
<td>4.29 (4.24, 4.33)</td>
</tr>
<tr>
<td>Female</td>
<td>5,359</td>
<td>581 (572, 590)</td>
<td>4.16 (4.12, 4.20)</td>
</tr>
<tr>
<td>P-difference</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Educational Attainment‡</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>≤11 years</td>
<td>2,157</td>
<td>497 (484, 509)</td>
<td>4.13 (4.07, 4.19)</td>
</tr>
<tr>
<td>13 years</td>
<td>4,377</td>
<td>525 (515, 534)</td>
<td>4.27 (4.22, 4.31)</td>
</tr>
<tr>
<td>16 years+</td>
<td>3,074</td>
<td>547 (537, 558)</td>
<td>4.23 (4.18, 4.28)</td>
</tr>
<tr>
<td>P-trend</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Household</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income (£/year)§</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20,000</td>
<td>1,234</td>
<td>504 (488, 520)</td>
<td>4.14 (4.06, 4.21)</td>
</tr>
<tr>
<td>20,000–40,000</td>
<td>3,192</td>
<td>523 (512, 533)</td>
<td>4.22 (4.17, 4.28)</td>
</tr>
<tr>
<td>&gt;40,000</td>
<td>4,543</td>
<td>538 (528, 548)</td>
<td>4.28 (4.23, 4.33)</td>
</tr>
<tr>
<td>P-trend</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.002</td>
</tr>
</tbody>
</table>

* Adjusted for gender; † Adjusted for age; ‡ Adjusted for gender and age. Additionally adjusted for energy intake (MJ/day) when F&V intake or crude dietary costs was the dependent variable. Three percent (309 individuals) had missing data on educational attainment. § Adjusted for gender, age, and household composition. Additionally adjusted for energy intake (MJ/day) when F&V intake or crude dietary costs was the dependent variable. Seven percent (686 individuals) had missing values on household composition, and three percent (303 individuals) had missing values on income.
Participant characteristics and dietary intakes were systematically associated with diet cost. Table 2.4.1.2 shows the characteristics of participants within quartiles of energy-adjusted diet cost. Participants with lower energy-adjusted dietary costs were on average younger, more likely to be male, consuming less alcohol and to be a current smoker. Mean F&V intake was 50% lower among those in the lowest quartile of energy adjusted dietary costs compared with the highest (742 grams/day vs. 375 grams/day, respectively).

The association between dietary costs and F&V intake by strata of SEP is presented in two figures. Figure 2.4.1.1a shows the adjusted mean (95% CI) F&V intake per day by energy-adjusted dietary cost quartiles for those with lowest and highest educational attainment. Dietary cost was significantly and positively associated with F&V intake for all strata of education but the association was strongest for those with lowest educational attainment. In the highest quartile of dietary cost, individuals with low educational attainment achieved similar levels of fruit and vegetable intake as individuals with intermediate (not shown) and highest educational attainment. However, at lower quartiles of dietary cost, significant differences in F&V intake were apparent, and at the lowest quartile, those with lowest education consumed 76 grams per day (20%) less F&V than those with highest education (p for difference <0.001).

The inter relationship between income and dietary costs was slightly different. Figure 2.4.1.1b shows the association between F&V intake across dietary costs quartiles for highest and lowest income strata. In the lowest quartile of dietary cost, those with lowest income consumed 30 grams per day (8%) less F&V than those with highest income. F&V intakes were similar between the two income groups in quartiles two and three and a reversal was observed in the highest quartile of dietary cost, where those with lowest income consumed 67 grams per day (10%) more than those with highest incomes.

Interaction terms for SEP indicators and energy-adjusted dietary costs confirmed the pattern shown in Figure 1 and 2; difference in fruit and vegetable intake between participants with highest and lowest dietary costs was largest in those with low education (F-value for interaction-term=4.1, p<0.001) and low income (F=4.5, p<0.001). Adjusting the analysis with the education-dietary costs interaction for income and vice versa did not alter the results.
Table 2.4.1.2. Characteristics of individuals within quartiles of energy-adjusted dietary costs in the Fenland Study (n=10,020). Values in brackets indicate the range in crude costs within each quartiles. Numbers are means (SD) or percentages. Q1 represents the lowest quartile of dietary costs while Q4 represents the highest quartile of dietary costs.

