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Ability of a dietary index based on the updated algorithm underpinning the Nutri-Score to discriminate food consumption and nutrient intake in a French population of children and adolescents

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ABSTRACT

Introduction: Preventing chronic diseases among children and adolescents requires a comprehensive approach. The Nutri-Score, a front-of-pack nutrition labeling system, may play an important role in public health by enhancing overall nutritional quality of dietary intake, a key modifiable risk factor. The aim of this study was to investigate the ability of the 2015 and 2023 NS-NPM to discriminate food consumption and nutrient intake in a population of French children and adolescents.

Methods: Children and adolescents (6–17 years old) participating in the cross-sectional representative ESTEBAN survey conducted in mainland France were included. Food consumption was assessed with three repeated 24 h dietary recalls. To obtain a dietary score at the individual level, the Nutri-Score nutrient profiling model dietary index (NS-NPM DI) was computed as an energy-weighted mean using the 2015 and the 2023 NS-NPMs and categorized into quartiles. Linear contrasts were used to assess the linearity of the association between the indexes and the intakes.

Results: 1279 participants (50.2 % boys and 49.8 % girls, mean age 11 years) were included in this study. Using the 2023 NS-NPM DI, participants with more favorable DI (lower NS-NPM DI) consumed higher amounts of fruits, vegetables, whole grain cereals, milk, poultry, fish and seafood and vegetable oils and lower amounts of, processed meat and sweetened foods. In addition, using the NS-NPM DI 2023, participants with more favorable DI (thus more favorable Nutri-Score) had higher intakes of proteins, fiber, vitamins and minerals, and lower intakes of lipids, SFA, MUFA and simple sugars. Compared to the NS-NPM DI 2015, with the updated algorithm, higher differences between quartiles were observed for tubers, fish and seafood, poultry, red meat, processed meat, vegetable oils and vitamin D and E, all in the expected direction (better discrimination).

Conclusion: The results of the present study suggest that the NS-NPM algorithm underlying Nutri-Score is a useful tool for characterizing the diet quality of children and adolescents. The updated version of this algorithm showed a more discriminatory ability when assessing some animal food groups and vitamin D and E, indicating that the revision of the Nutri-Score represents an improvement for public health purposes.

Abbreviations: NS-NPM DI, Nutri-Score nutrient profiling model dietary index; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty; FSA NPS, Food Standard Agency Nutrient Profiling System.

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1. Introduction

Addressing the growing burden of chronic diseases in children and adolescents and fostering prevention for long-term health requires a multi aspect approach. The World Obesity Federation estimates that 206 million children and adolescents aged 5 to 19 years will be obese by 2025, and 254 million by 2030 (Lobstein, 2019). Among the key modifiable risk factors, efforts should focus on promoting healthy lifestyles, mainly, improving access to nutritious and healthy foods, regulating advertising food high in fat, sugar and salt, increasing opportunities for physical activity, and creating supportive environments for children's well-being (De Rezende et al., 2014; Escalon et al., 2021; Kelishadi, 2019; Weihrauch-Blüher et al., 2018; WHO, 2017). One of the main public health strategies that aims to reduce the prevalence of chronic diseases in children and adolescents, is the implementation of preventive policies with a goal of promoting healthier eating such as the implementation of front-of-pack nutrition labels (Pettigrew et al., 2022; UNICEF, 2021). Nutri-Score is a front-of-pack nutrition labeling system that may contribute to public health efforts by promoting healthier food choices and to help consumers to improve the nutritional quality of their diets (Alrige et al., 2017). It is used to provide consumers with easily understandable information about the nutritional quality of a food product (Egnell et al., 2019). The Nutri-Score system is based on the UK Food Standard Agency Nutrient Profiling System (FSA NPS) originally developed to discriminate foods based on their nutritional composition in the context of the regulation of television commercials targeting children. This system assigns a color-coded grade to each food product, ranging from dark green (A) to dark orange (E), wherein A signifies the healthier option and E indicates less healthy option (Hercberg et al., 2021). The purpose of Nutri-Score is to represent in a simplified way the global nutritional quality of a product, allowing consumers to compare easily different products – with the same utilization – and quickly at the point of sale. By helping consumers to identify the nutritional value of food products and the possibility at a glance to compare food products, Nutri-Score aims to improve public health and encourage healthier eating habits (Julia et al., 2014, 2016).

Nutri-Score has been first implemented in France in 2017 and adopted by 8 European countries to date. Recently, the international scientific committee of Nutri-Score has updated the algorithm underlying the label to correct some identified limitations, while maintaining the overall consistency of the system and the classification of the products and permitting a better alignment to current nutritional recommendations (Merz et al., 2024). This update includes a higher strictness for high-sugar and high-salt products, as well as improved classification for fibers and for specific food groups including fish, vegetable oils and nuts (Merz et al., 2024).

Although the Nutri-Score algorithm has been long validated and proved its adequacy to evaluate the nutritional quality of diets (Andreeva et al., 2021; Barrett et al., 2024; Julia et al., 2014, 2016; Montericcio et al., 2024), further investigations are needed to assess the validity and applicability of the updated algorithm, in particular among children. Additionally, the efforts to address chronic diseases through diet, have been focused mainly on the adult population, with limited investigation in children and adolescents. Therefore, the aim of this study is to investigate the ability of the 2015 and 2023 NS-NPM to discriminate food consumption and nutrient intake in a population of French children and adolescents.

2. Material and methods

2.1. Study design and participants

A total of 1279 children and adolescents aged between 6 and 17 years old from the French national ESTEBAN study were included in the present analysis. ESTEBAN is a cross-sectional survey conducted from 2014 to 2016, aimed to assess dietary intake, physical activity,

sedentary behaviors, and nutritional status of the French population. The survey ensured a representative sample of the general population through a multi-stage sampling approach, involving random selection of geographic zones (stratified by regions and degree of urbanization), random selection of households based on a randomly generated phone lists, and random selection of eligible subjects. Recruitment occurred across mainland France for 1 year to consider seasonal dietary variations. The survey's protocol included socio-demographic assessments and dietary surveys with three 24-hour recalls. Detailed information about the ESTEBAN study design can be found elsewhere (Balicco et al., 2017).

