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Demographic and socioeconomic disparity in nutrition: application of a novel predictive approach

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Abstract

Objectives: This study aimed to explore the association of a range of demographic and socioeconomic factors with diet quality, evaluated in terms of compliance to national dietary recommendations, selection of healthy and unhealthy food choices, energy density, and food variety. We hypothesized that different demographic and socioeconomic factors may show disparate effects on the quality of diet.

Study design: Nationwide cross-sectional population-based study

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

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

Results: Increasing age, being male, and living below the poverty threshold were predominant predictors of eating a high energy density diet. Education level was an important predictor of healthy and adequate food choices, whereas economic resources were predominant determinants of food diversity and energy density. Compared to Luxembourgers, Portuguese participants were significantly more compliant to national nutritional recommendations, and selected more recommended and diverse food items.

Conclusion: Multiple demographic and socioeconomic circumstances predicted different diet quality indicators. Efforts to improve diet quality for high risk groups need an important public health focus.

Strong points

Research with respect to socioeconomic status (SES) is still challenging and characterized by a number of conceptual and methodological problems that hinder a relevant conclusion about the real association of socioeconomic factors on diet quality and health.

This study suggested a novel global analytic approach, Correlated Component Regression (CCR), to explore the importance of each SES factor with regard to the quality of diet. It constitutes a step toward moving the field of SES-nutrition research forwards.

The CCR approach demonstrated simultaneous factor-specific contributions to diet quality.

The CCR approach allowed to measure the magnitude of the shared associations which have been unmeasured by previous studies.

The diet quality indicators were calculated using a validated FFQ, where several quality control measures were undertaken to provide complete and coherent data.

Weak points

Similar to other studies, limitations are related to the self-reported dietary data and the cross-sectional nature of the study which precludes causality inferences between socioeconomic circumstances and diet quality.

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.

Background

Socioeconomic disparity in nutrition is well documented [1; 2; 3; 4; 5] which helps to explain some of the observed social inequalities in health[2], [6]. The more affluent populations are more likely to have healthier food habits whereas the disadvantaged groups 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 behaviors are areas of active public health concern.

Despite the importance of these two areas, research with respect to socioeconomic status (SES) is still challenging and characterized by a number of conceptual and methodological problems that hinder a relevant conclusion about the real impact of socioeconomic factors on diet quality and health[8], [9]. A single "best" indicator approach, to determine social classification among societies, is not theoretically compelling because it may emphasize 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[15]. 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 and a flow of resources over a defined time period [14].

The pathway mechanisms linking education, occupation and income with diet are conceptually distinct [9]. Additionally, these traditional SES are interrelated, which make it difficult to determine the specific contribution of each factor to food choices [2], [16].

Beyond household income, Daly *et al* (2002) suggests wealth as a standard economic component for monitoring links between SES and health [14]. 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 [14].

Another challenge to SES research, is that these indicators are not interchangeable[17]; both cumulative effects[12], [18] and unique contributions from each indicator may exist [9], [14]. 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 effect of a range of demographic and socioeconomic factors on diet quality, as measured by several selected dietary indicators. The importance and explanatory power 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 effects of multi-collinearity[19]. The CCR helps to ascertain the classification of key SES predictors that influence diet quality according to their importance, thus providing better performance than traditional regression techniques. It permits simultaneous adjustment for the effect of each indicator on the other, and hence to demonstrate the independent unique contribution of each indicator. Beside the traditional SES indicators of education, occupation status and income, we included country of birth, marital status and perceived wealth. Diet quality was evaluated in terms of compliance to national food- and nutrient-based recommendations, selection of healthy and unhealthy food choices, energy density, and food variety. 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 first nationwide nutritional population-based study. A comprehensive description of the ORISCAV-LUX survey design, sampling method and sample representativeness has been published elsewhere[(16), (20), (21)]. Briefly, a random sample stratified according to age (18 to 69 years), gender 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 upon which the sample size was calculated[(21)]. The participants attended the nearest study center after telephone appointment and were interviewed by a trained research staff. After eliminating missing data on various dietary measures and SES indicators, data from 1352 participants were available for the analyses.

Predictor variables: Demographic and socioeconomic indicators

Self-reported information on demographic and socio-economic variables were collected via a questionnaire, including age, gender, country of birth, education level, marital status, professional 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 nonacademic qualification (but at least first 9 years of mandatory schooling). Marital status was recorded into two groups: "live alone" which included single, divorced and 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, constituting about 15.9% of the total Luxembourg population in 2001[22]. Economic status was ascertained by asking the participants to select one of seven categories as best representing total household monthly income; <750 euro/month, 750–1499 euro/month, 1500-2249 euro/month, 2250-2999 euro/month, 3000-4999 euro/month, 5000-10000 euro/month, and >10000 euro/month. The number of adults and children living in the same household was also requested. 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 euro/month, as published by the national institute of statistics (STATEC). Then, the economic status variable was dichotomized as: "above poverty threshold" (APT) and "below poverty threshold" (BPT). Wealth adequacy perception was assessed by using 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 semi-quantified food frequency questionnaire (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 answers. Several measures were evaluated to cover different aspects of diet quality, including compliance to national dietary recommendations, appropriate food choices, energy density, and food variety/diversity.

Participant's compliance to national dietary recommendations was evaluated using the previously developed Recommendation Compliance Index (RCI)[1]. It is a composite of 13 food- 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 results in higher scores.

Appropriate food choices were assessed by means of two scores: A Recommended Food Score (RFS) [25] and a non-Recommended Food Score (non-RFS)[26]. The RFS gives an indication of the frequency of consumption of foods items that are recommended to increase (good choices). 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. One point was given for consumption of non-recommended foods at least two to four times per week [27; 28], 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, energy density (ED) was used as an indicator of diet quality [(29), (30)]. It was defined as ratio of total energy intake over daily weight of total food consumed (Kcal/g), based on all foods and beverages, excluding drinking water. By choosing the lower energy density option, one can eat more food for the same number of calories. Therefore, higher value of ED indicates more energy per gram of food consumed.

Food variety (diversity), another dimension of diet quality, was measured as described by Patterson *et al* (1994) [(31)], to build the Dietary Diversity Score (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) and variety within protein sources (meat/poultry, fish, dairy, and eggs) to give a total DDS of 20 points.

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 subjects.

Statistical analysis

For descriptive purposes, diet quality indicators and participants' demographic and socioeconomic characteristics were compared by gender. Then, univariate associations between each diet quality indicator with demographic, and socioeconomic factors were examined. For these analyses, P-values were calculated by using the X^2 test for categorical variables, the *t*-test and Kruskal-Wallis test for normally and non-normally distributed variables, respectively.

The CCR analysis[32] was performed, using XLStat version 2014.2.07, to identify the optimal demographic and socioeconomic predictors of dietary outcomes. All selected predictors (age, gender, country of birth, education, marital status, work status, economic status, and wealth perception) were simultaneously introduced. The categorical variables were recoded as dummy variables. "Women" were selected as referent for sex, "live with partner" for marital status, "employed" for professional status, "Luxembourg" for country of birth, "below 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, to 3=postgraduate education)[33]. Mathematically, variable selection is based on a stepping-down procedure which initializes with the full model including all the variables and then gradually eliminates variables with the smallest standardized 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 regularization[34]. Compared to Partial Least Square method (PLS), the CCR provides easy interpretable parameter estimates [19]. Variable importance was compared using both standardized regression coefficient (β) and cross-validation predictor counts that reflect the number of occasions where the variable appeared 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® version 18.0 software (formerly SPSS Statistics Inc.) Results were considered significant at the 5% critical level (P<0.05).

Results

Description of demographic, socioeconomic and dietary indicators

Significant gender-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). ED and the DDS were significantly higher in men than women (Table 1).

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 2).

Modeling of SES factors to predict diet quality

Figures 1-5 (referent tables are presented in Appendix 1-5) depict the demographic and socioeconomic predictors of diet quality according to their importance. i.e., to the power of independent contribution. In general, age, gender, country of birth, and education appeared to be the most consistent predictors of diet quality, whereas economic, work and marital status were least frequent predictors.

Adherence to national dietary recommendations, as measured by the RCI, was associated with Portuguese, increased age, higher education level, and living above poverty threshold. However, men, not employed, living alone with difficult wealth perception were significant predictors of low compliance to national recommendations. Likewise, lower RFS (lower intakes of recommended foods) was typically associated with men, living alone and having a difficult wealth perception. Male gender, and living alone were positively associated with the non-RFS (higher intakes of non-recommended food items). ED was positively associated with being male but inversely associated with increased age and living above poverty threshold.

Discussion

No adult-population study has directly examined the importance and magnitude of the effect of each SES indicator in a global analytic approach. This study explored the simultaneous role of several demographic and socioeconomic factors in relation to diet quality of a representative sample of the adult population in Luxembourg.

