

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-006814
Article Type:	Research
Date Submitted by the Author:	06-Oct-2014
Complete List of Authors:	Alkerwi, Ala'a; Centre de Recherch Public-Santé, Public Health Vernier, Cédéric; Centre de Recherche Public-Santé, Public Health Sauvageot, Nicolas; Centre de Recherche Public-Santé, Public Health Crichton, Georgina E.; Centre de Recherche Public-Santé, Public Health Elias, Merrill F.; Department of Psychology, University of Maine,,
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Epidemiology, Public health, Sociology
Keywords:	NUTRITION & DIETETICS, PUBLIC HEALTH, SOCIAL MEDICINE

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

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8
9 *Running title.* Socioeconomic-diet quality

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

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3 **19 Abstract**
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5 **20 Objectives:** This study aimed to explore the association of a range of demographic and
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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.

25 Study design: Nationwide cross-sectional population-based study

26 Participants: A total of 1352 apparently healthy and non-institutionalized subjects, aged 18-69
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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.

30 Outcome measures: Diet quality as measured by five dietary indicators, namely,
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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.

35 Results: Increasing age, being male, and living below the poverty threshold were predominant
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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.

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3 41 **Conclusion:** Multiple demographic and socioeconomic circumstances predicted different diet
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6 42 quality indicators. Efforts to improve diet quality for high risk groups need an important public
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8 43 health focus.
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Strong points

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16 Research with respect to socioeconomic status (SES) is still challenging and characterized by a
17 number of conceptual and methodological problems that hinder a relevant conclusion about the
18 real association of socioeconomic factors on diet quality and health.
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21 This study suggested a novel global analytic approach, Correlated Component Regression
22 (CCR), to explore the importance of each SES factor with regard to the quality of diet. It
23 constitutes a step toward moving the field of SES-nutrition research forwards.

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

26
27 The CCR approach allowed to measure the magnitude of the shared associations which have
28 been unmeasured by previous studies.

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

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34 Similar to other studies, limitations are related to the self-reported dietary data and the cross-
35 sectional nature of the study which precludes causality inferences between socioeconomic
36 circumstances and diet quality.
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39 The relatively low response rate (32.2%) did not influence the present findings, as a detailed
40 study of non-participants showed comparable demographic and clinical characteristics of
41 participants and non-participants, hence providing population-representative estimates.
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49 Background

50 Socioeconomic disparity in nutrition is well documented^(1; 2; 3; 4; 5) which helps to explain some
51 of the observed social inequalities in health^{(2), (6)}. The more affluent populations are more likely
52 to have healthier food habits whereas the disadvantaged groups have dietary profiles less
53 consistent with nutritional recommendations or dietary guidelines, hence contributing to their
54 poorer health status^{(6), (7)}. Therefore, both social inequity and diet quality, reflected by healthy
55 dietary behaviors are areas of active public health concern.

56 Despite the importance of these two areas, research with respect to socioeconomic status
57 (SES) is still challenging and characterized by a number of conceptual and methodological
58 problems that hinder a relevant conclusion about the real impact of socioeconomic factors on diet
59 quality and health^{(8), (9)}. A single “best” indicator approach, to determine social classification
60 among societies, is not theoretically compelling because it may emphasize a particular aspect of
61 social stratification which may be only relevant to specific health outcomes^{(10), (11)} and at
62 different stages of the life course⁽¹²⁾. The most widely used SES indicators (education,
63 occupation and income)^{(8), (9), (13)} are limited in their ability to capture the complex
64 multidimensional forces that dominate social structure⁽¹⁵⁾. While education and occupation are
65 markers of social relationships and command over life-long skills, income is more indicative of a
66 current standard of living and a flow of resources over a defined time period⁽¹⁴⁾.

67 The pathway mechanisms linking education, occupation and income with diet are
68 conceptually distinct⁽⁹⁾. Additionally, these traditional SES are interrelated, which make it
69 difficult to determine the specific contribution of each factor to food choices^{(2), (16)}.

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3 70 Beyond household income, Daly *et al* (2002) suggests wealth as a standard economic
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5 71 component for monitoring links between SES and health ⁽¹⁴⁾. Household income consists of a
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8 72 flow of resources over a defined time period, whereas wealth captures the accumulated stock of
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10 73 assets (housing, cars, investments, inheritance and pension rights) or economic reserves over the
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12 74 life course), although both are positively correlated ⁽¹⁴⁾.

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16 75 Another challenge to SES research, is that these indicators are not interchangeable⁽¹⁷⁾;
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18 76 both cumulative effects^{(12), (18)} and unique contributions from each indicator may exist ^{(9), (14)}.
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20 77 Thus it is still difficult to directly attribute the observed variation in diet quality to a specific SES
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22 78 indicator because different indicators may show disparate effects on food habits ⁽¹³⁾.

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26 79 The objective of the present study was to examine the simultaneous effect of a range of
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28 80 demographic and socioeconomic factors on diet quality, as measured by several selected dietary
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30 81 indicators. The importance and explanatory power of each SES factor with regard to the quality
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32 82 of diet was explored by using the novel Correlated Component Regression (CCR)⁽¹⁹⁾ technique.
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34 83 The CCR provides an alternative method to capture important suppressor variables among a set
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36 84 of predictors, especially when these are moderately to highly correlated, by dealing with the
37
38 85 problems of confounding and effects of multi-collinearity⁽¹⁹⁾. The CCR helps to ascertain the
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40 86 classification of key SES predictors that influence diet quality according to their importance, thus
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42 87 providing better performance than traditional regression techniques. It permits simultaneous
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44 88 adjustment for the effect of each indicator on the other, and hence to demonstrate the
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46 89 independent unique contribution of each indicator. Beside the traditional SES indicators of
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48 90 education, occupation status and income, we included country of birth, marital status and
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50 91 perceived wealth. Diet quality was evaluated in terms of compliance to national food- and
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52 92 nutrient-based recommendations, selection of healthy and unhealthy food choices, energy
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3 93 density, and food variety. The findings are important to gain a better understanding of
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5 94 socioeconomic disparities in nutrition with the consequent impacts on health in order to develop
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8 95 strategies aimed at tackling the problem of SES disparities in nutrition in a global context.
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11 **Methods**

12 13 14 97 *Studied population*

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17 98 Analyses were conducted on data from the Observation of Cardiovascular Risk Factors in
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19 99 Luxembourg (ORISCAV-LUX), a first nationwide nutritional population-based study. A
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22 100 comprehensive description of the ORISCAV-LUX survey design, sampling method and sample
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24 101 representativeness has been published elsewhere^{(16), (20), (21)}. Briefly, a random sample stratified
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26 102 according to age (18 to 69 years), gender and district of residence, was selected from the national
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29 103 health insurance registry. A total of 1432 participants were recruited with a participation rate
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31 104 (32.2%) corresponding to the theoretically expected rate upon which the sample size was
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34 105 calculated⁽²¹⁾. The participants attended the nearest study center after telephone appointment and
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36 106 were interviewed by a trained research staff. After eliminating missing data on various dietary
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38 107 measures and SES indicators, data from 1352 participants were available for the analyses.
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41 108 42 43 109 *Predictor variables: Demographic and socioeconomic indicators*

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46 110 Self-reported information on demographic and socio-economic variables were collected via a
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48 111 questionnaire, including age, gender, country of birth, education level, marital status,
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50 112 professional status, monthly household income, and perceived wealth. Education level, based on
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52 113 the highest diploma obtained, was classified into three groups: “tertiary level” equivalent to
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54 114 university or more; “secondary level” equivalent to classical or technical qualification; and
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3 115 “primary level” corresponding to nonacademic qualification (but at least first 9 years of
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6 116 mandatory schooling). Marital status was recorded into two groups: “live alone” which included
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8 117 single, divorced and widowed subjects; and “living with partner”. Work status was classified as
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10 118 “employed” comprising participants currently engaged in a remunerated occupation;
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13 119 “unemployed” including students; “retired/sick leave and disabled”; and “home
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15 120 duties/housewives”. The participants were classified according to their country of birth, into four
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17 121 major groups: “Luxembourg”; “Portugal”; “Other European country”; and “non-European
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19 122 country”. The Portuguese are representing the major European immigrant community in
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21 123 Luxembourg, constituting about 15.9% of the total Luxembourg population in 2001⁽²²⁾.
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24 124 Economic status was ascertained by asking the participants to select one of seven categories as
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26 125 best representing total household monthly income; <750 euro/month, 750–1499 euro/month,
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28 126 1500-2249 euro/month, 2250-2999 euro/month, 3000-4999 euro/month, 5000-10000
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30 127 euro/month, and >10000 euro/month. The number of adults and children living in the same
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32 128 household was also requested. Adult Equivalent Income (AEI) was calculated as the ratio of the
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34 129 midpoint of the self-declared family income to the square root of the number of persons in the
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36 130 household. The risk of poverty was referred to the national AEI which is equivalent to 1432
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38 131 euro/month, as published by the national institute of statistics (STATEC). Then, the economic
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40 132 status variable was dichotomized as: “above poverty threshold” (APT) and “below poverty
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42 133 threshold” (BPT). Wealth adequacy perception was assessed by using the question “to what
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44 134 extent does your current income and other available resources allow you to provide for your
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46 135 needs?” and was classified as: “difficult” or “easy”.

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54 136 *Dependent variables: Diet quality measures*
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3 137 Dietary intake was assessed using a validated semi-quantified food frequency questionnaire
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5 138 (FFQ)⁽²³⁾, ⁽²⁴⁾ which collects information on the frequency and quantity (portion size) of 134
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8 139 items consumed over the preceding 3 months of the interview. Research staff provided detailed
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10 140 instructions on how to complete the FFQ, and then checked the correctness and completeness of
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12 141 answers. Several measures were evaluated to cover different aspects of diet quality, including
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14 142 compliance to national dietary recommendations, appropriate food choices, energy density, and
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16 143 food variety/diversity.

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20 144 Participant's compliance to national dietary recommendations was evaluated using the
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22 145 previously developed Recommendation Compliance Index (RCI)⁽¹⁾. It is a composite of 13 food-
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24 146 and nutrient-based components, and ranges between -0.5 (due to a negative half point for
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26 147 excessive salt intake) and 14 points (2 points for high daily fruit and vegetable servings), where a
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28 148 higher degree of adherence results in higher scores.

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33 149 Appropriate food choices were assessed by means of two scores: A Recommended Food
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35 150 Score (RFS)⁽²⁵⁾ and a non-Recommended Food Score (non-RFS)⁽²⁶⁾. The RFS gives an
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37 151 indication of the frequency of consumption of foods items that are recommended to increase
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39 152 (good choices). It comprised 18 food items (including fruit, vegetables, legumes, wholegrain
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41 153 cereal products, low fat dairy products, fish, and nuts). One point was given for consumption of
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43 154 any of the recommended foods at least once per week⁽²⁵⁾, to give a total score out of 18. The
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45 155 non-RFS gives an indication of the frequency of consumption of foods that are recommended to
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47 156 reduce (bad choices). It comprised 14 food items, including processed meats, refined grains,
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49 157 solid fats, added sugars, and alcohol. One point was given for consumption of non-recommended
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51 158 foods at least two to four times per week^(27; 28), to give a total non-RFS out of 14, with a higher
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53 159 value indicating a higher consumption of non-recommended food items.
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3 160 Consistent with other studies, energy density (ED) was used as an indicator of diet
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6 161 quality ⁽²⁹⁾, ⁽³⁰⁾. It was defined as ratio of total energy intake over daily weight of total food
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8 162 consumed (Kcal/g), based on all foods and beverages, excluding drinking water. By choosing the
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10 163 lower energy density option, one can eat more food for the same number of calories. Therefore,
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13 164 higher value of ED indicates more energy per gram of food consumed.

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16 166 Food variety (diversity), another dimension of diet quality, was measured as described by
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18 167 Patterson *et al* (1994) ⁽³¹⁾, to build the Dietary Diversity Score (DDS). It comprised two
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20 168 components: overall variety (daily consumption of at least one serving from each of the five food
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22 169 groups: meat/poultry/fish/egg, dairy products, grains, fruit, and vegetables) and variety within
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24 170 protein sources (meat/poultry, fish, dairy, and eggs) to give a total DDS of 20 points.

25 26 171 *Ethical aspects*

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29 172 The present study was conducted according to the guidelines laid down in the Declaration of
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31 173 Helsinki and all procedures involving human subjects were approved by the National Research
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33 174 Ethics Committee and the National Commission for Private Data Protection. Written informed
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35 175 consent was obtained from all subjects.

36 37 176 38 177 *Statistical analysis*

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43 178 For descriptive purposes, diet quality indicators and participants' demographic and
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45 179 socioeconomic characteristics were compared by gender. Then, univariate associations between
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47 180 each diet quality indicator with demographic, and socioeconomic factors were examined. For
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49 181 these analyses, P-values were calculated by using the X^2 test for categorical variables, the *t*-test
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51 182 and Kruskal-Wallis test for normally and non-normally distributed variables, respectively.
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3 183 The CCR analysis⁽³²⁾ was performed, using XLStat version 2014.2.07, to identify the
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6 184 optimal demographic and socioeconomic predictors of dietary outcomes. All selected predictors
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8 185 (age, gender, country of birth, education, marital status, work status, economic status, and wealth
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10 186 perception) were simultaneously introduced. The categorical variables were recoded as dummy
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12 187 variables. “Women” were selected as referent for sex, “live with partner” for marital status,
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14 188 “employed” for professional status, “Luxembourg” for country of birth, “below poverty
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16 189 threshold” for economic status, and “easy” for wealth adequacy perception. Education was coded
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18 190 in an ordinal ranking, from lowest to highest education (1= no diploma, to 3=postgraduate
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20 191 education)⁽³³⁾. Mathematically, variable selection is based on a stepping-down procedure which
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22 192 initializes with the full model including all the variables and then gradually eliminates variables
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24 193 with the smallest standardized coefficients one at a time, resulting in a final model with a
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26 194 relatively small number of predictors. This method provides better prediction and coefficient
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28 195 estimates closer to the true values, than traditional stepwise regression approaches, which impose
29
30 196 no regularization⁽³⁴⁾. Compared to Partial Least Square method (PLS), the CCR provides easy
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32 197 interpretable parameter estimates⁽¹⁹⁾. Variable importance was compared using both
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34 198 standardized regression coefficient (β) and cross-validation predictor counts that reflect the
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36 199 number of occasions where the variable appeared as a predictor in regression models. The cross
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38 200 validated R^2 (CV-R2) measures the goodness of fit to describe how well the statistical models fit
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40 201 the selected set of predictors.
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49 202 The descriptive and univariate analyses were performed by using PASW[®] for Windows[®]
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51 203 version 18.0 software (formerly SPSS Statistics Inc.) Results were considered significant at the
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53 204 5% critical level ($P < 0.05$).
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56 205 **Results**

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3 206 *Description of demographic, socioeconomic and dietary indicators*
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6 207 Significant gender-specific differences for education level ($P=0.02$) and work status ($P<0.001$)
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8 208 were observed. Women consumed significantly more recommended foods (higher RFS), and
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10 209 fewer non-recommended foods (lower non-RFS). ED and the DDS were significantly higher in
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12 210 men than women (Table 1).
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16 211 *Univariate associations between SES factors and dietary outcomes*
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19 212 The selected diet quality indicators were significantly associated with different demographic and
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21 213 socioeconomic factors. The mean RFS increased with education level, and the non-RFS
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23 214 decreased (Table 2).
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27 215 *Modeling of SES factors to predict diet quality*
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30 216 Figures 1-5 (referent tables are presented in Appendix 1-5) depict the demographic and
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32 217 socioeconomic predictors of diet quality according to their importance. i.e., to the power of
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34 218 independent contribution. In general, age, gender, country of birth, and education appeared to be
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36 219 the most consistent predictors of diet quality, whereas economic, work and marital status were
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38 220 least frequent predictors.
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42 221 Adherence to national dietary recommendations, as measured by the RCI, was associated
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44 222 with Portuguese, increased age, higher education level, and living above poverty threshold.
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46 223 However, men, not employed, living alone with difficult wealth perception were significant
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48 224 predictors of low compliance to national recommendations. Likewise, lower RFS (lower intakes
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50 225 of recommended foods) was typically associated with men, living alone and having a difficult
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52 226 wealth perception. Male gender, and living alone were positively associated with the non-RFS
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227 (higher intakes of non-recommended food items). ED was positively associated with being male
228 but inversely associated with increased age and living above poverty threshold.