This study received approval from the Advisory Committee on Information Treatment in Health Research (CCTIRS n° 13,002,294), the French Data Protection Authority (Cnil n° 2013-040), and the Personal Protection Committee (CPP n°2012-A00456-34). All participants provided informed consent.

2.2. Sociodemographic data

Social and demographic data were obtained through face-to-face questionnaires, which covered information about sex, age, educational level and occupational situation of the head of household.

2.3. Dietary data

Dietary information was gathered through three non-consecutive 24-hour dietary records (for participants aged between 6 and 10 years) or three non-consecutive 24-hour dietary recalls (for participants aged 11 and 17 years), scheduled on varied days (two weekdays and one weekend day) and distributed randomly over a two-week duration. This process was conducted either via a specialized online platform or through telephone interviews conducted by trained dietitians (Lassale et al., 2015; Touvier et al., 2011). Participants were given the choice between an online or telephone interview based on their preference, with all interviews overseen and supervised by trained dietitians. Individuals were requested to provide comprehensive details about their food consumption, including details about homemade recipes and quantities consumed. To facilitate the description of portion sizes, a validated photographic guide displaying food portions or standard measurements such as grams or household containers was utilized (Moulllec et al., 1996). Consequently, the average mean dietary intakes from these 24-hour dietary records and recalls of each participant were computed. Amounts consumed from composite dishes were estimated using pre-validated French recipes. Homemade dishes were deconstructed to list the specific ingredients used in their preparation and mean daily intakes were estimated using a detailed food composition table (Inserm, 2013). Under-reporters for energy intake were identified using the Black method and excluded from the analysis (Black, 2000).

2.4. NS-NPM underpinning the Nutri-Score

The scoring for a given food or beverage is determined by assigning points based on its content per 100 g or 100 ml. This algorithm considers both positive scoring components and negative components (Hercberg et al., 2021), overall, the points from the “favorable” component are subtracted from those of the “unfavorable” component, thus leading to a final score based on a discrete continuous scale going from –15 to +40 points for the 2015 NS-NPM (Hercberg et al., 2021). This final score is then translated into a grade from A to E, corresponding to a color from dark green to dark orange.

2.4.1. 2023 NS-NPM underpinning the Nutri-Score update

The 2023 NS-NPM, determined and validated by an international scientific committee aimed to integrate the latest scientific evidence and align with the primary food-based dietary guidelines of European countries.

The updated algorithm functions similarly to its predecessor, however some modifications have been considered. These include an increase in the maximal number of points for sugar and salt, resulting in less favorable ratings for foods high in these components. Additionally, stricter criteria were applied to the allocation of points for the fiber and protein components, requiring a higher content of fiber or protein to earn positive points. Specific rules were introduced for red meat, limiting the maximum points it could receive in the positive category. For beverages, the presence of non-nutritive sweeteners was added as an extra unfavorable factor. Finally, the thresholds for converting the final score into a rating were adjusted to align with the new algorithm (Merz et al., 2024). More details for the comparison and calculation of the initial and updated versions of the Nutri-Score, can be found in [Supplementary Material File S1](#).

2.5. NS-NPM standardization

In order to take into account the differing range of distribution of values of the (2023 or 2015) NS-NPM in foods and beverages, we converted the (2023 or 2015) NS-NPM scores to a standardized scale of 0–100 for foods and beverages respectively. Therefore, a range from the healthiest (0 points), to the least healthy (100 points) was used, following this formula (Pan et al., 2020):

$$\text{Standardized score} = \frac{\text{Score} - \text{Minimum possible score}}{\text{Maximum possible score} - \text{Minimum possible score}} * 100 \quad (1)$$

2.6. Dietary index computation (at the individual level)

To obtain a dietary score at the individual level, the 2015 and 2023 NS-NPM DI were computed as an energy-weighted mean of the NS-NPM scores of all foods and beverages consumed by each participant per day, using the following equation:

$$\text{Dietary Index} = \frac{\sum_{i=1}^n \text{NS} - \text{NPM}_i * E_i}{\sum_{i=1}^n E_i} \quad (2)$$

Where “i” signifies a food or beverage consumed by the participant, “NS-NPM_i” represents the score of the food (or beverage) obtained from Eq. (1), “E_i” signifies the mean daily energy intake from this food (or beverage) and “n” the number of different foods consumed.

Therefore, higher NS-NPM DI scores reflected lower nutritional quality in the total foods consumed. The dietary index reflects the whole diet excluding only alcoholic beverages and herbs/spices. Consequently, both the 2015 and 2023 NS-NPM DI provide a comprehensive representation of the overall dietary patterns.

2.7. Statistical analysis

Analysis of descriptive characteristics of sociodemographic variables was carried out and reported as percentages. Participants were categorized into quartiles of the NS-NPM DI (for the 2 versions), ranging from quartile 1 (Q1) –representing the highest nutritional quality– to quartile 4 (Q4) –indicating the lowest nutritional quality–. The Chi-square test for categorical variables and Kruskal-Wallis for continuous variables were used to compare the characteristics across the quartiles.

The two computed dietary indexes were categorized into quartiles, where lower quartile represented the individuals with healthier diet, and highest quartile represented the individuals with the least healthy

diet. All nutrient intakes were adjusted for energy intake using the residual method (Willett & Stampfer, 1986).

Spearman correlation coefficients were computed to measure the relationships between the two versions of Nutri-Score algorithm (continuous coding). The correlation coefficients were interpreted in terms of their strength, considering a correlation above 0.50 in absolute value as indicative of a high correlation (Hemphill, 2003).