In general, the most important demographic and socioeconomic circumstances independently associated with diet quality, as expressed by healthy choices and adherence to dietary guidelines were age, gender, country of birth and educational level. Economic resources and wealth perception also contributed 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. On the other hand, our previous findings showed that Portuguese participants were more overweight and obese compared to Luxembourgers [35]. These findings are consistent with a French study [36], suggesting that obese subjects were more likely to be better compliers with national dietary guidelines than normal weight subjects. This higher compliance among overweight and obese persons is most likely due to their awareness of their weight status which has led them to change their eating habits accordingly. The cross-sectional nature of the present study hinders confirmation of any cause–effect relationship.

As may be expected, living alone with difficult wealth perception were independent discriminating factors, contributing prominently to 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 health care [(14)]. This cumulative and dynamic nature of socioeconomic structures, ascertained by wealth as perceived by the subject, is rarely considered in epidemiological studies.

In addition, this study demonstrated that males, younger subjects, and those living below the poverty threshold were predominant predictors of eating a high energy density diet. An often cited reason for poor eating patterns among low income households is the cost of healthy food [(29), (37)]. In the US, more affluent populations consume higher quality diets than do disadvantaged populations[(38)]. People with financial constraints are likely to consume fewer fruits and vegetables and instead consume lower quality and high energy dense foods (e.g., processed) that are high in added sugars and saturated fat[(39)].

Globally, our results support previous findings reporting socioeconomic gradients in dietary intake[(40)]. Low education and limited economic resources may jointly bring people to choose low-cost, unhealthy energy-dense foods composed of fat, refined grains and added sugar. Generally poor socioeconomic circumstances lead to poor health which may be explained by the exposure to inadequate dietary factors.

Several strong points characterize the present study. The CCR approach demonstrated simultaneous factor-specific contributions to diet quality. It allowed us to measure the magnitude of the shared associations which have been unmeasured by previous studies [(9), (12)]. Our findings demonstrate that multiple demographic and socioeconomic circumstances independently associated with different diet quality indicators, and highlight 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 might influence food choices by facilitating or constraining a subject's ability to understand the information communicated by a healthcare professional or on food labels [9]. Occupation may effect diet through work-based cultures and social networks[12]. It determines income and therefore, access to certain food products. Income may determine dietary quality by making healthy and nutritious food more affordable [14], suggesting that unequal distribution of resources may lead to nutritional disparities and consequent health inequity. This CCR procedure allowed to sort out 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 to a single proxy indicator approach, our findings support the fact that SES is a multi-dimensional 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 gender were showed to be relevant indicators of social inequity.

This study is a step toward moving the field of SES-nutrition research forwards. To our knowledge, only one Australian study has used this CCR method to describe the socioeconomic gradients in children's diets[33]. Further, several sensitivity analyses were performed by using the PLS and the linear regression methods showing similar findings (data not shown).

The diet quality indicators were calculated using a validated FFQ, where several quality control measures were undertaken to provide complete and coherent data[20]. The participants were evenly distributed across socioeconomic strata. Limitations include the self-reported dietary data and the cross-sectional nature of the study which precludes causality inferences between socioeconomic circumstances and diet quality.

In conclusion, multiple demographic and socioeconomic circumstances independently associated with diverse diet quality indicators. Age, gender, country of birth and education level were important predictors of healthy and adequate foods choices, whereas economic resources determined food diversity and energy density. From a public health standpoint, these findings are important in delineating the groups at risk for inappropriate dietary behaviors, given the substantial evidence of dietary contribution to health inequalities.

Authors' contribution

AA was involved in the conception and design of the ORISCAV-LUX survey, coordinated the field data collection. All the authors (AA, CV, NS, GEC, MFE) fulfill the ICMJE guidelines, as regards:1) substantial contributions to conception and design, analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

Conflict of interest: None

Data sharing: No additional data available

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Tables and legends

Table 1 Demographic, socio-economic characteristics, and dietary indicators by gender, ORISCAV-LUX study

Table 2 Diet quality indicators by demographic and socio-economic factors, ORISCAV-LUX study

Figure 1 Demographic and socioeconomic determinants of compliance to dietary recommendations

Figure 2 Demographic and socioeconomic determinants of selecting healthy food choices

Figure 3 Demographic and socioeconomic determinants of selecting unhealthy food choices

Figure 4 Demographic and socioeconomic determinants of diverse foods items

Figure 5 Demographic and socioeconomic determinants of energy density

Appendix 1-5 Results of correlated component regression analyses for the five selected dietary outcomes

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Table 1 Demographic, socio-economic characteristics, and dietary indicators by gender, ORISCAV-LUX study, 2007-2008

	Men N=657	Women N=695	Total N=1352	*P*-value
Demographic and socio-economic 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[a] (n=1352)	16.1 ± 0.10	15.7 ± 0.10	15.9 ± 0.07	0.007

RCI: Recommendation Compliance Index; RFS: Recommended Foods Score; n-RFS: non-Recommended Foods Score; ED: Energy Density; DDS: Dietary Diversity Score.

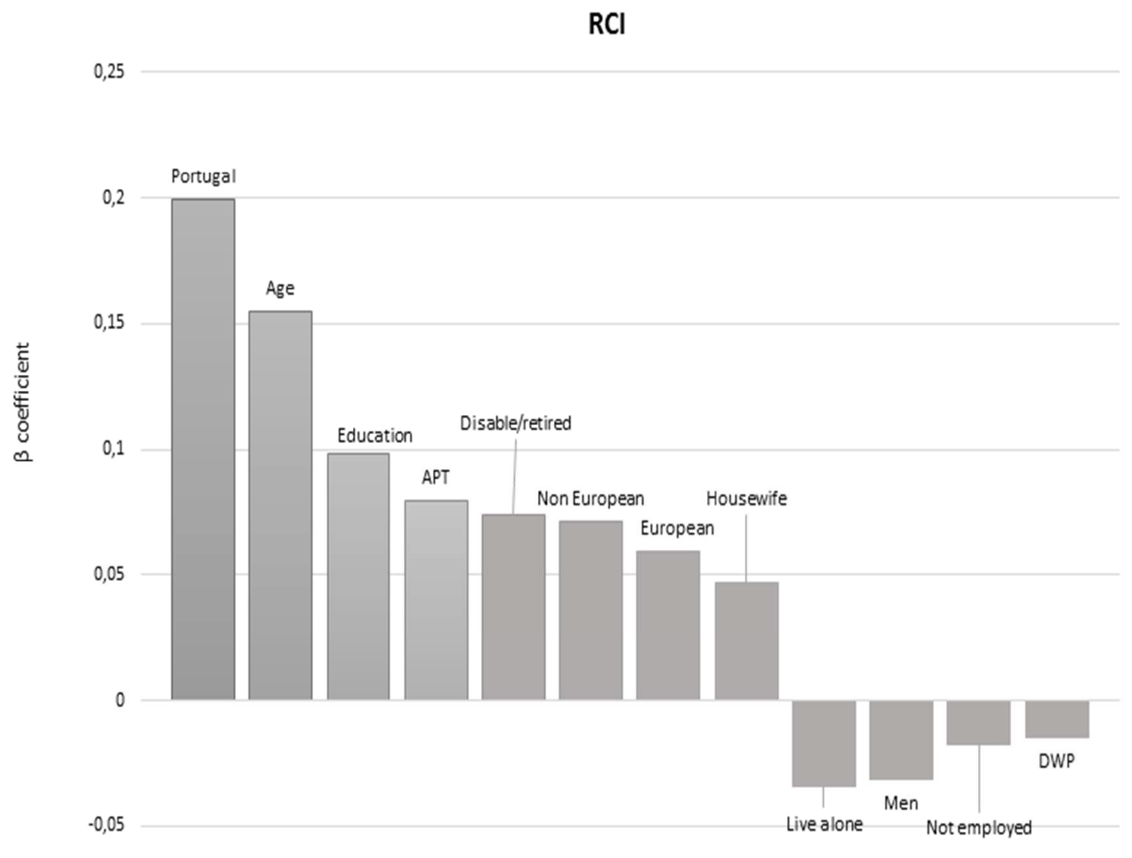
Results are presented N (%) for qualitative variables and mean ± SE for quantitative variables.
P-value from *X* test and *t*-test for qualitative and quantitative outcomes respectively
[a] P-value from Kruskal-Wallis non-parametric test

Table 2 Diet quality indicators by demographic and socio-economic factors, ORISCAV-LUX study, 2007-2008

	RCI n=1234		RFS n=1338		Non-RFS n=1352		ED n=1346		DDS[a] 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 y	6.0 ± 0.17		9.5 ± 0.23		4.1 ± 0.14		110.8 ± 2.1		15.4 ± 0.21	
30-49 y	6.8 ± 0.09		10.4 ± 0.11		3.7 ± 0.07		103.8 ± 1.0		16.1 ± 0.94	
50-69 y	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	

