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Demographic and socioeconomic disparity in nutrition: application of a novel Correlated Component Regression approach

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ABSTRACT

Objectives: This study aimed to examine the most important demographic and socioeconomic factors associated with diet quality, evaluated in terms of compliance with national dietary recommendations, selection of healthy and unhealthy food choices, energy density and food variety. We hypothesised that different demographic and socioeconomic factors may show disparate associations with diet quality.

Study design: A nationwide, cross-sectional, population-based study.

Participants: A total of 1352 apparently healthy and non-institutionalised subjects, aged 18–69 years, participated in the Observation of Cardiovascular Risk Factors in Luxembourg (ORISCAV-LUX) study in 2007–2008. The participants attended the nearest study centre after a telephone appointment, and were interviewed by trained research staff.

Outcome measures: Diet quality as measured by 5 dietary indicators, namely, recommendation compliance index (RCI), recommended foods score (RFS), non-recommended foods score (non-RFS), energy density score (EDS), and dietary diversity score (DDS). The novel Correlated Component Regression (CCR) technique was used to determine the importance and magnitude of the association of each socioeconomic factor with diet quality, in a global analytic approach.

Results: Increasing age, being male and living below the poverty threshold were predominant factors associated with eating a high energy density diet. Education level was an important factor associated with healthy and adequate food choices, whereas economic resources were predominant factors associated with food diversity and energy density.

Conclusions: Multiple demographic and socioeconomic circumstances were associated with different diet quality indicators. Efforts to improve diet quality for high-risk groups need an important public health focus.

BACKGROUND

Socioeconomic disparity in nutrition is well documented[1–5] which helps to explain some of the observed social inequalities in health.[2 6] People with high socioeconomic status (SES) are more likely to have healthier food habits, whereas people with low SES have dietary profiles less consistent with nutritional recommendations or dietary guidelines, hence contributing to their poorer health status.[6 7] Therefore, both social inequity and diet quality, reflected by healthy dietary behaviours are areas of active public health concern.

Despite the importance of these two areas, research with regard to SES is still challenging and characterised by a number of conceptual and methodological problems that hinder advances in knowledge about how and why SES is related to diet.[8 9] A single 'best' indicator approach, to determine social classification among societies is not theoretically compelling because it may emphasise a particular aspect of social stratification which may be only relevant to specific health outcomes[10 11] and at different stages of the life course.[12] The most widely used SES indicators (education, occupation and income)[8 9 13] are limited in their ability to capture the complex multidimensional forces that dominate social structure.[14] While education and occupation are markers of social relationships and command over life-long skills, income is more indicative of a current standard of living.[15] Additionally, these traditional SES are interrelated, which makes it difficult to determine the specific contribution of each factor to food choices.[2 16]

Beyond household income, Daly et al[15] suggest wealth as a standard economic component for monitoring links between SES and health. Household income consists of a flow of resources over a defined time period, whereas wealth captures the accumulated stock of assets (housing, cars, investments, inheritance and pension rights or economic

reserves over the life course), although both are positively correlated.[15]

Another challenge to SES research is that these indicators are not interchangeable online;[17] both cumulative effects[12,18] and unique contributions from each indicator may exist.[9,15] Thus, it is still difficult to directly attribute the observed variation in diet quality to a specific SES indicator because different indicators may show disparate effects on food habits.[13]

The objective of the present study was to examine the simultaneous association of a range of demographic and socioeconomic factors with diet quality, as measured by several selected dietary indicators. The importance and explanatory power (power of independent contribution) of each SES factor with regard to the quality of diet was explored by using the novel Correlated Component Regression (CCR)[19] technique. The CCR provides an alternative method to capture important suppressor variables among a set of predictors, especially when these are moderately to highly correlated, by dealing with the problems of confounding and the effects of multicollinearity.[19] The CCR helps to ascertain the classification of key SES indicators that influence diet quality according to their importance, thus providing better performance than traditional regression techniques.

The findings are important to gain a better understanding of socioeconomic disparities in nutrition with the consequent impacts on health in order to develop strategies aimed at tackling the problem of SES disparities in nutrition in a global context.

METHODS
Studied population
Analyses were conducted on data from the Observation of Cardiovascular Risk Factors in Luxembourg (ORISCAV-LUX), a nationwide nutritional population-based study. A comprehensive description of the ORISCAV-LUX survey design sampling methods has been published elsewhere.[16,20,21] Briefly, a random sample stratified by age (18–69 years), sex and district of residence was selected from the national health insurance registry. A total of 1432 participants were recruited with a participation rate (32.2%) corresponding to the theoretically expected rate on which the sample size was calculated.[21] The participants attended the nearest study centre after a telephone appointment, and were interviewed by a trained member of the research staff. After data cleaning, particularly for poorly completed food frequency questionnaire (FFQ), data from 1352 participants were available for analyses.

