

## Original article

## Food consumption based on the nutrient profile system underlying the Nutri-Score and renal function in older adults

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## ARTICLE INFO

## Article history:

Received 14 February 2022

Accepted 7 May 2022

## Keywords:

Nutri-Score

Renal function

Seniors-ENRICA 1 study

Public health

## SUMMARY

**Background:** The impact of the Nutri-Score labelling system on renal function is unknown.

**Objective:** To assess the association between food consumption based on the nutrient profile system underlying the Nutri-Score and renal function decline in older adults.

**Methods:** We used data from the Spain-based Seniors-ENRICA cohort, a study with 1312 community-dwelling adults aged  $\geq 60$  years recruited during 2008–2010 and followed up to December 2015. At baseline, a validated dietary history was obtained. Based on their nutritional quality, foods consumed were categorized into five labels (A/Green—best quality, B, C, D, E/Red—worst quality) using the established Nutri-Score algorithm. For each participant, a Nutri-Score dietary index (DI) was calculated in g/day/kg of weight. At baseline and at follow-up, measured serum creatinine (SCr) and estimated glomerular filtration rate (eGFR) levels were obtained, and time changes were calculated. A combined outcome for renal decline was defined as: any increase in SCr or any decrease in eGFR beyond expected-for-age. Statistical analyses were performed with logistic regression adjusting for socioeconomic, life-style, total energy intake, fresh foods, and comorbidity confounders.

**Results:** A total of 183 cases of renal-function decline occurred over a mean 6-year follow-up. Participants with a higher (less favorable) Nutri-Score DI (interquartile range (IQR) 13.2–17.7 (g/day/kg of weight); 46 cases) had higher probability of renal decline than those with a lower Nutri-Score DI (IQR 36.6–46.2; 44 cases); the corresponding odds ratios (95% confidence interval) across increasing quartiles of Nutri-Score DI were 1 (reference), 1.26 (0.78–2.04), 1.55 (0.92–2.62), and 1.82 (1.01–3.30), P-trend = 0.045. Per each 10-point increase in the Nutri-Score DI the odds of renal decline increased by 27% (6%–52%).

**Conclusions:** Higher Nutri-Score DI, reflecting the consumption of foods with less favourable Nutri-Score rating, was associated with higher kidney function decline in older adults. Consequently, Nutri-Score labeling might be a useful policy tool for preventing kidney function decline, adding to the potential health benefits of this front-of-pack labelling system.

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## 1. Background

Kidney disease is a public health problem, affecting more than 10% of the world's population [1] and reaching 15% in Spain [2]. Chronic kidney disease (CKD) increases substantially the risk of overall mortality [3,4], especially from cardiovascular disease (CVD) [5]. Because there is substantial evidence on the impact of

certain dietary habits on the development and progression of CKD [6], diet-based prevention of renal disease is potentially achievable.

Healthy dietary patterns, based on fresh products and rich in fruits, vegetables and dietary fiber are inversely associated with kidney function decline [7], CKD [8], and CKD mortality [9]. On the contrary, Westernized diets, high in energy, saturated fat, sugar, salt, and ultra-processed foods, have been associated with higher mortality [10,11], several chronic diseases including CVD [12,13], and kidney function decline [14].

The world is experiencing a shift in dietary patterns, whereby traditional healthy diets based on local foods are progressively eroding and being replaced by diets characterized by industrial and globalized foods. Accordingly, in the Spanish market there has been an increase of unhealthy processed foods, which are energy-dense and with a high content of sugar, saturated fat, salt, and additives, but low in dietary fiber and vitamins [15].

With the aim of helping consumers choose those food products with better nutritional quality, different health policies are emerging [16–18]. Recently, a front-of-pack labelling system called Nutri-Score was developed in France to translate the nutritional information in the back of each food package into a simple and intuitive logo placed on the front. The Nutri-Score logo includes five letters matched (A to E) with colors, with the letter A (green) indicating the highest nutritional quality, and the letter E (dark orange) indicating the worst [19,20]. Some studies, such as the SU.VI.MAX, the NutriNet-Santé, the EPIC, The SUN project, and the ENRICA cohorts, have consistently reported that consumption of foods with lower nutritional quality according to the nutrient profile system underlying the Nutri-Score is associated with higher risk of death [21,22], CVD [23,24] and cancer [25–27].

Therefore, this study aimed to assess the association between food consumption based on the nutrient profile system underlying the Nutri-Score classification and the risk of renal-function decline in the Seniors-ENRICA-1 study, a population-based cohort of older adults from Spain.

## 2. Methods

### 2.1. Study design and participants

Analyses were conducted retrospectively in 2021 using data from a cohort recruited in 208–2010 and followed-up to 2015. The methods of the Seniors-ENRICA-1 cohort have been previously reported [28,29]. In brief, this cohort was established between 2008 and 2010 with non-institutionalized individuals aged  $\geq 60$  years, who were followed-up until 2015 to update data collection. The Clinical Research Ethics Committee of La Paz University Hospital in Madrid (Spain) approved the study, and all participants gave informed consent.