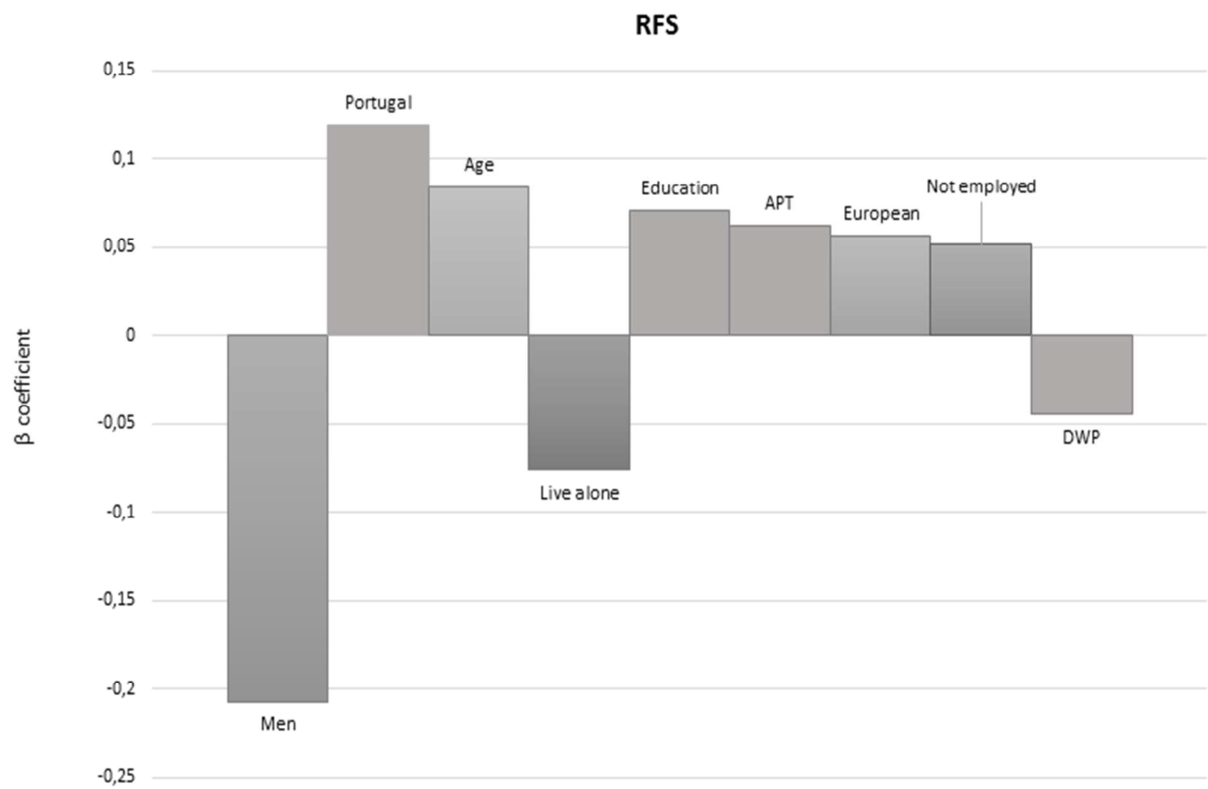
RCI: Recommendation Compliance Index; RFS: Recommended Foods Score; n-RFS: non-Recommended Foods Score; ED: Energy Density; DDS: Dietary Diversity Score. Mean ± SE are presented. [a] P-value from Kruskall-Wallis test, otherwise from *t*-test.

Figure 1 Demographic and socioeconomic determinants of compliance to dietary recommendations



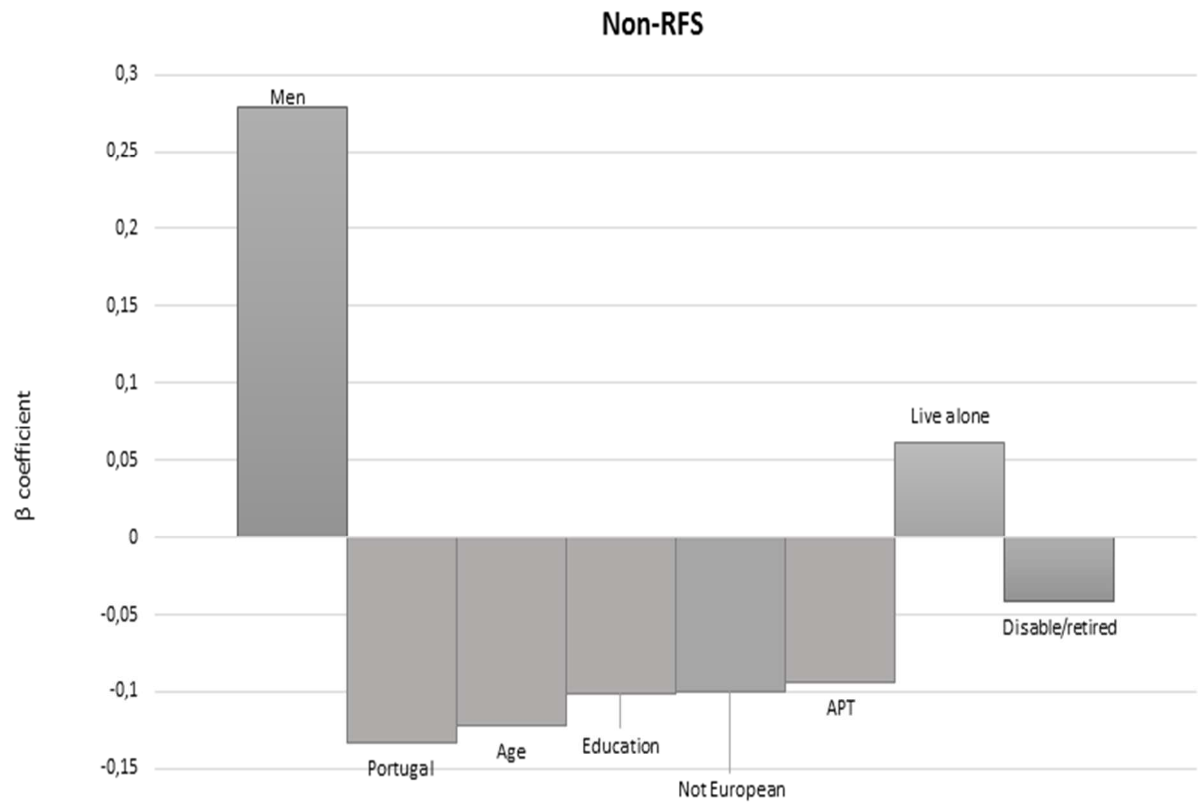
RCI: Recommedation Compliance Index; APT: above poverty threshold; DWP: Difficult wealth perception

Figure 2 Demographic and socioeconomic determinants of selecting healthy food choices



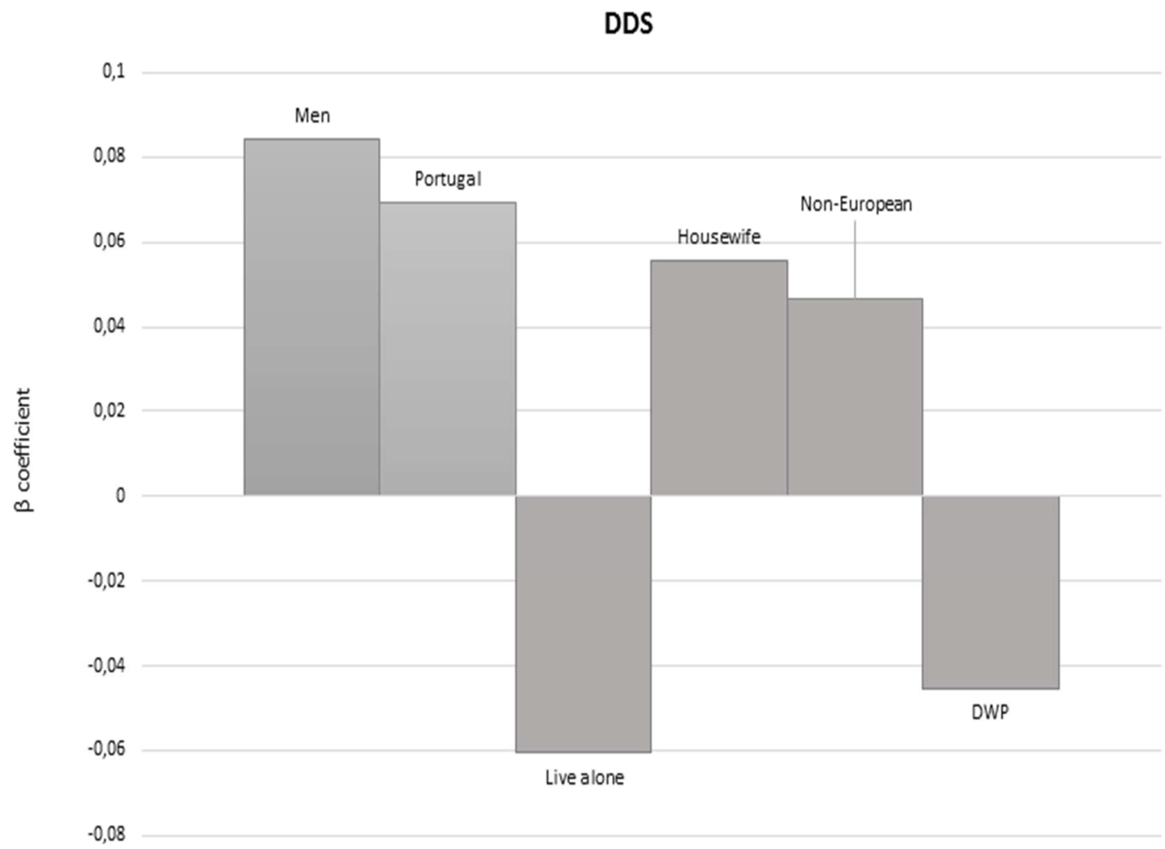
RFS: Recommendation Food Score; APT: above poverty threshold; DWP: Difficult wealth perception