<table>
<thead>
<tr>
<th></th>
<th>Q1 [0.7-3.6]</th>
<th>Q2 [3.6-4.1]</th>
<th>Q3 [4.1-5.0]</th>
<th>Q4 [5.0-14.9]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>46.7 (7.5)</td>
<td>47.4 (7.4)</td>
<td>48.3 (7.4)</td>
<td>49.0 (7.2)</td>
</tr>
<tr>
<td>Gender (% women)</td>
<td>42.9%</td>
<td>52.4%</td>
<td>57.2%</td>
<td>63.2%</td>
</tr>
<tr>
<td>Percentage low education*</td>
<td>26.1%</td>
<td>21.3%</td>
<td>21.0%</td>
<td>21.3%</td>
</tr>
<tr>
<td>Percentage low income†</td>
<td>18.2%</td>
<td>13.1%</td>
<td>11.8%</td>
<td>11.7%</td>
</tr>
<tr>
<td>Percentage current smoker</td>
<td>15.2%</td>
<td>13.2%</td>
<td>9.4%</td>
<td>14.1%</td>
</tr>
<tr>
<td>Alcohol intake (g/day)</td>
<td>86.3 (149.2)</td>
<td>118.5 (172.4)</td>
<td>158.7 (230.2)</td>
<td>244.9 (351.2)</td>
</tr>
<tr>
<td>Fruit intake (g/day)</td>
<td>167.7 (134.0)</td>
<td>214.1 (147.5)</td>
<td>258.5 (170.7)</td>
<td>350.0 (285.8)</td>
</tr>
<tr>
<td>Vegetable intake (g/day)</td>
<td>202.6 (95.7)</td>
<td>243.1 (99.1)</td>
<td>289.3 (109.1)</td>
<td>386.6 (192.7)</td>
</tr>
<tr>
<td>Combined F&amp;V intake (g/day)</td>
<td>370.3 (179.8)</td>
<td>457.3 (187.0)</td>
<td>547.7 (214.4)</td>
<td>736.6 (381.0)</td>
</tr>
<tr>
<td>Energy intake (MJ/day)</td>
<td>8.5 (2.7)</td>
<td>7.8 (2.3)</td>
<td>7.8 (2.2)</td>
<td>8.4 (2.3)</td>
</tr>
</tbody>
</table>

* Low education was defined as ‘less than 11 years of education’ (included no qualifications and general certificate of secondary education). 309 individuals had missing values on educational attainment.
† Low income was defined as ‘£20,000 per year’. 303 individuals had missing values on income.
Table 2.4.1.2. Characteristics of individuals within quartiles of energy-adjusted dietary costs in the Fenland Study (n=10,020). Values in brackets indicate the range in crude costs within each quartile. Numbers are means (SD) or percentages. Q1 represents the lowest quartile of dietary costs while Q4 represents the highest quartile of dietary costs.

<table>
<thead>
<tr>
<th>Quartile</th>
<th>Range (Crude Costs)</th>
<th>Age (years)</th>
<th>Gender (women %)</th>
<th>Low Education (%)</th>
<th>Low Income (%)</th>
<th>Current Smoker (%)</th>
<th>Alcohol Intake (g/day)</th>
<th>Fruit Intake (g/day)</th>
<th>Vegetable Intake (g/day)</th>
<th>Combined F&amp;V Intake (g/day)</th>
<th>Energy Intake (MJ/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>0.7-3.6</td>
<td>46.7 (7.5)</td>
<td>42.9%</td>
<td>26.1%</td>
<td>18.2%</td>
<td>15.2%</td>
<td>86.3 (149.2)</td>
<td>167.7 (134.0)</td>
<td>202.6 (95.7)</td>
<td>370.3 (179.8)</td>
<td>8.5 (2.7)</td>
</tr>
<tr>
<td>Q2</td>
<td>3.6-4.1</td>
<td>47.4 (7.4)</td>
<td>52.4%</td>
<td>21.3%</td>
<td>13.1%</td>
<td>13.2%</td>
<td>118.5 (172.4)</td>
<td>214.1 (147.5)</td>
<td>243.1 (99.1)</td>
<td>457.3 (187.0)</td>
<td>7.8 (2.3)</td>
</tr>
<tr>
<td>Q3</td>
<td>4.1-5.0</td>
<td>48.3 (7.4)</td>
<td>57.2%</td>
<td>21.0%</td>
<td>11.8%</td>
<td>9.4%</td>
<td>158.7 (230.2)</td>
<td>258.5 (170.7)</td>
<td>289.3 (109.1)</td>
<td>547.7 (214.4)</td>
<td>7.8 (2.2)</td>
</tr>
<tr>
<td>Q4</td>
<td>5.0-14.9</td>
<td>49.0 (7.2)</td>
<td>63.2%</td>
<td>21.3%</td>
<td>11.7%</td>
<td>14.1%</td>
<td>244.9 (351.2)</td>
<td>350.0 (285.8)</td>
<td>386.6 (192.7)</td>
<td>736.6 (381.0)</td>
<td>8.4 (2.3)</td>
</tr>
</tbody>
</table>