### 2.2. Baseline data collection

Baseline data were collected in three stages by trained and certified personnel. First, information on sociodemographic variables, health status, lifestyle, morbidity, and health services use was collected through a computer-assisted telephone interview using a structured questionnaire; second, personnel visited the participant's households to obtain fasting blood and urine samples; and third, they conducted a subsequent household visit to perform a physical exam and to assess food consumption [29].

### 2.3. Dietary assessment and computation of Nutri-score-based food consumption

Habitual food consumption in the previous year was obtained with a validated computer-based dietary history (DH-ENRICA), which consists of a structured questionnaire administered by a trained interviewer. The DH-ENRICA collects standardized information on 880 foods and 184 recipes for dishes commonly eaten in Spain. When it was not possible to use home measurements to quantify the consumption of a given food, a set of 3 photographs (small plate, large plate, and normal plate) were used to assist in their quantification and to estimate the food portions. The software includes aids for the correct classification of some foods (e.g., fermented milk or butter and margarine) [30]. Spanish standard food composition tables allowed for the calculation of the intake of energy and nutrients [31,32].

The Nutri-Score used a modified version of the British FSA algorithm, with adaptations in the allocation of points for beverages, cheese, and added fats [19,33]. This adaptation of the original British Nutri-score was developed by the Higher Council of Public Health (Haut Conseil de la Santé Publique, HCSP) to improve the differentiation of products within the food groups and to ensure a higher consistency with food-based dietary guidelines [34]. The Nutri-Score was calculated from the nutrient content of foods suitable for packaging (i.e., excluding fresh foods) consumed in the Seniors-ENRICA-1 cohort. Fresh food items were mainly fruit, vegetables, meat, and fish. Each non-fresh food item consumed received positive points (0–10) for total energy (kJ), sugar (g), saturated fat (g), and sodium content (mg). Each food item also received negative points (0–5) according to their content of fruit, vegetables, pulses, nuts, and rapeseed, walnut, and olive oils(g), dietary fiber (g), and protein content (g). Thus, the continuous Nutri-Score ranges from +40 (least healthy food) to –15 (most healthy food). This continuous score was divided into five categories to derive the 5-CNS, containing five letters (A, B, C, D, E) with corresponding colors, from dark green (letter A) indicating the highest nutritional quality, to light green (letter B), yellow (letter C), light orange (letter D), and dark orange (letter E), the latter representing the worst nutritional quality. These five categories/colors were established to ensure a high discriminating power, while maintaining a central category in order to avoid dichotomous thinking food as only being good or bad [33].

For each participant, we calculated two dietary indexes (DI):

1. **Five-colour Nutri-Score DI:** calculated as  $\Sigma$  (amount consumed in grams from each non-fresh food and beverage times its corresponding 5-CNS value ranging from A rated 1 to E rated 5)/(body weight in kg).
2. **Continuous Nutri-Score DI:** calculated as  $\Sigma$  (amount consumed in grams from each non-fresh food and beverage times its corresponding continuous Nutri-Score value ranging from +40 to –15)/(body weight in kg).

For both Nutri-Score DIs, a higher value represents lower nutritional quality for the whole diet.

### 2.4. Renal function decline

At baseline and at the end of follow-up, subjects provided a 12-h fasting blood sample and a spot fasting urine sample. Laboratory determinations were performed centrally at the Center of Biological Diagnosis of the Hospital Clinic (Barcelona) [29]. Serum creatinine (Scr) was determined by the Jaffé, alkaline picrate by kinetic reaction. The estimated glomerular filtration rate (eGFR) was

estimated from SCr and age with the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) Equation [35].

Composite outcome for renal function decline was defined as increase in SCr or decrease in eGFR beyond expected for age, from baseline (2008–10) to follow-up (2015), and was calculated in 3 steps: (i) eGFR based on baseline SCr and age at follow-up; (ii) eGFR based on both SCr and age at follow-up; and (iii) subtracting ii from i [14].

## 2.5. Other variables

Information on sex, age, educational level (no formal education, primary, and secondary or higher), and smoking status (current, former, and never smoker) was self-reported. Weight and height were measured by under standardized conditions, and body mass index (BMI) was calculated as weight (kg) divided by squared height (m). Physical activity was ascertained using the validated EPIC questionnaire and expressed in metabolic equivalents (MET)–hour/week; a 4-level physical activity index was calculated to categorize individuals into: inactive, moderately inactive, moderately active, and active [36]. A nurse checked the number of medications used against drug packages. Hypercholesterolemia was defined as fasting serum total cholesterol  $\geq 200$  mg/dL or taking lipid-lowering medications; hypertension as  $\geq 140/90$  mm Hg or taking antihypertensive medication; and diabetes was deemed to exist when self-reported or if taking antidiabetic medication. Other physician-diagnosed chronic conditions (chronic respiratory disease, coronary disease, stroke, heart failure, osteoarthritis/arthritis, cancer, and depression requiring treatment) were also self-reported.