229 Discussion

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

234 In general, the most important demographic and socioeconomic circumstances
235 independently associated with diet quality, as expressed by healthy choices and adherence to
236 dietary guidelines were age, gender, country of birth and educational level. Economic resources
237 and wealth perception also contributed to a lesser extent. Consistent with our previous
238 findings⁽¹⁾, Portuguese participants seemed significantly more compliant with national dietary
239 guidelines and were more likely to select healthy and diverse food items, than other Europeans
240 and non-Europeans. On the other hand, our previous findings showed that Portuguese
241 participants were more overweight and obese compared to Luxembourgers⁽³⁵⁾. These findings
242 are consistent with a French study⁽³⁶⁾, suggesting that obese subjects were more likely to be
243 better compliers with national dietary guidelines than normal weight subjects. This higher
244 compliance among overweight and obese persons is most likely due to their awareness of their
245 weight status which has led them to change their eating habits accordingly. The cross-sectional
246 nature of the present study hinders confirmation of any cause–effect relationship.

247 As may be expected, living alone with difficult wealth perception were independent
248 discriminating factors, contributing prominently to decreased dietary variety. Limited financial

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3 249 resources and an absence of family life may explain the restricted access to diverse food choices.
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5 250 Good perceived wealth may indicate access to better quality material resources such as healthy
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8 251 foods, whereas the absence of good perceived wealth may negatively affect the appropriateness
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10 252 and diversity of choices. Wealth is higher for families with histories of higher earnings, more
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12 253 savings and, in some cases, fewer expenditures on health care⁽¹⁴⁾. This cumulative and dynamic
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14 254 nature of socioeconomic structures, ascertained by wealth as perceived by the subject, is rarely
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17 255 considered in epidemiological studies.

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20 256 In addition, this study demonstrated that males, younger subjects, and those living below
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22 257 the poverty threshold were predominant predictors of eating a high energy density diet. An often
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24 258 cited reason for poor eating patterns among low income households is the cost of healthy food
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26 259^{(29), (37)}. In the US, more affluent populations consume higher quality diets than do disadvantaged
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28 260 populations⁽³⁸⁾. People with financial constraints are likely to consume fewer fruits and
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30 261 vegetables and instead consume lower quality and high energy dense foods (e.g., processed) that
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32 262 are high in added sugars and saturated fat⁽³⁹⁾.

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35 263 Globally, our results support previous findings reporting socioeconomic gradients in
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37 264 dietary intake⁽⁴⁰⁾. Low education and limited economic resources may jointly bring people to
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39 265 choose low-cost, unhealthy energy-dense foods composed of fat, refined grains and added sugar.
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41 266 Generally poor socioeconomic circumstances lead to poor health which may be explained by the
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43 267 exposure to inadequate dietary factors.

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45 268 Several strong points characterize the present study. The CCR approach demonstrated
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47 269 simultaneous factor-specific contributions to diet quality. It allowed us to measure the magnitude
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49 270 of the shared associations which have been unmeasured by previous studies^{(9), (12)}. Our findings
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51 271 demonstrate that multiple demographic and socioeconomic circumstances independently
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3 272 associated with different diet quality indicators, and highlight the importance of considering the
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5 273 overall context of SES when explaining nutritional disparities. It is widely agreed that the
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8 274 pathway mechanisms linking education, occupation and income with diet are conceptually
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10 275 distinct⁽⁹⁾. For example, education might influence food choices by facilitating or constraining a
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12 276 subject's ability to understand the information communicated by a healthcare professional or on
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14 277 food labels⁽⁹⁾. Occupation may effect diet through work-based cultures and social networks⁽¹²⁾. It
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16 278 determines income and therefore, access to certain food products. Income may determine dietary
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18 279 quality by making healthy and nutritious food more affordable⁽¹⁴⁾, suggesting that unequal
19
20 280 distribution of resources may lead to nutritional disparities and consequent health inequity. This
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22 281 CCR procedure allowed to sort out shared and predictor-specific effect on diet quality.
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24 282 Identifying the key SES predictors is important to capture the variation in diet quality and to
25
26 283 offer a better understanding of the underlying mechanisms relating to specific exposures⁽⁸⁾.
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28 284 Compared to a single proxy indicator approach, our findings support the fact that SES is a multi-
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30 285 dimensional concept that should encompass other facets, mainly country of birth, marital status,
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32 286 and wealth, as each reflects a different conceptual underpinning on how SES influences diet⁽⁹⁾.
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34 287 Likewise, age and gender were showed to be relevant indicators of social inequity.
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42 288 This study is a step toward moving the field of SES-nutrition research forwards. To our
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44 289 knowledge, only one Australian study has used this CCR method to describe the socioeconomic
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46 290 gradients in children's diets⁽³³⁾. Further, several sensitivity analyses were performed by using the
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48 291 PLS and the linear regression methods showing similar findings (data not shown).
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52 292 The diet quality indicators were calculated using a validated FFQ, where several quality
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54 293 control measures were undertaken to provide complete and coherent data⁽²⁰⁾. The participants
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56 294 were evenly distributed across socioeconomic strata. Limitations include the self-reported dietary
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3 295 data and the cross-sectional nature of the study which precludes causality inferences between
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5 296 socioeconomic circumstances and diet quality.
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9 297 In conclusion, multiple demographic and socioeconomic circumstances independently
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11 298 associated with diverse diet quality indicators. Age, gender, country of birth and education level
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13 299 were important predictors of healthy and adequate foods choices, whereas economic resources
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15 300 determined food diversity and energy density. From a public health standpoint, these findings are
16
17 301 important in delineating the groups at risk for inappropriate dietary behaviors, given the
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19 302 substantial evidence of dietary contribution to health inequalities.
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24 304 **Authors' contribution**

25 305
26 306 AA was involved in the conception and design of the ORISCAV-LUX survey, coordinated the
27 307 field data collection. All the authors (AA, CV, NS, GEC, MFE) fulfill the ICMJE guidelines, as
28 308 regards: 1) substantial contributions to conception and design, analysis and interpretation of data;
29 309 2) drafting the article or revising it critically for important intellectual content; and 3) final
30 310 approval of the version to be published.
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38 313 **Conflict of interest: None**

39 314

40 315 **Data sharing: No additional data available**

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45 317 **Acknowledgement:** AA is supported by a grant from the FNR (*Fond National de Recherche*) for
46 318 the project DIQUA-LUX, 5870404), Luxembourg.
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3 320 **Tables and legends**
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7 322 Table 1 Demographic, socio-economic characteristics, and dietary indicators by gender, ORISCAV-LUX
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15 325 Figure 1 Demographic and socioeconomic determinants of compliance to dietary recommendations
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29 330 Appendix 1-5 Results of correlated component regression analyses for the five selected dietary outcomes
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422 Table 1 Demographic, socio-economic characteristics, and dietary indicators by gender, ORISCAV-LUX
423 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
<i>Primary</i>	149 (22.9)	202 (29.4)	351 (26.2)	
<i>Secondary</i>	324 (49.8)	308 (44.8)	632 (47.2)	
<i>Tertiary</i>	178 (27.3)	177 (25.8)	355 (26.5)	
Country of birth (n=1352)				0.27
<i>Luxembourg</i>	401 (61.0)	421 (60.6)	822 (60.8)	
<i>Portugal</i>	88 (13.4)	74 (10.6)	162 (12.0)	
<i>Other European</i>	131 (19.9)	162 (23.3)	293 (21.7)	
<i>Non-European</i>	37 (5.6)	38 (5.5)	75 (5.5)	
Work Status (n1351)				<0.001
<i>Employed</i>	472 (71.8)	397 (57.2)	869 (64.3)	
<i>Not employed</i>	58 (8.8)	60 (8.6)	118 (8.7)	
<i>Housewives</i>	2 (0.3)	172 (24.8)	174 (12.9)	
<i>Retired or disabled</i>	125 (19.0)	65 (9.4)	190 (14.1)	
Marital Status (n=1352)				0.34
<i>Live with partner</i>	474 (72.1)	484 (69.6)	958 (70.9)	
<i>Live alone</i>	183 (27.9)	211 (30.4)	394 (29.1)	
Economic status (n=1174)				0.97
<i>Below poverty threshold</i>	127 (21.4)	125 (21.5)	252 (21.5)	
<i>Above poverty threshold</i>	466 (78.6)	456 (78.5)	922 (78.5)	
Wealth adequacy perception (n=1279)				0.21
<i>Easy</i>	483 (77.9)	532 (80.7)	1015 (79.4)	
<i>Difficult</i>	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

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

426 Results are presented N (%) for qualitative variables and mean ± SE for quantitative variables.

427 P-value from χ^2 test and t -test for qualitative and quantitative outcomes respectively

428 ^a P-value from Kruskal-Wallis non-parametric test

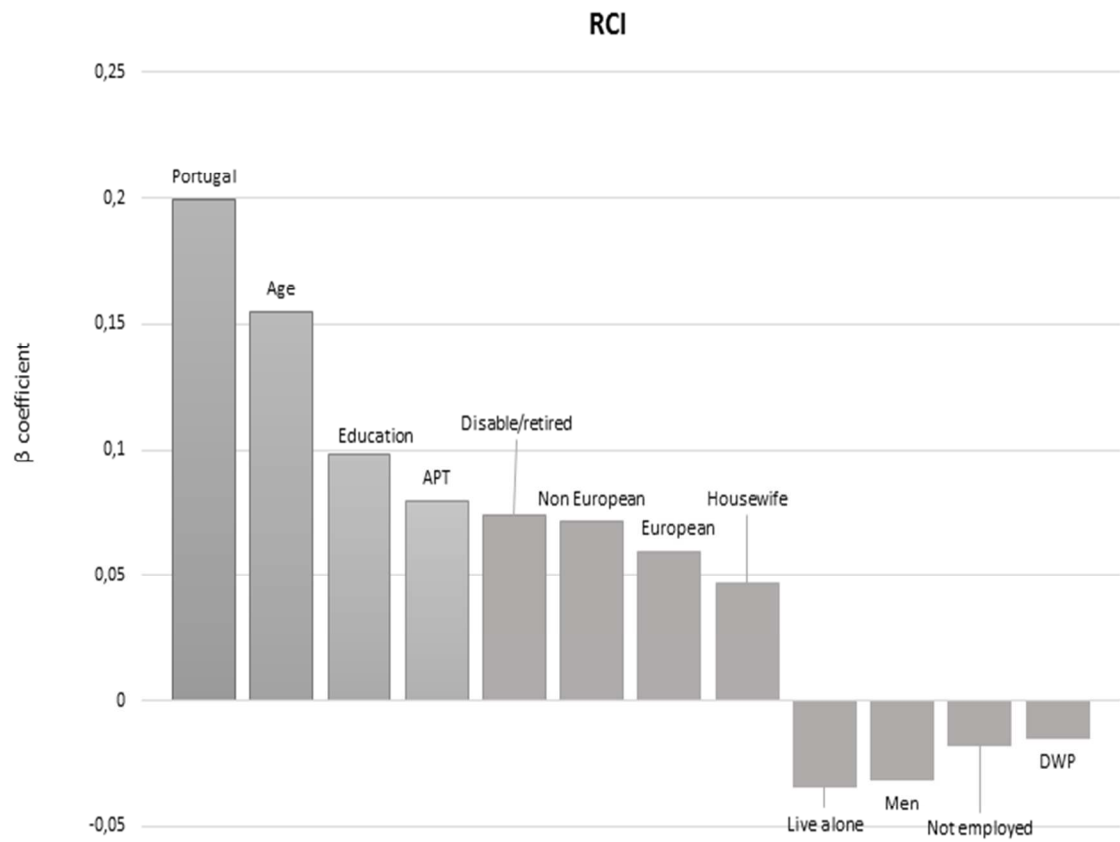
Table 2 Diet quality indicators by demographic and socio-economic factors, ORISCAV-LUX study, 2007-2008

	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 Kruskal-Wallis test, otherwise from *t*-test.

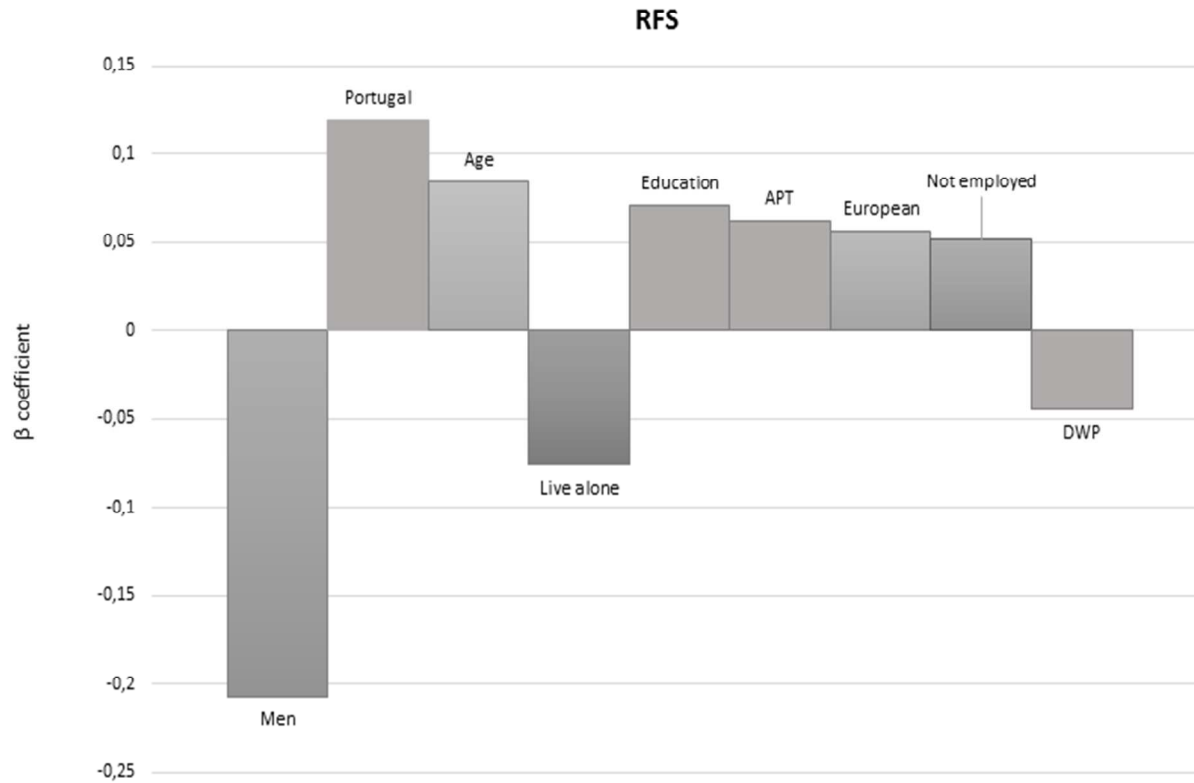
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Figure 1 Demographic and socioeconomic determinants of compliance to dietary recommendations