Figure 3 Demographic and socioeconomic determinants of selecting unhealthy food choices



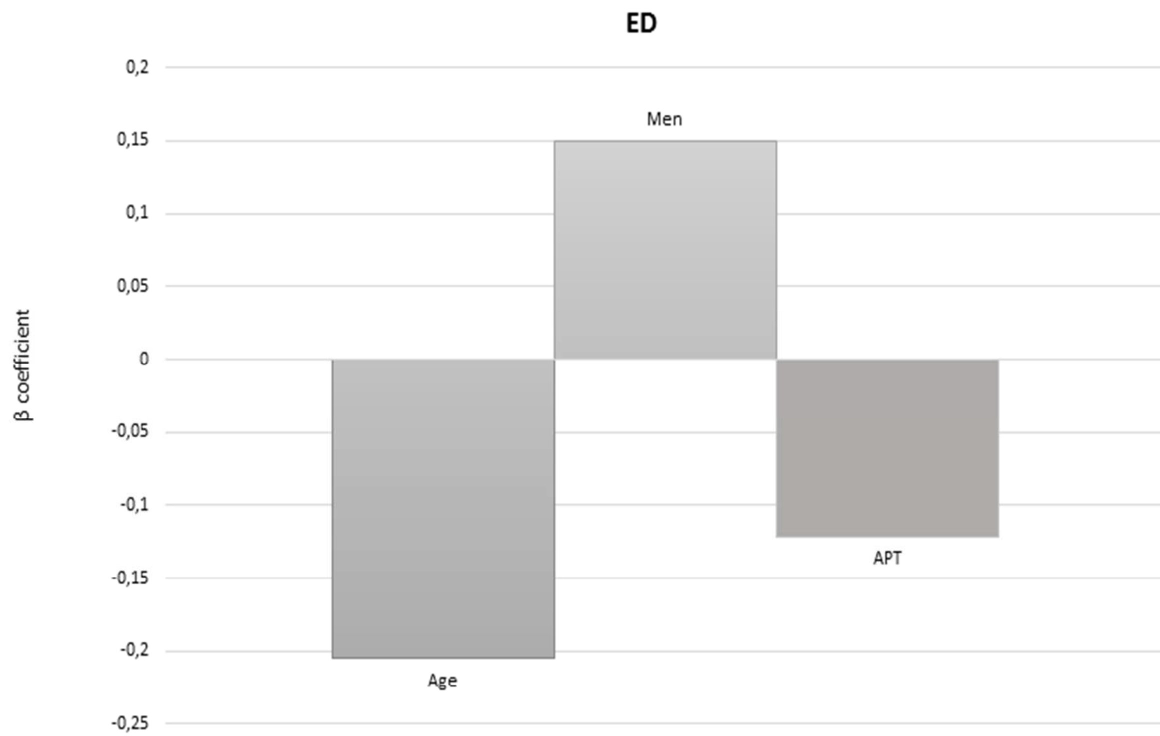
Non-RFS: non Recommended Food Score; APT: above poverty threshold

Figure 4 Demographic and socioeconomic determinants of diverse foods items



DDS: Dietary Diversity Score; DWP: Difficult wealth perception

Figure 5 Demographic and socioeconomic determinants of energy density



ED: Energy Density; APT: above poverty threshold

Appendix 1-5 Results of correlated component regression analyses for the five selected dietary outcomes

Table 1 Recommandation Compliance Index (RCI)

RCI (12 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Portugal	0,199	100	n=1058
Age	0,155	100	
Education	0,098	100	R^2=0.075
Above poverty threshold (APT)	0,080	99	R^2 (CV)=0.053
Non-European	0,071	90	SD (CV)=0.002
European	0,059	89	
Home duties/housewife	0,047	89	
Disable/retired	0,074	88	
Living alone	-0,034	73	
Man	-0,031	71	
Unemployed	-0,017	66	
Difficult wealth perception	-0,015	65	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 2 Recommended Food Score (RFS)

RFS (9 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man	-0,207	100	n=1137
Portugal	0,119	100	
Age	0,084	100	R^2=0.071
Education	0,071	100	R^2 (CV)=0.050
Living alone	-0,076	100	SD (CV)=0.003
Above poverty threshold (APT)	0,062	100	
European	0,057	100	
Unemployed	0,052	98	
Difficult wealth perception	-0,045	94	
Non-European		22	
Disable/retired		14	
Home duties/housewife		2	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 3 Non-Recommended Food Score (non-RFS)

nRFS (8 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man	0,278	100	n=1149
Portugal	-0,133	100	
Age	-0,123	100	R^2=0.119
Education	-0,102	100	R^2 (CV)=0.105
Non-European	-0,100	100	SD (CV)=0.002
Above poverty threshold (APT)	-0,094	100	
Living alone	0,062	90	
Disable/retired	-0,042	60	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 4 Diversity Dietary Score (DDS)

DDS (6 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man	0,084	100	n=1149
Portugal	0,069	100	
Living alone	-0,061	100	R^2=0.019
Home duties/housewife	0,056	99	R^2 (CV)=0.007
Non-European	0,047	92	SD (CV)=0.002
Difficult wealth perception	-0,045	86	
Age		5	
European		5	
Unemployed		2	
Disable/retired		1	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 5 Energy Density

ED (3 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Age	-0,205	100	n=1143
Man	0,150	100	K=3
Above poverty threshold (APT)	-0,121	100	R^2=0.083
Portugal		10	R^2 (CV)=0.076
Education		10	SD (CV)=0.002
Living alone		9	
Non-European		1	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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

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

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Keywords: Socioeconomic status; diet quality; Correlated Component Analyses;

Abstract

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

Study design: 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 center after a telephone appointment and were interviewed by trained research staff.

Outcome measures: Diet quality as measured by five 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.

Conclusion: 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.

Strong points

Research with respect to socioeconomic status (SES) is still challenging and characterised by a number of conceptual and methodological problems that hinder advances in knowledge about the real association between socioeconomic factors and diet quality and health.

This study suggested a novel global analytic approach, Correlated Component Regression (CCR), to explore the importance of each SES factor with regard to diet quality. It constitutes a step toward moving the field of SES-nutrition research forwards.

The CCR approach showed simultaneous factor-specific associations with diet quality.

The CCR approach allowed the measurement of the magnitude of the shared associations which have been unmeasured by previous studies.

The diet quality indicators were calculated using a validated FFQ, where several quality control measures were undertaken to provide complete and coherent data.

Weak points

Similar to other studies, limitations are related to the self-reported dietary data and the cross-sectional nature of the study which precludes establishment of the temporal sequence between socioeconomic circumstances and diet quality.

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.

Background

Socioeconomic disparity in nutrition is well documented [1; 2; 3; 4; 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]. In addition, 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* (2002) suggest wealth as a standard economic component for monitoring links between SES and health [15]. 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[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 effects of multi-collinearity[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 to 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 upon which the sample size was calculated[21]. The participants attended the nearest study center after telephone appointment and were interviewed by a trained research staff. After data cleaning, particularly for poorly completed FFQ, data from 1352 participants were available for analyses.

Independent demographic and socioeconomic variables

Self-reported information on demographic and socio-economic 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, constituting about 16.1% of the total Luxembourg population in 2011[22]. Economic status was ascertained by asking participants to select one of seven categories as best representing total household monthly income: <750 euro/month, 750–1499 euro/month, 1500-2249 euro/month, 2250-2999 euro/month, 3000-4999 euro/month, 5000-10000 euro/month, and >10000 euro/month. The number of adults and children living in the same household was also requested. 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 euro/month, as published by the national institute of statistics (STATEC). The economic status variable was then dichotomized 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 semi-quantified food frequency questionnaire (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 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), (31), (32), (33)].

The previously developed RCI[(1)] was used to evaluate participant's compliance to national dietary recommendations. It is a composite of 13 food- 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 foods 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 two to four 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, energy density score (EDS) was used as an indicator of diet quality [(30)], [(31)]. It was defined as 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 Dietary Diversity Score (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 (e.g., 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 subjects.

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 X^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 version 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 to the Partial Least Square method (PLS), 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® version 18.0 software (formerly SPSS Statistics Inc.) 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 women (*P* <0.001 and *P*=0.007, respectively) (Table 1).