## 2.6. Statistical analysis

Of the 2519 baseline participants who reported data in 2015, we excluded: 118 with baseline eGFR  $< 60$  mL/min/1.73 m<sup>2</sup> [37]; 19 with extreme data on energy intake ( $< 600$  or  $> 4200$  kcal/day in men,  $< 400$  or  $> 3500$  kcal/day in women); 1062 without data for eGFR at follow-up; and 8 with missing data on covariates. Thus, the analytical sample consisted of 1312 individuals without evidence of renal function impairment at baseline (Fig. 1).

Participants were categorized into sex-specific quartiles of the two calculated Nutri-Score DI, the five-colour Nutri-Score DI and the continuous Nutri-Score DI. Odds ratios (OR) and corresponding 95% confidence intervals (CI) of kidney function decline according to quartiles (lowest as reference) of both Nutri-score DIs were estimated using logistic regression. Also, intake from foods classified as D and E were summed up and divided by body weight (g/kg), and sex-specific quartiles were analyzed. The linear trend across quartiles was tested by calculating the median in each quartile and modelling it as a continuous variable. Receiver operating characteristic (ROC) curve analysis were performed for assessing how well the Nutri-Score can discriminate between individuals who experience kidney function decline and individuals who do not.

Additionally, subgroup analyses were performed, stratifying the sample (above or below the median) by possible effect modifiers, such as age ( $\leq$  or  $>$  67 years), sex, BMI ( $\leq$  or  $>$  28 kg/m<sup>2</sup>), and hypertension. P for interaction was obtained using the likelihood ratio test of the models with and without the interaction term.

We built three models with progressive adjustment for potential confounders [38]. Model 1 adjusted for sex, age (years), and total energy intake (Kcal/day); Model 2 further adjusted for fruits and vegetables intake (g/d), meat and fish intake (g/d), BMI (kg/m<sup>2</sup>), education (no formal education, primary, secondary or higher), smoking status (never, former, current smoker), time spent watching TV (h/week), former drinking (yes/no), number of

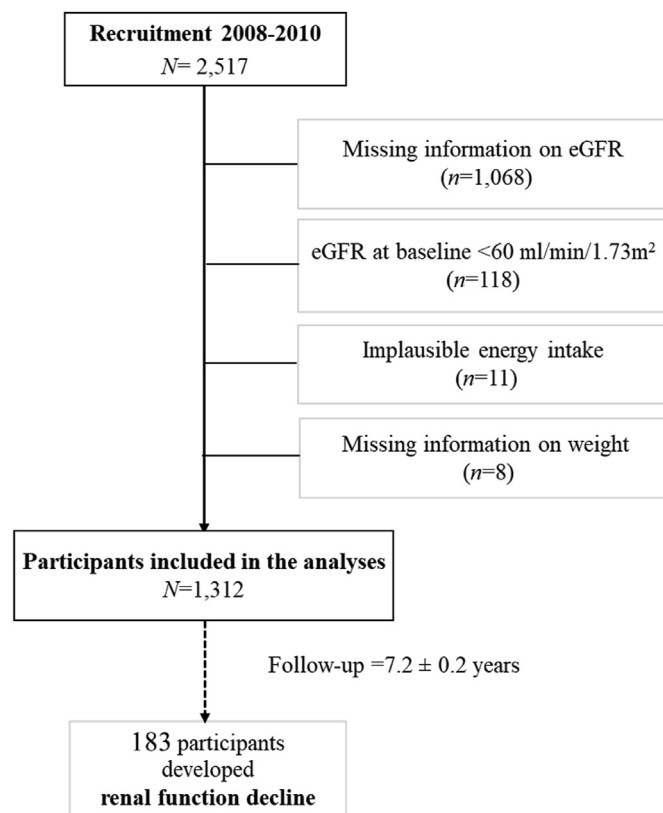


Fig. 1. Flow chart.

medications taken (0, 1 to 3,  $> 3$ ); and Model 3 additionally adjusted for prevalent diabetes (yes/no), hypercholesterolemia (yes/no), hypertension (yes/no), and number of the other chronic conditions (categorized into 0, 1, and  $> 1$ ).

Adjusted restricted cubic splines with 3 knots (at the 10th, 50th, and 90th percentiles of the distribution) were modelled to visualize the smooth function of the continuous Nutri-Score DI and the consumption of foods labelled as D or E in association with renal function decline.

Analyses were carried out using STATA/SE version 15.1 (Stata-Corp, College Station, TX, USA). P values were two-tailed and  $p < 0.05$  was considered statistically significant.

## 3. Results

The corresponding mean energy intake from the consumption of all foods classified in each Nutri-score label was (in percentage): 13.2% (=kcal from label A/total kcal consumed), 22.4% (from label B), 14.3% (from label C), 12.7% (from label D) and 9.6% (from label E). The resulting 27.8% of calories come from fresh foods. Those with the less healthy Nutri-Score DIs reflecting the consumption of foods with less favorable Nutri-Score rating (i.e., those in the highest quartile) consumed more energy but less fruits and vegetables, had a lower BMI, were more frequently former-drinkers, consumed less medications, and presented less often diabetes and hypertension (Table 1).