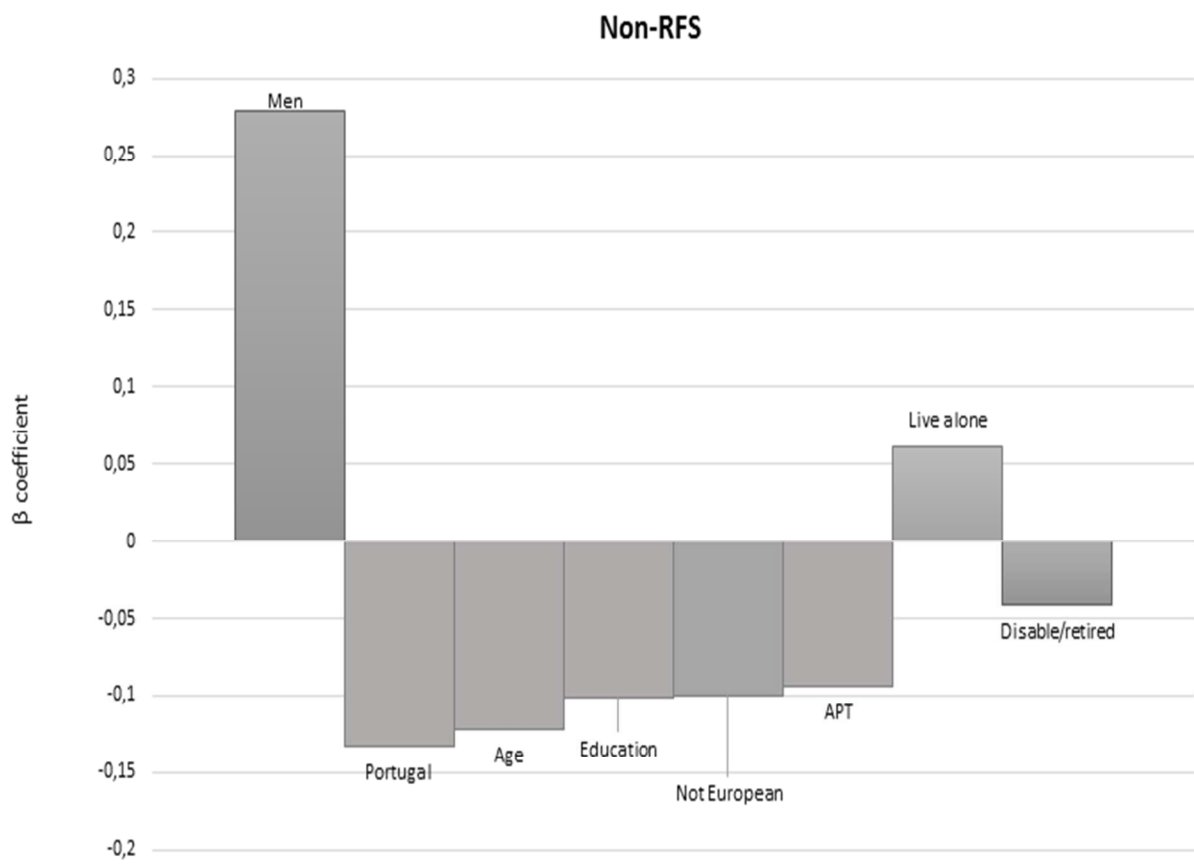
RCI: Recommendation Compliance Index; APT: above poverty threshold; DWP: Difficult wealth perception

Figure 2 Demographic and socioeconomic determinants of selecting healthy food choices



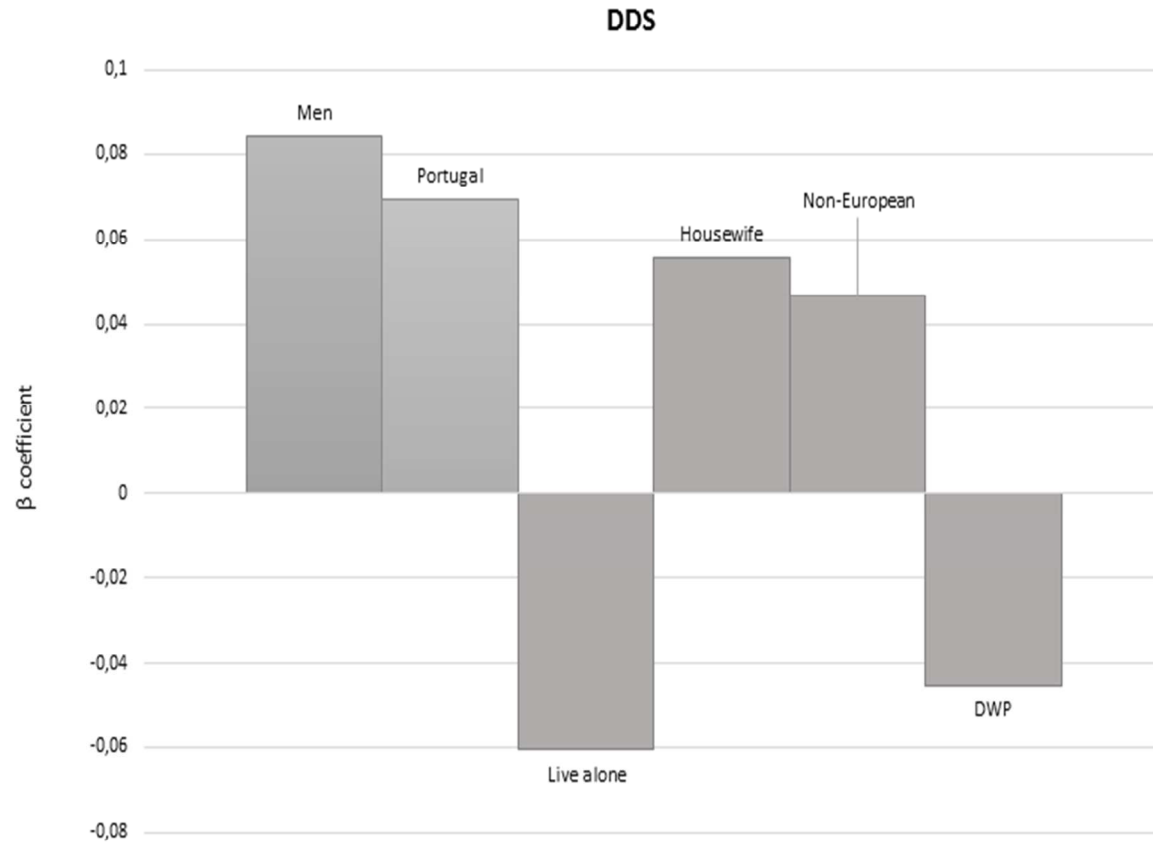
RFS: Recommendation Food Score; APT: above poverty threshold; DWP: Difficult wealth perception

Figure 3 Demographic and socioeconomic determinants of selecting unhealthy food choices



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

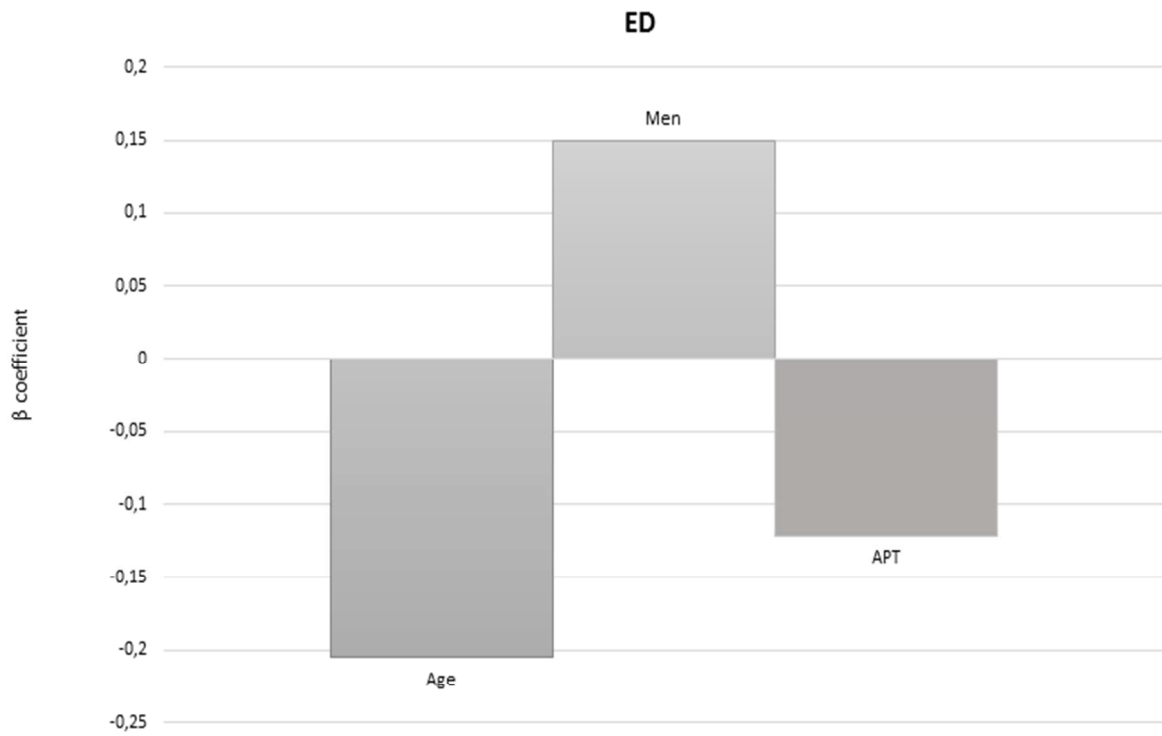
Figure 4 Demographic and socioeconomic determinants of diverse foods items



DDS: Dietary Diversity Score; DWP: Difficult wealth perception

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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 Recommendation 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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —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.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-006814.R1
Article Type:	Research
Date Submitted by the Author:	16-Mar-2015
Complete List of Authors:	Alkerwi, Ala'a; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherch Public-Santé, Population Health Vernier, Cédéric; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherche Public-Santé, Population Health Sauvageot, Nicolas; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherche Public-Santé, Population Health Crichton, Georgina E.; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherche Public-Santé, Population Health Elias, Merrill F.; Department of Psychology, University of Maine,,
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Epidemiology, Public health, Sociology
Keywords:	NUTRITION & DIETETICS, PUBLIC HEALTH, SOCIAL MEDICINE

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3 1 Demographic and socioeconomic disparity in nutrition: application of a novel
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5 2 “Correlated Component Regression” approach
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7

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24 10 *Running title.* Socioeconomic-diet quality
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59 21 *Keywords:* Socioeconomic status; diet quality; Correlated Component Analyses;
60

1
2
3 **22 Abstract**
4

5 **23 Objectives:** This study aimed to examine the most important demographic and socioeconomic
6
7
8 24 factors associated with diet quality, evaluated in terms of compliance to national dietary
9
10 25 recommendations, selection of healthy and unhealthy food choices, energy density, and food
11
12 26 variety. We hypothesized that different demographic and socioeconomic factors may show
13
14
15 27 disparate associations with diet quality.
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17
18 **28 Study design:** Nationwide cross-sectional population-based study.
19

20
21 **29 Participants:** A total of 1352 apparently healthy and non-institutionalised subjects, aged 18-69
22
23 30 years, participated in the Observation of Cardiovascular Risk Factors in Luxembourg
24
25 31 (ORISCAV-LUX) study in 2007-2008. The participants attended the nearest study center after a
26
27
28 32 telephone appointment and were interviewed by trained research staff.
29

30
31 **33 Outcome measures:** Diet quality as measured by five dietary indicators, namely,
32
33 34 recommendation compliance index (RCI), recommended foods score (RFS), non-recommended
34
35 35 foods score (non-RFS), energy density score (EDS), and dietary diversity score (DDS). The
36
37 36 novel Correlated Component Regression (CCR) technique was used to determine the importance
38
39 37 and magnitude of the association of each socioeconomic factor with diet quality, in a global
40
41 38 analytic approach.
42

43
44
45 39 **Results:** Increasing age, being male, and living below the poverty threshold were predominant
46
47 40 factors associated with eating a high energy density diet. Education level was an important factor
48
49 41 associated with healthy and adequate food choices, whereas economic resources were
50
51 42 predominant factors associated with food diversity and energy density.
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3 43 **Conclusion:** Multiple demographic and socioeconomic circumstances were associated with
4
5 44 different diet quality indicators. Efforts to improve diet quality for high risk groups need an
6
7
8 45 important public health focus.
9
10

Strong points

11
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16 Research with respect to socioeconomic status (SES) is still challenging and characterised by a
17 number of conceptual and methodological problems that hinder advances in knowledge about
18 the real association between socioeconomic factors and diet quality and health.
19

20
21 This study suggested a novel global analytic approach, Correlated Component Regression
22 (CCR), to explore the importance of each SES factor with regard to diet quality. It constitutes a
23 step toward moving the field of SES-nutrition research forwards.

24
25 The CCR approach showed simultaneous factor-specific associations with diet quality.

26
27 The CCR approach allowed the measurement of the magnitude of the shared associations
28 which have been unmeasured by previous studies.

29
30 The diet quality indicators were calculated using a validated FFQ, where several quality control
31 measures were undertaken to provide complete and coherent data.
32

Weak points

33
34 Similar to other studies, limitations are related to the self-reported dietary data and the cross-
35 sectional nature of the study which precludes establishment of the temporal sequence between
36 socioeconomic circumstances and diet quality.
37

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39 The relatively low response rate (32.2%) did not influence the present findings, as a detailed
40 study of non-participants showed comparable demographic and clinical characteristics of
41 participants and non-participants, hence providing population-representative estimates.
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49 Background

50 Socioeconomic disparity in nutrition is well documented^(1; 2; 3; 4; 5) which helps to explain some
51 of the observed social inequalities in health^{(2), (6)}. People with high socioeconomic status (SES)
52 are more likely to have healthier food habits whereas people with low SES have dietary profiles
53 less consistent with nutritional recommendations or dietary guidelines, hence contributing to
54 their poorer health status^{(6), (7)}. Therefore, both social inequity and diet quality, reflected by
55 healthy dietary behaviours are areas of active public health concern.

56 Despite the importance of these two areas, research with regard to SES is still challenging
57 and characterised by a number of conceptual and methodological problems that hinder advances
58 in knowledge about how and why SES is related to diet^{(8), (9)}. A single “best” indicator approach,
59 to determine social classification among societies, is not theoretically compelling because it may
60 emphasise a particular aspect of social stratification which may be only relevant to specific
61 health outcomes^{(10), (11)} and at different stages of the life course⁽¹²⁾. The most widely used SES
62 indicators (education, occupation and income)^{(8), (9), (13)} are limited in their ability to capture the
63 complex multidimensional forces that dominate social structure⁽¹⁴⁾. While education and
64 occupation are markers of social relationships and command over life-long skills, income is more
65 indicative of a current standard of living⁽¹⁵⁾. In addition, these traditional SES are interrelated,
66 which makes it difficult to determine the specific contribution of each factor to food choices^{(2),}
67 ⁽¹⁶⁾.

68 Beyond household income, Daly *et al* (2002) suggest wealth as a standard economic
69 component for monitoring links between SES and health⁽¹⁵⁾. Household income consists of a
70 flow of resources over a defined time period, whereas wealth captures the accumulated stock of

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3 71 assets (housing, cars, investments, inheritance and pension rights or economic reserves over the
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5 72 life course), although both are positively correlated⁽¹⁵⁾.
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9 73 Another challenge to SES research, is that these indicators are not interchangeable⁽¹⁷⁾;
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11 74 both cumulative effects^{(12), (18)} and unique contributions from each indicator may exist^{(9), (15)}.
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13 75 Thus it is still difficult to directly attribute the observed variation in diet quality to a specific SES
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15 76 indicator because different indicators may show disparate effects on food habits⁽¹³⁾.
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19 77 The objective of the present study was to examine the simultaneous association of a range
20
21 78 of demographic and socioeconomic factors with diet quality, as measured by several selected
22
23 79 dietary indicators. The importance and explanatory power (power of independent contribution)
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25 80 of each SES factor with regard to the quality of diet was explored by using the novel Correlated
26
27 81 Component Regression (CCR)⁽¹⁹⁾ technique. The CCR provides an alternative method to capture
28
29 82 important suppressor variables among a set of predictors, especially when these are moderately
30
31 83 to highly correlated, by dealing with the problems of confounding and effects of multi-
32
33 84 collinearity⁽¹⁹⁾. The CCR helps to ascertain the classification of key SES indicators that influence
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35 85 diet quality according to their importance, thus providing better performance than traditional
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37 86 regression techniques.
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43 87 The findings are important to gain a better understanding of socioeconomic disparities in
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45 88 nutrition with the consequent impacts on health in order to develop strategies aimed at tackling
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47 89 the problem of SES disparities in nutrition in a global context.
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50 51 90 **Methods**

52 53 54 91 *Studied population*

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3 92 Analyses were conducted on data from the Observation of Cardiovascular Risk Factors in
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5 93 Luxembourg (ORISCAV-LUX), a nationwide nutritional population-based study. A
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8 94 comprehensive description of the ORISCAV-LUX survey design, sampling methods has been
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10 95 published elsewhere^{(16), (20), (21)}. Briefly, a random sample stratified by age (18 to 69 years), sex,
11
12 96 and district of residence, was selected from the national health insurance registry. A total of 1432
13
14 97 participants were recruited with a participation rate (32.2%) corresponding to the theoretically
15
16 98 expected rate upon which the sample size was calculated⁽²¹⁾. The participants attended the nearest
17
18 99 study center after telephone appointment and were interviewed by a trained research staff. After
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20
21 100 data cleaning, particularly for poorly completed FFQ, data from 1352 participants were available
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23 101 for analyses.