Discriminations across quartiles of NS-NPM DI and dietary intakes were examined using ANOVA with linear contrast across quartiles of the 2015 and 2023 NS-NPM DI expressed as mean (SE). This analysis allowed the assessment of how food consumption varied across quartile 4 and quartile 1 of the dietary indexes. Relative differences between Q4 and Q1 were computed as descriptive indicators of the discrimination power of each NS-NPM DI. These relative differences were computed across the study population to quantify how consistently the two NS-NPM DI rank the nutritional quality of individual diets. The relative difference contextualizes this gap in percentage terms, making it easier to compare across different score ranges. It helps determine whether the indices discriminate between diets similarly or differently using this formula:

$$\text{Relative difference} = (\text{Q4} - \text{Q1}/\text{Q1}) * 100 \quad (3)$$

When absolute and relative differences varied by more than 5 per-

centage points between 2015 NS-NPM DI and 2023 NS-NPM DI the differences in discriminating power were considered substantial.

Data were weighted to account for potential selection bias and for the complex survey design and calibration using the “svyset” procedure. The statistical significance threshold for the results was set at $p < 0.01$. All analyses were conducted using the Stata 14 software program (StataCorp).

3. Results

A total of 1279 participants (50.2% boys and 49.8% girls, with mean age of 11 years) were included in this study. Socio-demographic characteristics of the participants across quartiles of the NS-NPM DI (2023 and 2015 version) are shown in [Table 1](#). For both Nutri-Score algorithms, no differences across quartiles of NS-NPM DI were observed for age, sex and occupational and education level of the head of household.

Spearman correlation coefficient between the dietary indexes using the new and old version of Nutri-Score algorithm was of 0.953 (p -value < 0.001) ([Table 2](#)).

Food group assessment across quartiles of NS-NPM DI (2023 and 2015 version) in children and adolescents of the ESTEBAN study are shown in [Table 3](#). For both Nutri-score versions (2015 and 2023), participants with a lower NS-NPM DI (meaning a higher nutritional quality of the diet) showed a higher consumption of fruits, vegetables, tubers, whole grain cereals, milk, poultry, fish and seafood and vegetable oil compared to those in quartile 4. Additionally, they showed a lower consumption of processed meat and sweetened products (food and beverages).

The relative differences between participants in the extreme quartiles of NS-NPM DI for both Nutri-Score versions (2015 and 2023) were similar regarding the intake of fruits, vegetables, cereals, milk, yogurt and Greek yogurt, eggs, and sweetened beverages.

The relative differences between participants in the extreme quartiles of NS-NPM DI were higher with the 2023 NS-NPM DI compared to

Table 1

Socio-demographic characteristics across quartiles of NS-NPM DI (2023 and 2015 versions) in children and adolescents of the ESTEBAN study (n = 1,279).

	Quartiles of 2023 NS-NPM DI (New version)				p-value	Quartiles of 2015 NS-NPM DI (Old version)				p-value
	Q1 (%) (Highest nutritional quality)	Q2 (%)	Q3 (%)	Q4 (%) (Lowest nutritional quality)		Q1 (%) (Highest nutritional quality)	Q2 (%)	Q3 (%)	Q4 (%) (Lowest nutritional quality)	
Age					0.464					0.257
6 to 10 years	23.7	21.4	27	27.9		21.7	25	25.5	27.9	
11 to 14 years	24.6	27.8	22.8	24.8		24.3	26.6	23.1	26	
15 to 17 years	28.9	26.2	20.2	24.7		32.5	19.4	25.2	22.9	
Sex					0.507					0.234
Boys	23.3	27.1	22.8	26.8		22.2	26.7	25.3	25.8	
Girls	27.2	23.5	24.4	24.8		28.4	22.1	23.4	26.1	
Occupational situation (head of household)					0.758					0.747
Employed	23.9	25.4	24.4	26.3		23.8	25.2	25.1	25.9	
Unemployed	34.1	24.6	23.6	17.8		37.2	15.4	26.4	21	
Student, student in training, unpaid internship	38.3	22.8	20.7	18.2		32.2	28.9	22.6	16.3	
Retired, pre-retired	37.1	18.0	14.5	30.4		25	30.2	33.1	11.8	
Housewife or house-husband	27.0	28.9	12	32.1		29.5	22.8	13.1	34.6	
Other inactive (pension, disabled, etc.)	11.1	22.9	45.3	20.7		11.7	22.2	23.3	42.7	
Parents education level					0.221					0.169
Primary or lower education	27.9	32.8	14.7	24.6		25.8	32.3	13.9	27.9	
High school education	25.0	22	24.9	28.1		24.9	21.2	26.1	27.8	
University education	24.8	29.9	22.8	22.5		25.4	28.9	24	21.7	

Abbreviations: NS-NPM DI: Nutri-Score nutrient profiling model dietary index.

Data were expressed as percentages for categorical variables.

P-values for comparisons were tested by chi-square test according to the NS-NPM DI quartiles.

Table 2

Spearman correlation coefficients between the 2015 NS-NPM DI version and the 2023 NS-NPM DI.

	2023 NS-NPM DI (new version)	2015 NS-NPM DI (old version)
2023 NS-NPM DI (new version)	1	–
2015 NS-NPM DI (old version)	0.953*	1

* p-value < 0.001.

the 2015 NS-NPM DI for the consumption of tubers, poultry, fish and seafood, red meat, processed meat, nuts, and vegetable oil, demonstrating an enhanced discriminatory power for these food groups.

The relative differences between participants in the extreme quartiles of NS-NPM DI were slightly lower for the 2023 NS-NPM DI compared to the 2015 NS-NPM DI in case of the intake of bread, whole grain cereals, sweetened foods, and fruits and vegetable juices, showing a slightly lower discriminatory power.