Among the 1312 participants (51% women; mean age:  $67 \pm 5.5$  years), we ascertained 183 cases of renal function decline over the  $7.2 \pm 0.2$  years follow-up period. Those with higher five-colour Nutri-Score DI had a greater probability of renal function decline; the corresponding OR (95% CI) across increasing quartiles of five-colour Nutri-Score DI were 1 (reference), 1.26 (0.78–2.04), 1.55 (0.92–2.62),

and 1.82 (1.01–3.30),  $P$ -trend = 0.045. Likewise, per each 10-point increase in the five-colour Nutri-ScoreDI, the odds of renal function decline increased by 27% (6%–52%). After controlling for foods labelled as A, B, or C, the odds of renal function decline doubled for those with higher consumption of foods labelled as D and E, compared to those with lower consumption ( $P$ -trend = 0.023) (Table 2 and Fig. 2). These associations were not mediated by hypercholesterolemia, high blood pressure, diabetes, or other chronic conditions (Model 3). Likewise, the fully adjusted OR (95% CI) for renal decline according to increasing quartiles of the continuous Nutri-Score DI were 1 (ref.), 0.83 (0.52–1.34), 0.98 (0.59–1.60) and 1.57 (0.92–2.66),  $P$ -trend = 0.042. The higher probability of sustaining renal function decline associated with each 10-point increase in the continuous Nutri-Score DI was 8% (1%–16%) (Table 3, Fig. 2). Overall, the area under ROC curve (AUC) was 0.70. While no significant interactions were detected in the stratified analyses, the association between the consumption of foods with less favorable Nutri-Score rating and renal decline may be stronger in hypertensive participants than in normotensive (Table 4).

#### 4. Discussion

This research found that the likelihood of renal function decline raised up to 30% (ranging from 6% to 52%) per each 10-unit increase in the five-colour Nutri-Score DI after adjusting for demographic,

lifestyle, and clinical covariates. Regarding the potential population impact suggested in this study, if the entire Spanish population >60 years old shift from having the less favorable rating in the five-colour Nutri-Score DI to having the most favorable rating, on average, it could be prevented 22 (CI 95%: 0.5–34) persons from renal function decline for every 100 Spanish citizens >60 years old.

Although this association was less strong when the Nutri-Score DI was measured as continuous (the likelihood of renal function decline was 8%, from 1% to 16%, per each 10-unit increase in the continuous Nutri-Score DI, overall findings suggest that Nutri-score labeling may be a useful tool for preventing kidney function decline in the adult population  $\geq 60$  years old.

The Nutri-Score is based on a series of thresholds for specific nutritional components, with negative grades (sugar, saturated fat, salt, and energy density), or positive ones (protein, fiber, proportion of fruit and vegetables). Diets with a low intake of simple sugars, fats, and salt are consistently associated with a lower risk of kidney injury. In turn, the consumption of fruit, vegetables, and dietary fiber have also revealed protective associations with kidney disease [6]. On the other hand, Western diets, characterized by a high consumption of refined carbohydrates, added sugars, saturated and trans fats, salt and ultra-processed food and drink products, and a low intake of fiber and micronutrients, are associated with increased systemic inflammation, albuminuria, lower GFR and loss of renal function [14,39–41].

**Table 1**

Baseline characteristics of the cohort participants according to quartiles of the Nutri-Score Dietary Indexes (DI) in the Seniors-ENRICA-1 Cohort Study (N = 1312).

