



A new measure of health motivation influencing food choices and its association with food intakes and nutritional biomarkers in European adolescents

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Abstract

Objective: To develop a scale to assess health motivation influencing food choices and to explore its performance in the associations with food intakes and nutritional biomarkers.

Design: Psychometric study using cross-sectional self-report questionnaires and nutritional biomarkers.

Setting: Multi-centre investigation conducted in ten European cities.

Participants: 2954 adolescents who were included in the HELENA study and completed the Food Choices and Preferences (FCP) questionnaire.

Results: Nineteen out of 124 items of the FCP questionnaire were in the same dimension. Sixteen presented adequate parameters for the Scale of evaluation of Food choices (SOFIE). The scores were positively associated with the intakes of cereals, dairy products, meats and eggs, and fish, as well as with blood concentrations of vitamin C, β -carotene, *n*-3 fatty acids, cobalamin, holo-transcobalamin and folate; scores were negatively associated with the intake of alcohol.

Conclusions: SOFIE can improve the assessment of motivation influencing food choices based on items with the best performance and is proposed as a new measure to health-related studies.

Keywords
Health
Food
Choice behaviour
Psychometrics
Biomarkers

Worldwide, epidemiological studies have shown a high prevalence of overweight and unhealthy lifestyles among children and adolescents^(1,2). The food environment plays

an important role in this context, with an impact on young people's health⁽³⁾.

While a dietary assessment investigates food and nutrient intakes, a study of food choices confines to the selection of foods and does not reach what foods are eaten⁽⁴⁾. Furthermore, the assessment of food choices has

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to consider the different factors motivating the selection of one food over another, such as taste, familiarity and/or health⁽⁵⁾.

In order to investigate the food choices of adolescents motivated by health, researchers from the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study developed the Food Choices and Preferences (FCP) questionnaire based on focus group discussions with European adolescents concerning their insights about healthy eating and lifestyle, food choices and preferences^(6,7). This questionnaire has been analysed based on a classic approach that takes into account the percentage of answers; however, this analysis focused on specific topics of the FCP⁽⁸⁾. In this regard, there is a need to obtain a more detailed information about health motivation influencing food choices.

The Item Response Theory (IRT) analysis has been suggested as an approach to measure attitudes and abilities complementing the classical analysis underlying the percentage of responses. The IRT analysis provides a discrimination of the latent trace for each item of the questionnaire and considers the proximity between individuals and items to calculate the scores^(9–11). However, the use of IRT analysis is relatively recent in the evaluation of food attitudes^(12,13), especially when considering the proximity factor between individuals and the studied items.

For these reasons, we aimed (i) to develop a scale to assess health motivation influencing food choices using a generalised graded unfolding model (GGUM) of the IRT; and (ii) to explore the performance of the scale in association with food intakes and nutritional biomarkers. In order to assess these objectives, the motivation influencing food choices was considered a latent trace in the current analysis.

Methods

Study design and subjects

The HELENA study is a cross-sectional, multi-centre investigation in ten European cities of more than 100 000 inhabitants: Vienna (Austria), Gent (Belgium), Lille (France), Dortmund (Germany), Athens and Heraklion (Greece), Pécs (Hungary), Rome (Italy), Zaragoza (Spain) and Stockholm (Sweden)⁽¹⁴⁾. It was carried out on a random cluster sample of 3528 European adolescents aged 12.5–17.5 years, stratified for geographical location, age and socioeconomic status. Overall, ten schools and 15–20 classes (350–400 students) were selected from each centre of investigation. At the selected schools, the eligibility of each class was based on the percentage of students who agreed to participate in the HELENA study, equal to at least 70%. From the total sample, it was decided to obtain blood samples from a random selected group of one-third of adolescents (*n* 1089).

Exclusions from the study were carried out *a posteriori* when the adolescents presented simultaneous participation

in another clinical trial; age <12.5 or ≥17.5 years; and/or acute infection within 1 week before inclusion. Those adolescents who completed the FCP questionnaire were included (*n* 2954) for factor analysis. To estimate the IRT parameters, a random sample of 2000 adolescents was selected in accordance to the maximum number of respondents for analyses using the GGUM 2004 software. No differences were observed between those who participated in the current analyses and those who did not, except for their age; adolescents who were included in the current analyses are older than the whole sample (online Supplementary Table S1).