Correlation between selected SES factors

While the selected SES indicators were significantly inter-correlated (*P*<0.05), sex was only correlated to 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 Appendix A 1-5) depict the demographic and socioeconomic factors associated with diet quality according to their importance. i.e., 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 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

A few, if any, adult-population studies have directly examined the importance and magnitude of the effect of each SES factor using a global analytic approach. This study explored the simultaneous role of several demographic and socioeconomic factors in relation to diet quality amongst a representative sample of the adult population in Luxembourg.

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 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. On the other hand, our previous findings showed that Portuguese participants were more overweight and obese compared to Luxembourgers [(41)]. These findings are consistent with a French study [(42)], suggesting that obese subjects had greater compliance with national dietary guidelines than normal weight subjects. 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 perception 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 health care [15]. However, wealth perception by the subject may also be influenced by one's needs, love of money, level of aspirations, and materialistic inclinations[43]. Recent research has shown that two dimensions of money attitudes affect the subjective perception of wealth: individuals' perceived financial control (the ability to budget, monitor, and control their money) and money anxiety (worry and indecisiveness regarding money-related issues)[43]. This cumulative and dynamic nature of socioeconomic structures, ascertained by wealth as perceived by the subject, is rarely considered in epidemiological studies.

In addition, 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], [44]. In the US, more affluent populations consume higher quality diets than do disadvantaged populations[45]. People with financial constraints are likely to consume fewer fruits and vegetables and consume more high energy dense foods of lower quality (e.g., processed) that are high in added sugars and saturated fat[46].

Globally, our results support previous findings reporting socioeconomic gradients in dietary intake[47]. American 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 [48]. 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 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 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 to a single proxy indicator approach, our findings support the fact that SES is a multi-dimensional 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[49]. Numerous diet quality indices have been suggested in the literature to reflect various aspects of diet quality[50]. These indices aim mainly to identify whether different population subgroups are consuming "good/healthy" or "detrimental/unhealthy" foods [50], 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[51], probably because most of these indices focus on healthy dietary patterns, nevertheless, they may not 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[52]. 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[53] 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 dataset[52].

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 [24], [54] 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. In addition, 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 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 was 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 energy density score 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 upon self-report, and therefore are subject to imprecision (under- 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 toward 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 foods 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.

Authors' contribution

AA was involved in the conception and design of the ORISCAV-LUX survey, coordinated the field data collection. All the authors (AA, CV, NS, GEC, MFE) fulfill the ICMJE guidelines, as regards:1) substantial contributions to conception and design, analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

Conflict of interest: None

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Tables and legends

Table 1 Demographic, socio-economic characteristics, and dietary indicators by sex

Table 2 Correlation between the SES factors

Table 3 Diet quality indicators by demographic and socio-economic factors

Figure 1 Demographic and socioeconomic factors associated with compliance to dietary recommendations

Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices

Figure 3 Demographic and socioeconomic factors associated with selecting unhealthy food choices

Figure 4 Demographic and socioeconomic factors associated with diverse foods items

Figure 5 Demographic and socioeconomic factors associated with energy density

Appendix A 1-5 Results of correlated component regression analyses for the five selected dietary outcomes

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

	Men N=657	Women N=695	Total N=1352	*P*-value
Demographic and socio-economic 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[a] (n=1352)	16.1 ± 0.10	15.7 ± 0.10	15.9 ± 0.07	0.007

RCI: Recommendation Compliance Index; RFS: Recommended Foods Score; n-RFS: non-Recommended Foods Score; ED: Energy Density; DDS: Dietary Diversity Score.

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
[a] P-value from Kruskal-Wallis non-parametric test

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							

* indicated by P-values from Chi square test

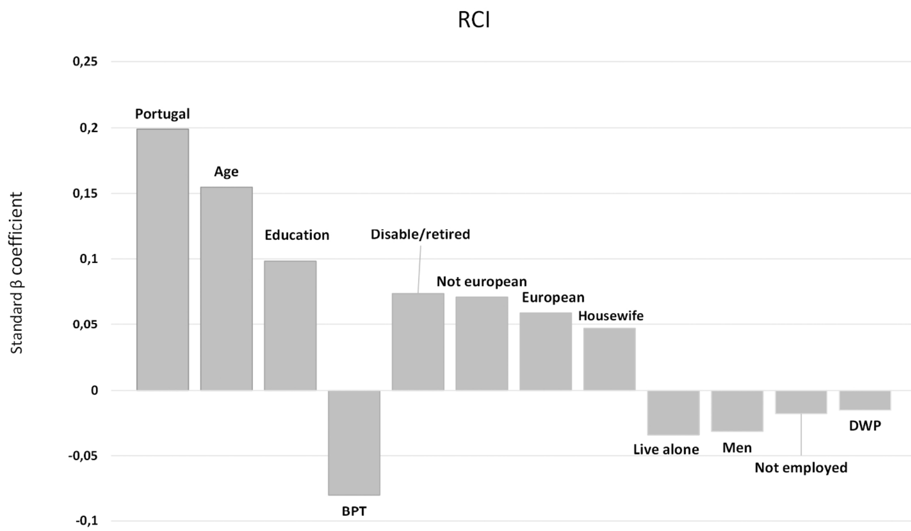
§ Age was categorized here in 3 categories (18-29; 30-49; 50-69)

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

	RCI n=1234		**RFS** n=1338		**Non-RFS** n=1352		**EDS** n=1346		**DDS**[a] 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 y	6.0 ± 0.17		9.5 ± 0.23		4.1 ± 0.14		110.8 ± 2.1		15.4 ± 0.21	
30-49 y	6.8 ± 0.09		10.4 ± 0.11		3.7 ± 0.07		103.8 ± 1.0		16.1 ± 0.94	
50-69 y	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	

RCI: Recommendation Compliance Index; RFS: Recommended Foods Score; n-RFS: non-Recommended Foods Score; ED: Energy Density; DDS: Dietary Diversity Score. Mean ± SE are presented. [a] P-value from Kruskall-Wallis test, otherwise from *t*-test.

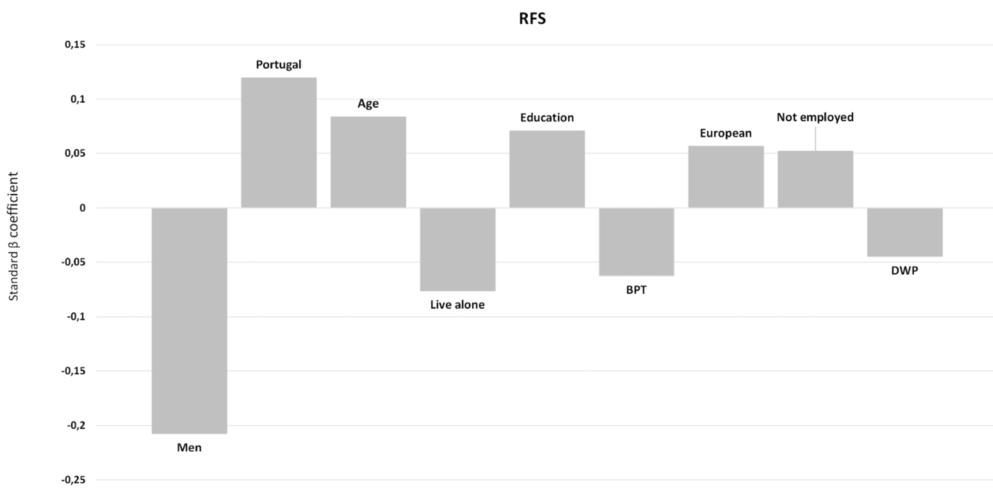
Figure 1 Demographic and socioeconomic factors associated with compliance to dietary recommendations



RCI: Recommedation Compliance Index; BPT: below poverty threshold; DWP: Difficult wealth perception

204x134mm (300 x 300 DPI)

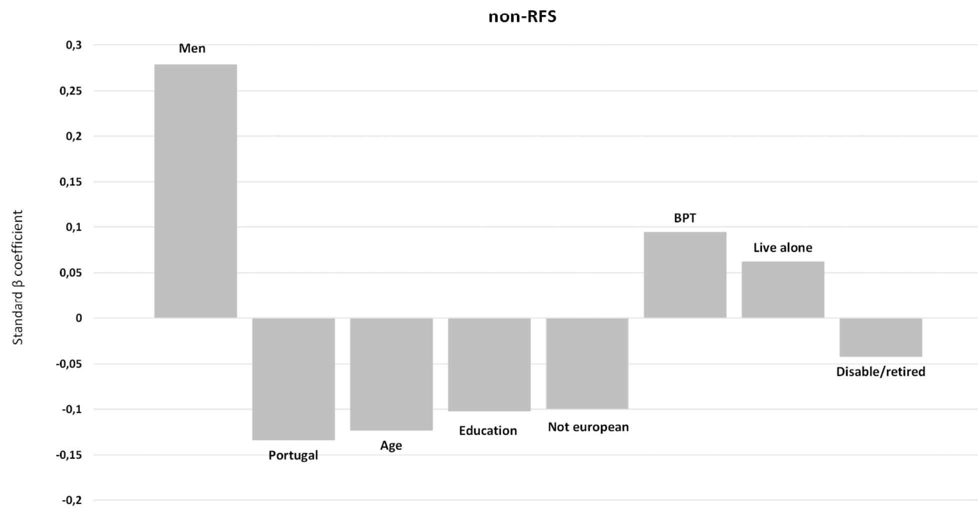
Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices



RFS: Recommendation Food Score; BPT: below poverty threshold; DWP: Difficult wealth perception

224x138mm (300 x 300 DPI)

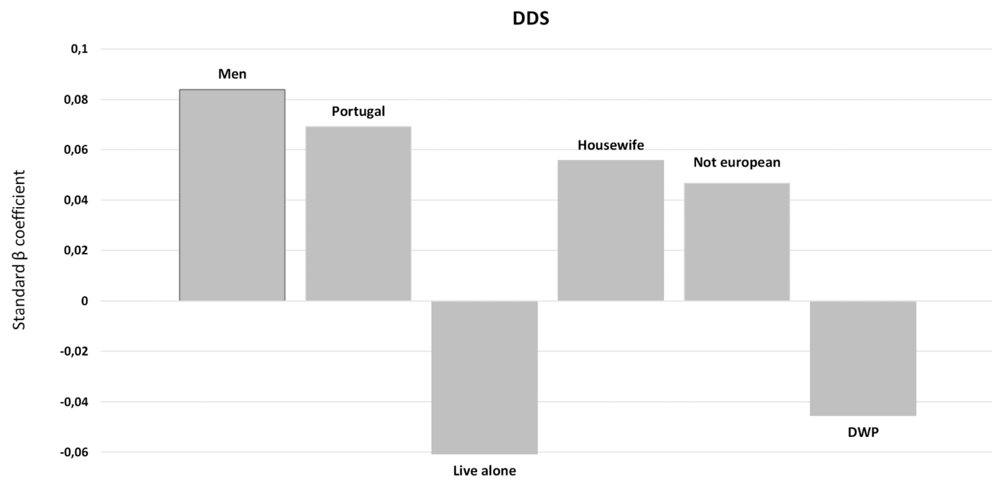
Figure 3 Demographic and socioeconomic factors associated with selecting unhealthy food choices



Non-RFS: non Recommended Food Score; BPT: below poverty threshold

207x138mm (300 x 300 DPI)

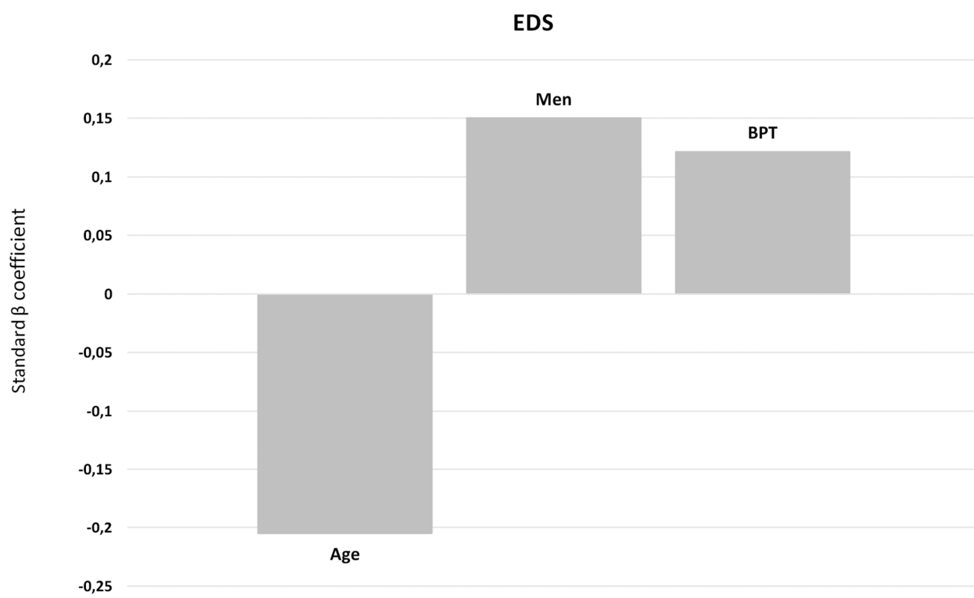
Figure 4 Demographic and socioeconomic factors associated with diverse foods items



DDS: Dietary Diversity Score; DWP: Difficult wealth perception

193x138mm (300 x 300 DPI)

Figure 5 Demographic and socioeconomic factors associated with energy density



ED: Energy Density; BPT: below poverty threshold

160x134mm (300 x 300 DPI)

Appendix B 1-5 Results of correlated component regression analyses for the five selected dietary outcomes

Table 1 Recommandation Compliance Index (RCI)

RCI (12 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Portugal *vs* Luxembourg	0,199	100	n=1058
Age	0,155	100	
Education	0,098	100	R^2=0.075
Below *vs* above poverty threshold	-0,080	99	R^2 (CV)=0.053
Non-European *vs* Luxembourg	0,071	90	SD (CV)=0.002
European *vs* Luxembourg	0,059	89	
Home duties/housewife *vs* employed	0,047	89	
Disable/retired *vs* employed	0,074	88	
Living alone *vs* live with partner	-0,034	73	
Man	-0,031	71	
Unemployed *vs* employed	-0,017	66	
Difficult *vs* easy wealth perception	-0,015	65	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 2 Recommended Food Score (RFS)

RFS (9 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man vs women	-0,207	100	n=1137
Portugal *vs* Luxembourg	0,119	100	
Age	0,084	100	R^2=0.071
Education	0,071	100	R^2 (CV)=0.050
Living alone *vs* live with partner	-0,076	100	SD (CV)=0.003
Below *vs* above poverty threshold	-0,062	100	
European *vs* Luxembourg	0,057	100	
Unemployed *vs* employed	0,052	98	
Difficult *vs* easy wealth perception	-0,045	94	
Non-European *vs* Luxembourg		22	
Disable/retired *vs* employed		14	
Home duties/housewife *vs* employed		2	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 3 Non-Recommended Food Score (non-RFS)

nRFS (8 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man *vs* women	0,278	100	n=1149
Portugal *vs* Luxembourg	-0,133	100	
Age	-0,123	100	R^2=0.119
Education	-0,102	100	R^2 (CV)=0.105
Non-European *vs* Luxembourg	-0,100	100	SD (CV)=0.002
Below *vs* above poverty threshold	0,094	100	
Living alone *vs* live with partner	0,062	90	
Disable/retired *vs* employed	-0,042	60	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 4 Diversity Dietary Score (DDS)

DDS (6 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man *vs* women	0,084	100	n=1149
Portugal *vs* Luxembourg	0,069	100	
Living alone *vs* live with partner	-0,061	100	R^2=0.019
Home duties/housewife *vs* employed	0,056	99	R^2 (CV)=0.007
Non-European *vs* Luxembourg	0,047	92	SD (CV)=0.002
Difficult *vs* easy wealth perception	-0,045	86	
Age		5	
European *vs* Luxembourg		5	
Unemployed *vs* employed		2	
Disable/retired *vs* employed		1	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 5 Energy Density

ED (3 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Age	-0,205	100	n=1143
Man *vs* women	0,150	100	K=3
Below *vs* above poverty threshold	0,121	100	R^2=0.083
Portugal *vs* Luxembourg		10	R^2 (CV)=0.076
Education		10	SD (CV)=0.002
Living alone *vs* live with partner		9	
Non-European *vs* Luxembourg		1	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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

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

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Keywords: Socioeconomic status; diet quality; Correlated Component Analyses;

Abstract

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

Study design: 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 center after a telephone appointment and were interviewed by trained research staff.

Outcome measures: Diet quality as measured by five 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.

Conclusion: 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.

Strong points

Research with respect to socioeconomic status (SES) is still challenging and characterised by a number of conceptual and methodological problems that hinder advances in knowledge about the real association between socioeconomic factors and diet quality and health.

This study suggested a novel global analytic approach, Correlated Component Regression (CCR), to explore the importance of each SES factor with regard to diet quality. It constitutes a step toward moving the field of SES-nutrition research forwards.

The CCR approach showed simultaneous factor-specific associations with diet quality.

The CCR approach allowed the measurement of the magnitude of the shared associations which have been unmeasured by previous studies.

The diet quality indicators were calculated using a validated FFQ, where several quality control measures were undertaken to provide complete and coherent data.

Weak points

Similar to other studies, limitations are related to the self-reported dietary data and the cross-sectional nature of the study which precludes establishment of the temporal sequence between socioeconomic circumstances and diet quality.

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.

Background

Socioeconomic disparity in nutrition is well documented [1; 2; 3; 4; 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]. In addition, 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* (2002) suggest wealth as a standard economic component for monitoring links between SES and health [15]. 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[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 effects of multi-collinearity[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 to 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 upon which the sample size was calculated[(21)]. The participants attended the nearest study center after telephone appointment and were interviewed by a trained research staff. After data cleaning, particularly for poorly completed FFQ, data from 1352 participants were available for analyses.