Independent demographic and socioeconomic variables
Self-reported information on demographic and socioeconomic variables were collected via a questionnaire, including age, sex, country of birth, education level, marital status, work status, monthly household income, and perceived wealth. Education level, based on the highest diploma obtained, was classified into three

groups: 'tertiary level' equivalent to university or more; 'secondary level' equivalent to classical or technical qualification and 'primary level' corresponding to non-academic qualification (no diploma, at least 9 years of mandatory schooling). Marital status was recorded into either: 'live alone' which included single, divorced or widowed subjects; and 'living with partner'. Work status was classified as 'employed' comprising participants currently engaged in a remunerated occupation, 'unemployed' including students, 'retired/sick leave and disabled', and 'home duties/housewives'. The participants were classified according to their country of birth into four major groups: 'Luxembourg, 'Portugal', 'Other European country' and 'non-European country'. The Portuguese are representing the major European immigrant community in Luxembourg, which constituted about 16.1% of the total population of Luxembourg in 2011.[22] Economic status was ascertained by asking participants to select one of seven categories as best representing total household monthly income: <€750, €750–€1499, €1500–€2249, €2250–€2999, €3000–€4999, €5000–€10 000 and >€10 000 per month. The number of adults and children living in the same household was also ascertained. Adult Equivalent Income (AEI) was calculated as the ratio of the midpoint of the self-declared family income to the square root of the number of persons in the household. The risk of poverty was referred to the national AEI which is equivalent to €1432 per month, as published by the national institute of statistics (STATEC). The economic status variable was then dichotomised as: 'above poverty threshold' (APT) and 'below poverty threshold' (BPT). Wealth adequacy perception was assessed by asking the question "To what extent does your current income and other available resources allow you to provide for your needs?" and was classified as: 'difficult' or 'easy'.

Dependent variables: diet quality measures
Dietary intake was assessed using a validated semiquantified FFQ[23,24] which collects information on the frequency and quantity (portion size) of 134 items consumed over the preceding 3 months of the interview. Research staff provided detailed instructions on how to complete the FFQ, and then checked the correctness and completeness of the answers.

Five diet quality indicators were selected: the Recommendation Compliance Index (RCI),[1] Recommended Food Score (RFS),[25] non-Recommended Food Score (non-RFS),[26] Energy Density Score (EDS)[27] and Dietary Diversity Score (DDS)[28] to cover the multi-dimensional nature of diet quality.[29] Adherence to national dietary recommendations, appropriate food choices, energy density and food variety/diversity were identified as key elements of high-quality diets.[27,30–33]

The previously developed RCI[1] was used to evaluate a participant's compliance with national dietary recommendations. It is a composite of 13 food-based and nutrient-based components, and ranges between −0·5 (due to a

negative half point for excessive salt intake) and 14 points (2 points for high daily fruit and vegetable servings), where a higher degree of adherence is indicated by higher scores.

The RFS and non-RFS, used in numerous past studies on diet quality[25 34 35] were used to assess food choices. They were computed following the methods of Kant et al[25] and modified by Kaluza et al[35] The RFS gives an indication of the frequency of consumption of food items that are recommended to increase (good choices), based on the 2010 Dietary Guidelines for Americans.[36] It comprised 18 food items (including fruit, vegetables, legumes, wholegrain cereal products, low fat dairy products, fish and nuts). One point was given for consumption of any of the recommended foods at least once per week,[25] to give a total score out of 18. The non-RFS gives an indication of the frequency of consumption of foods that are recommended to reduce (bad choices). It comprised 14 food items, including processed meats, refined grains, solid fats, added sugars and alcohol. Consumption of non-recommended foods at least 2–4 times per week was assigned a score of 1; otherwise 0 points were assigned,[35 37] to give a total non-RFS out of 14, with a higher value indicating a higher consumption of non-recommended food items.

Consistent with other studies, EDS was used as an indicator of diet quality.[30 31] It was defined as the ratio of total energy intake over daily weight of total food consumed (kcal/g), based on all foods and beverages, excluding drinking water.[27] By selecting the lower energy density option, one can eat a greater volume or weight of an isocaloric food. Therefore, a higher EDS indicates more energy per gram of food consumed.

Food variety (diversity), another dimension of diet quality, was measured as described by Kim et al,[28] to form the DDS. It comprised two components: overall variety (daily consumption of at least one serving from each of the five food groups: meat/poultry/fish/egg, dairy products, grains, fruit and vegetables, 0–15 points) and variety within protein sources (meat/poultry, fish, dairy, beans and eggs, 0–5 points), to give a total DDS of 20 points (optimal diversity). A diet that has variety within similar food groups, as well as overall variety, is believed to be superior to a diet with a monotonous source.[28] Variety among protein sources is included to illustrate the benefits of including diverse sources of food in the diet from within the same food group.[28] Each item within these food groups provides important nutrient and non-nutrient components (eg, essential fatty acids from the fish group and phytochemicals from the beans group).

Ethical aspects

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the National Research Ethics Committee and the National Commission for Private Data Protection. Written informed consent was obtained from all participants.

Statistical analysis

For descriptive purposes, diet quality indicators and participants' demographic and socioeconomic characteristics were compared by sex. Then, the diet quality indicators were compared by demographic and socioeconomic factors, and p values were calculated by using the χ^2 test for categorical variables, the t test and Kruskal-Wallis test for normally and non-normally distributed variables, respectively.