24 25 26 27 28 102 *Independent demographic and socioeconomic variables*

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31 103 Self-reported information on demographic and socio-economic variables were collected via a
32
33 104 questionnaire, including age, sex, country of birth, education level, marital status, work status,
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35 105 monthly household income, and perceived wealth. Education level, based on the highest diploma
36
37 106 obtained, was classified into three groups: “tertiary level” equivalent to university or more;
38
39 107 “secondary level” equivalent to classical or technical qualification; and “primary level”
40
41 108 corresponding to non-academic qualification (no diploma, at least 9 years of mandatory
42
43 109 schooling). Marital status was recorded into either: “live alone” which included single, divorced
44
45 110 or widowed subjects; and “living with partner”. Work status was classified as “employed”
46
47 111 comprising participants currently engaged in a remunerated occupation, “unemployed” including
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49 112 students, “retired/sick leave and disabled”, and “home duties/housewives”. The participants were
50
51 113 classified according to their country of birth into four major groups: “Luxembourg”, “Portugal”,
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53 114 “Other European country”, and “non-European country”. The Portuguese are representing the
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3 115 major European immigrant community in Luxembourg, constituting about 16.1% of the total
4
5 116 Luxembourg population in 2011⁽²²⁾. Economic status was ascertained by asking participants to
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7
8 117 select one of seven categories as best representing total household monthly income: <750
9
10 118 euro/month, 750–1499 euro/month, 1500-2249 euro/month, 2250-2999 euro/month, 3000-4999
11
12 119 euro/month, 5000-10000 euro/month, and >10000 euro/month. The number of adults and
13
14 120 children living in the same household was also requested. Adult Equivalent Income (AEI) was
15
16 121 calculated as the ratio of the midpoint of the self-declared family income to the square root of the
17
18 122 number of persons in the household. The risk of poverty was referred to the national AEI which
19
20 123 is equivalent to 1432 euro/month, as published by the national institute of statistics (STATEC).
21
22 124 The economic status variable was then dichotomized as: “above poverty threshold” (APT) and
23
24 125 “below poverty threshold” (BPT). Wealth adequacy perception was assessed by asking the
25
26 126 question “to what extent does your current income and other available resources allow you to
27
28 127 provide for your needs?” and was classified as: “difficult” or “easy”.

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34 128 *Dependent variables: Diet quality measures*

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37 129 Dietary intake was assessed using a validated semi-quantified food frequency questionnaire
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39 130 (FFQ)⁽²³⁾, ⁽²⁴⁾ which collects information on the frequency and quantity (portion size) of 134
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41 131 items consumed over the preceding 3 months of the interview. Research staff provided detailed
42
43 132 instructions on how to complete the FFQ, and then checked the correctness and completeness of
44
45 133 answers.

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49 134 Five diet quality indicators were selected: the Recommendation Compliance Index (RCI)⁽¹⁾,
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51 135 Recommended Food Score (RFS)⁽²⁵⁾, non-Recommended Food Score (non-RFS)⁽²⁶⁾, Energy
52
53 136 Density Score (EDS)⁽²⁷⁾, and Dietary Diversity Score (DDS)⁽²⁸⁾ to cover the multi-dimensional
54
55 137 nature of diet quality⁽²⁹⁾. Adherence to national dietary recommendations, appropriate food

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3 138 choices, energy density, and food variety/diversity were identified as key elements of high
4
5 139 quality diets^{(27), (30), (31), (32), (33)}.

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8 140 The previously developed RCI⁽¹⁾ was used to evaluate participant's compliance to
9
10 141 national dietary recommendations. It is a composite of 13 food- and nutrient-based components,
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12 142 and ranges between -0.5 (due to a negative half point for excessive salt intake) and 14 points (2
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14 143 points for high daily fruit and vegetable servings), where a higher degree of adherence is
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16 144 indicated by higher scores.

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20 145 The RFS and non-RFS, used in numerous past studies on diet quality^(25; 34; 35) were used
21
22 146 to assess food choices. They were computed following the methods of Kant *et al*⁽²⁵⁾ and
23
24 147 modified by Kaluza *et al*⁽³⁵⁾. The RFS gives an indication of the frequency of consumption of
25
26 148 foods items that are recommended to increase (good choices), based on the 2010 Dietary
27
28 149 Guidelines for Americans⁽³⁶⁾. It comprised 18 food items (including fruit, vegetables, legumes,
29
30 150 wholegrain cereal products, low fat dairy products, fish, and nuts). One point was given for
31
32 151 consumption of any of the recommended foods at least once per week⁽²⁵⁾, to give a total score
33
34 152 out of 18. The non-RFS gives an indication of the frequency of consumption of foods that are
35
36 153 recommended to reduce (bad choices). It comprised 14 food items, including processed meats,
37
38 154 refined grains, solid fats, added sugars, and alcohol. Consumption of non-recommended foods at
39
40 155 least two to four times per week was assigned a score of 1; otherwise 0 points were assigned^{(35;}
41
42 156 ³⁷⁾, to give a total non-RFS out of 14, with a higher value indicating a higher consumption of
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44 157 non-recommended food items.

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49 158 Consistent with other studies, energy density score (EDS) was used as an indicator of diet
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51 159 quality^{(30), (31)}. It was defined as ratio of total energy intake over daily weight of total food
52
53 160 consumed (Kcal/g), based on all foods and beverages, excluding drinking water⁽²⁷⁾. By selecting
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3 161 the lower energy density option, one can eat a greater volume or weight of an isocaloric food.
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5 162 Therefore, a higher EDS indicates more energy per gram of food consumed.
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9 163 Food variety (diversity), another dimension of diet quality, was measured as described by
10
11 164 Kim *et al*⁽²⁸⁾, to form the Dietary Diversity Score (DDS). It comprised two components: overall
12
13 165 variety (daily consumption of at least one serving from each of the five food groups:
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15 166 meat/poultry/fish/egg, dairy products, grains, fruit, and vegetables, 0-15 points), and variety
16
17 167 within protein sources (meat/poultry, fish, dairy, beans and eggs, 0-5 points), to give a total DDS
18
19 168 of 20 points (optimal diversity). A diet that has variety within similar food groups, as well as
20
21 169 overall variety, is believed to be superior to a diet with a monotonous source⁽²⁸⁾. Variety among
22
23 170 protein sources is included to illustrate the benefits of including diverse sources of food in the
24
25 171 diet from within the same food group⁽²⁸⁾. Each item within these food groups provides important
26
27 172 nutrient and non-nutrient components (e.g., essential fatty acids from the fish group and
28
29 173 phytochemicals from the beans group).
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35 174 *Ethical aspects*

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37
38 175 The present study was conducted according to the guidelines laid down in the Declaration of
39
40 176 Helsinki and all procedures involving human subjects were approved by the National Research
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42 177 Ethics Committee and the National Commission for Private Data Protection. Written informed
43
44 178 consent was obtained from all subjects.
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46

47 180 *Statistical analysis*

48
49 181 For descriptive purposes, diet quality indicators and participants' demographic and
50
51 182 socioeconomic characteristics were compared by sex. Then, the diet quality indicators were
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53 183 compared by demographic, and socioeconomic factors, and P-values were calculated by using
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3 184 the X^2 test for categorical variables, the t -test and Kruskal-Wallis test for normally and non-
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5
6 185 normally distributed variables, respectively.

7
8 186 The CCR analysis⁽³⁸⁾ was performed using XLStat version 2014.2.07, to identify the
9
10 187 optimal demographic and socioeconomic factors associated with dietary outcomes. It allows
11
12 188 simultaneous adjustment for the effect of each indicator on the other, and hence shows the
13
14 189 independent and unique contribution of each indicator. Beside the traditional SES indicators of
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16 190 education, work status and income, country of birth, marital status and perceived wealth were
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18 191 included. All selected predictors were simultaneously introduced. The categorical variables were
19
20 192 recoded as dummy variables. The referent variables for each indicator were as follows: “women”
21
22 193 for sex, “live with partner” for marital status, “employed” for work status, “Luxembourg” for
23
24 194 country of birth, “above poverty threshold” for economic status, and “easy” for wealth adequacy
25
26 195 perception. Education was coded in an ordinal ranking, from lowest to highest education (1= no
27
28 196 diploma, 2= secondary level, 3=postgraduate education, in an increasing continuous order)⁽³⁹⁾.
29
30 197 Mathematically, variable selection is based on a stepping-down procedure which initialises with
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32 198 the full model including all the variables and then gradually eliminates variables with the
33
34 199 smallest standardised coefficients one at a time, resulting in a final model with a relatively small
35
36 200 number of predictors. This method provides better prediction and coefficient estimates closer to
37
38 201 the true values, than traditional stepwise regression approaches, which impose no
39
40 202 regularisation⁽⁴⁰⁾. Compared to the Partial Least Square method (PLS), the CCR provides easy
41
42 203 interpretable parameter estimates⁽¹⁹⁾. Variable importance was compared using both standardised
43
44 204 regression coefficient (β) and cross-validation predictor counts that reflect the number of
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46 205 occasions where the variable appears as a predictor in regression models. The cross validated R^2
47
48 206 (CV-R2) measures the goodness of fit to describe how well the statistical models fit the selected
49
50 207 set of predictors.

51
52 208 The descriptive and univariate analyses were performed by using PASW[®] for Windows[®]
53
54 209 version 18.0 software (formerly SPSS Statistics Inc.) Results were considered significant at the
55
56 210 5% critical level ($P < 0.05$).

57 58 59 60 211 **Results**

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3 212 *Description of demographic, socioeconomic and dietary indicators*
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5

6 213 Significant sex-specific differences for education level ($P=0.02$) and work status ($P<0.001$) were
7
8 214 observed. Women consumed significantly more recommended foods (higher RFS), and fewer
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10 215 non-recommended foods (lower non-RFS) ($P<0.001$). EDS and DDS were significantly higher in
11
12 216 men than women ($P <0.001$ and $P=0.007$, respectively) (Table 1).
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14
15

16 217 *Correlation between selected SES factors*
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19 218 While the selected SES indicators were significantly inter-correlated ($P<0.05$), sex was only
20
21 219 correlated to education level and work status (Table 2).
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23

24 220 *Univariate associations between SES factors and dietary outcomes*
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26

27 221 The selected diet quality indicators were significantly associated with different demographic and
28
29 222 socioeconomic factors. The mean RFS increased with education level, and the non-RFS
30
31 223 decreased (Table 3).
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35 224 *Modeling of SES factors to predict diet quality*
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38 225 Figures 1-5 (referent tables are presented in Appendix A 1-5) depict the demographic and
39
40 226 socioeconomic factors associated with diet quality according to their importance. i.e., to the
41
42 227 power of independent contribution. In general, age, sex, country of birth, and education appeared
43
44 228 to be the most consistent factors associated with diet quality, whereas economic, work and
45
46 229 marital status were least frequently associated with diet quality
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50 230 Adherence to national dietary recommendations, as measured by the RCI, was associated
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52 231 with being Portuguese, increased age, and higher education level. However, men, unemployed,
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54 232 living alone, below the poverty threshold, and with difficult wealth perception were all
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3 233 significant factors associated with low compliance to national recommendations (Figure 1).
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5 234 Similarly, men, living alone, below the poverty threshold, and having a difficult wealth
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8 235 perception were also associated with a lower RFS (lower intakes of recommended foods) (Figure
9
10
11 236 2). Male sex, living alone, and below the poverty threshold were positively associated with the
12
13 237 non-RFS (higher intakes of non-recommended food items) (Figure 3). DDS was inversely
14
15 238 associated with living alone and with difficult wealth perception, but positively associated with
16
17 239 being male and from Portugal (Figure 4). EDS was inversely associated with increased age but
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19
20 240 positively associated with being male and living below the poverty threshold (Figure 5).
21

22 23 241 **Discussion**

24
25
26 242 A few, if any, adult-population studies have directly examined the importance and magnitude of
27
28 243 the effect of each SES factor using a global analytic approach. This study explored the
29
30 244 simultaneous role of several demographic and socioeconomic factors in relation to diet quality
31
32 245 amongst a representative sample of the adult population in Luxembourg.
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35
36 246 In general, the most important demographic and socioeconomic circumstances
37
38 247 independently associated with diet quality, as indicated by healthy choices and adherence to
39
40 248 dietary guidelines, were age, sex, country of birth and education level. Economic resources and
41
42 249 wealth perception also contributed to a lesser extent. Consistent with our previous findings⁽¹⁾,
43
44 250 Portuguese participants seemed significantly more compliant with national dietary guidelines and
45
46 251 were more likely to select healthy and diverse food items, than other Europeans and non-
47
48 252 Europeans. On the other hand, our previous findings showed that Portuguese participants were
49
50 253 more overweight and obese compared to Luxembourgers⁽⁴¹⁾. These findings are consistent with
51
52 254 a French study⁽⁴²⁾, suggesting that obese subjects had greater compliance with national dietary
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54 255 guidelines than normal weight subjects. This may be due to their awareness of their weight status
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3 256 which has led them to change their eating habits accordingly, or it may be that overweight people
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6 257 under-report poor choices and over report healthy choices.
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9 258 As may be expected, living alone with difficult wealth perception were independent
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11 259 discriminating factors, associated with decreased dietary variety. Limited financial resources and
12
13 260 an absence of family life may explain the restricted access to diverse food choices. Good
14
15 261 perceived wealth may indicate access to better quality material resources such as healthy foods,
16
17 262 whereas the absence of good perceived wealth may negatively affect the appropriateness and
18
19 263 diversity of choices. Wealth is higher for families with histories of higher earnings, more savings
20
21 264 and, in some cases, fewer expenditures on health care⁽¹⁵⁾. However, wealth perception by the
22
23 265 subject may also be influenced by one's needs, love of money, level of aspirations, and
24
25 266 materialistic inclinations⁽⁴³⁾. Recent research has shown that two dimensions of money attitudes
26
27 267 affect the subjective perception of wealth: individuals' perceived financial control (the ability to
28
29 268 budget, monitor, and control their money) and money anxiety (worry and indecisiveness
30
31 269 regarding money-related issues)⁽⁴³⁾. This cumulative and dynamic nature of socioeconomic
32
33 270 structures, ascertained by wealth as perceived by the subject, is rarely considered in
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35 271 epidemiological studies.
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42 272 In addition, this study showed that being male, younger, and living below the poverty
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44 273 threshold were predominant factors associated with eating a high energy density diet. An often
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46 274 cited reason for poor eating patterns among low income households is the cost of healthy food
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48 275^{(30), (44)}. In the US, more affluent populations consume higher quality diets than do disadvantaged
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50 276 populations⁽⁴⁵⁾. People with financial constraints are likely to consume fewer fruits and
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52 277 vegetables and consume more high energy dense foods of lower quality (e.g., processed) that are
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54 278 high in added sugars and saturated fat⁽⁴⁶⁾.
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3 279 Globally, our results support previous findings reporting socioeconomic gradients in
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5 280 dietary intake⁽⁴⁷⁾. American research has also shown associations between living below the
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8 281 poverty threshold with more unhealthy/less healthy food choices and being less likely to meet
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10 282 dietary recommendations⁽⁴⁸⁾. Low education and limited economic resources may jointly
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12 283 contribute to people choosing low-cost, unhealthy energy-dense foods, high in fat and sugar.
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14 284 Generally speaking, poor socioeconomic circumstances lead to poor health which may be
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16 285 explained in part by less than optimal diet.
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20 286 Several strong points characterise the present study. The data were derived from a recent
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22 287 nationwide sample of the general adult population. The CCR approach showed simultaneous
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24 288 factor-specific contributions to diet quality. It allowed us to measure the magnitude of the shared
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26 289 associations, not been measured in previous studies^{(9), (12)}. Although the variances explained by
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28 290 each model were small- indicating that other factors would also be involved, our findings
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30 291 showed that multiple demographic and socioeconomic circumstances were independently
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32 292 associated with different diet quality indicators, and highlighted the importance of considering
33
34 293 the overall context of SES when explaining nutritional disparities. It is widely agreed that the
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36 294 pathway mechanisms linking education, occupation and income with diet are conceptually
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38 295 distinct⁽⁹⁾. For example, education may influence food choices by facilitating or constraining a
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40 296 person's ability to understand the information communicated by a healthcare professional or on
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42 297 food labels⁽⁹⁾. Work status may affect diet through work-based cultures and social networks⁽¹²⁾.
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44 298 Employment largely determines income and therefore, affordability of certain food products,
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46 299 such as more healthy and nutritious food⁽¹⁵⁾, suggesting that unequal distribution of resources
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48 300 may lead to nutritional disparities and consequent health inequity. This CCR procedure allowed
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50 301 the ability to distinguish shared and predictor-specific effect on diet quality. Identifying the key
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3 302 SES predictors is important to capture the variation in diet quality and to offer a better
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5 303 understanding of the underlying mechanisms relating to specific exposures⁽⁸⁾. Compared to a
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8 304 single proxy indicator approach, our findings support the fact that SES is a multi-dimensional
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10 305 concept that should encompass other facets, mainly country of birth, marital status, and wealth,
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12 306 as each reflects a different conceptual underpinning on how SES influences diet⁽⁹⁾. Likewise,
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14 307 age and sex were shown to be relevant SES indicators associated with various dietary quality
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17 308 scores.