Independent demographic and socioeconomic variables

Self-reported information on demographic and socio-economic 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, constituting about 16.1% of the total Luxembourg population in 2011[22]. Economic status was ascertained by asking participants to select one of seven categories as best representing total household monthly income: <750 euro/month, 750–1499 euro/month, 1500-2249 euro/month, 2250-2999 euro/month, 3000-4999 euro/month, 5000-10000 euro/month, and >10000 euro/month. The number of adults and children living in the same household was also requested. 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 euro/month, as published by the national institute of statistics (STATEC). The economic status variable was then dichotomized 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 semi-quantified food frequency questionnaire (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 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], [31], [32], [33].

The previously developed RCI[1] was used to evaluate participant's compliance to national dietary recommendations. It is a composite of 13 food- 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 foods 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 two to four 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, energy density score (EDS) was used as an indicator of diet quality [30], [31]. It was defined as 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 Dietary Diversity Score (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 (e.g., 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 subjects.

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 X^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 version 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 to the Partial Least Square method (PLS), 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® version 18.0 software (formerly SPSS Statistics Inc.) 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 women (P <0.001 and P=0.007, respectively) (Table 1).

Correlation between selected SES factors

While the selected SES indicators were significantly inter-correlated (P<0.05), sex was only correlated to 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 Appendix A 1-5) depict the demographic and socioeconomic factors associated with diet quality according to their importance. i.e., 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 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 amongst a representative sample of the adult population in Luxembourg. It is one of a few adult-population studies [13], [41] which have directly examined the importance and magnitude of the effect of each SES factor using a global analytic 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 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. On the other hand, our previous findings showed that Portuguese participants were more overweight and obese compared to Luxembourgers [42]. These findings are consistent with a French study [43], suggesting that obese subjects had greater compliance with national dietary guidelines than normal weight subjects. 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 perception 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 health care [15]. However, wealth perception by the subject 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: 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 subject, is rarely considered in epidemiological studies.

In addition, 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 US, 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 (e.g., processed) that are high in added sugars and saturated fat[47].

Globally, our results support previous findings reporting socioeconomic gradients in dietary intake[48]. American 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 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 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 to a single proxy indicator approach, our findings support the fact that SES is a multi-dimensional 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 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 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 dataset[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 [24], [55] 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. In addition, 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 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 was 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 energy density score 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[56]. Although the FFQ has been shown to be sufficiently convenient and inexpensive to use in large-scale, population-based studies [57], responses rely upon self-report, and therefore are subject to imprecision (under- and over-reporting) and biases related to social desirability [58].

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 toward 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 foods 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.

Authors' contribution

AA was involved in the conception and design of the ORISCAV-LUX survey, coordinated the field data collection. All the authors (AA, CV, NS, GEC, MFE) fulfill the ICMJE guidelines, as regards:1) substantial contributions to conception and design, analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

Conflict of interest: None

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Tables and legends

Table 1 Demographic, socio-economic characteristics, and dietary indicators by sex

Table 2 Correlation between the SES factors

Table 3 Diet quality indicators by demographic and socio-economic factors

Figure 1 Demographic and socioeconomic factors associated with compliance to dietary recommendations

Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices

Figure 3 Demographic and socioeconomic factors associated with selecting unhealthy food choices

Figure 4 Demographic and socioeconomic factors associated with diverse foods items

Figure 5 Demographic and socioeconomic factors associated with energy density

Appendix A 1-5 Results of correlated component regression analyses for the five selected dietary outcomes

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538 Table 1 Demographic, socio-economic characteristics, and dietary indicators by sex, ORISCAV-LUX
539 study, 2007-2008

	Men N=657	Women N=695	Total N=1352	*P*-value
Demographic and socio-economic 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[a] (n=1352)	16.1 ± 0.10	15.7 ± 0.10	15.9 ± 0.07	0.007

540 RCI: Recommendation Compliance Index; RFS: Recommended Foods Score; n-RFS: non-Recommended Foods
541 Score; ED: Energy Density; DDS: Dietary Diversity Score.

542 Results are presented N (%) for qualitative variables and mean ± SE for quantitative variables.
543 P-value from *X* test and *t*-test for qualitative and quantitative outcomes respectively
544 [a] P-value from Kruskal-Wallis non-parametric test

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							

* indicated by P-values from Chi square test

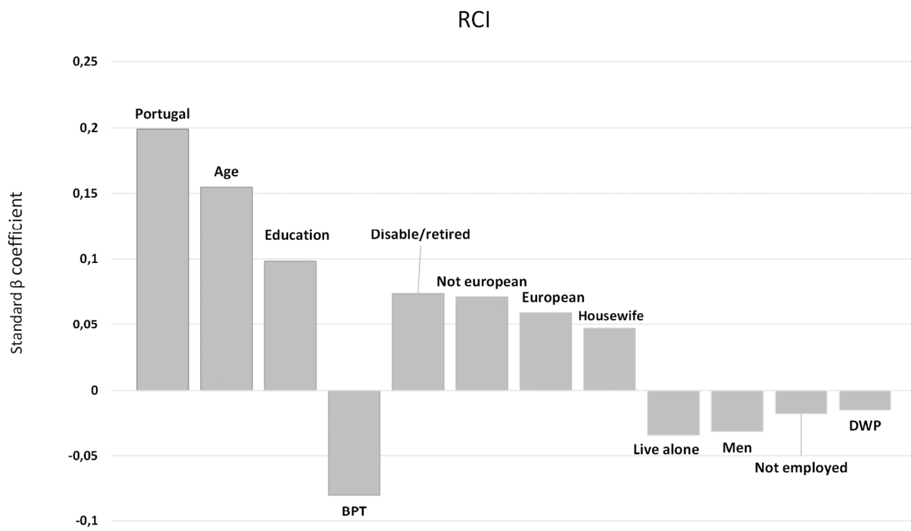
§ Age was categorized here in 3 categories (18-29; 30-49; 50-69)

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

	RCI n=1234		RFS n=1338		Non-RFS n=1352		EDS n=1346		DDS[a] 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 y	6.0 ± 0.17		9.5 ± 0.23		4.1 ± 0.14		110.8 ± 2.1		15.4 ± 0.21	
30-49 y	6.8 ± 0.09		10.4 ± 0.11		3.7 ± 0.07		103.8 ± 1.0		16.1 ± 0.94	
50-69 y	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	

RCI: Recommendation Compliance Index; RFS: Recommended Foods Score; n-RFS: non-Recommended Foods Score; ED: Energy Density; DDS: Dietary Diversity Score. Mean ± SE are presented. [a] P-value from Kruskall-Wallis test, otherwise from *t*-test.

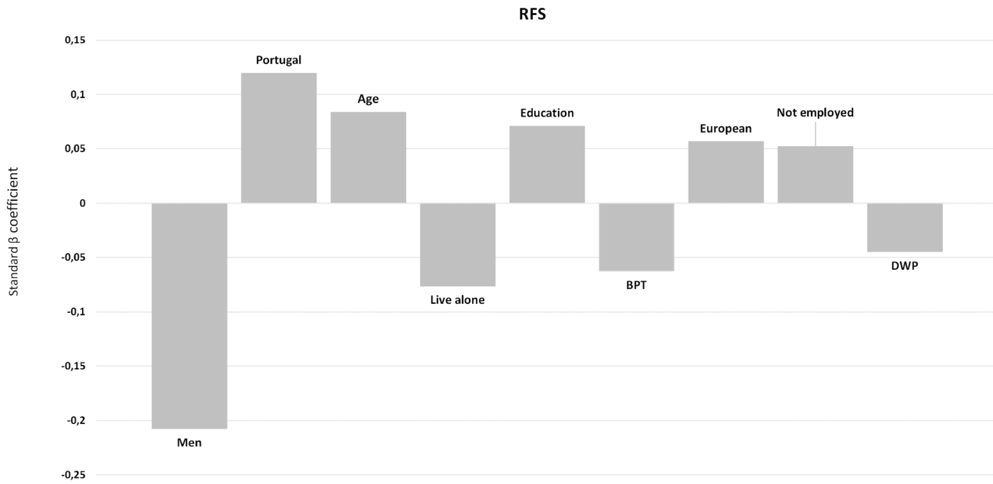
Figure 1 Demographic and socioeconomic factors associated with compliance to dietary recommendations



RCI: Recommedation Compliance Index; BPT: below poverty threshold; DWP: Difficult wealth perception

204x134mm (300 x 300 DPI)