* Low education was defined as ‘less than 11 years of education’ (included no qualifications and general certificate of secondary education). 309 individuals had missing values on educational attainment.
† Low income was defined as ‘<£ 20,000 per year’. 303 individuals had missing values on income.

Figure 2.4.1.1a. Estimated mean (95% CI) fruit and vegetable consumption (grams/day) by quartiles of energy-adjusted dietary cost, stratified for educational attainment. Range of energy-adjusted dietary costs is indicated beneath each quartile. Estimates are presented for highest (16+ years of education) and lowest (less than 11 years of education) educational attainment only.

Figure 2.4.1.1b. Estimated mean (95% CI) fruit and vegetable consumption (grams/day) by quartiles of dietary cost, stratified for household income. Range of energy-adjusted dietary costs is indicated beneath each quartile. Estimates are presented for highest (>£40,000 per year) and lowest (<£ 20,000 per year) income groups only.
Discussion

In the present study we confirm earlier research that higher dietary costs were associated with more healthful dietary patterns, more specifically, with higher F&V intakes. Moreover, we provide novel evidence that dietary costs may play a stronger role in low socioeconomic groups. While higher F&V intakes were associated with higher dietary costs for the sample overall, educational differences were not evident in the stratum of adults with highest dietary costs but amplified among those with lower-cost diets. Within the lowest dietary costs quartile, those with highest education consumed approximately 20% more F&V (80 grams per day - equivalent to one serving) than those with lowest levels of education. This finding was consistent with our hypothesis that dietary costs would be more strongly related to F&V intake for people of low SEP than people of high SEP.

The greater educational inequalities in F&V intake at low levels of dietary costs may reflect the importance of other, unmeasured individual factors such as one’s ability to use dietary knowledge and attitudes to achieve better quality diets within a given food budget.[19,20] This is consistent with literature indicating that higher SEP (income, education and occupation) is associated with nutrition and health literacy and other psychosocial resources[19,22–24] and may explain why more highly-educated individuals consumed more F&V even at a lower diet cost. Alternatively, other –unmeasured - material resources (e.g., access to health-promoting goods and services[42]) may have explained the accentuated educational inequalities. Yet, the lack of a socioeconomic gradient in F&V intake at higher dietary cost levels may indicate that sufficient (food-related) material resources can compensate for a potential lack of psychosocial resources.

As demonstrated before,[43] the use of different socioeconomic indicators generated slightly different results. First, differences in F&V consumption between income groups in the lowest dietary cost group were much smaller than between educational groups. This may reflect the fact that income is a proxy for food budgets.[44] For the low income-F&V intake association, food purchasing power may be the most important factor,[45] while for the low education-F&V intake association nutritional knowledge and other psychosocial resources (i.e.[19,24]) may additionally play a role. Second, individuals with the highest diet cost on lowest incomes consumed even more F&V than those with highest incomes. Examples exist of population groups who consume healthy diets despite lower income than the general population (e.g.[46,47]). Alternatively, our crude income measure may not adequately reflect socioeconomic status of the person in charge of the food shopping.