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20 309 Obtaining detailed overall diet quality assessments is challenging in population-based
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22 310 studies⁽⁴⁹⁾. Numerous diet quality indices have been suggested in the literature to reflect various
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24 311 aspects of diet quality⁽⁵⁰⁾. These indices aim mainly to identify whether different population
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26 312 subgroups are consuming “good/healthy” or “detrimental/unhealthy” foods⁽⁵⁰⁾, using a variety of
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28 313 definitions to describe these terms. From among a plethora of such descriptors, we focused on
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30 314 five indices to cover different aspects of diet quality, including compliance to national dietary
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32 315 recommendations, appropriate food choices, energy density, and food variety/diversity. These
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34 316 five diet quality indices were highly correlated in the study population⁽⁵¹⁾, probably because most
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36 317 of these indices focus on healthy dietary patterns, nevertheless, they may not fully indicative of a
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38 318 healthy diet regardless of SES. Further research on which dietary indicators better predict
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40 319 nutritional status is warranted.

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47 320 In calculations of energy density, the treatment of beverages is important. As beverages
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49 321 have a high water content, they tend to have a lower energy density than most foods and may
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51 322 disproportionately influence dietary energy density values⁽⁵²⁾. The best method for calculating
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53 323 energy density depends on the purpose of the analysis, the outcome of interest, and the study
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55 324 population. Associations with weight or health status may possibly be weakened or missed⁽⁵³⁾

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3 325 when using energy density based on food and all beverages excluding water, however this was
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5 326 not the objective of the present study. Using foods and all beverages excluding water is
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8 327 convenient and requires no special manipulation of the dietary intake dataset⁽⁵²⁾.
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11 328 The selected diet quality indicators were calculated using a validated FFQ, where several
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13 329 quality control measures were undertaken to provide complete and coherent data⁽²⁰⁾. Two
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15 330 extensive validation studies ⁽²⁴⁾, ⁽⁵⁴⁾ showed that the FFQ performed well in assessing intakes of
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18 331 several foods and micronutrients and the observed correlations were within the range noted by
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20 332 other investigators. In addition, intensive efforts were made to minimise dietary reporting
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22 333 inaccuracies through extensive control procedures ⁽²⁰⁾.
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26 334 This study fills a knowledge gap, and enhances the research on socioeconomic disparities
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28 335 in nutrition by addressing a novel method, defined as CCR, to identify the most important
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30 336 demographic and socioeconomic circumstances independently associated with diet quality. To
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32 337 our knowledge, only one Australian study has used this CCR method to describe the
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34 338 socioeconomic gradients in children's diets⁽³⁹⁾.
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38 339 Further, several sensitivity analyses, by using linear regression and PLS methods,
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40 340 confirmed results obtained with CCR (data not shown). Consistent with CCR analyses, linear
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42 341 regression showed that being older, from Portugal or non-European countries, having higher
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44 342 education, and living above the poverty threshold were associated with a higher RCI. A higher
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46 343 RFS was also noticed in women, older people, from Portugal, with higher education.
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48 344 Concerning dietary diversity, higher scores was associated with male sex, being Portuguese, and
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50 345 those living with a partner. A higher non-RFS was associated with men, living alone, whereas
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52 346 people with a higher education, living above the poverty threshold and from Portugal, were more
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54 347 likely to have a lower non-RFS. Similarly, the energy density score was negatively associated
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3 348 with age, while male sex and people living below the poverty threshold were more likely to eat
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5 349 energy-dense foods. A PLS regression was also performed with diet quality scores as dependent
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8 350 variables and all selected demographic and SES factors as explicative variables. The first linear
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10 351 combination had high positive loadings for age, higher education, living above the poverty
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12 352 threshold, being housewives and disabled or retired. High negative loadings were noted for men,
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14 353 living alone and being employed. This first linear combination was positively associated with the
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16 354 RCI, RFS and negatively associated with the non-RFS and energy density.
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21 355 Certain shortcomings should also be recognised, related mainly to the current absence of
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23 356 a gold standard for dietary assessment. An optimal dietary intake assessment strategy still
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25 357 challenges nutrition research⁽⁵⁵⁾. Although the FFQ has been shown to be sufficiently convenient
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27 358 and inexpensive to use in large-scale, population-based studies⁽⁵⁶⁾, responses rely upon self-
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29 359 report, and therefore are subject to imprecision (under- and over-reporting) and biases related to
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31 360 social desirability⁽⁵⁷⁾.
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35 361 Other potential limitations include factors related to the cross-sectional design, which
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37 362 precludes establishment of the temporal sequence between socioeconomic circumstances and
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39 363 diet quality. Of course, all but prospective studies would be encumbered by this limitation. The
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41 364 relatively low response rate (32.2%) did not influence the present findings, as a detailed study of
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43 365 non-participants showed comparable demographic and clinical characteristics of participants and
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45 366 non-participants, hence providing population-representative estimates⁽²¹⁾.
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50 367 In conclusion, this study is a step toward moving the field of SES-nutrition research
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52 368 forwards. Multiple demographic and socioeconomic circumstances were independently
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54 369 associated with diverse diet quality indicators. Age, sex, country of birth and education level
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56 370 were important factors associated with healthy and adequate foods choices, whereas economic
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3 371 resources were associated with food diversity and energy density. From a public health
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6 372 standpoint, these findings are important in delineating the groups at risk in terms of their
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8 373 demographic and socioeconomic circumstances.
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11 374
12 375 **Authors' contribution**
13 376

14 377 AA was involved in the conception and design of the ORISCAV-LUX survey, coordinated the
15
16 378 field data collection. All the authors (AA, CV, NS, GEC, MFE) fulfill the ICMJE guidelines, as
17
18 379 regards: 1) substantial contributions to conception and design, analysis and interpretation of data;
19
20 380 2) drafting the article or revising it critically for important intellectual content; and 3) final
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22 381 approval of the version to be published.
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25 383
26 384 **Conflict of interest: None**
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32 387 **Acknowledgement:** AA is supported by a grant from the FNR (*Fond National de Recherche*) for
33
34 388 the project DIQUA-LUX, 5870404), Luxembourg. GEW is supported by a Sidney Sax Research
35
36 389 Fellowship (National Health and Medical Research Council, Australia, grant number
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39 390 APP1054567).
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3 391 **Tables and legends**
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7 393 Table 1 Demographic, socio-economic characteristics, and dietary indicators by sex
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10 394 Table 2 Correlation between the SES factors
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13 395 Table 3 Diet quality indicators by demographic and socio-economic factors
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15 396 Figure 1 Demographic and socioeconomic factors associated with compliance to dietary
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17 397 recommendations
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20 398 Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices
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23 399 Figure 3 Demographic and socioeconomic factors associated with selecting unhealthy food choices
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26 400 Figure 4 Demographic and socioeconomic factors associated with diverse foods items
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29 401 Figure 5 Demographic and socioeconomic factors associated with energy density
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32 402 Appendix A 1-5 Results of correlated component regression analyses for the five selected dietary
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34 403 outcomes
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535 Table 1 Demographic, socio-economic characteristics, and dietary indicators by sex, ORISCAV-LUX
536 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
<i>Primary</i>	149 (22.9)	202 (29.4)	351 (26.2)	
<i>Secondary</i>	324 (49.8)	308 (44.8)	632 (47.2)	
<i>Tertiary</i>	178 (27.3)	177 (25.8)	355 (26.5)	
Country of birth (n=1352)				0.27
<i>Luxembourg</i>	401 (61.0)	421 (60.6)	822 (60.8)	
<i>Portugal</i>	88 (13.4)	74 (10.6)	162 (12.0)	
<i>Other European</i>	131 (19.9)	162 (23.3)	293 (21.7)	
<i>Non-European</i>	37 (5.6)	38 (5.5)	75 (5.5)	
Work Status (n1351)				<0.001
<i>Employed</i>	472 (71.8)	397 (57.2)	869 (64.3)	
<i>Not employed</i>	58 (8.8)	60 (8.6)	118 (8.7)	
<i>Housewives</i>	2 (0.3)	172 (24.8)	174 (12.9)	
<i>Retired or disabled</i>	125 (19.0)	65 (9.4)	190 (14.1)	
Marital Status (n=1352)				0.34
<i>Live with partner</i>	474 (72.1)	484 (69.6)	958 (70.9)	
<i>Live alone</i>	183 (27.9)	211 (30.4)	394 (29.1)	
Economic status (n=1174)				0.97
<i>Below poverty threshold</i>	127 (21.4)	125 (21.5)	252 (21.5)	
<i>Above poverty threshold</i>	466 (78.6)	456 (78.5)	922 (78.5)	
Wealth adequacy perception (n=1279)				0.21
<i>Easy</i>	483 (77.9)	532 (80.7)	1015 (79.4)	
<i>Difficult</i>	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

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

539 Results are presented N (%) for qualitative variables and mean ± SE for quantitative variables.

540 P-value from χ^2 test and t -test for qualitative and quantitative outcomes respectively

541 ^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

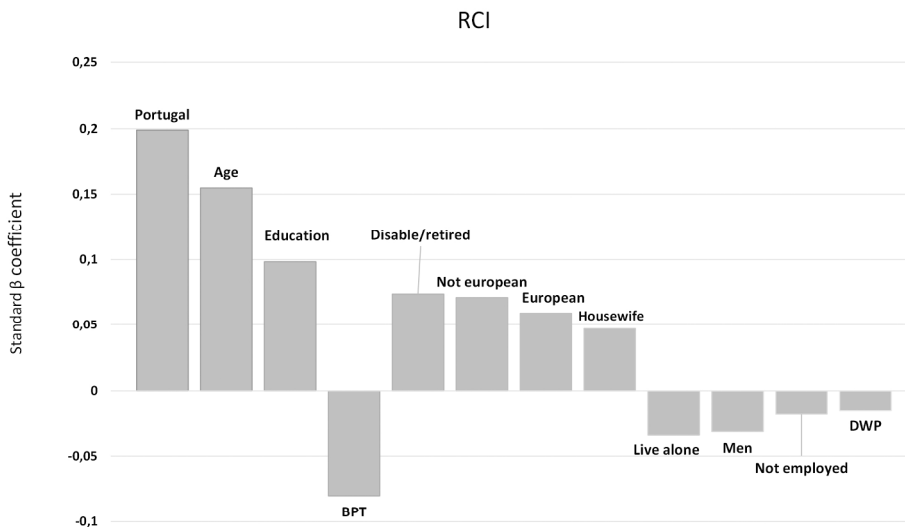
§ Age was categorized here in 3 categories (18-29; 30-49; 50-69)

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 Kruskal-Wallis test, otherwise from *t*-test.

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



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

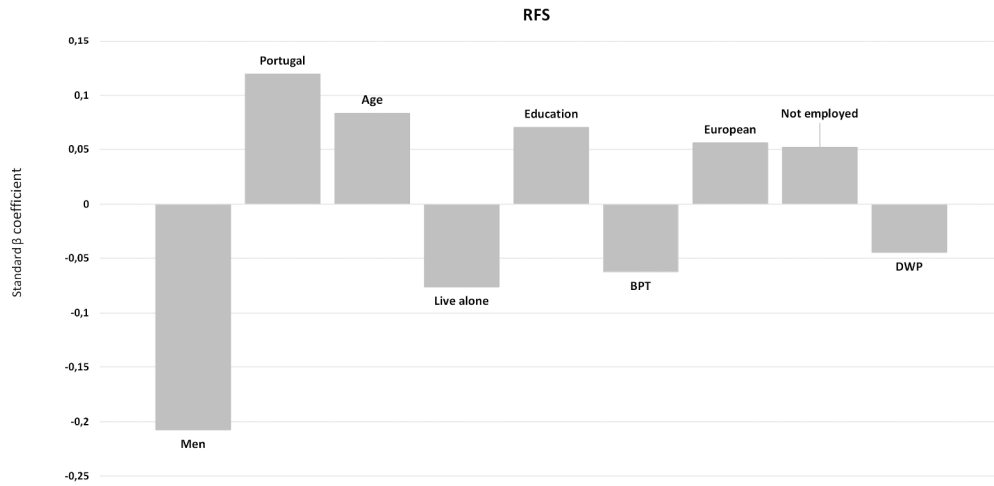
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Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices

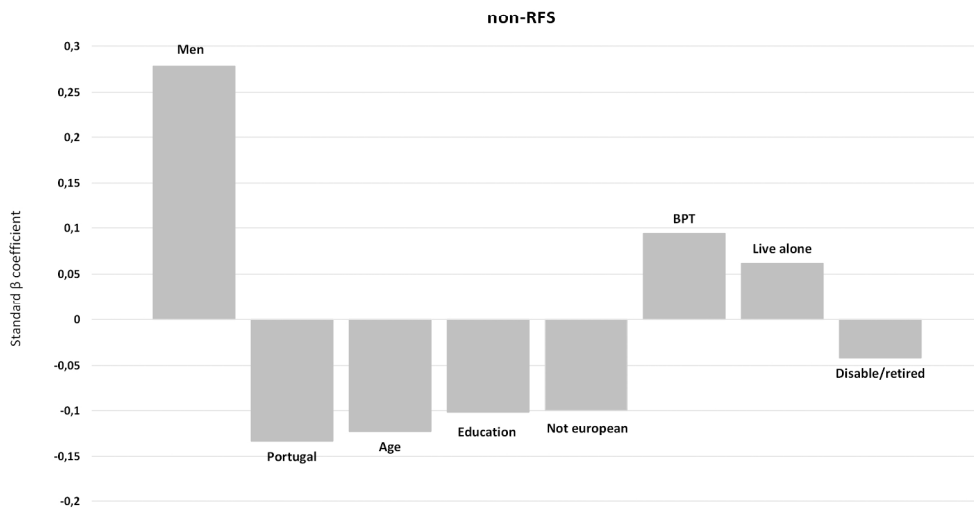


RFS: Recommendation Food Score; BPT: below poverty threshold; DWP: Difficult wealth perception