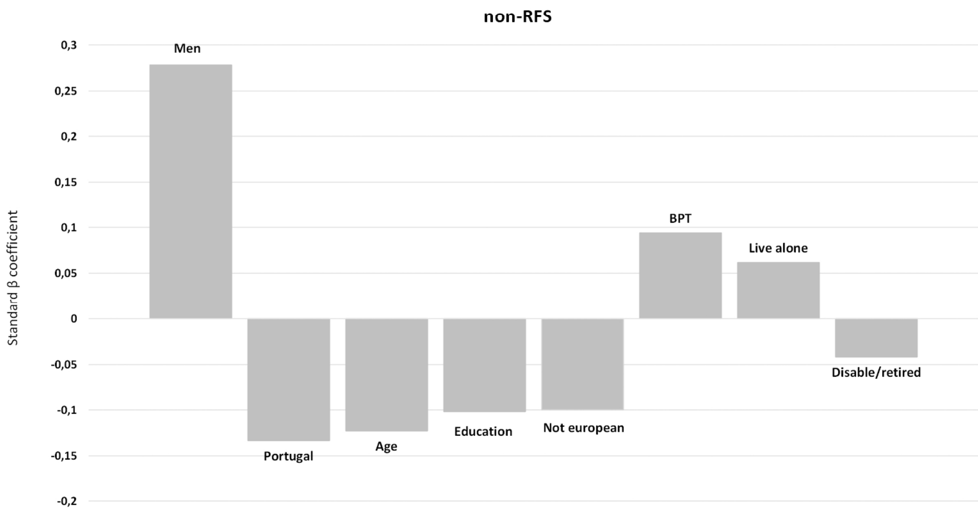
Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices



RFS: Recommendation Food Score; BPT: below poverty threshold; DWP: Difficult wealth perception

224x138mm (300 x 300 DPI)

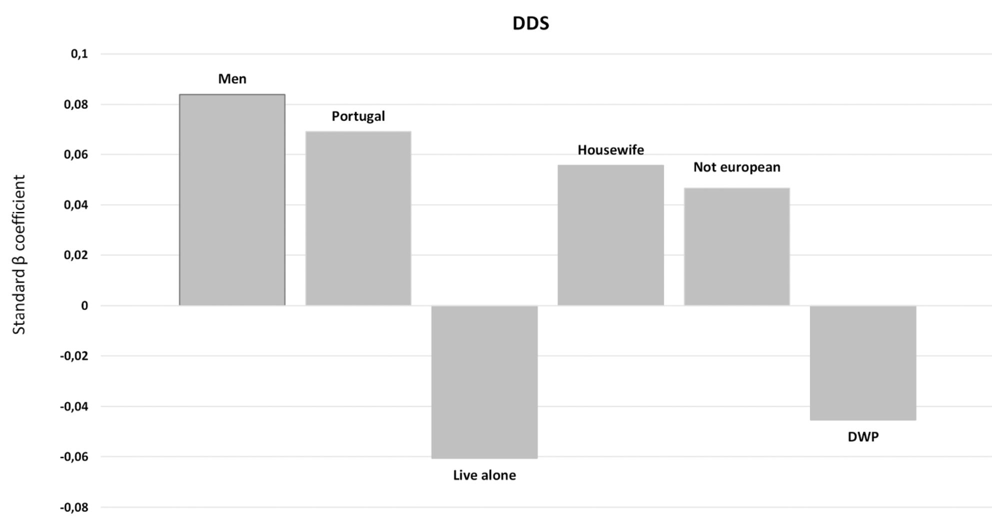
Figure 3 Demographic and socioeconomic factors associated with selecting unhealthy food choices



Non-RFS: non Recommended Food Score; BPT: below poverty threshold

207x138mm (300 x 300 DPI)

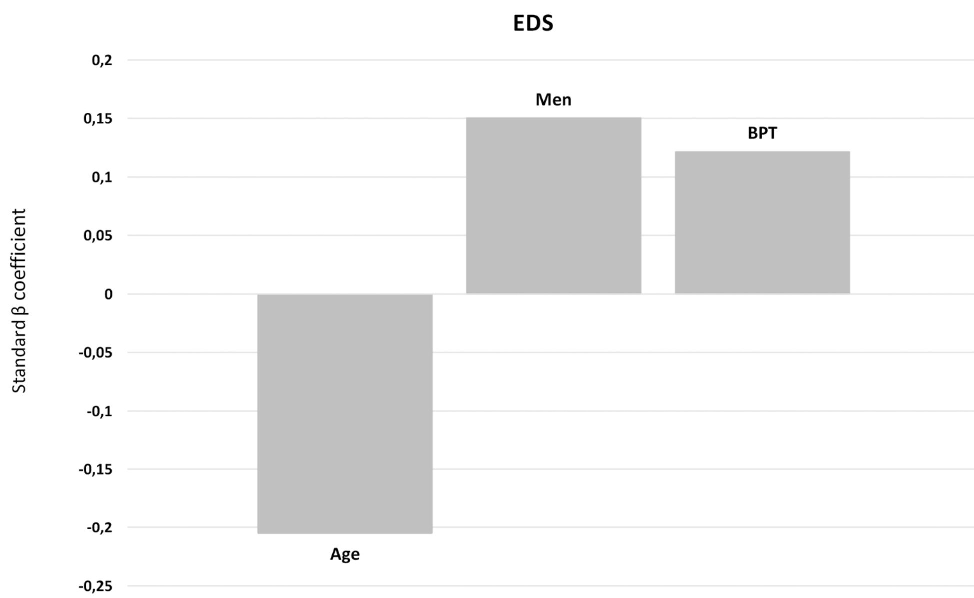
Figure 4 Demographic and socioeconomic factors associated with diverse foods items



DDS: Dietary Diversity Score; DWP: Difficult wealth perception

193x138mm (300 x 300 DPI)

Figure 5 Demographic and socioeconomic factors associated with energy density



ED: Energy Density; BPT: below poverty threshold

160x134mm (300 x 300 DPI)

Appendix B 1-5 Results of correlated component regression analyses for the five selected dietary outcomes

Table 1 Recommandation Compliance Index (RCI)

RCI (12 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Portugal *vs* Luxembourg	0,199	100	n=1058
Age	0,155	100	
Education	0,098	100	R^2=0.075
Below *vs* above poverty threshold	-0,080	99	R^2 (CV)=0.053
Non-European *vs* Luxembourg	0,071	90	SD (CV)=0.002
European *vs* Luxembourg	0,059	89	
Home duties/housewife *vs* employed	0,047	89	
Disable/retired *vs* employed	0,074	88	
Living alone *vs* live with partner	-0,034	73	
Man	-0,031	71	
Unemployed *vs* employed	-0,017	66	
Difficult *vs* easy wealth perception	-0,015	65	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 2 Recommended Food Score (RFS)

RFS (9 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man vs women	-0,207	100	n=1137
Portugal *vs* Luxembourg	0,119	100	
Age	0,084	100	R^2=0.071
Education	0,071	100	R^2 (CV)=0.050
Living alone *vs* live with partner	-0,076	100	SD (CV)=0.003
Below *vs* above poverty threshold	-0,062	100	
European *vs* Luxembourg	0,057	100	
Unemployed *vs* employed	0,052	98	
Difficult *vs* easy wealth perception	-0,045	94	
Non-European *vs* Luxembourg		22	
Disable/retired *vs* employed		14	
Home duties/housewife *vs* employed		2	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 3 Non-Recommended Food Score (non-RFS)

nRFS (8 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man *vs* women	0,278	100	n=1149
Portugal *vs* Luxembourg	-0,133	100	
Age	-0,123	100	R^2=0.119
Education	-0,102	100	R^2 (CV)=0.105
Non-European *vs* Luxembourg	-0,100	100	SD (CV)=0.002
Below *vs* above poverty threshold	0,094	100	
Living alone *vs* live with partner	0,062	90	
Disable/retired *vs* employed	-0,042	60	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 4 Diversity Dietary Score (DDS)

DDS (6 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Man *vs* women	0,084	100	n=1149
Portugal *vs* Luxembourg	0,069	100	
Living alone *vs* live with partner	-0,061	100	R^2=0.019
Home duties/housewife *vs* employed	0,056	99	R^2 (CV)=0.007
Non-European *vs* Luxembourg	0,047	92	SD (CV)=0.002
Difficult *vs* easy wealth perception	-0,045	86	
Age		5	
European *vs* Luxembourg		5	
Unemployed *vs* employed		2	
Disable/retired *vs* employed		1	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

Table 5 Energy Density

ED (3 predictors)	β	CV predictor count[a]	Model goodness of fit indices[b]
Age	-0,205	100	n=1143
Man *vs* women	0,150	100	K=3
Below *vs* above poverty threshold	0,121	100	R^2=0.083
Portugal *vs* Luxembourg		10	R^2 (CV)=0.076
Education		10	SD (CV)=0.002
Living alone *vs* live with partner		9	
Non-European *vs* Luxembourg		1	

β indicates standard regression coefficient.

[a] Cross-validation predictor count. It represents number of regressions in which predictor appeared. Predictor count of 100 indicates that predictor was present in all 100 regression models. It indicates importance of predictor together with standard regression coefficient (β).

[b] Model goodness of fit indices: R^2 (CV)= cross-validated R^2; SD (CV)= Standard deviation for cross-validated R^2.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.