The CCR analysis[38] was performed using XLStat V.2014.2.07, to identify the optimal demographic and socioeconomic factors associated with dietary outcomes. It allows simultaneous adjustment for the effect of each indicator on the other, and hence shows the independent and unique contribution of each indicator. Beside the traditional SES indicators of education, work status and income, country of birth, marital status and perceived wealth were included. All selected predictors were simultaneously introduced. The categorical variables were recoded as dummy variables. The referent variables for each indicator were as follows: 'women' for sex, 'live with partner' for marital status, 'employed' for work status, 'Luxembourg' for country of birth, 'above poverty threshold' for economic status and 'easy' for wealth adequacy perception. Education was coded in an ordinal ranking, from lowest to highest education (1=no diploma, 2=secondary level, 3=postgraduate education, in an increasing continuous order).[39] Mathematically, variable selection is based on a stepping-down procedure which initialises with the full model including all the variables and then gradually eliminates variables with the smallest standardised coefficients one at a time, resulting in a final model with a relatively small number of predictors. This method provides better prediction and coefficient estimates closer to the true values, than traditional stepwise regression approaches, which impose no regularisation.[40] Compared with the Partial Least Square (PLS) method, the CCR provides easy interpretable parameter estimates.[19] Variable importance was compared using both standardised regression coefficient (β) and cross-validation predictor counts that reflect the number of occasions where the variable appears as a predictor in regression models. The cross-validated R^2 (CV-R2) measures the goodness of fit to describe how well the statistical models fit the selected set of predictors.

The descriptive and univariate analyses were performed by using PASW for Windows V.18.0 software (formerly SPSS Statistics). Results were considered significant at the 5% critical level ($p < 0.05$).

RESULTS
Description of demographic, socioeconomic and dietary indicators

Significant sex-specific differences for education level (p=0.02) and work status (p<0.001) were observed. Women consumed significantly more recommended foods (higher RFS), and fewer non-recommended foods

(lower non-RFS) (p<0.001). EDS and DDS were significantly higher in men than in women (p<0.001 and 0.007, respectively) (table 1).

Correlation between selected SES factors

While the selected SES indicators were significantly intercorrelated (p<0.05), sex was only correlated with education level and work status (table 2).

Univariate associations between SES factors and dietary outcomes

The selected diet quality indicators were significantly associated with different demographic and socioeconomic factors. The mean RFS increased with education level, and the non-RFS decreased (table 3).

Modeling of SES factors to predict diet quality

Figures 1–5 (referent tables are presented in online supplementary appendix A 1–5) depict the demographic and socioeconomic factors associated with diet quality

according to their importance, that is, to the power of independent contribution. In general, age, sex, country of birth and education appeared to be the most consistent factors associated with diet quality, whereas economic, work and marital status were least frequently associated with diet quality.

Adherence to national dietary recommendations, as measured by the RCI, was associated with being Portuguese, increased age and higher education level. However, men, unemployed, living alone, below the poverty threshold, and with difficult wealth perception were all significant factors associated with low compliance to national recommendations (figure 1). Similarly, men, living alone, below the poverty threshold, and having a difficult wealth perception were also associated with a lower RFS (lower intakes of recommended foods) (figure 2). Male sex, living alone, and below the poverty threshold were positively associated with the non-RFS (higher intakes of non-recommended food items) (figure 3). DDS was inversely associated with living alone

Table 1 Demographic, socioeconomic characteristics and dietary indicators by sex, ORISCAV-LUX study, 2007–2008

	Men n=657	Women n=695	Total n=1352	p Value
Demographic and socioeconomic characteristics				
Age	44.3±0.5	44.3±0.5	44.3±0.4	0.97
Education level (n=1338)				0.02
Primary	149 (22.9)	202 (29.4)	351 (26.2)	
Secondary	324 (49.8)	308 (44.8)	632 (47.2)	
Tertiary	178 (27.3)	177 (25.8)	355 (26.5)	
Country of birth (n=1352)				0.27
Luxembourg	401 (61.0)	421 (60.6)	822 (60.8)	
Portugal	88 (13.4)	74 (10.6)	162 (12.0)	
Other European	131 (19.9)	162 (23.3)	293 (21.7)	
Non-European	37 (5.6)	38 (5.5)	75 (5.5)	
Work status (n1351)				<0.001
Employed	472 (71.8)	397 (57.2)	869 (64.3)	
Not employed	58 (8.8)	60 (8.6)	118 (8.7)	
Housewives	2 (0.3)	172 (24.8)	174 (12.9)	
Retired or disabled	125 (19.0)	65 (9.4)	190 (14.1)	
Marital status (n=1352)				0.34
Live with partner	474 (72.1)	484 (69.6)	958 (70.9)	
Live alone	183 (27.9)	211 (30.4)	394 (29.1)	
Economic status (n=1174)				0.97
Below poverty threshold	127 (21.4)	125 (21.5)	252 (21.5)	
Above poverty threshold	466 (78.6)	456 (78.5)	922 (78.5)	
Wealth adequacy perception (n=1279)				0.21
Easy	483 (77.9)	532 (80.7)	1015 (79.4)	
Difficult	137 (22.1)	127 (19.3)	264 (20.6)	
Diet quality indicators				
RCI (n=1234)	6.7±0.09	6.8±0.10	6.8±0.07	0.57
RFS (n=1338)	9.7±0.12	10.8±0.11	10.2±0.08	<0.001
nRFS (n=1352)	4.1±0.07	3.2±0.06	3.6±0.05	<0.001
ED (n=1346)	105.8±1.0	98.1±1.1	101.9±0.7	<0.001
DDS* (n=1352)	16.1±0.10	15.7±0.10	15.9±0.07	0.007

Results are presented N (%) for qualitative variables and mean±SE for quantitative variables.
p Value from X test and t test for qualitative and quantitative outcomes respectively.
*p Value from Kruskal-Wallis non-parametric test.
DDS, Dietary Diversity Score; ED, Energy Density; n-RFS, non-Recommended Foods Score; ORISCAV-LUX , Observation of Cardiovascular Risk Factors in Luxembourg; RCI, Recommendation Compliance Index.