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



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

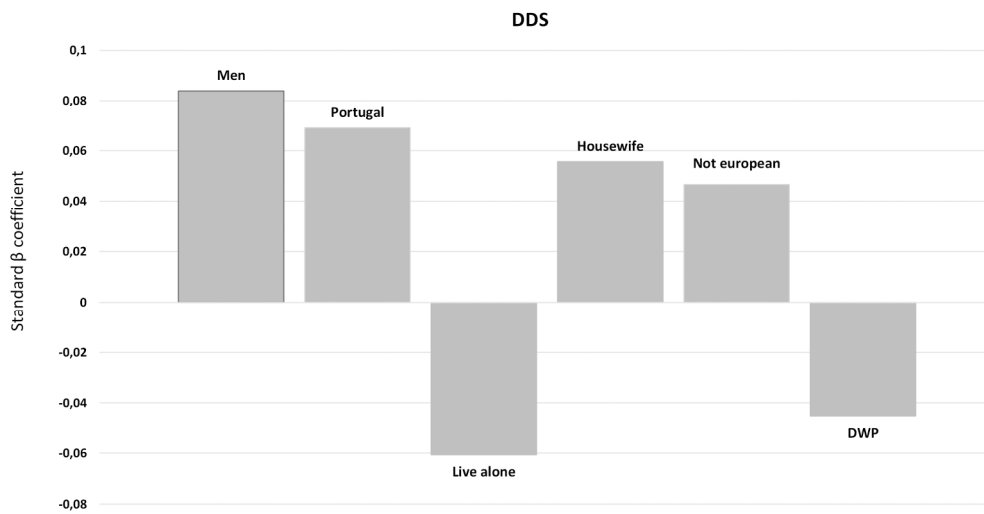
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Figure 4 Demographic and socioeconomic factors associated with diverse foods items

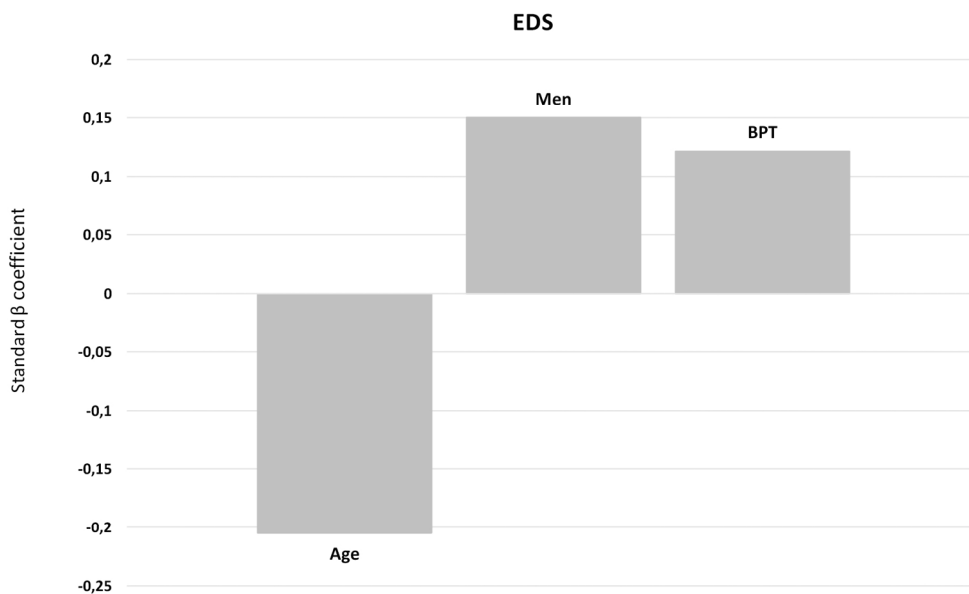


DDS: Dietary Diversity Score; DWP: Difficult wealth perception

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View only

Figure 5 Demographic and socioeconomic factors associated with energy density



ED: Energy Density; BPT: below poverty threshold

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

Table 1 Recommendation Compliance Index (RCI)

RCI (12 predictors)	β	CV predictor count ^a	Model goodness of fit indices ^b
Portugal <i>vs</i> Luxembourg	0,199	100	n=1058
Age	0,155	100	
Education	0,098	100	R ² =0.075
Below <i>vs</i> above poverty threshold	-0,080	99	R ² (CV)=0.053
Non-European <i>vs</i> Luxembourg	0,071	90	SD (CV)=0.002
European <i>vs</i> Luxembourg	0,059	89	
Home duties/housewife <i>vs</i> employed	0,047	89	
Disable/retired <i>vs</i> employed	0,074	88	
Living alone <i>vs</i> live with partner	-0,034	73	
Man	-0,031	71	
Unemployed <i>vs</i> employed	-0,017	66	
Difficult <i>vs</i> 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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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

nRFS (8 predictors)	β	CV predictor count ^a	Model goodness of fit indices ^b
Man <i>vs</i> women	0,278	100	n=1149
Portugal <i>vs</i> Luxembourg	-0,133	100	
Age	-0,123	100	R ² =0.119
Education	-0,102	100	R ² (CV)=0.105
Non-European <i>vs</i> Luxembourg	-0,100	100	SD (CV)=0.002
Below <i>vs</i> above poverty threshold	0,094	100	
Living alone <i>vs</i> live with partner	0,062	90	
Disable/retired <i>vs</i> 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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

Table 4 Diversity Dietary Score (DDS)

DDS (6 predictors)	β	CV predictor count ^a	Model goodness of fit indices ^b
Man <i>vs</i> women	0,084	100	n=1149
Portugal <i>vs</i> Luxembourg	0,069	100	
Living alone <i>vs</i> live with partner	-0,061	100	R ² =0.019
Home duties/housewife <i>vs</i> employed	0,056	99	R ² (CV)=0.007
Non-European <i>vs</i> Luxembourg	0,047	92	SD (CV)=0.002
Difficult <i>vs</i> easy wealth perception	-0,045	86	
Age		5	
European <i>vs</i> Luxembourg		5	
Unemployed <i>vs</i> employed		2	
Disable/retired <i>vs</i> 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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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 <i>vs</i> women	0,150	100	K=3
Below <i>vs</i> above poverty threshold	0,121	100	R ² =0.083
Portugal <i>vs</i> Luxembourg		10	R ² (CV)=0.076
Education		10	SD (CV)=0.002
Living alone <i>vs</i> live with partner		9	
Non-European <i>vs</i> 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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —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
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*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.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-006814.R2
Article Type:	Research
Date Submitted by the Author:	10-Apr-2015
Complete List of Authors:	Alkerwi, Ala'a; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherch Public-Santé, Population Health Vernier, Cédéric; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherche Public-Santé, Population Health Sauvageot, Nicolas; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherche Public-Santé, Population Health Crichton, Georgina E.; Luxembourg Institute of Health L.I.H. (formerly Centre de Recherche Public-Santé, Population Health Elias, Merrill F.; Department of Psychology, University of Maine,,
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Epidemiology, Public health, Sociology
Keywords:	NUTRITION & DIETETICS, PUBLIC HEALTH, SOCIAL MEDICINE

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Correlated Component Regression approach

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9
10 *Running title.* Socioeconomic-diet quality

11
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18 alaa.alkerwi@lih.lu

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20
21 *Keywords:* Socioeconomic status; diet quality; Correlated Component Analyses;

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3 **22 Abstract**
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5 **23 Objectives:** This study aimed to examine the most important demographic and socioeconomic
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8 24 factors associated with diet quality, evaluated in terms of compliance to national dietary
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10 25 recommendations, selection of healthy and unhealthy food choices, energy density, and food
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12 26 variety. We hypothesized that different demographic and socioeconomic factors may show
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15 27 disparate associations with diet quality.
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18 **28 Study design:** Nationwide cross-sectional population-based study.
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21 **29 Participants:** A total of 1352 apparently healthy and non-institutionalised subjects, aged 18-69
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23 30 years, participated in the Observation of Cardiovascular Risk Factors in Luxembourg
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25 31 (ORISCAV-LUX) study in 2007-2008. The participants attended the nearest study center after a
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28 32 telephone appointment and were interviewed by trained research staff.
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31 **33 Outcome measures:** Diet quality as measured by five dietary indicators, namely,
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33 34 recommendation compliance index (RCI), recommended foods score (RFS), non-recommended
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35 35 foods score (non-RFS), energy density score (EDS), and dietary diversity score (DDS). The
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37 36 novel Correlated Component Regression (CCR) technique was used to determine the importance
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39 37 and magnitude of the association of each socioeconomic factor with diet quality, in a global
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41 38 analytic approach.
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45 39 **Results:** Increasing age, being male, and living below the poverty threshold were predominant
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47 40 factors associated with eating a high energy density diet. Education level was an important factor
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49 41 associated with healthy and adequate food choices, whereas economic resources were
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51 42 predominant factors associated with food diversity and energy density.
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3 43 **Conclusion:** Multiple demographic and socioeconomic circumstances were associated with
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5 44 different diet quality indicators. Efforts to improve diet quality for high risk groups need an
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8 45 important public health focus.
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14 ***Strong points***

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16 Research with respect to socioeconomic status (SES) is still challenging and characterised by a
17 number of conceptual and methodological problems that hinder advances in knowledge about
18 the real association between socioeconomic factors and diet quality and health.
19

20 This study suggested a novel global analytic approach, Correlated Component Regression
21 (CCR), to explore the importance of each SES factor with regard to diet quality. It constitutes a
22 step toward moving the field of SES-nutrition research forwards.
23

24 The CCR approach showed simultaneous factor-specific associations with diet quality.
25

26 The CCR approach allowed the measurement of the magnitude of the shared associations
27 which have been unmeasured by previous studies.
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29 The diet quality indicators were calculated using a validated FFQ, where several quality control
30 measures were undertaken to provide complete and coherent data.
31

32 ***Weak points***

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34 Similar to other studies, limitations are related to the self-reported dietary data and the cross-
35 sectional nature of the study which precludes establishment of the temporal sequence between
36 socioeconomic circumstances and diet quality.
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38 The relatively low response rate (32.2%) did not influence the present findings, as a detailed
39 study of non-participants showed comparable demographic and clinical characteristics of
40 participants and non-participants, hence providing population-representative estimates.
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49 Background

50 Socioeconomic disparity in nutrition is well documented^(1; 2; 3; 4; 5) which helps to explain some
51 of the observed social inequalities in health^{(2), (6)}. People with high socioeconomic status (SES)
52 are more likely to have healthier food habits whereas people with low SES have dietary profiles
53 less consistent with nutritional recommendations or dietary guidelines, hence contributing to
54 their poorer health status^{(6), (7)}. Therefore, both social inequity and diet quality, reflected by
55 healthy dietary behaviours are areas of active public health concern.

56 Despite the importance of these two areas, research with regard to SES is still challenging
57 and characterised by a number of conceptual and methodological problems that hinder advances
58 in knowledge about how and why SES is related to diet^{(8), (9)}. A single “best” indicator approach,
59 to determine social classification among societies, is not theoretically compelling because it may
60 emphasise a particular aspect of social stratification which may be only relevant to specific
61 health outcomes^{(10), (11)} and at different stages of the life course⁽¹²⁾. The most widely used SES
62 indicators (education, occupation and income)^{(8), (9), (13)} are limited in their ability to capture the
63 complex multidimensional forces that dominate social structure⁽¹⁴⁾. While education and
64 occupation are markers of social relationships and command over life-long skills, income is more
65 indicative of a current standard of living⁽¹⁵⁾. In addition, these traditional SES are interrelated,
66 which makes it difficult to determine the specific contribution of each factor to food choices^{(2),}
67 ⁽¹⁶⁾.

68 Beyond household income, Daly *et al* (2002) suggest wealth as a standard economic
69 component for monitoring links between SES and health⁽¹⁵⁾. Household income consists of a
70 flow of resources over a defined time period, whereas wealth captures the accumulated stock of

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3 71 assets (housing, cars, investments, inheritance and pension rights or economic reserves over the
4
5 72 life course), although both are positively correlated⁽¹⁵⁾.
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9 73 Another challenge to SES research, is that these indicators are not interchangeable⁽¹⁷⁾;
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11 74 both cumulative effects^{(12), (18)} and unique contributions from each indicator may exist^{(9), (15)}.
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13 75 Thus it is still difficult to directly attribute the observed variation in diet quality to a specific SES
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15 76 indicator because different indicators may show disparate effects on food habits⁽¹³⁾.
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19 77 The objective of the present study was to examine the simultaneous association of a range
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21 78 of demographic and socioeconomic factors with diet quality, as measured by several selected
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23 79 dietary indicators. The importance and explanatory power (power of independent contribution)
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25 80 of each SES factor with regard to the quality of diet was explored by using the novel Correlated
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27 81 Component Regression (CCR)⁽¹⁹⁾ technique. The CCR provides an alternative method to capture
28
29 82 important suppressor variables among a set of predictors, especially when these are moderately
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31 83 to highly correlated, by dealing with the problems of confounding and effects of multi-
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33 84 collinearity⁽¹⁹⁾. The CCR helps to ascertain the classification of key SES indicators that influence
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35 85 diet quality according to their importance, thus providing better performance than traditional
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37 86 regression techniques.
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43 87 The findings are important to gain a better understanding of socioeconomic disparities in
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45 88 nutrition with the consequent impacts on health in order to develop strategies aimed at tackling
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47 89 the problem of SES disparities in nutrition in a global context.
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50 51 90 **Methods**

52 53 54 91 *Studied population*

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3 92 Analyses were conducted on data from the Observation of Cardiovascular Risk Factors in
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5 93 Luxembourg (ORISCAV-LUX), a nationwide nutritional population-based study. A
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8 94 comprehensive description of the ORISCAV-LUX survey design, sampling methods has been
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10 95 published elsewhere^{(16), (20), (21)}. Briefly, a random sample stratified by age (18 to 69 years), sex,
11
12 96 and district of residence, was selected from the national health insurance registry. A total of 1432
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14 97 participants were recruited with a participation rate (32.2%) corresponding to the theoretically
15
16 98 expected rate upon which the sample size was calculated⁽²¹⁾. The participants attended the nearest
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18 99 study center after telephone appointment and were interviewed by a trained research staff. After
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21 100 data cleaning, particularly for poorly completed FFQ, data from 1352 participants were available
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23 101 for analyses.
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28 102 *Independent demographic and socioeconomic variables*

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31 103 Self-reported information on demographic and socio-economic variables were collected via a
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33 104 questionnaire, including age, sex, country of birth, education level, marital status, work status,
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35 105 monthly household income, and perceived wealth. Education level, based on the highest diploma
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37 106 obtained, was classified into three groups: “tertiary level” equivalent to university or more;
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39 107 “secondary level” equivalent to classical or technical qualification; and “primary level”
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41 108 corresponding to non-academic qualification (no diploma, at least 9 years of mandatory
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43 109 schooling). Marital status was recorded into either: “live alone” which included single, divorced
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45 110 or widowed subjects; and “living with partner”. Work status was classified as “employed”
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47 111 comprising participants currently engaged in a remunerated occupation, “unemployed” including
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49 112 students, “retired/sick leave and disabled”, and “home duties/housewives”. The participants were
50
51 113 classified according to their country of birth into four major groups: “Luxembourg”, “Portugal”,
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53 114 “Other European country”, and “non-European country”. The Portuguese are representing the
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3 115 major European immigrant community in Luxembourg, constituting about 16.1% of the total
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5 116 Luxembourg population in 2011⁽²²⁾. Economic status was ascertained by asking participants to
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7
8 117 select one of seven categories as best representing total household monthly income: <750
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10 118 euro/month, 750–1499 euro/month, 1500-2249 euro/month, 2250-2999 euro/month, 3000-4999
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12 119 euro/month, 5000-10000 euro/month, and >10000 euro/month. The number of adults and
13
14 120 children living in the same household was also requested. Adult Equivalent Income (AEI) was
15
16 121 calculated as the ratio of the midpoint of the self-declared family income to the square root of the
17
18 122 number of persons in the household. The risk of poverty was referred to the national AEI which
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20 123 is equivalent to 1432 euro/month, as published by the national institute of statistics (STATEC).
21
22 124 The economic status variable was then dichotomized as: “above poverty threshold” (APT) and
23
24 125 “below poverty threshold” (BPT). Wealth adequacy perception was assessed by asking the
25
26 126 question “to what extent does your current income and other available resources allow you to
27
28 127 provide for your needs?” and was classified as: “difficult” or “easy”.