Characteristics	Five-colour Nutri-Score DI			Continuous Nutri-Score DI		
	Sex-specific quartiles			Sex-specific quartiles		
	Q1 (best nutrient quality)	Q4 (worst nutrient quality)	P trend	Q1 (best nutrient quality)	Q4 (worst nutrient quality)	P trend
n	329	327		329	327	
<b>5-CNS DI</b>	15.0 $\pm$ 3.30	42.9 $\pm$ 9.65	<0.01	18.5 $\pm$ 6.8	40.5 $\pm$ 11.4	<0.01
<b>Continuous Nutri-Score DI</b>	11.6 $\pm$ 12.8	66.4 $\pm$ 31.3	<0.01	4.4 $\pm$ 8.3	73.1 $\pm$ 24.8	<0.01
Packaged foods (g/d)	606.7 $\pm$ 170.7	1171.9 $\pm$ 238.6	<0.01	754.5 $\pm$ 265.3	1075.8 $\pm$ 261.9	<0.01
Labelled as A	275.2 $\pm$ 179.2	264.3 $\pm$ 189.0	0.35	358.3 $\pm$ 214.7	228.8 $\pm$ 158.7	<0.01
Labelled as B	197.8 $\pm$ 116.1	440.0 $\pm$ 221.7	<0.01	262.1 $\pm$ 184.4	366.5 $\pm$ 191.3	<0.01
Labelled as C	62.8 $\pm$ 51.4	162.1 $\pm$ 116.3	<0.01	80.5 $\pm$ 69.7	150.8 $\pm$ 114.1	<0.01
Labelled as D	44.7 $\pm$ 35.4	132.4 $\pm$ 113.0	<0.01	36.7 $\pm$ 29.0	141.3 $\pm$ 114.0	<0.01
Labelled as E	26.3 $\pm$ 36.5	172.9 $\pm$ 136.8	<0.01	16.8 $\pm$ 18.2	188.3 $\pm$ 129.4	<0.01
Women (%)	169 (51.37)	168 (51.38)	1.00	169 (51.37)	168 (51.38)	1.00
Age (y)	67 $\pm$ 5.1	67 $\pm$ 5.8	0.13	67 $\pm$ 5.3	67 $\pm$ 5.7	0.11
Total energy intake (kcal/d)	1661.3 $\pm$ 496.1	2440.5 $\pm$ 531.6	<0.01	1724.9 $\pm$ 515.9	2416.8 $\pm$ 530.2	<0.01
Fruits and vegetables intake (g/d)	629.3 $\pm$ 275.1	501.2 $\pm$ 232.9	<0.01	626.4 $\pm$ 275.8	489.6 $\pm$ 218.3	<0.01
Meat and fish intake (g/d)	330.6 $\pm$ 205.3	332.0 $\pm$ 234.0	0.19	328.4 $\pm$ 230.9	328.6 $\pm$ 236.8	0.03
Body mass index (%)	29.6 $\pm$ 4.6	27.1 $\pm$ 3.5	<0.01	28.5 $\pm$ 4.4	27.9 $\pm$ 3.8	0.01
Educational level (%)			0.38			0.38
No formal education	91 (27.7)	66 (20.2)		75 (22.8)	80 (24.5)	
Primary	80 (24.3)	99 (30.3)		82 (24.9)	97 (29.7)	
Secondary or higher	158 (48.0)	162 (49.5)		172 (452.3)	150 (45.8)	
Smoking status (%)			0.82			0.82
Current smoker	38 (11.6)	43 (13.1)		30 (9.1)	47 (14.4)	
Former smoker	109 (33.1)	97 (29.7)		103 (31.3)	105 (32.1)	
Never smoker	182 (55.3)	187 (57.2)		196 (59.6)	175 (53.5)	
Time spent watching TV (h/wk)	2.48 $\pm$ 1.57	2.25 $\pm$ 1.37	0.10	2.53 $\pm$ 1.61	2.39 $\pm$ 1.57	0.35
Former-drinker (%)	23 (7.0)	38 (11.6)	0.01	25 (7.6)	35 (10.7)	0.01
Number of medications (%)			<0.01			<0.01
0	80 (24.3)	120 (36.7)		98 (29.8)	103 (31.5)	
1 to 3	185 (56.2)	163 (49.8)		169 (51.4)	173 (52.9)	
>3	64 (19.5)	44 (13.5)		62 (18.8)	51 (15.6)	
Prevalent diabetes	60 (18.2)	37 (11.3)	<0.01	55 (16.7)	44 (13.5)	<0.01
Hypercholesterolemia (%)	235 (71.4)	241 (73.7)	0.39	236 (71.7)	243 (74.3)	0.39
Hypertension (%)	226 (69.1)	176 (54.2)	<0.01	206 (63.2)	183 (56.1)	<0.01
Number of chronic conditions <sup>a</sup> (%)			0.85			0.85
0	151 (45.9)	144 (44.1)		153 (46.5)	153 (46.8)	
1	137 (41.6)	142 (43.4)		137 (41.6)	128 (39.1)	
>1	41 (12.5)	41 (12.5)		39 (12.9)	46 (14.1)	

Only extreme quartiles are presented. Continuous variables presented as mean  $\pm$  standard error and categorical variables as percentage and number of participants. Percentages may not sum to 100 because of rounding.

<sup>a</sup> Chronic respiratory disease, coronary disease, stroke, heart failure, osteoarthritis/arthritis, cancer, and depression requiring treatment.

**Table 2**

Odds ratios (95% confidence intervals) of renal function decline according to sex-specific quartiles of the five-colour Nutri-Score Dietary Index (DI).

	Sex-specific quartiles of the five-colour Nutri-Score DI				P-trend	Per 10-unit- increment
	Q1	Q2	Q3	Q4		
Interquartile range (g/day/kg of weight)	13.2–17.7	20.9–23.9	27.1–30.9	36.6–46.2		
N participants	329	328	328	327		
Cases	46	46	47	44		
Model 1, OR (95% CI)	1 (Ref.)	1.19 (0.75–1.89)	1.37 (0.84–2.22)	1.48 (0.87–2.53)	0.144	1.19 (1.01–1.39)
Model 2, OR (95% CI)	1 (Ref.)	1.24 (0.77–1.99)	1.52 (0.91–2.55)	1.82 (1.01–3.29)	0.042	1.27 (1.07–1.52)
Model 3, OR (95% CI)	1 (Ref.)	1.26 (0.78–2.04)	1.55 (0.92–2.62)	1.82 (1.01–3.30)	0.045	1.27 (1.06–1.52)