Table 2 Correlation* between the SES factors, ORISCAV-LUX study, 2007–2008

	Education level	Age†	Economic status	Marital status	Wealth perception	Country of birth	Work status
Sex	0.02	0.74	0.96	0.31	0.21	0.27	<0.0001
Education level		<0.0001	<0.0001	0.49	<0.0001	<0.0001	<0.0001
Age†			0.0029	<0.0001	0.0013	<0.0001	<0.0001
Economic status				0.0051	<0.0001	<0.0001	<0.0001
Marital status					0.27	0.04	<0.0001
Wealth perception						<0.0001	0.0003
Country of birth							<0.0001
Work status							

*p Values from χ^2 test.
†Age was categorised here in three categories (18–29; 30–49; 50–69).
ORISCAV-LUX, Observation of Cardiovascular Risk Factors in Luxembourg.

and with difficult wealth perception, but positively associated with being male and from Portugal (figure 4). EDS was inversely associated with increased age but positively associated with being male and living below the poverty threshold (figure 5).

DISCUSSION

This study explored the simultaneous role of several demographic and socioeconomic factors in relation to diet quality among a representative sample of the adult population in Luxembourg. It is one of a few adult population studies[13 41] which has directly examined the importance and magnitude of the effect of each SES factor using a global analytical approach.

In general, the most important demographic and socioeconomic circumstances independently associated with diet quality, as indicated by healthy choices and adherence to dietary guidelines, were age, sex, country of birth and education level. Economic resources and wealth perception also contributed, but to a lesser extent. Consistent with our previous findings,[1] Portuguese participants seemed significantly more compliant with national dietary guidelines and were more likely to select healthy and diverse food items, than other Europeans and non-Europeans. However, our previous findings showed that Portuguese participants were more overweight and obese compared with Luxembourgers.[42] These findings are consistent with a French study,[43] suggesting that obese individuals had greater compliance with national dietary guidelines than those with normal weight. This may be due to their awareness of their weight status which has led them to change their eating habits accordingly, or it may be that overweight people under-report poor choices and over-report healthy choices.

As may be expected, living alone with difficult wealth perceptions were independent discriminating factors, associated with decreased dietary variety. Limited financial resources and an absence of family life may explain the restricted access to diverse food choices. Good perceived wealth may indicate access to better quality material resources such as healthy foods, whereas the absence of good perceived wealth may negatively affect the

appropriateness and diversity of choices. Wealth is higher for families with histories of higher earnings, more savings and, in some cases, fewer expenditures on healthcare.[15] However, wealth perception by the individual may also be influenced by one's needs, love of money, level of aspirations and materialistic inclinations.[44] Recent research has shown that two dimensions of money attitudes affect the subjective perception of wealth: the individuals' perceived financial control (the ability to budget, monitor and control their money), and money anxiety (worry and indecisiveness regarding money-related issues).[44] This cumulative and dynamic nature of socioeconomic structures, ascertained by wealth as perceived by the individual, is rarely considered in epidemiological studies.

Additionally, this study showed that being male, younger and living below the poverty threshold were predominant factors associated with eating a high energy density diet. An often cited reason for poor eating patterns among low-income households is the cost of healthy food.[30 45] In the USA, more affluent populations consume higher quality diets than do disadvantaged populations.[46] People with financial constraints are likely to consume fewer fruits and vegetables and consume more high energy dense foods of lower quality (eg, processed) that are high in added sugars and saturated fat.[47]

Globally, our results support previous findings reporting socioeconomic gradients in dietary intake.[48] The US research has also shown associations between living below the poverty threshold with more unhealthy/less healthy food choices and being less likely to meet dietary recommendations.[49] Low education and limited economic resources may jointly contribute to people choosing low-cost, unhealthy, energy-dense foods, high in fat and sugar. Generally speaking, poor socioeconomic circumstances lead to poor health, which may be explained, in part, by less than optimal diet.

Several strong points characterise the present study. The data were derived from a recent nationwide sample of the general adult population. The CCR approach showed simultaneous factor-specific contributions to diet

Table 3 Diet quality indicators by demographic and socioeconomic factors, ORISCAV-LUX study, 2007–2008