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34 128 *Dependent variables: Diet quality measures*

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37 129 Dietary intake was assessed using a validated semi-quantified food frequency questionnaire
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39 130 (FFQ)⁽²³⁾, ⁽²⁴⁾ which collects information on the frequency and quantity (portion size) of 134
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41 131 items consumed over the preceding 3 months of the interview. Research staff provided detailed
42
43 132 instructions on how to complete the FFQ, and then checked the correctness and completeness of
44
45 133 answers.

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49 134 Five diet quality indicators were selected: the Recommendation Compliance Index (RCI)⁽¹⁾,
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51 135 Recommended Food Score (RFS)⁽²⁵⁾, non-Recommended Food Score (non-RFS)⁽²⁶⁾, Energy
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53 136 Density Score (EDS)⁽²⁷⁾, and Dietary Diversity Score (DDS)⁽²⁸⁾ to cover the multi-dimensional
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55 137 nature of diet quality⁽²⁹⁾. Adherence to national dietary recommendations, appropriate food

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3 138 choices, energy density, and food variety/diversity were identified as key elements of high
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5 139 quality diets^{(27), (30), (31), (32), (33)}.

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8 140 The previously developed RCI⁽¹⁾ was used to evaluate participant's compliance to
9
10 141 national dietary recommendations. It is a composite of 13 food- and nutrient-based components,
11
12 142 and ranges between -0.5 (due to a negative half point for excessive salt intake) and 14 points (2
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14 143 points for high daily fruit and vegetable servings), where a higher degree of adherence is
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17 144 indicated by higher scores.

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20 145 The RFS and non-RFS, used in numerous past studies on diet quality^(25; 34; 35) were used
21
22 146 to assess food choices. They were computed following the methods of Kant *et al*⁽²⁵⁾ and
23
24 147 modified by Kaluza *et al*⁽³⁵⁾. The RFS gives an indication of the frequency of consumption of
25
26 148 foods items that are recommended to increase (good choices), based on the 2010 Dietary
27
28 149 Guidelines for Americans⁽³⁶⁾. It comprised 18 food items (including fruit, vegetables, legumes,
29
30 150 wholegrain cereal products, low fat dairy products, fish, and nuts). One point was given for
31
32 151 consumption of any of the recommended foods at least once per week⁽²⁵⁾, to give a total score
33
34 152 out of 18. The non-RFS gives an indication of the frequency of consumption of foods that are
35
36 153 recommended to reduce (bad choices). It comprised 14 food items, including processed meats,
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38 154 refined grains, solid fats, added sugars, and alcohol. Consumption of non-recommended foods at
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40 155 least two to four times per week was assigned a score of 1; otherwise 0 points were assigned^{(35;}
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42 156 ³⁷⁾, to give a total non-RFS out of 14, with a higher value indicating a higher consumption of
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44 157 non-recommended food items.

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47 158 Consistent with other studies, energy density score (EDS) was used as an indicator of diet
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49 159 quality^{(30), (31)}. It was defined as ratio of total energy intake over daily weight of total food
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51 160 consumed (Kcal/g), based on all foods and beverages, excluding drinking water⁽²⁷⁾. By selecting

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3 161 the lower energy density option, one can eat a greater volume or weight of an isocaloric food.
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6 162 Therefore, a higher EDS indicates more energy per gram of food consumed.
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9 163 Food variety (diversity), another dimension of diet quality, was measured as described by
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11 164 Kim *et al*⁽²⁸⁾, to form the Dietary Diversity Score (DDS). It comprised two components: overall
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14 165 variety (daily consumption of at least one serving from each of the five food groups:
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16 166 meat/poultry/fish/egg, dairy products, grains, fruit, and vegetables, 0-15 points), and variety
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18 167 within protein sources (meat/poultry, fish, dairy, beans and eggs, 0-5 points), to give a total DDS
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21 168 of 20 points (optimal diversity). A diet that has variety within similar food groups, as well as
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23 169 overall variety, is believed to be superior to a diet with a monotonous source⁽²⁸⁾. Variety among
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26 170 protein sources is included to illustrate the benefits of including diverse sources of food in the
27
28 171 diet from within the same food group⁽²⁸⁾. Each item within these food groups provides important
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30 172 nutrient and non-nutrient components (e.g., essential fatty acids from the fish group and
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33 173 phytochemicals from the beans group).
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36 174 *Ethical aspects*

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39 175 The present study was conducted according to the guidelines laid down in the Declaration of
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41 176 Helsinki and all procedures involving human subjects were approved by the National Research
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43 177 Ethics Committee and the National Commission for Private Data Protection. Written informed
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45 178 consent was obtained from all subjects.
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47 180 *Statistical analysis*

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49 181 For descriptive purposes, diet quality indicators and participants' demographic and
50
51 182 socioeconomic characteristics were compared by sex. Then, the diet quality indicators were
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54 183 compared by demographic, and socioeconomic factors, and P-values were calculated by using
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3 184 the X^2 test for categorical variables, the t -test and Kruskal-Wallis test for normally and non-
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6 185 normally distributed variables, respectively.

7
8 186 The CCR analysis⁽³⁸⁾ was performed using XLStat version 2014.2.07, to identify the
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10 187 optimal demographic and socioeconomic factors associated with dietary outcomes. It allows
11
12 188 simultaneous adjustment for the effect of each indicator on the other, and hence shows the
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14 189 independent and unique contribution of each indicator. Beside the traditional SES indicators of
15
16 190 education, work status and income, country of birth, marital status and perceived wealth were
17
18 191 included. All selected predictors were simultaneously introduced. The categorical variables were
19
20 192 recoded as dummy variables. The referent variables for each indicator were as follows: “women”
21
22 193 for sex, “live with partner” for marital status, “employed” for work status, “Luxembourg” for
23
24 194 country of birth, “above poverty threshold” for economic status, and “easy” for wealth adequacy
25
26 195 perception. Education was coded in an ordinal ranking, from lowest to highest education (1= no
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28 196 diploma, 2= secondary level, 3=postgraduate education, in an increasing continuous order)⁽³⁹⁾.
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30 197 Mathematically, variable selection is based on a stepping-down procedure which initialises with
31
32 198 the full model including all the variables and then gradually eliminates variables with the
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34 199 smallest standardised coefficients one at a time, resulting in a final model with a relatively small
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36 200 number of predictors. This method provides better prediction and coefficient estimates closer to
37
38 201 the true values, than traditional stepwise regression approaches, which impose no
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40 202 regularisation⁽⁴⁰⁾. Compared to the Partial Least Square method (PLS), the CCR provides easy
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42 203 interpretable parameter estimates⁽¹⁹⁾. Variable importance was compared using both standardised
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44 204 regression coefficient (β) and cross-validation predictor counts that reflect the number of
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46 205 occasions where the variable appears as a predictor in regression models. The cross validated R^2
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48 206 (CV-R2) measures the goodness of fit to describe how well the statistical models fit the selected
49
50 207 set of predictors.

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52 208 The descriptive and univariate analyses were performed by using PASW[®] for Windows[®]
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54 209 version 18.0 software (formerly SPSS Statistics Inc.) Results were considered significant at the
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56 210 5% critical level ($P < 0.05$).

57 58 59 60 211 **Results**

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3 212 *Description of demographic, socioeconomic and dietary indicators*
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6 213 Significant sex-specific differences for education level ($P=0.02$) and work status ($P<0.001$) were
7
8 214 observed. Women consumed significantly more recommended foods (higher RFS), and fewer
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10 215 non-recommended foods (lower non-RFS) ($P<0.001$). EDS and DDS were significantly higher in
11
12 216 men than women ($P <0.001$ and $P=0.007$, respectively) (Table 1).
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16 217 *Correlation between selected SES factors*
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19 218 While the selected SES indicators were significantly inter-correlated ($P<0.05$), sex was only
20
21 219 correlated to education level and work status (Table 2).
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24 220 *Univariate associations between SES factors and dietary outcomes*
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27 221 The selected diet quality indicators were significantly associated with different demographic and
28
29 222 socioeconomic factors. The mean RFS increased with education level, and the non-RFS
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31 223 decreased (Table 3).
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35 224 *Modeling of SES factors to predict diet quality*
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38 225 Figures 1-5 (referent tables are presented in Appendix A 1-5) depict the demographic and
39
40 226 socioeconomic factors associated with diet quality according to their importance. i.e., to the
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42 227 power of independent contribution. In general, age, sex, country of birth, and education appeared
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44 228 to be the most consistent factors associated with diet quality, whereas economic, work and
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46 229 marital status were least frequently associated with diet quality
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50 230 Adherence to national dietary recommendations, as measured by the RCI, was associated
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52 231 with being Portuguese, increased age, and higher education level. However, men, unemployed,
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54 232 living alone, below the poverty threshold, and with difficult wealth perception were all
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3 233 significant factors associated with low compliance to national recommendations (Figure 1).
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5 234 Similarly, men, living alone, below the poverty threshold, and having a difficult wealth
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8 235 perception were also associated with a lower RFS (lower intakes of recommended foods) (Figure
9
10 236 2). Male sex, living alone, and below the poverty threshold were positively associated with the
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12 237 non-RFS (higher intakes of non-recommended food items) (Figure 3). DDS was inversely
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14 238 associated with living alone and with difficult wealth perception, but positively associated with
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16 239 being male and from Portugal (Figure 4). EDS was inversely associated with increased age but
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18 240 positively associated with being male and living below the poverty threshold (Figure 5).
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23 241 **Discussion**

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26 242 This study explored the simultaneous role of several demographic and socioeconomic factors in
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28 243 relation to diet quality amongst a representative sample of the adult population in Luxembourg.
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30 244 It is one of a few adult-population studies^{(13), (41)} which have directly examined the importance
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32 245 and magnitude of the effect of each SES factor using a global analytic approach.
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36 246 In general, the most important demographic and socioeconomic circumstances
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38 247 independently associated with diet quality, as indicated by healthy choices and adherence to
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40 248 dietary guidelines, were age, sex, country of birth and education level. Economic resources and
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42 249 wealth perception also contributed to a lesser extent. Consistent with our previous findings⁽¹⁾,
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44 250 Portuguese participants seemed significantly more compliant with national dietary guidelines and
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46 251 were more likely to select healthy and diverse food items, than other Europeans and non-
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48 252 Europeans. On the other hand, our previous findings showed that Portuguese participants were
49
50 253 more overweight and obese compared to Luxembourgers⁽⁴²⁾. These findings are consistent with
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52 254 a French study⁽⁴³⁾, suggesting that obese subjects had greater compliance with national dietary
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54 255 guidelines than normal weight subjects. This may be due to their awareness of their weight status
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3 256 which has led them to change their eating habits accordingly, or it may be that overweight people
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6 257 under-report poor choices and over report healthy choices.
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9 258 As may be expected, living alone with difficult wealth perception were independent
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11 259 discriminating factors, associated with decreased dietary variety. Limited financial resources and
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13 260 an absence of family life may explain the restricted access to diverse food choices. Good
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15 261 perceived wealth may indicate access to better quality material resources such as healthy foods,
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17 262 whereas the absence of good perceived wealth may negatively affect the appropriateness and
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19 263 diversity of choices. Wealth is higher for families with histories of higher earnings, more savings
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21 264 and, in some cases, fewer expenditures on health care ⁽¹⁵⁾. However, wealth perception by the
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23 265 subject may also be influenced by one's needs, love of money, level of aspirations, and
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25 266 materialistic inclinations⁽⁴⁴⁾. Recent research has shown that two dimensions of money attitudes
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27 267 affect the subjective perception of wealth: individuals' perceived financial control (the ability to
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29 268 budget, monitor, and control their money) and money anxiety (worry and indecisiveness
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31 269 regarding money-related issues)⁽⁴⁴⁾. This cumulative and dynamic nature of socioeconomic
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33 270 structures, ascertained by wealth as perceived by the subject, is rarely considered in
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35 271 epidemiological studies.
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42 272 In addition, this study showed that being male, younger, and living below the poverty
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44 273 threshold were predominant factors associated with eating a high energy density diet. An often
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46 274 cited reason for poor eating patterns among low income households is the cost of healthy food
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48 275 ^{(30), (45)}. In the US, more affluent populations consume higher quality diets than do disadvantaged
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50 276 populations⁽⁴⁶⁾. People with financial constraints are likely to consume fewer fruits and
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52 277 vegetables and consume more high energy dense foods of lower quality (e.g., processed) that are
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54 278 high in added sugars and saturated fat⁽⁴⁷⁾.
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3 279 Globally, our results support previous findings reporting socioeconomic gradients in
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5 280 dietary intake⁽⁴⁸⁾. American research has also shown associations between living below the
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8 281 poverty threshold with more unhealthy/less healthy food choices and being less likely to meet
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10 282 dietary recommendations⁽⁴⁹⁾. Low education and limited economic resources may jointly
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12 283 contribute to people choosing low-cost, unhealthy energy-dense foods, high in fat and sugar.
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14 284 Generally speaking, poor socioeconomic circumstances lead to poor health which may be
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16 285 explained in part by less than optimal diet.
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20 286 Several strong points characterise the present study. The data were derived from a recent
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22 287 nationwide sample of the general adult population. The CCR approach showed simultaneous
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24 288 factor-specific contributions to diet quality. It allowed us to measure the magnitude of the shared
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26 289 associations, not been measured in previous studies^{(9), (12)}. Although the variances explained by
27
28 290 each model were small- indicating that other factors would also be involved, our findings
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30 291 showed that multiple demographic and socioeconomic circumstances were independently
31
32 292 associated with different diet quality indicators, and highlighted the importance of considering
33
34 293 the overall context of SES when explaining nutritional disparities. It is widely agreed that the
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36 294 pathway mechanisms linking education, occupation and income with diet are conceptually
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38 295 distinct⁽⁹⁾. For example, education may influence food choices by facilitating or constraining a
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40 296 person's ability to understand the information communicated by a healthcare professional or on
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42 297 food labels⁽⁹⁾. Work status may affect diet through work-based cultures and social networks⁽¹²⁾.
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44 298 Employment largely determines income and therefore, affordability of certain food products,
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46 299 such as more healthy and nutritious food⁽¹⁵⁾, suggesting that unequal distribution of resources
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48 300 may lead to nutritional disparities and consequent health inequity. This CCR procedure allowed
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50 301 the ability to distinguish shared and predictor-specific effect on diet quality. Identifying the key
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3 302 SES predictors is important to capture the variation in diet quality and to offer a better
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5 303 understanding of the underlying mechanisms relating to specific exposures⁽⁸⁾. Compared to a
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8 304 single proxy indicator approach, our findings support the fact that SES is a multi-dimensional
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10 305 concept that should encompass other facets, mainly country of birth, marital status, and wealth,
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12 306 as each reflects a different conceptual underpinning on how SES influences diet⁽⁹⁾. Likewise,
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14 307 age and sex were shown to be relevant SES indicators associated with various dietary quality
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17 308 scores.

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20 309 Obtaining detailed overall diet quality assessments is challenging in population-based
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22 310 studies⁽⁵⁰⁾. Numerous diet quality indices have been suggested in the literature to reflect various
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24 311 aspects of diet quality⁽⁵¹⁾. These indices aim mainly to identify whether different population
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26 312 subgroups are consuming “good/healthy” or “detrimental/unhealthy” foods⁽⁵¹⁾, using a variety of
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28 313 definitions to describe these terms. From among a plethora of such descriptors, we focused on
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30 314 five indices to cover different aspects of diet quality, including compliance to national dietary
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32 315 recommendations, appropriate food choices, energy density, and food variety/diversity. These
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34 316 five diet quality indices were highly correlated in the study population⁽⁵²⁾, probably because most
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36 317 of these indices focus on healthy dietary patterns, nevertheless, they may not fully indicative of a
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38 318 healthy diet regardless of SES. Further research on which dietary indicators better predict
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40 319 nutritional status is warranted.