Nutrient intake assessment across quartiles of NS-NPM DI (utilizing the 2023 and 2015 version of Nutri-Score) in children and adolescents of the ESTEBAN study is shown in Table 4. Children with a lower 2023 NS-NPM DI (meaning a higher nutritional quality of the diet), showed a higher intake of proteins, carbohydrates, fibers, calcium, potassium, magnesium, phosphorus, iron, zinc, vitamin B1, B2, B9 and B12, β-carotene and vitamin C, D and E compared to those in quartile 4. Additionally, they showed a lower intake of energy, lipids, MUFA and SFA and simple sugars.

The relative differences between extreme quartiles of NS-NPM DI for both Nutri-Score versions (2023 and 2015) were consistent in case of energy intake and age-adjusted energy intake, proteins, carbohydrates, lipids, SFA, MUFA, simple sugars, added sugars, fibers, calcium, potassium, magnesium, phosphorus, sodium, iron, zinc, retinol, vitamin B1, B2, B9, B12, β-Carotene. Relative differences for lipids and vitamin C between participants in the extreme quartiles were lower when using the

2023 NS-NPM DI, meaning a lower discriminating power for these groups in the case of the updated algorithm. In addition, relative differences for vitamin D and vitamin E between participants in the extreme quartiles were higher when using the 2023 NS-NPM DI, meaning a higher discriminating capacity for these vitamins in the case of the updated algorithm.

4. Discussion

To the best of our knowledge, the present study is the first that assessed the relevance of the 2023 updated Nutri-Score algorithm on evaluating its discriminatory power and comparing to the 2015 version of the algorithm in French children and adolescents. Our results showed that nutritional quality of the diet is in general higher for participants in the lowest quartile of NS-NPM DI compared to those in the highest quartile, meaning that both Nutri-Score algorithms are able to characterize the quality of children and adolescent’s diet. In addition, our results suggest that compared to the previous algorithm, with the updated algorithm higher discriminative differences between quartiles were observed for tubers, fish and seafood, poultry, red meat, processed meat, vegetable oils, vitamin D and vitamin E, all in the expected direction, indicating that this updated version of the algorithm of Nutri-Score represents an improvement to characterize diet quality.

In our study, participants with more favorable DI (lower NS-NPM DI) corresponding to participants consuming foods with more favorable rating in the Nutri-Score scale, consumed higher amounts of fruits, vegetables, whole grain cereals, milk, poultry, fish and seafood, vegetable oils, proteins, carbohydrates, fibers and vitamins and minerals. Additionally, they consumed lower amounts of, processed meat, sweetened foods, lipids, SFA, MUFA and simple sugars.

Past studies conducted in adult populations, assessed the validity and the discriminatory power of the initial Nutri-Score and found that overall, the updated FSA NPS demonstrates strong consistency in characterizing individual diets within the French context and different other countries (Dréano-Trécant et al., 2020; Julia et al., 2014, 2016; Lee et al., 2023; Szabo De Edelenyi et al., 2019). In a recent Canadian study

Table 3

Food groups assessment across quartiles of NS-NPM DI (2023 and 2015 versions) in children and adolescents of the ESTEBAN study (n = 1,279).