	RCI n=1234		RFS n=1338		Non-RFS n=1352		EDS n=1346		DDS* n=1352	
	Mean±SE	p Value	Mean±SE	p Value	Mean±SE	p Value	Mean±SE	p Value	Mean±SE	p Value
Age, %		<0.001		<0.001		<0.001		<0.001		<0.001
18–29	6.0±0.17		9.5±0.23		4.1±0.14		110.8±2.1		15.4±0.21	
30–49	6.8±0.09		10.4±0.11		3.7±0.07		103.8±1.0		16.1±0.94	
50–69	7.1±0.11		10.3±0.13		3.3±0.08		95.2±1.2		15.8±0.12	
Education level, %		0.33		0.025		0.004		0.26		0.52
Primary	6.7±0.13		10.0±0.18		3.6±0.09		102.8±1.5		15.8±0.14	
Secondary	6.7±0.09		10.1±0.11		3.8±0.07		102.5±1.0		16.0±0.10	
Tertiary	6.9±0.13		10.6±0.15		3.4±0.09		99.9±1.4		15.8±0.14	
Country of birth, %		0.015		0.044		0.06		0.71		0.02
Luxembourg	6.6±0.08		10.0±0.10		3.7±0.06		101.6±0.9		15.8±0.09	
Portugal	7.3±0.17		10.5±0.24		3.4±0.13		103.7±1.7		16.4±0.19	
Other European	6.9±0.14		10.5±0.18		3.6±0.10		101.1±1.8		16.3±0.28	
Non-European	6.8±0.35		10.2±0.38		3.3±0.19		103.7±3.3		15.9±0.15	
Economic status, %		0.009		0.011		<0.001		<0.001		0.81
Below poverty threshold	6.4±0.15		9.8±0.20		4.0±0.11		108.8±1.8		16.0±0.16	
Above poverty threshold	6.9±0.08		10.4±0.10		3.5±0.05		100.0±0.8		16.0±0.09	
Work status, %		<0.001		0.026		<0.001		<0.001		0.65