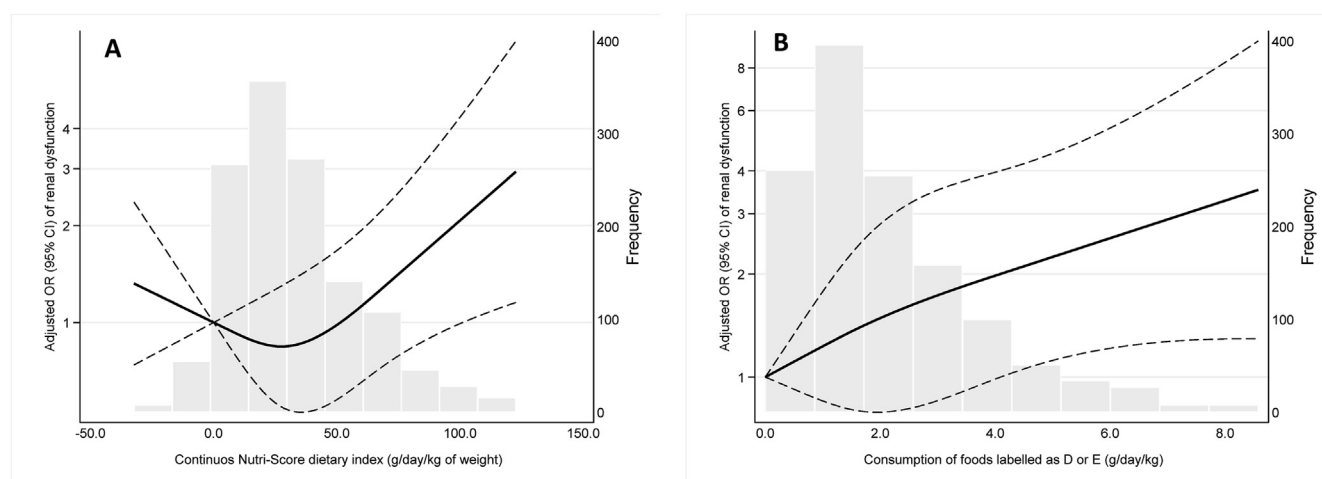
	Sex-specific quartiles of foods labelled as D and E consumption <sup>a</sup>				P-trend	Per 1 g/day/kg increment
	Q1	Q2	Q3	Q4		
Interquartile range (g/day/kg of weight)	13.9–22.1	18.4–26.4	23.6–32.1	32.7–45.3		
N participants	329	328	328	327		
Cases	44	49	39	51		
Model 1, OR (95% CI)	1 (Ref.)	1.34 (0.85–2.12)	1.17 (0.71–1.92)	1.87 (1.12–3.10)	0.021	1.14 (1.04–1.25)
Model 2 <sup>b</sup> , OR (95% CI)	1 (Ref.)	1.40 (0.87–2.23)	1.24 (0.74–2.08)	1.95 (1.12–3.38)	0.025	1.16 (1.05–1.28)
Model 3 <sup>b</sup> , OR (95% CI)	1 (Ref.)	1.40 (0.88–2.25)	1.29 (0.76–2.18)	1.98 (1.13–3.44)	0.023	1.16 (1.05–1.28)

Abbreviations: CI: Confidence Intervals, DI: dietary index; OR: odds ratio.

Logistic regression **Model 1** adjusted for sex, age and total energy intake; **Model 2** further adjusted for fruits and vegetables intake (g/d), meat and fish intake (g/d), BMI (continuous, kg/m<sup>2</sup>), education (no formal education, primary and secondary or higher), smoking status (never, former, and current smoker), time spent watching TV (h/week), former drinker (yes/no), number of medications (0, 1 to 3 and > 3); **Model 3** further adjusted for prevalent diabetes (yes/no), hypercholesterolemia (yes/no), hypertension (yes/no), and number of chronic conditions (categorized into 0, 1, and > 1).

<sup>a</sup> Dietary index only including foods classified as D and E, which were summed up and divided by body weight (g/kg).

<sup>b</sup> Further adjusted for consumption of foods labelled as A, B and C.



**Fig. 2.** Odds ratios (95% confidence interval) of renal function decline according to the continuous Nutri-score DI (A) and the consumption of foods labelled as D or E (B). Lines are restricted cubic splines, showing the shape of the association of the continuous Nutri-score DI (A) and the consumption of foods labelled as D or E with renal function decline (B). The solid line represents the adjusted odds ratio, and the dashed lines indicate the lower and upper 95% CIs. The knots were located at the 10th, 50th, and 90th percentiles. Logistic regression adjusted for sex, age, total energy intake, fruits and vegetables intake (g/d), meat and fish intake (g/d), BMI (continuous, kg/m<sup>2</sup>), education (no formal education, primary and secondary or higher), smoking status (never, former, and current smoker), time spent watching TV (h/week), former drinker (yes/no), number of medications (0, 1 to 3 and > 3); **Model 3** further adjusted for prevalent diabetes (yes/no), hypercholesterolemia (yes/no), hypertension (yes/no), and number of chronic conditions (categorized into 0, 1, and > 1).