	Quartiles of 2023 NS-NPM DI <i>New version</i>							Quartiles of 2015 NS-NPM DI <i>Old version</i>						
	Q1 (Highest nutritional quality)	Q2	Q3	Q4 (Lowest nutritional quality)	p-value (Linear contrast)	Δ_{Q4-Q1}	Relative difference (%)	Q1 (Highest nutritional quality)	Q2	Q3	Q4 (Lowest nutritional quality)	p-value (Linear contrast)	Δ_{Q4-Q1}	Relative difference (%)
Food groups; mean (SE)														
Fruits (g/day)	153 (11.6)	129 (7.77)	114 (7.77)	72.4 (6.24)	<0.001	-80.2 (13.2)	-53 %	153 (11.7)	122 (7.56)	122 (7.56)	72.1 (6.28)	<0.001	-81.2 (13.3)	-53 %
Vegetables (g/day)	158 (6.53)	146 (6.97)	119 (5.14)	93.2 (4.93)	<0.001	-64.8 (8.23)	-41 %	160 (6.26)	137 (5.88)	127 (6.90)	92.5 (4.84)	<0.001	-67.9 (7.96)	-42 %
Tubers (g/day)	65.3 (3.99)	52.0 (4.47)	55.4 (3.16)	49.8 (3.84)	0.005	-15.5 (5.54)	-24 %	61.9 (3.89)	54.1 (4.59)	55.1 (3.32)	51.3 (3.80)	0.053	-10.5 (5.44)	-17 %
Bread (g/day)	65.2 (3.08)	59.4 (3.65)	61.1 (3.11)	61.9 (3.38)	0.477	-3.25 (4.56)	-5%	70.3 (3.18)	61.9 (3.90)	59.3 (3.13)	56.2 (2.99)	0.001	-14.1 (4.34)	-25 %
Cereals (g/day)	130 (6.46)	114 (5.39)	92.1 (4.15)	87.2 (4.88)	<0.001	-42.6 (8.05)	-33 %	130.3 (6.82)	110 (5.04)	96.1 (4.18)	87.0 (4.81)	<0.001	-43.3 (8.29)	-33 %
Breakfast cereals (g/day)	12.3 (1.25)	18.9 (1.70)	12.1 (1.41)	11.2 (1.29)	0.556	-1.06 (1.79)	-9%	14.8 (1.46)	14.9 (1.65)	13.7 (1.37)	11.3 (1.29)	0.072	-3.52 (1.95)	-24 %
Whole grain cereals (g/day)	14.4 (2.16)	10.8 (1.78)	6.92 (1.12)	4.89 (1.17)	<0.001	-9.54 (2.44)	-66 %	14.7 (2.19)	11.3 (1.77)	7.13 (1.14)	7.13 (1.14)	<0.001	-10.5 (2.46)	-72 %
Milk (g/day)	213 (11.7)	212 (11.8)	159 (10.3)	99.7 (8.43)	<0.001	-114 (13.6)	-53 %	219 (11.5)	207 (11.5)	156 (9.58)	104 (8.56)	<0.001	-114 (14.4)	-53 %
Cheese (g/day)	25.5 (1.73)	27.2 (1.59)	31.0 (1.57)	30.6 (1.79)	0.041	5.06 (2.48)	20 %	24.9 (1.69)	25.2 (1.45)	32.1 (1.58)	31.9 (1.86)	0.005	6.99 (2.50)	28 %
Yogurt and Greek yogurt (g/day)	110 (6.25)	103 (5.74)	94.0 (5.74)	76.9 (5.72)	<0.001	-33.4 (8.49)	-30 %	117 (6.88)	101 (5.29)	88.1 (5.19)	77.4 (5.73)	<0.001	-39.6 (8.97)	-34 %
Red meat (g/day)	56.2 (3.36)	53.9 (3.50)	44.5 (2.66)	39.8 (2.78)	<0.001	-16.4 (4.35)	-29 %	55.3 (3.39)	53.0 (3.54)	44.5 (2.55)	41.8 (2.96)	0.003	-13.5 (4.49)	-24 %
Poultry (g/day)	45.3 (3.93)	34.9 (3.28)	24.0 (2.01)	22.8 (2.94)	<0.001	-22.5 (4.92)	-50 %	42.8 (3.98)	34.1 (2.95)	26.2 (2.53)	24.5 (3.02)	<0.001	-18.3 (4.99)	-43 %
Eggs (g/day)	14.2 (1.92)	10.4 (1.14)	10.3 (1.11)	7.11 (1.26)	0.002	-7.05 (2.29)	-50 %	13.7 (1.81)	10.4 (1.25)	10.7 (1.17)	7.23 (1.27)	0.004	-6.45 (2.22)	-47 %
Fish and Seafood (g/day)	29.9 (2.75)	19.2 (1.72)	20.9 (2.16)	14.4 (2.03)	<0.001	-15.5 (3.42)	-52 %	27.7 (2.61)	23.3 (2.17)	18.8 (1.88)	14.7 (2.05)	<0.001	-12.9 (3.32)	-47 %
Processed meat (g/day)	24.8 (1.71)	27.7 (1.92)	36.3 (2.30)	50.4 (2.92)	<0.001	25.6 (3.39)	103 %	26.6 (1.81)	28.9 (2.16)	34.8 (2.25)	48.6 (2.85)	<0.001	21.9 (3.38)	83 %
Nuts (g/day)	1.29 (0.26)	1.55 (0.30)	1.11 (0.28)	0.58 (0.14)	0.018	-0.71 (0.29)	-55 %	1.17 (0.26)	1.48 (0.26)	1.28 (0.33)	0.62 (0.15)	0.068	-0.54 (0.29)	-47 %
Sweetened foods (g/day)	94.8 (3.14)	116 (4.11)	141 (3.98)	157 (5.36)	<0.001	61.9 (6.18)	66 %	91.6 (3.20)	120 (4.24)	137 (3.76)	158 (5.34)	<0.001	66.6 (6.21)	72 %
Vegetable oil (g/day)	9.00 (0.61)	7.60 (0.42)	6.81 (0.39)	6.51 (0.62)	0.004	-2.49 (0.88)	-28 %	8.17 (0.58)	7.56 (0.49)	7.45 (0.41)	6.78 (0.62)	0.105	-1.38 (0.85)	-17 %
Animal fats (g/day)	12.65 (0.78)	13.3 (0.90)	14.6 (1.17)	11.8 (0.77)	0.461	-0.81 (1.09)	-7%	12.5 (0.75)	12.8 (0.93)	14.9 (1.09)	12.1 (0.83)	0.695	-0.44 (1.12)	-3%
Sweetened beverages (g/day)	87.3 (6.75)	99.5 (9.71)	126 (9.47)	212 (19.4)	<0.001	125 (20.6)	143 %	83.4 (6.41)	99.9 (9.17)	136 (9.91)	205 (19.7)	<0.001	122 (20.8)	146 %
Artificially sweetened beverages (g/day)	12.9 (3.95)	3.42 (1.14)	12.7 (2.86)	10.3 (3.79)	0.630	-2.63 (5.48)	-20 %	12.4 (3.95)	3.37 (1.04)	11.8 (2.77)	11.3 (3.82)	0.840	-1.11 (5.49)	-9%
Fruit and vegetables juices (g/day)	67.1 (5.37)	74.9 (6.78)	74.9 (8.27)	54.1 (6.09)	0.111	-13.0 (8.15)	-19 %	73.3 (5.67)	75.1 (6.43)	75.4 (8.66)	47.4 (5.59)	0.001	-25.9 (7.99)	-35 %
Water (g/day)	802 (30.7)	777 (42.4)	690 (26.4)	681 (32.2)	0.007	-121 (44.9)	-15 %	821 (32.5)	771 (41.7)	698 (27.7)	664 (30.8)	0.001	-157 (45.0)	-19 %

Abbreviations: NS-NPM DI: Nutri-Score nutrient profiling model dietary index.

Data were expressed as mean (SE) across quartiles.

Deltas expressed as mean difference (SE).

All values were adjusted for total energy intake using the residual method except for energy intake (kcal/day).

Table 4
Nutrient intake assessment across quartiles of NS-NPM DI (2023 and 2015 versions) in children and adolescents of the ESTEBAN study (n = 1,279).