Employed	6.7±0.08		10.1±0.10		3.7±0.06		102.8±0.9		15.9±0.09	
Not employed	6.0±0.23		9.8±0.30		4.3±0.19		113.6±3.0		15.7±0.28	
Housewife	7.0±0.19		10.8±0.23		3.2±0.12		95.0±2.0		16.1±0.18	
Retired or disabled	7.3±0.18		10.3±0.21		3.4±0.12		97.1±1.8		15.9±0.18	
Marital status, %		0.001		0.001		<0.001		<0.001		0.038
Live with partner	6.9±0.08		10.4±0.09		3.5±1.7		99.9±0.8		16.0±0.08	
Live alone	6.5±0.12		9.8±0.16		3.9±1.9		106.6±1.5		15.6±0.14	
Wealth adequacy perception, %		0.11		0.11		0.12		0.004		0.81
Easy	6.8±0.07		10.3±2.9		3.6±0.06		100.6±0.8		15.9±0.17	
Difficult	6.6±0.15		10.0±3.3		3.8±0.11		105.9±1.7		15.8±50.08	

Mean±SE are presented.
*p Value from Kruskall-Wallis test, otherwise from t test.
DDS, Dietary Diversity Score; ED, Energy Density; n-RFS, non-Recommended Foods Score; ORISCAV-LUX, Observation of Cardiovascular Risk Factors in Luxembourg; RCI, Recommendation Compliance Index.
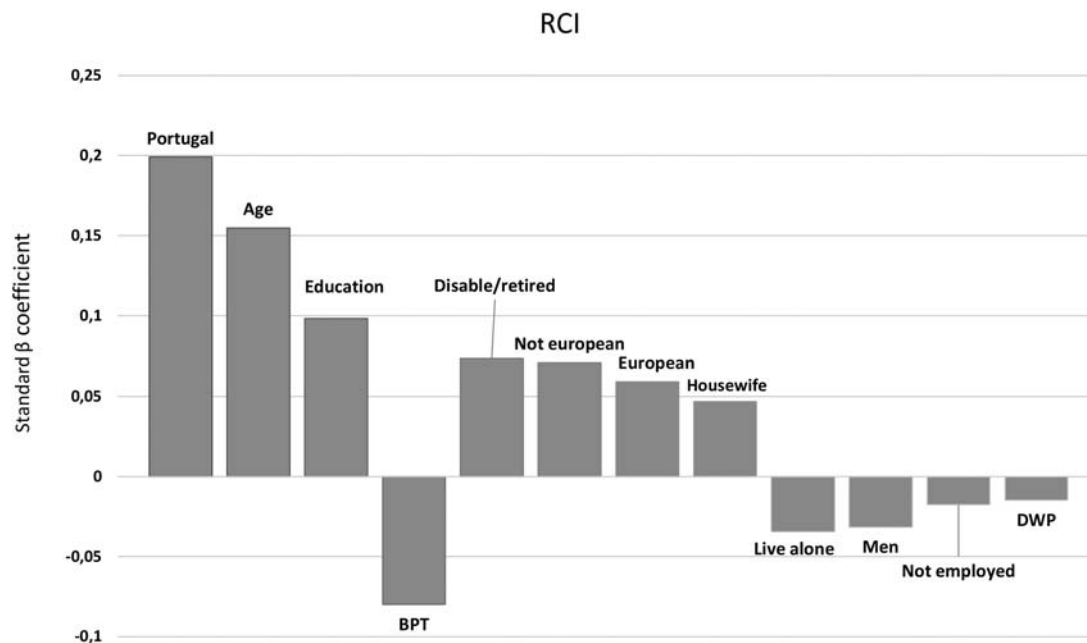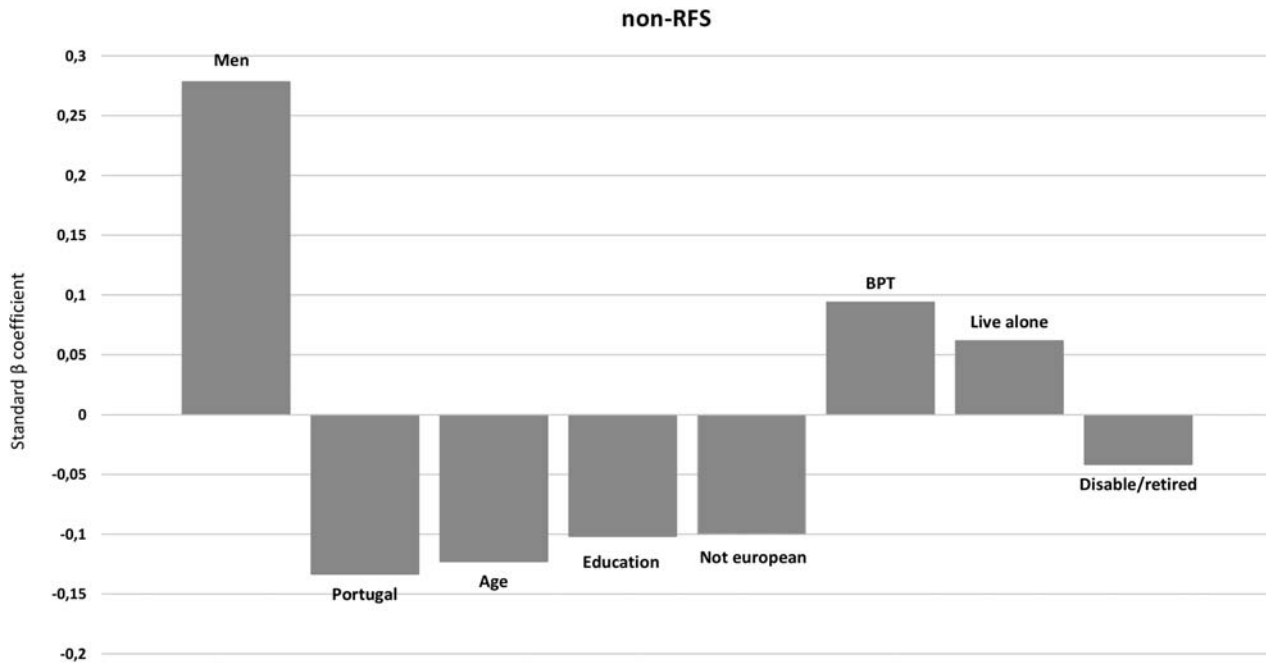
Figure 1 Demographic and socioeconomic factors associated with compliance with dietary recommendations (BPT, below poverty threshold; DWP, difficult wealth perception; RCI, Recommendation Compliance Index).