The IRT scores could only be estimated for 2000 adolescents. For the mixed model linear regression analyses, adolescents had to provide complete information on IRT scores, dietary intake, biomarkers and corresponding confounding factors. Adolescents who had information on dietary intake (*n* 1945) were included to investigate associations between food intakes and IRT scores. Those who had information on blood testing (*n* 641) were included to investigate associations between biomarkers and IRT scores. These analyses were also processed excluding under-reporting of energy intake. When evaluating energy under-reporting, we considered the Black⁽¹⁵⁾ approach using the Goldberg *et al.*⁽¹⁶⁾ cut-off points. A total of 311 adolescents under-reported energy intake.

Food choices assessment

Food choices were evaluated using the FCP questionnaire (online Supplemental Figure 1) that investigated adolescent attitudes and opinions about food choices, preferences, healthy eating and lifestyle^(6,17). Adolescents answered the questionnaire while in the classroom.

The FCP questionnaire presented 166 questions with different response models, but 161 of them required selecting only one answer. When performing IRT analysis, and due to the hedonic nature of the scale, only questions with one possible answer can be included. Those questions with more than one possible answer and those with a non-hedonic scale were excluded (*n* 42), with 124 questions remaining in the present analyses. In the FCP questionnaire, the questions were displayed in three sections⁽⁶⁾. From these sections, the following subsections presented the criteria to be included in the present study:

- (1) Opinions about food choices, preferences, diet and health, with subsection 1.1 'Opinions about food choices, preferences and healthy eating' (seven-point hedonic scale);
- (2) Choices and preferences of snack foods and drinks, with subsections 2.1 'How much the adolescent liked each food and drink from a popular list of snack foods and drinks' (five-point hedonic scale); and 2.2 'How healthy the adolescent perceived each of those foods and drinks to be' (five-point hedonic scale);



- (3) Important influences on food choices and preferences, with subsection 3.1 'Important influences on food choices at breakfast, main meal and snacks' (five-point hedonic scale).

Sociodemographic characteristics

Socioeconomic status was evaluated with a self-reported questionnaire that collected data on living conditions, family structure, employment status and parental occupation, and educational level⁽¹⁸⁾. The Family Affluence Scale index was calculated based on this questionnaire and used as an indicator of adolescents' material affluence. The final score ranged from 0 to 8 and was dichotomised into 'low familial wealth' (0–4) and 'high familial wealth' (5–8). Maternal education levels were categorised in 'primary education', 'lower secondary education', 'higher secondary education' and 'university degree'⁽¹⁹⁾.

Dietary assessment

Dietary intake was assessed via two non-consecutive computerised 24-h recalls, including weekdays and Sundays, and using the HELENA-Dietary Intake Assessment Tool (HELENA-DIAT). The second 24-h recall was administered 2 weeks after the first⁽²⁰⁾. Both 24-h recalls were completed at the school setting, and trained nutritionists assisted the students when required. Adolescents autonomously selected all the consumed foods and beverages from a food list that included six 'meal occasions'. Some questions were presented to respondents to help them remember what they ate the day before⁽²¹⁾.

In order to remove the effect of day-to-day variability and random error in 24-h recalls, the individual's usual food intake was estimated by the multiple source method⁽²²⁾. This analysis takes into consideration information from the food frequency questionnaire (FFQ) as a covariate of the two 24-h dietary recalls. This FFQ was designed by the Healthy Behaviour in School-aged Children study⁽²³⁾ and includes fifteen items and seven response categories ranging from 'never' to 'more than once a day, every day'⁽²⁰⁾.

Food and beverage consumption was expressed as g/d and ml/d, respectively. Fifteen food groups were computed according to similarity in nutritional content and health-related characteristics: (i) vegetables (excluding potatoes); (ii) fruits; (iii) vegetables (excluding potatoes) and fruits; (iv) sweets (including carbonated/soft/isotonic drinks, cakes, biscuits, chocolate and other sugar products); (v) cereals; (vi) nuts and seeds; (vii) vegetable oils; (viii) olives and avocado; (ix) alcohol; (x) dairy products (including milk and yogurt); (xi) pulses; (xii) water; (xiii) meats and eggs; (xiv) fish; and (xv) savoury snacks.

Body composition

Weight was measured using of an electronic scale (model SECA 861; precision 0.1 kg). Height was measured, with

participants barefoot in the Frankfort plane, using a telescopic height-measuring instrument (model SECA 225; precision 0.1 cm; range 70–200 cm). All measurements were taken by trained staff⁽²⁴⁾.