	Quartiles of 2023 NS-NPM DI <i>New version</i>							Quartiles of 2015 NS-NPM DI <i>Old version</i>						
	Q1 (Highest nutritional quality)	Q2	Q3	Q4 (Lowest nutritional quality)	p-value (Linear contrast)	Δ_{Q4-Q1}	Relative difference (%)	Q1 (Highest nutritional quality)	Q2	Q3	Q4 (Lowest nutritional quality)	p-value (Linear contrast)	Δ_{Q4-Q1}	Relative difference (%)
Nutrients; mean (SE)														
Energy intake (kcal/day)	1675 (29.8)	1913 (40.8)	1855 (34.8)	2051 (47.8)	<0.001	376 (55.9)	22 %	1697 (32.4)	1875 (40.9)	1859 (35.4)	2062 (46.3)	<0.001	365 (56.1)	22 %
Age-adjusted energy intake (kcal/day)	1658 (31.5)	1904 (38.8)	1858 (35.0)	2049 (46.1)	<0.001	391 (55.4)	24 %	1673 (33.4)	1877 (38.7)	1856 (35.9)	2062 (44.3)	<0.001	389 (55.1)	23 %
Proteins %	17.8 (0.26)	16.4 (0.22)	15.3 (0.16)	14.3 (0.20)	<0.001	-3.51 (0.33)	-20 %	17.7 (0.26)	16.4 (0.21)	15.2 (0.18)	14.4 (0.21)	<0.001	-3.27 (0.33)	-19 %
Carbohydrates %	45.4 (0.45)	45.8 (0.40)	44.8 (0.42)	44.7 (0.47)	0.247	-0.75 (0.65)	-2%	46.3 (0.43)	45.7 (0.42)	44.9 (0.41)	43.8 (0.46)	<0.001	-2.49 (0.64)	-5%
Lipids %	36.4 (0.39)	37.5 (0.31)	39.5 (0.35)	40.8 (0.42)	<0.001	4.42 (0.57)	12 %	35.5 (0.35)	37.6 (0.33)	39.4 (0.31)	41.5 (0.42)	<0.001	5.93 (0.54)	17 %
SFA (g/day)	30.3 (0.38)	33.0 (0.47)	35.6 (0.42)	37.2 (0.48)	<0.001	6.84 (0.62)	23 %	29.8 (0.37)	32.8 (0.42)	35.5 (0.41)	37.9 (0.51)	<0.001	8.16 (0.63)	27 %
MUFA (g/day)	27.7 (0.41)	28.5 (0.34)	29.7 (0.36)	30.9 (0.49)	<0.001	3.21 (0.63)	12 %	27.1 (0.39)	28.7 (0.37)	29.7 (0.33)	31.4 (0.48)	<0.001	4.26 (0.62)	16 %
PUFA (g/day)	11.6 (0.33)	10.8 (0.22)	11.1 (0.30)	11.0 (0.28)	0.136	-0.64 (0.43)	-5%	11.2 (0.28)	11.1 (0.28)	11.1 (0.22)	11.2 (0.33)	0.991	0.01 (0.44)	0 %
Simple sugars (g/day)	102 (1.86)	107 (1.99)	108 (1.72)	111 (1.91)	<0.001	9.34 (2.66)	9 %	103 (1.96)	105 (1.76)	109 (1.87)	109 (1.94)	0.026	6.15 (2.75)	6 %
Added sugars (g/day)	47.1 (1.15)	55.7 (1.49)	62.0 (1.31)	74.2 (1.81)	<0.001	27.1 (2.15)	58 %	47.2 (1.15)	56.1 (1.52)	61.7 (1.29)	73.9 (1.81)	<0.001	26.6 (2.15)	57 %
Fibers (g/day)	16.3 (0.31)	15.1 (0.25)	14.0 (0.23)	12.7 (0.23)	<0.001	-3.31 (0.39)	-22 %	16.6 (0.30)	14.9 (0.24)	14.1 (0.24)	12.5 (0.22)	<0.001	-4.08 (0.38)	-25 %
Vitamins and minerals														
Calcium (mg/day)	952 (18.5)	933 (16.9)	891 (18.6)	812 (19.1)	<0.001	-139 (26.5)	-15 %	972 (20.3)	917 (15.9)	880 (15.8)	819 (19.6)	<0.001	-153 (28.2)	-16 %
Potassium (mg/day)	2802 (33.3)	2598 (28.7)	2407 (25.9)	2131 (29.7)	<0.001	-671 (44.5)	-24 %	2819 (33.2)	2566 (27.8)	2431 (25.5)	2129 (30.1)	<0.001	-690 (44.9)	-24 %
Magnesium (mg/day)	277 (3.19)	258 (2.40)	242 (2.59)	220 (2.76)	<0.001	-57.2 (4.23)	-21 %	277 (3.08)	257 (2.56)	245 (2.46)	218 (2.71)	<0.001	-59.5 (4.10)	-21 %
Phosphorus (mg/day)	1280 (13.8)	1219 (12.9)	1137 (11.8)	1072 (15.5)	<0.001	-208 (20.8)	-16 %	1279 (14.3)	1215 (12.3)	1134 (11.1)	1082 (15.9)	<0.001	-197 (21.5)	-15 %
Sodium (mg/day)	2664 (38.1)	2584 (42.1)	2552 (42.5)	2645 (52.9)	0.772	-18.9 (65.2)	-1%	2705 (39.3)	2591 (38.8)	2572 (45.0)	2579 (51.9)	0.054	-125 (65.1)	-5%
Iron (mg/day)	11.6 (0.23)	11.4 (0.19)	10.7 (0.17)	10.6 (0.36)	0.027	-0.95 (0.43)	-9%	11.6 (0.20)	11.3 (0.23)	10.9 (0.18)	10.6 (0.35)	0.017	-0.97 (0.41)	-9%
Zinc (mg/day)	10.8 (0.19)	10.2 (0.17)	9.45 (0.14)	8.95 (0.15)	<0.001	-1.82 (0.24)	-17 %	10.7 (0.19)	10.1 (0.17)	9.48 (0.15)	9.08 (0.16)	<0.001	-1.64 (0.25)	-15 %
Retinol (µg/day)	338 (11.6)	368 (16.9)	408 (16.9)	387 (16.6)	0.015	49.5 (20.3)	14 %	346 (18.2)	356 (10.5)	398 (15.6)	399 (17.1)	0.032	53.8 (25.0)	15 %
Vitamin B1 (mg/day)	1.22 (0.02)	1.23 (0.03)	1.11 (0.02)	1.11 (0.02)	0.001	-0.11 (0.03)	-9%	1.24 (0.03)	1.19 (0.03)	1.13 (0.02)	1.09 (0.02)	<0.001	-0.14 (0.03)	-12 %
Vitamin B2 (mg/day)	1.73 (0.03)	1.72 (0.03)	1.54 (0.03)	1.36 (0.02)	<0.001	-0.37 (0.04)	-21 %	1.75 (0.03)	1.67 (0.03)	1.55 (0.03)	1.38 (0.02)	<0.001	-0.37 (0.04)	-21 %
Vitamin B9 (µg/day)	268 (5.59)	269 (6.10)	240 (4.21)	211 (4.07)	<0.001	-56.4 (6.95)	-21 %	272 (5.63)	259 (5.32)	247 (5.57)	210 (4.00)	<0.001	-62.2 (6.94)	-23 %