quality. It allowed us to measure the magnitude of the shared associations, not been measured in previous studies.[9] [12] Although the variances explained by each model were small, indicating that other factors would also be involved, our findings showed that multiple demographic and socioeconomic circumstances were independently associated with different diet quality indicators, and highlighted the importance of considering the overall context of SES when explaining nutritional disparities. It is widely agreed that the pathway mechanisms linking education, occupation and income with diet are conceptually distinct.[9] For example, education may influence food choices by facilitating or constraining a person's ability to understand the information communicated by a healthcare professional or on food labels.[9] Work status may affect diet through work-based cultures and social networks.[12] Employment largely determines income and therefore, affordability of certain food
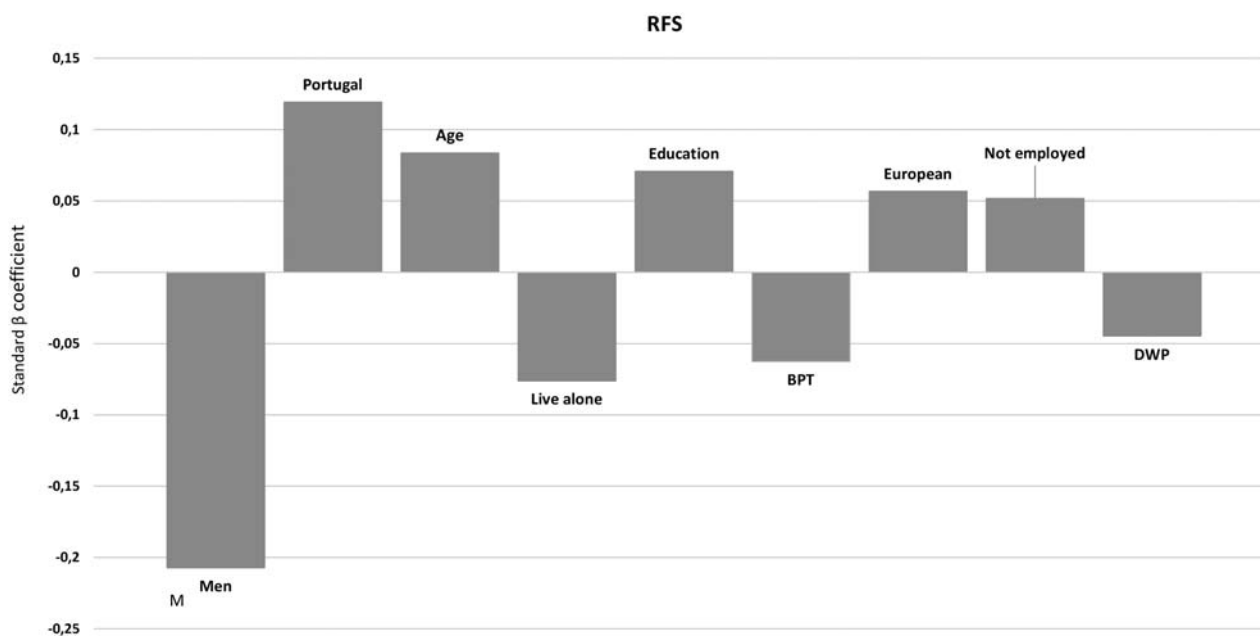
Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices (BPT, below poverty threshold; DWP, difficult wealth perception; RFS, Recommended Foods Score).
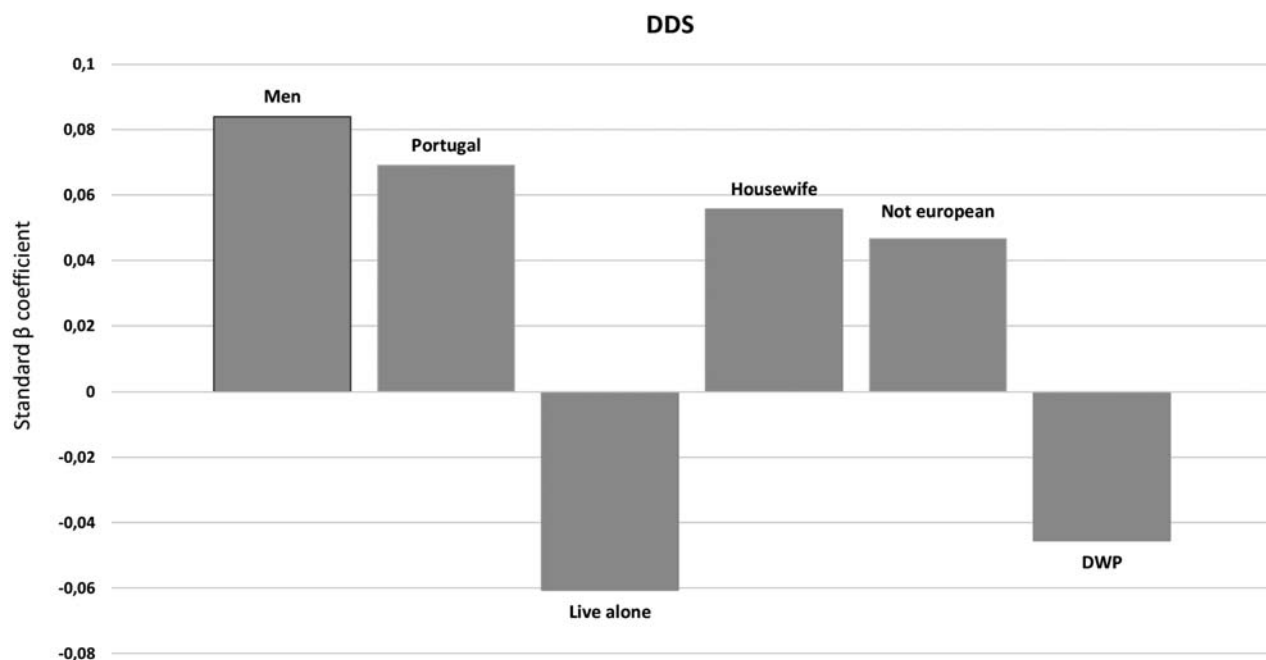
Figure 3 Demographic and socioeconomic factors associated with selecting unhealthy food choices (BPT, below poverty threshold; Non-RFS, non-Recommended Foods Score).