Body mass index (BMI) was calculated as weight (in kilograms) divided by the square of height (in meters). The values of BMI were categorised into 'thinness', 'normal weight', 'overweight' and 'obesity' using the BMI cut-offs defined by Cole *et al.*^(25,26).

Analysis of blood biomarkers

Blood collection was performed after 10 h of overnight fast following a standardised protocol. A handling and transport system was developed to guarantee quality assurance and stability of fresh blood samples⁽²⁷⁾.

Folate (plasma and erythrocyte) and cobalamin were measured by competitive immunoassay (Immunolite 2000; DPC Biermann GmbH). β -Carotene and vitamin C were analysed by HPLC (Sykam) via UV detection (UV-Vis 205; Merck Darmstadt). *n*-3 and trans-fatty acids concentrations were determined using capillary GC (Model 3900) after extraction by TLC. Holo-transcobalamin was measured by micro-particle enzyme immunoassay (Active B₁₂; Axis-Shield Limited) using an AxSym analyser (Abbott Diagnostics, Abbott Park)^(20,27).

Data analysis

The dimensionality of the FCP questionnaire was analysed by factor analysis using principal components analysis with varimax orthogonal rotation. Items that presented unidimensionality were maintained for further analyses. Conformability was based on the Kaiser–Meyer–Olkin (KMO) test (>0.50), Bartlett test ($P < 0.05$)⁽²⁸⁾, and communality of items derived from the two retained factors. One item was excluded when communality was <0.30 , indicating that these two retained factors represented $<30\%$ of its variation^(11,29). Factor analysis was repeated only with items with adequate communality and factor loadings >0.40 . In addition, the first factor had to explain $\geq 20\%$ of the total variance⁽³⁰⁾.

To perform IRT analysis with the estimation of IRT parameters, GGUM was used. This model allows measures of proximity of the individual to the item and can be represented by a single-peaked response function indicating that agreement will be higher when the proximity of the individual to the item is lower^(11,29). Regarding health motivation influencing food choices, both an individual with low motivation and another one with high motivation would present a high disagreement with the studied item. For example, for the item 'What is your opinion about: you feel well informed about what are healthy foods?' that presents seven possible responses (from 'strongly disagree' to 'strongly agree'), both individuals may think that they are not informed enough about healthy foods; therefore, the

distance between the item and the individual will be large in both cases.

GGUM is represented by the following equation:

$$P(Z_i = z|\theta_j) = \frac{\exp\left[\alpha_i\left(z(\theta_j - \delta_i) - \sum_{k=0}^z \tau_{ik}\right)\right] + \exp\left[\alpha_i(M - z)(\theta_j - \delta_i) - \sum_{k=0}^z \tau_{ik}\right]}{\sum_{v=0}^M \left[\exp\left[\alpha_i\left(v(\theta_j - \delta_i) - \sum_{k=0}^v \tau_{ik}\right)\right] + \exp\left[\alpha_i\left((M - v)(\theta_j - \delta_i) - \sum_{k=0}^v \tau_{ik}\right)\right] \right]}$$

where

Z_i = an observable response to item i ;

$z = 0, 1, 2, \dots, C$, where $z = 0$ corresponds to the strongest level of disagreement;

θ_j = the location of individual n on the continuum of motivation influencing food choices;

α_i = discrimination parameter of item i ;

δ_i = the location of item i on the continuum of motivation influencing food choices;

τ_{ik} = the relative location of the subjective response category threshold k on the continuum relative to a given item i ;

M = the number of subjective response categories minus 1.

Y_i = a subjective response to item i ;

$y = 0, 1, 2, 3, \dots, M$, where $y = 0$ corresponds to the strongest level of disagreement from below the item, whereas $y = M$ corresponds to the strongest level of disagreement from above the item.

α_i indicates the variation of a subjective response category between the items while the score changes along the continuum. Items with higher values for this parameter present a lower probability of change across categories when variation of the score is low. δ_i is estimated in the same scale of the parameter of location of an individual (θ_j), and it indicates if someone is located below or above the location of an item. τ_{ik} indicates the range of subjective responses for each item. Individual scores were obtained using a Bayesian estimation method: the Expected a Posteriori (EAP) with *a priori* distribution⁽¹⁰⁾.

All IRT parameters (α_i , δ_i and τ_{ik}) were estimated by marginal maximum likelihood with $N(0, 1)$ *a priori* distribution with mean = 0 and SE = 1. The estimates were analysed with the corresponding standard error. Items with a high δ_i standard error and with overlapping of the item characteristic curve were re-categorised. Items that remained with high δ_i standard errors after the re-categorisation and with low values for α_i were excluded for further analyses.