While previous studies have provided evidence that dietary costs are in the causal pathway between SEP and diet,[8,9,30,31] this study suggests that dietary costs are not equally important for F&V intake across all socioeconomic groups. Rather, educational differences in intake were only observed in individuals with the lowest diet cost. This is consistent with one study that showed that the income-diet cost-diet pathway was stronger in lower educated individuals than in higher educated individuals.[9] Dietary costs as a constraint on quality may therefore be more important for less-educated groups, who tend to prioritise low-cost in food choices.[18] Explanations for this prioritization may be other competing expenditures that take precedence, or a lack of capacity to resist unhealthy environments.[48]
Strength and limitations

A number of factors may have biased the results of this study. First, F&V intakes and dietary cost estimates were derived from an FFQ, an instrument that is subject to error and known biases.[33,49] The reported F&V intakes in our sample were relatively high. This may present an upward reporting bias (and the associated lack of heterogeneity), or over-estimation of intakes as imputed portion sizes may have been larger than portions actually consumed. If so, this may be one explanation for the relatively shallow socioeconomic patterning. Yet, the F&V intakes found in the present study are comparable to numbers presented in previous UK studies (e.g.[50]). Second, the definition of dietary costs used in this study should be viewed as an estimation of the intrinsic monetary value of diet, and not a measure of food expenditure.[8] Indeed, a study on the methods of deriving dietary costs demonstrated a downward bias, mainly for high SES individuals, which is likely to result in an underestimation of SES differentials.[35] Yet, it was also shown that this type of measurement of dietary cost is moderately related to actual food expenditures. Concluding, the use of the FFQ in combination with the food price variable to derive fruit and vegetable intake and dietary cost estimates has likely resulted in an underestimation of socioeconomic differences. Third, the use of this mostly white, more highly educated sample with higher household incomes may also have contributed to an underestimation of social gradients presented in this manuscript. Fourth, while individual data was collected between 2005 and 2013, dietary cost data was derived with 2012 food price data. A UK study showed that food prices had risen over the period 2002–2012, especially more healthy items.[51] This means that individuals who attended the study site in 2005 have been assigned to dietary costs from 2012 that are higher than their actual dietary costs in 2005. As this is especially true for individuals who consumed more F&V, this time lag may have amplified the association between dietary costs and F&V intake. Lastly, although in this study we found an association between SEP/dietary costs and F&V intake, this may be different for other food groups.

Strengths of this study included the large population-based sample with detailed sociodemographic and dietary measures. An additional strength is the derivation of individual-level dietary cost, which can provide some insights into the economic mechanisms that contribute to social patterns of dietary intake.[35,39] Advantages of using individual-level dietary costs in analysis is that the costs reflect the quantities and types of foods reported to be consumed.[35]

Conclusions

The present study has implications for epidemiological studies and public health policy. This study has provided insight into the importance of economic access to food; having higher dietary costs, a proxy for food spending,[35] was positively associated with F&V intake. Yet, the question of access to food has three components: economic access, physical access and behavioural and psychosocial resources that support access. It remains to be evaluated whether economic access acts as an independent factor. It is likely that environmental factors such as area deprivation or accessibility of healthy foods are important for a healthy diet as well, so future studies could assess the interplay between economic and physical access. Additionally, cohort studies with information on dietary costs could be complemented with more detailed information on psychosocial resources such as nutrition knowledge or executive functioning. Lastly, future studies could examine policies that have aimed to improve financial and physical access to food simultaneously, and evaluate their effectiveness. Potentially, a beneficial side-effect of reducing financial constraints in access to healthy food may be reduced dietary inequalities.
The strong association between dietary costs and diet quality underscores the importance of economic resources as an important determinant of adherence to a healthy diet. A recent trial that involved a 20% price-reduction intervention in combination with skill-building demonstrated significant increases in fruit and vegetable purchases.[52] Yet, lowering the economic barriers to fruit and vegetable consumption alone (e.g., by decreasing prices or increasing food budgets) may not diminish dietary inequalities by itself if other barriers are not addressed. Although food costs and economic resources should be considered in any evaluation of food access, addressing socioeconomic inequalities itself by a redistribution of income (e.g., distribution of vouchers) or improving dietary education (e.g., stimulating cooking skills) may prove to be a worthwhile investment. Public health initiatives to promote healthy diets should address the broader environmental determinants of healthy food intake, incorporating both affordability and accessibility to prevent further widening of dietary inequalities.
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References
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