**Table 3**

Odds ratios (95% confidence intervals) of renal function decline according to sex-specific quartiles of the continuous Nutri-Score Dietary Index (DI).

	Sex-specific quartiles of the continuous Nutri-score DI				P-trend	Per 10-unit increment
	Q1	Q2	Q3	Q4		
<b>Continuous Nutri-score DI</b> Interquartile range (g/day/kg of weight)	0.78–10.6	17.8–24.5	32.1–40.8	56.1–81.1		
N participants	329	328	328	327		
Cases	51	39	40	53		
Model 1, OR (95% CI)	1 (Ref.)	0.83 (0.52–1.32)	0.97 (0.60–1.56)	1.58 (0.97–2.59)	0.027	1.08 (1.02–1.15)
Model 2, OR (95% CI)	1 (Ref.)	0.83 (0.52–1.32)	0.96 (0.59–1.58)	1.57 (0.93–2.66)	0.039	1.08 (1.01–1.16)
Model 3, OR (95% CI)	1 (Ref.)	0.83 (0.52–1.34)	0.98 (0.59–1.60)	1.57 (0.92–2.66)	0.042	1.08 (1.01–1.16)

Abbreviations: CI: Confidence Intervals, DI: dietary index; OR: odds ratio.

Logistic regression **Model 1** adjusted for sex, age and total energy intake; **Model 2** further adjusted for fruits and vegetables intake (g/d), meat and fish intake (g/d), BMI (continuous, kg/m<sup>2</sup>), education (no formal education, primary and secondary or higher), smoking status (never, former, and current smoker), time spent watching TV (h/week), former drinker (yes/no), number of medications (0, 1 to 3 and > 3); **Model 3** further adjusted for prevalent diabetes (yes/no), hypercholesterolemia (yes/no), hypertension (yes/no), and number of chronic conditions (categorized into 0, 1, and > 1).

**Table 4**

Odds ratios (95% confidence intervals) of renal function decline according to sex-specific quartiles of the five-colour Nutri-Score dietary index by age, sex, body mass index and hypertension.

By age (years)	≤ 67 years (n=689)		P interaction	> 67 years (n=623)	
	Cases/n	OR (95%CI)		Cases/n	OR
Per 10-unit- increment	84/689	1.27 (1.00–1.63)	0.996	99/623	1.26 (0.96–1.65)
By sex	Women (n=673)		P interaction	Men (n=639)	
	Cases/n	OR		Cases/n	OR
Per 10-unit- increment	70/673	1.33 (1.00–1.77)	0.681	113/639	1.25 (0.98–1.59)
By body mass index	≤ 28 kg/m <sup>2</sup> (n=657)		P interaction	>28 kg/m <sup>2</sup> (n=655)	
	Cases/n	OR		Cases/n	OR
Per 10-unit- increment	84/657	1.35 (1.07–1.69)	0.080	99/655	1.11 (0.83–1.47)
By hypertension	No hypertensive (n=497)		P interaction	Hypertensive (n=807)	
	Cases/n	OR		Cases/n	OR
Per 10-unit- increment	55/497	1.16 (0.82–1.64)	0.171	126/807	1.34 (1.08–1.66)

Odds ratios (OR) and 95% confidence intervals (CI) adjusted for sex, age, total energy intake, fruits and vegetables intake (g/d), meat and fish intake (g/d), BMI (continuous, kg/m<sup>2</sup>), education (no formal education, primary and secondary or higher), smoking status (never, former, and current smoker), time spent watching TV (h/week), former drinker (yes/no), number of medications (0, 1 to 3 and > 3), prevalent diabetes (yes/no), hypercholesterolemia (yes/no), hypertension (yes/no), and number of chronic conditions (categorized into 0, 1, and >1).

Likewise, the nutritional components of the algorithm underpinning Nutri-Score have been individually associated with kidney disease. Thus, a higher intake of sodium is consistently associated with an increased risk of kidney disease and eGFR decline [42,43]. Additionally, when CKD is established, there is clinical trial evidence of the detrimental effect of sodium intake on blood pressure and proteinuria [44]. Intake of simple sugars also have a detrimental effect. High consumption of sugar-sweetened beverages is directly associated with kidney disease [45–47]. Fructose, which is found at high concentrations in sugar-sweetened beverages, can increase serum concentrations of urate and lead to kidney disease through renin production, vascular disease, and interstitial fibrosis [48,49]. Saturated fat has also been associated with high albuminuria [7,50]. Diets high in saturated fats and processed meats are associated with markers of inflammation [51], which, in turn, have been linked with high albuminuria [52]. Therefore, inflammation may be a pathologic link between saturated fat intake and high albuminuria.