products, such as more healthy and nutritious food,[15] suggesting that unequal distribution of resources may lead to nutritional disparities and consequent health inequity. This CCR procedure allowed the ability to distinguish shared and predictor-specific effect on diet quality. Identifying the key SES predictors is important to capture the variation in diet quality and to offer a better understanding of the underlying mechanisms relating to specific exposures.[8] Compared with a single

proxy indicator approach, our findings support the fact that SES is a multidimensional concept that should encompass other facets, mainly country of birth, marital status and wealth, as each reflects a different conceptual underpinning on how SES influences diet.[9] Likewise, age and sex were shown to be relevant SES indicators associated with various dietary quality scores.

Obtaining detailed overall diet quality assessments is challenging in population-based studies.[50] Numerous

Figure 4 Demographic and socioeconomic factors associated with diverse foods items (DDS, Dietary Diversity Score; DWP, difficult wealth perception).
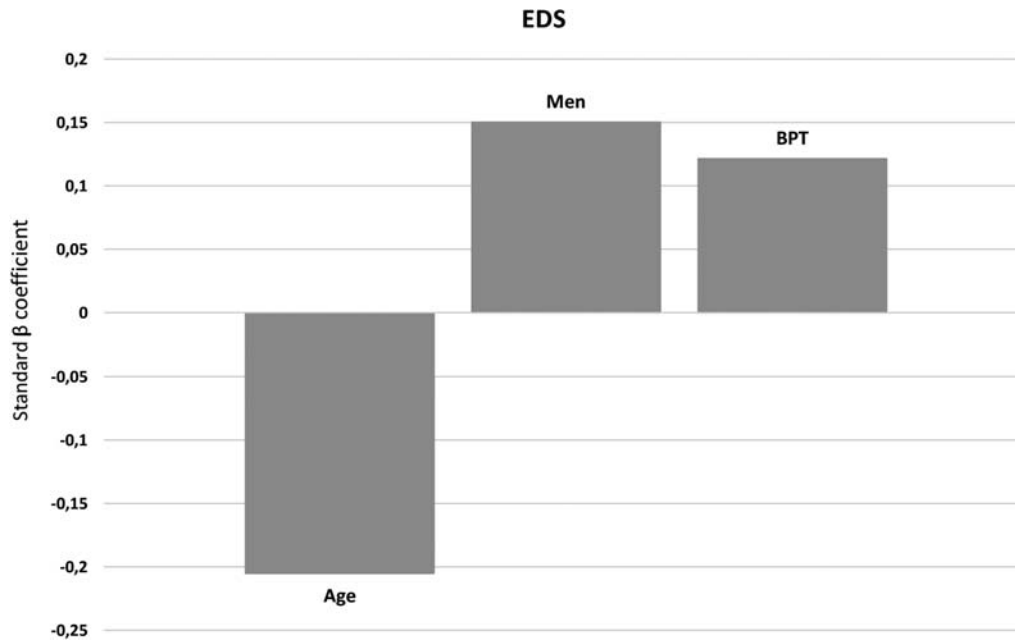
Figure 5 Demographic and socioeconomic factors associated with energy density (BPT, below poverty threshold; ED, Energy Density).

diet quality indices have been suggested in the literature to reflect various aspects of diet quality.[51] These indices aim mainly to identify whether different population subgroups are consuming 'good/healthy' or 'detrimental/unhealthy' foods,[51] using a variety of definitions to describe these terms. From among a plethora of such descriptors, we focused on five indices to cover different aspects of diet quality, including compliance to national dietary recommendations, appropriate food choices, energy density and food variety/diversity. These five diet quality indices were highly correlated in the study population,[52] probably because most of these indices focus on healthy dietary patterns; nevertheless, they may not be fully indicative of a healthy diet regardless of SES. Further research on which dietary indicators better predict nutritional status is warranted.

In calculations of energy density, the treatment of beverages is important. As beverages have a high water content, they tend to have a lower energy density than most foods, and may disproportionately influence dietary energy density values.[53] The best method for calculating energy density depends on the purpose of the analysis, the outcome of interest, and the study population. Associations with weight or health status may possibly be weakened or missed[54] when using energy density based on food and all beverages excluding water, however, this was not the objective of the present study. Using foods and all beverages, excluding water, is convenient and requires no special manipulation of the dietary intake data set.[53]

The selected diet quality indicators were calculated using a validated FFQ, where several quality control measures were undertaken to provide complete and coherent data.[20] Two extensive validation studies[23][24] showed

that the FFQ performed well in assessing intakes of several foods and micronutrients, and the observed correlations were within the range noted by other investigators. Additionally, intensive efforts were made to minimise dietary reporting inaccuracies through extensive control procedures.[20]

This study fills a knowledge gap and enhances the research on socioeconomic disparities in nutrition by addressing a novel method, defined as CCR, to identify the most important demographic and socioeconomic circumstances independently associated with diet quality. To the best of our knowledge, only one Australian study has used this CCR method to describe the socioeconomic gradients in children's diets.[39]

Further, several sensitivity analyses, by using linear regression and PLS methods, confirmed results obtained with CCR (data not shown). Consistent with CCR analyses, linear regression showed that being older, from Portugal or non-European countries, having higher education, and living above the poverty threshold were associated with a higher RCI. A higher RFS was also noticed in women, older people, from Portugal, with higher education. Concerning dietary diversity, higher scores were associated with male sex, being Portuguese, and those living with a partner. A higher non-RFS was associated with men living alone, whereas people with a higher education, living above the poverty threshold and from Portugal, were more likely to have a lower non-RFS. Similarly, the EDS was negatively associated with age, while male sex and people living below the poverty threshold were more likely to eat energy-dense foods. A PLS regression was also performed with diet quality scores as dependent variables and all selected demographic and SES factors as explicative variables. The first linear combination had high positive loadings for age,

higher education, living above the poverty threshold, being housewives, and disabled or retired. High negative loadings were noted for men, living alone and being employed. This first linear combination was positively associated with the RCI, RFS and negatively associated with the non-RFS and energy density.

Certain shortcomings should also be recognised, related mainly to the current absence of a gold standard for dietary assessment. An optimal dietary intake assessment strategy still challenges nutrition research.[55] Although the FFQ has been shown to be sufficiently convenient and inexpensive to use in large-scale, population-based studies,[56] responses rely on self-report and, therefore, are subject to imprecision (under-reporting and over-reporting) and biases related to social desirability.[57]

Other potential limitations include factors related to the cross-sectional design, which precludes establishment of the temporal sequence between socioeconomic circumstances and diet quality. Of course, all but prospective studies would be encumbered by this limitation. The relatively low response rate (32.2%) did not influence the present findings, as a detailed study of non-participants showed comparable demographic and clinical characteristics of participants and non-participants, hence providing population-representative estimates.[21]

In conclusion, this study is a step towards moving the field of SES nutrition research forwards. Multiple demographic and socioeconomic circumstances were independently associated with diverse diet quality indicators. Age, sex, country of birth and education level were important factors associated with healthy and adequate food choices, whereas economic resources were associated with food diversity and energy density. From a public health standpoint, these findings are important in delineating the groups at risk in terms of their demographic and socioeconomic circumstances.

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