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43 320 In calculations of energy density, the treatment of beverages is important. As beverages
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45 321 have a high water content, they tend to have a lower energy density than most foods and may
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47 322 disproportionately influence dietary energy density values⁽⁵³⁾. The best method for calculating
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49 323 energy density depends on the purpose of the analysis, the outcome of interest, and the study
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51 324 population. Associations with weight or health status may possibly be weakened or missed⁽⁵⁴⁾
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3 325 when using energy density based on food and all beverages excluding water, however this was
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5 326 not the objective of the present study. Using foods and all beverages excluding water is
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8 327 convenient and requires no special manipulation of the dietary intake dataset⁽⁵³⁾.
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11 328 The selected diet quality indicators were calculated using a validated FFQ, where several
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13 329 quality control measures were undertaken to provide complete and coherent data⁽²⁰⁾. Two
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15 330 extensive validation studies ⁽²⁴⁾, ⁽⁵⁵⁾ showed that the FFQ performed well in assessing intakes of
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18 331 several foods and micronutrients and the observed correlations were within the range noted by
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20 332 other investigators. In addition, intensive efforts were made to minimise dietary reporting
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22 333 inaccuracies through extensive control procedures ⁽²⁰⁾.
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26 334 This study fills a knowledge gap, and enhances the research on socioeconomic disparities
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28 335 in nutrition by addressing a novel method, defined as CCR, to identify the most important
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30 336 demographic and socioeconomic circumstances independently associated with diet quality. To
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32 337 our knowledge, only one Australian study has used this CCR method to describe the
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34 338 socioeconomic gradients in children's diets⁽³⁹⁾.
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38 339 Further, several sensitivity analyses, by using linear regression and PLS methods,
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40 340 confirmed results obtained with CCR (data not shown). Consistent with CCR analyses, linear
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42 341 regression showed that being older, from Portugal or non-European countries, having higher
43
44 342 education, and living above the poverty threshold were associated with a higher RCI. A higher
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46 343 RFS was also noticed in women, older people, from Portugal, with higher education.
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48 344 Concerning dietary diversity, higher scores was associated with male sex, being Portuguese, and
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50 345 those living with a partner. A higher non-RFS was associated with men, living alone, whereas
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52 346 people with a higher education, living above the poverty threshold and from Portugal, were more
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54 347 likely to have a lower non-RFS. Similarly, the energy density score was negatively associated
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3 348 with age, while male sex and people living below the poverty threshold were more likely to eat
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5 349 energy-dense foods. A PLS regression was also performed with diet quality scores as dependent
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8 350 variables and all selected demographic and SES factors as explicative variables. The first linear
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10 351 combination had high positive loadings for age, higher education, living above the poverty
11
12 352 threshold, being housewives and disabled or retired. High negative loadings were noted for men,
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14 353 living alone and being employed. This first linear combination was positively associated with the
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16 354 RCI, RFS and negatively associated with the non-RFS and energy density.
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21 355 Certain shortcomings should also be recognised, related mainly to the current absence of
22
23 356 a gold standard for dietary assessment. An optimal dietary intake assessment strategy still
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25 357 challenges nutrition research⁽⁵⁶⁾. Although the FFQ has been shown to be sufficiently convenient
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27 358 and inexpensive to use in large-scale, population-based studies⁽⁵⁷⁾, responses rely upon self-
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29 359 report, and therefore are subject to imprecision (under- and over-reporting) and biases related to
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31 360 social desirability⁽⁵⁸⁾.
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35 361 Other potential limitations include factors related to the cross-sectional design, which
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37 362 precludes establishment of the temporal sequence between socioeconomic circumstances and
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39 363 diet quality. Of course, all but prospective studies would be encumbered by this limitation. The
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41 364 relatively low response rate (32.2%) did not influence the present findings, as a detailed study of
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43 365 non-participants showed comparable demographic and clinical characteristics of participants and
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45 366 non-participants, hence providing population-representative estimates⁽²¹⁾.
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50 367 In conclusion, this study is a step toward moving the field of SES-nutrition research
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52 368 forwards. Multiple demographic and socioeconomic circumstances were independently
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54 369 associated with diverse diet quality indicators. Age, sex, country of birth and education level
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56 370 were important factors associated with healthy and adequate foods choices, whereas economic
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3 371 resources were associated with food diversity and energy density. From a public health
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6 372 standpoint, these findings are important in delineating the groups at risk in terms of their
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8 373 demographic and socioeconomic circumstances.
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11 374
12 375 **Authors' contribution**
13 376

14 377 AA was involved in the conception and design of the ORISCAV-LUX survey, coordinated the
15
16 378 field data collection. All the authors (AA, CV, NS, GEC, MFE) fulfill the ICMJE guidelines, as
17
18 379 regards: 1) substantial contributions to conception and design, analysis and interpretation of data;
19
20 380 2) drafting the article or revising it critically for important intellectual content; and 3) final
21
22 381 approval of the version to be published.
23

24 382
25 383
26 384 **Conflict of interest: None**
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28 385
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31
32 387 **Acknowledgement:** AA is supported by a grant from the FNR (*Fond National de Recherche*) for
33
34 388 the project DIQUA-LUX, 5870404), Luxembourg. GEW is supported by a Sidney Sax Research
35
36 389 Fellowship (National Health and Medical Research Council, Australia, grant number
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39 390 APP1054567).
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3 391 **Tables and legends**
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7 393 Table 1 Demographic, socio-economic characteristics, and dietary indicators by sex
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10 394 Table 2 Correlation between the SES factors
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13 395 Table 3 Diet quality indicators by demographic and socio-economic factors
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15 396 Figure 1 Demographic and socioeconomic factors associated with compliance to dietary
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26 400 Figure 4 Demographic and socioeconomic factors associated with diverse foods items
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29 401 Figure 5 Demographic and socioeconomic factors associated with energy density
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32 402 Appendix A 1-5 Results of correlated component regression analyses for the five selected dietary
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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
<i>Primary</i>	149 (22.9)	202 (29.4)	351 (26.2)	
<i>Secondary</i>	324 (49.8)	308 (44.8)	632 (47.2)	
<i>Tertiary</i>	178 (27.3)	177 (25.8)	355 (26.5)	
Country of birth (n=1352)				0.27
<i>Luxembourg</i>	401 (61.0)	421 (60.6)	822 (60.8)	
<i>Portugal</i>	88 (13.4)	74 (10.6)	162 (12.0)	
<i>Other European</i>	131 (19.9)	162 (23.3)	293 (21.7)	
<i>Non-European</i>	37 (5.6)	38 (5.5)	75 (5.5)	
Work Status (n1351)				<0.001
<i>Employed</i>	472 (71.8)	397 (57.2)	869 (64.3)	
<i>Not employed</i>	58 (8.8)	60 (8.6)	118 (8.7)	
<i>Housewives</i>	2 (0.3)	172 (24.8)	174 (12.9)	
<i>Retired or disabled</i>	125 (19.0)	65 (9.4)	190 (14.1)	
Marital Status (n=1352)				0.34
<i>Live with partner</i>	474 (72.1)	484 (69.6)	958 (70.9)	
<i>Live alone</i>	183 (27.9)	211 (30.4)	394 (29.1)	
Economic status (n=1174)				0.97
<i>Below poverty threshold</i>	127 (21.4)	125 (21.5)	252 (21.5)	
<i>Above poverty threshold</i>	466 (78.6)	456 (78.5)	922 (78.5)	
Wealth adequacy perception (n=1279)				0.21
<i>Easy</i>	483 (77.9)	532 (80.7)	1015 (79.4)	
<i>Difficult</i>	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 χ^2 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

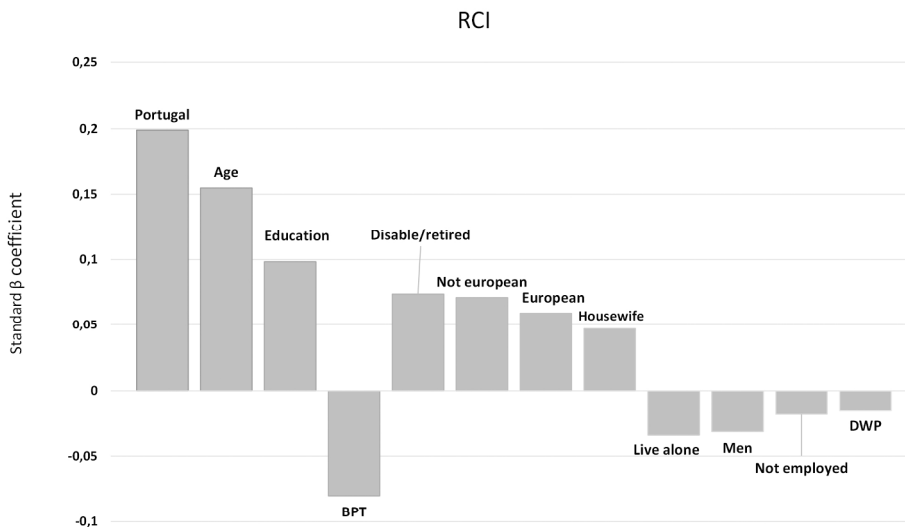
§ Age was categorized here in 3 categories (18-29; 30-49; 50-69)

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 Kruskal-Wallis test, otherwise from *t*-test.

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



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

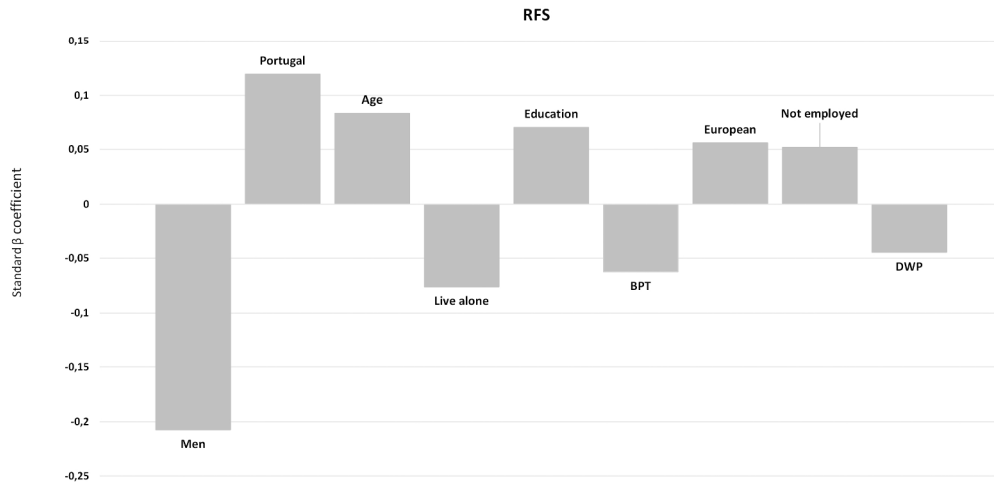
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Figure 2 Demographic and socioeconomic factors associated with selecting healthy food choices

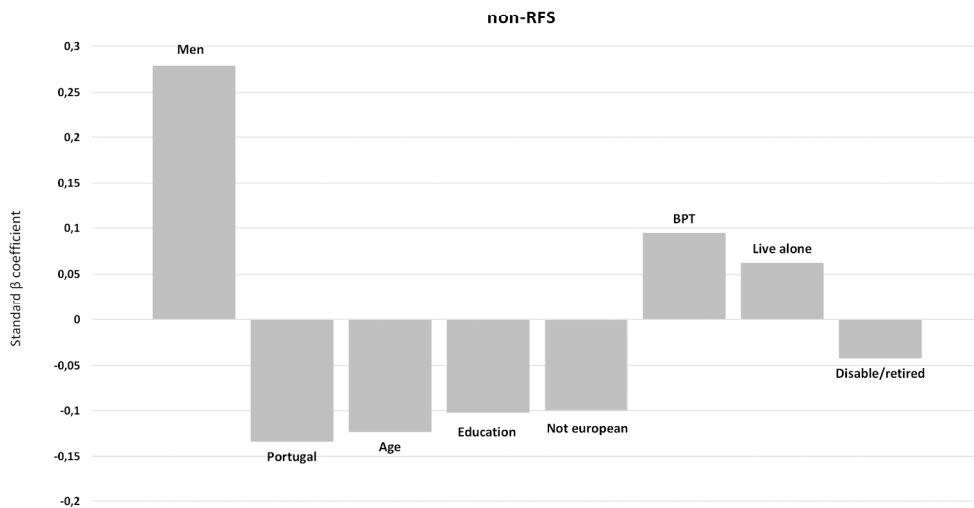


RFS: Recommendation Food Score; BPT: below poverty threshold; DWP: Difficult wealth perception

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



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

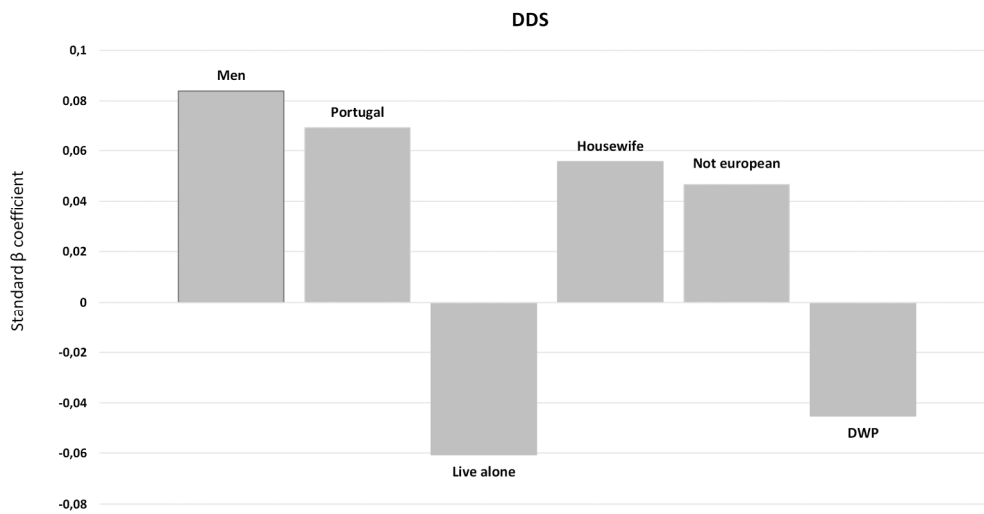
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Figure 4 Demographic and socioeconomic factors associated with diverse foods items

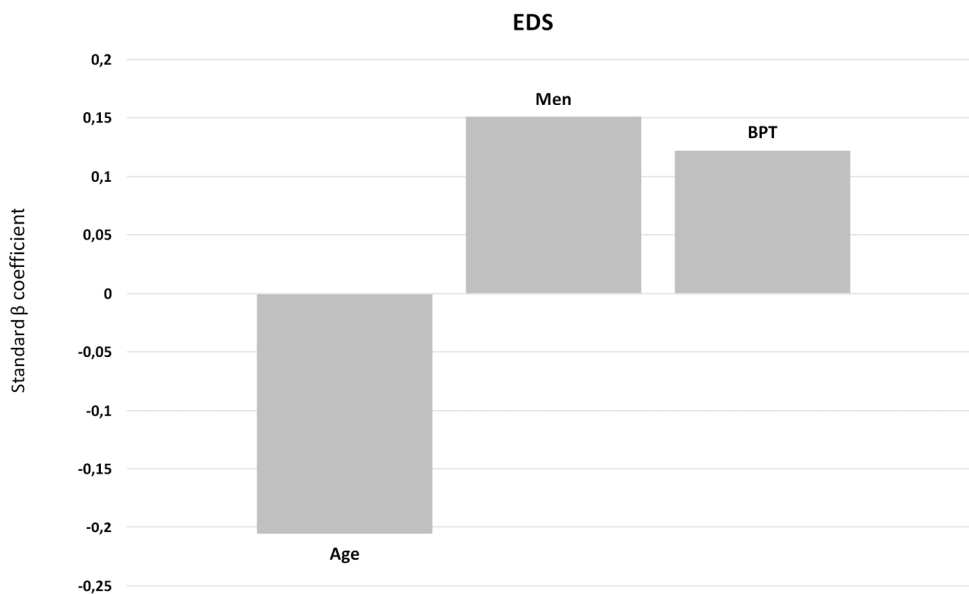


DDS: Dietary Diversity Score; DWP: Difficult wealth perception

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Figure 5 Demographic and socioeconomic factors associated with energy density



ED: Energy Density; BPT: below poverty threshold

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

Table 1 Recommendation 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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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: R² (CV)= cross-validated R²; SD (CV)= Standard deviation for cross-validated R².

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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —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 <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —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
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*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.