(continued on next page)

Table 4 (continued)

	Quartiles of 2023 NS-NPM DI					Quartiles of 2015 NS-NPM DI								
	New version					Old version								
	Q1 (Highest nutritional quality)	Q2	Q3	Q4 (Lowest nutritional quality)	p-value (Linear contrast)	Δ_{0+Q1}	Relative difference (%)	Q1 (Highest nutritional quality)	Q2	Q3	Q4 (Lowest nutritional quality)	p-value (Linear contrast)	Δ_{0+Q1}	Relative difference (%)
Vitamin B12 (µg/day)	4.55 (0.15)	3.89 (0.15)	3.89 (0.15)	3.44 (0.11)	<0.001	-1.11 (0.19)	-24 %	4.44 (0.15)	3.95 (0.12)	3.82 (0.14)	3.55 (0.12)	<0.001	-0.89 (0.19)	-20 %
β-Carotene (µg/day)	2445 (134)	1973 (89.8)	1855 (104)	1487 (97.7)	<0.001	-958 (167)	-39 %	2388 (116)	1964 (112)	1963 (107)	1456 (97.9)	<0.001	-932 (152)	-39 %
Vitamin C (mg/day)	99.0 (3.89)	97.4 (3.88)	94.1 (4.55)	75.8 (4.14)	<0.001	-23.3 (5.67)	-23 %	100 (4.09)	96.0 (3.51)	99.1 (4.84)	71.6 (3.82)	<0.001	-28.5 (5.58)	-28 %
Vitamin D (µg/day)	2.32 (0.17)	1.70 (0.07)	1.95 (0.09)	1.13 (0.11)	0.004	-0.59 (0.20)	-51 %	2.16 (0.15)	1.87 (0.11)	1.84 (0.07)	1.83 (0.12)	0.089	-0.33 (0.19)	-15 %
Vitamin E (mg/day)	11.9 (0.37)	10.9 (0.25)	11.0 (0.36)	10.6 (0.29)	0.005	-1.35 (0.48)	-11 %	11.5 (0.33)	11.1 (0.32)	11.1 (0.25)	10.8 (0.38)	0.145	0.74 (0.50)	-6 %

Abbreviations: NS-NPM DI: Nutri-Score nutrient profiling model dietary index; SFA: saturated fatty acids; MUFA monounsaturated fatty acids; PUFA: polyunsaturated fatty acids. Data were expressed as mean (SE) across quartiles. Deltas expressed as mean difference (SE). All values were adjusted for total energy intake using the residual method except for energy intake (kcal/day).

conducted by Lee et al., with 13,495 adult participants, it was reported that the NS-NPM DI based on 2015 Nutri-Score algorithm, showed better capacity to discriminate diet quality than the Dietary Approach to Stop Hypertension (DASH) dietary index, showing a moderate alignment with the dietary index scoring system based on Canada’s Food Guide (Lee et al., 2023). In addition, Paper et al., assessed the cross-sectional association between dietary indexes that underpin 3 front-of-pack labels: the Nutri-Score, the proposed Canadian ‘High In’ Symbol and the Diabetes Canada Clinical Practice Guidelines in 1,836 adults from the ESTEBAN study and found that the dietary index underpinning the Nutri-Score algorithm discriminated adequately individuals according to the nutritional quality of their diets through food consumption and nutrient intakes (Paper et al., 2023). These results reinforce our findings and show the consistency of the algorithm to be applied in populations of different life stages.

Some of the observed results in our study can be linked to the elements taken into account in the Nutri-Score algorithm and its ability to assess the overall nutritional quality of foods and beverages (Julia & Herberg, 2017). The NS-NPM, takes into account various nutrients and food components, assigning scores that reflect the overall nutritional of a product. Since energy, saturated fat, simple sugars, salt, fibers, and proteins are factored into the computation of Nutri-Score (Herberg et al., 2021), it is anticipated that a discrimination would be observed at the individual level. In addition, while vitamins and minerals are linked to the presence of proteins, fruits, and vegetables (elements considered in the score calculation), they are not explicitly included in the algorithm, which strengthens the discriminatory ability of the NS-NPM to characterize the overall nutritional quality beyond the elements taken directly into consideration in the NS-NPM algorithm.