On the other hand, plant-based diets rich in fiber are related to decreased kidney disease incidence. Moreover, total fiber intake has also shown an inverse association with incident CKD, with a 11% risk reduction for each 5g increase in fiber [53]. Fiber also improves glycemic control and insulin secretion, which is associated with a lower risk of albuminuria and proteinuria [54]. Finally, an adequate amount of dietary fiber favors the growth of the bacteria that make up the intestinal microbiota, keeping the epithelial barrier intact. Intestinal dysbiosis is commonly observed in kidney disease populations [55].

The risk of renal function decline doubled for those with higher consumption of foods ranking as D and E, the food categories with the worst nutritional quality. Examples of foods ranking as D and E are pastries, processed meat products, margarine, mayonnaise and other creams and sauces, soft drinks, most of cheeses, jam, or fruit confitures, and some fruit juices (already described in more detail elsewhere [21]) (Supplementary Table 1). About 84% of foods ranked by Nutri-Score as D and E are ultra-processed food and drink products [56].

Ultra-processed food and drink products are industrially formulated products, generally low in fiber and micronutrients, but usually, although not systematically, rich in refined carbohydrates, added sugars, saturated and trans-fatty acids, and sodium [15]. There is substantial evidence that ultra-processed foods increase

the incidence of several chronic diseases, including renal function decline [14,57]. In a recent the study, almost 40% of the increase in all-cause and CVD mortality associated with ultra-processed food and drink products consumption was explained by altered renal function [10]. Because Nutri-Score and the NOVA classification for food processing are two different dimensions [58], the most favorable Nutri-Score categories also contains a significant percentage of ultra-processed food and drink products. The highest nutritional quality category (A) includes ~30% of ultra-processed food and drink products, the B category includes ~50%, and the C category reaches the ~60% of ultra-processed food and drink products [56]. Consequently, the Nutri-Score system do not inform about all the health dimensions of foods as some ultra-processed food and drink products containing many additives could have a good nutrient content [56,59]. Special mention of the additive phosphate is required because its effects on kidney function. Phosphates are currently being added to many processed foods products including meats, cheeses, dressings, beverages, and bakery products [60]. Elevated serum phosphorus is associated with increased CVD morbidity and mortality in kidney disease patients [61,62]. Regardless of all the oral phosphorus binders available in the market, dietary restriction of this mineral remains a cornerstone for the prevention and treatment of hyperphosphatemia [61,63]. Phosphate added during food processing is an important source of this mineral because of its magnitude and high bioavailability. Thus, the Nutri-score labelling system would improve as a public health tool if accompanied by additional information on processing and additives added to the food products [56].

The Nutri-score is proposed to be complementary and efficient form of visible and simplified nutrition information, faster and easier to understand than the back-of-pack nutrition information [20]. It is increasing research-based evidence on Nutri-score effectiveness in shifting consumers toward healthier shopping baskets [64]. Since older population may have more difficulty understanding and interpreting tedious lists of ingredients and their percentages, it is even more important to create favorable environments where older people are supported and encouraged to make healthier choices. In addition, older people are more concerned about their health, and that makes them more susceptible to this type of nutritional intervention. However, changing consumption behaviors is challenging and more evidence of efficacy is

needed, particularly in older people. Finally, the evidence generated in this epidemiological investigation also aims to encourage the food industry to reformulate products to improve its nutritional quality. We acknowledge some study limitations. First, as in most nutritional epidemiology studies, diet was self-reported so some recall bias cannot be excluded. Second, diet was only measured at baseline, assuming that the participant's diet remained in the same category during follow-up. However, the possibility of dietary changes during follow-up cannot be ruled out, being a limitation of the study. Third, due to the observational study design, some residual confounding can persist. Fourth, renal function decline was based on two creatinine measurements, at baseline and at follow-up, which may lead to some non-differential misclassification and conservative results. And finally, the study database is not made up of branded products, so it has not been possible to calculate the Nutri-Score value directly from the nutritional declaration on the package. The nutritional values of the most common products of each category have been used, not being able to differentiate between different products of the same category.

Among study strengths, are its relatively long follow-up period, the validated and detailed habitual dietary assessment performed, using a computerized dietary history that included a larger number and variety of foods than a typical food frequency questionnaire. Moreover, many confounders were accounted for in the analysis.

These findings extend previous findings and reinforce the far-reaching of this front-of-pack labelling system on health. While further studies need to confirm these results, Nutri-Score labeling is proposed to be a useful policy tool for preventing kidney function decline.

## Funding information

FIS grants 17/1709, 19/319, 19/665 and 20/144 (Instituto de Salud Carlos III, State Secretary of R + D + I, and FEDER/FSE), the CIBERESP (Instituto de Salud Carlos III).

## Conflict of interest

The authors have declared that no competing interests exist.

## Acknowledgments

The authors' responsibilities were as follows- MS-H and CD-V: developed the study hypothesis and deeply reviewed the manuscript; MS-H: conducted data analysis and wrote the first draft of the manuscript; MS-H, CD-V and PG-C: had primary responsibility for final content; JRB and FR-A: contributed to data collection, results interpretation, and study funding; and all authors: reviewed the manuscript for important intellectual content, and approved the final manuscript.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.clnu.2022.05.004>.

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