Furthermore, both DIs showed an adequate ability to discriminate the intake of added sugars. While the two algorithms (2015 and 2023 NS-NPM) only take into account total sugars, the results showed that the classification is consistent and that the main type of sugar discriminated is indeed added sugars not the sugars naturally present in fruit or dairy products, which is of importance for public health purposes for addressing obesity, particularly in children who have a high intake of added/free sugars.

Overall, the distribution of the various food groups within the updated Nutri-Score was aligned with the previous one. The recent update has resulted in improved ratings for certain food groups, specifically tubers, fish and seafood, vegetable oils, poultry, red meat and processed meat. These enhancements can be attributed to the adjustment in the maximum points allocated for protein and fiber content and for nuts and vegetable oils. This adjustment helps offset the higher caloric density of these foods, which are rich in essential micronutrients, such as vitamin D in fish. Additionally, the modifications in the attribution of protein points in the updated algorithm improved the initial classification and ensured a good discrimination between red meat (including processed meat) and poultry. Consequently, while poultry received relatively favorable ratings in both versions of the Nutri-Score algorithm, unprocessed meat classification – except for very lean cuts – was shifted towards less favorable ratings in the updated version. These modifications may explain the higher discrimination in the consumption of poultry and red meat in the 2023 NS-NPM DI compared to the 2015 NS-NPM DI.

The 2023 NS-NPM modified the overall classification for breakfast cereals, with a shift towards less favorable rating. This shift tended to group these products within similar ratings and somewhat reduced the algorithms discriminant capacity within this specific food group, which may explain the relatively lower discriminatory capacity of the 2023 NS-NPM DI in this group compared to the 2015 version. Furthermore, in our analysis, when using the 2015 NS-NPM DI, we observed an unexpected direction in bread and breakfast cereals consumption among participants. We found that participants in quartile 4 consumed less bread/breakfast cereals compared to those in quartile 1 (better nutritional quality). Typically, we might expect higher consumption in quartile 4, as

those products tend to have lower nutritional quality overall (high sugar content and/or low fiber content) However, it is important to note that while the relative difference in bread consumption between the quartiles was statistically significant for the 2015 NS-NPM, it was no longer the case for the 2023 NS-NPM. Although bread and breakfast cereals consumption trends between the highest and lowest quartiles did not align with initial expectations for the 2015 NS-NPM, the lack of statistical significance in the 2023 NS-NPM DI suggests an enhancement in the reliability and validity of the updated dietary index.

Our study has some limitations that need to be discussed. Firstly, it is important to approach the generalization of the present findings with caution, as the participants in this study were primarily healthy children and adolescents from mainland France. Another limitation is inherent to the use of 24-hour records, which may bias the estimation of the intake of nutrient intakes, which in turn is crucial for the correct estimation of the NS-NPM DI. The use of three 24-hour dietary recalls offers a robust estimate of average intake, however, it may not fully account for day-to-day variability in food and beverage consumption. However, while food frequency questionnaires would likely provide a more accurate reflection of typical dietary patterns and corresponding Nutri-Score values, they may not entirely capture the variability in food choices within specific food groups considering the somewhat limited number of food items available. Nevertheless, we employed high-quality dietary data, incorporating repeated 24-hour records obtained through a validated web-based tool (Ma et al., 2009) for better precision. Thirdly, NS-NPM DI should not be interpreted as a direct indicator of individual health. Instead, it serves as a proxy for the nutritional quality of food intake. While a lower Nutri-Score is associated with healthier food choices at the population level and it is a useful tool to understand the nutritional profile of diets holistically, drawing definitive conclusions about an individual's health status or whether their diet is "healthier" would require additional studies involving long-term follow-up of health status.

The main strengths of our study notably include the utilization of a large representative sample size of the French population. In addition, to the best of our knowledge, this is the first study that assessed the discriminatory power of the 2023 NS-NPM DI at the individuals level in children and adolescents. Moreover, the translation of nutrient profiles from the food level to individual dietary indices enabled us to consider the complexity of the entire diet. This approach facilitates a more comprehensive evaluation of dietary quality, considering the interactive or synergistic effects that individual dietary nutrients may exert within the context of the food matrix (Jacobs et al., 2009).

5. Conclusion

In conclusion, the results of the present study suggest that the Nutri-Score algorithm accurately discriminates diet quality, reinforcing the utility of this nutritional front-of-pack nutrition label as a useful tool for promoting healthier dietary choices in children and adolescents. Furthermore, the 2023 NS-NPM DI exhibited greater discriminatory power in assessing tubers, fish and seafood, poultry, red meat, processed meat, vegetable oils, vitamin E and vitamin D compared to the previous version. Understanding how the algorithm performs in children helps to ensure that nutritional guidance tools are appropriate for shaping healthier dietary habits early in life, which may have lasting effects. This enhancement indicates that this revision represents a valuable improvement for public health purposes.

CRedit authorship contribution statement

Nadine Khoury: Writing – original draft, Formal analysis. **Barthélémy Sarda:** Writing – review & editing, Supervision, Formal analysis. **Mathilde Touvier:** Writing – review & editing, Supervision. **Emmanuelle Kesse-Guyot:** Writing – review & editing, Formal analysis. **Jordi Salas-Salvadó:** Writing – review & editing. **Nancy Babio:**

Writing – review & editing. **María Ángeles Martínez:** Writing – review & editing. **Serge Hercberg:** Writing – review & editing. **Pilar Galan:** Writing – review & editing. **Pauline Ducrot:** Writing – review & editing, Project administration, Formal analysis. **Valérie Deschamps:** Writing – review & editing, Methodology, Conceptualization. **Chantal Julia:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Prof Salas-Salvadó reported being a nonpaid member of the scientific boards of the International Nut and Dried Fruit Foundation, Danone Institute International, and Fundación Eroski; receiving institutional grants from the International Nut and Dried Fruit Foundation; and receiving personal fees from Danone Institute Spain.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodres.2024.115287>.

Data availability

The authors do not have permission to share data.

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