Fifty quadrature points were used equally spaced between -4 and $+4$ with P value < 0.001 for convergence. For each pair of θ_j and δ_i , a signed difference was calculated, and this difference was divided into homogenous groups of size $n = 100$.

The range of scores from health motivation influencing food choices between which individuals are most likely to agree with the latter category was assessed from the equation $\Delta \pm \tau$ of the last category. Item fit was assessed using unweighted mean squared error (outfit) and weighed

mean squared error (infit). Items that presented these statistics not equal or close to 1 were excluded⁽³¹⁾. Two nutritionists (TSSS and CJ) did the characterisation of each scale level.

Chi-square tests were performed to evaluate differences between demographic, socioeconomic and BMI categories within each scale level. Mixed model linear regression analyses were used to verify associations between food group intakes, nutritional biomarkers and IRT scores (as continuous data). Food group and biomarker variables were included separately in the model, and centre of investigation was included as the random intercept. Age, gender, maternal education, Family Affluence Scale index, BMI and energy intake were entered as covariates in the model.

Analyses were carried out using the statistical software package STATA version 14.0 and GGUM 2004 software^(11,32).

Results

As suggested by factor analysis, items from the three sections of the FCP questionnaire did not present unidimensionality. Nevertheless, some items presented low values of communality and factor loadings. Items referring to the subsection 2.1 (*How much the adolescent liked each food and drink from a popular list of snack foods and drinks*) were excluded from further analyses as they were grouped into a different factor compared with other subsections.

Factor analysis was repeated for subsections 1.1 (*Opinions about food choices, preferences and healthy eating*), 2.2 (*How healthy the adolescents perceived each of those foods and drinks*) and 3.1 (*Important influences on food choices at breakfast, main meal and snacks*). No items from subsections 1.1 and 2.2 presented adequate values of communality and factor loadings. Only some items of subsection 3.1 presented adequate values of communality and factor loadings, suggesting that these items were related to a different latent trace than the items from subsections 1.1 and 2.2.

The aforementioned analyses indicate that the items from subsections 2.1 (*How much the adolescents liked each food and drinks from a popular list of snack foods and drinks*) and 3.1 (*Important influences on food choices at breakfast, main meal and snacks*) measured a latent trace other than health motivation influencing food choices. Factor analysis was repeated for the other two subsections (1.1 and 2.2). On the rotated solution, nineteen items (seven from subsection 1.1 and twelve from subsection 2.2) presented adequate communality and factor loadings and explained 22% of the total variance. The data were suitable for factor analysis considering the KMO test (0.89) and the Bartlett test ($\chi^2 = 20\,058.4$; $df = 171$; $P = 0.000$).

These nineteen items were analysed with GGUM (online Supplemental Table S2). Sixteen of these items

Table 1 Total number of categories, generalised graded unfolding model item parameter estimates, range of scores, outfit and infit for each item from the SOFIE scale (*n* 2000)

Item	N_{cat}	α_i	SE	δ_i	SE	τ_{i2}	τ_{i3}	τ_{i4}	τ_{i5}	Range	Outfit	Infit
How healthy you perceived ...												
Chocolate milk	4*	1.13	0.07	-0.11	0.03	-2.38	-1.16	-0.53	-	-0.64; 0.43	1.11	1.09
Cheese products (e.g. cheddar, brie, cheese strings)	4*	1.18	0.07	-0.03	0.03	-2.48	-1.66	-1.31	-	-1.33; 1.28	1.36	1.27
Sandwiches, toasties and panini	4*	1.13	0.07	-0.02	0.03	-2.21	-1.26	-0.19	-	-0.21; 0.17	1.16	1.12
Cereal bars	4*	1.18	0.08	-0.01	0.03	-2.52	-2.09	-1.24	-	-1.25; 1.23	1.30	1.22
Yoghurt and yoghurt products	5†	1.18	0.07	0.01	0.03	-2.93	-2.43	-1.64	-0.27	-0.27; 0.28	1.19	1.16
Bowl of cereal	4‡	1.40	0.08	0.03	0.03	-1.95	-1.43	-0.16	-	-0.13; 0.19	1.15	1.14
Juices	5†	1.06	0.07	0.04	0.03	-2.74	-2.07	-1.85	-0.61	-0.57; 0.65	1.26	1.22
Bread and toast	4*	1.46	0.09	0.05	0.03	-2.61	-1.81	-0.98	-	-0.93; 1.03	1.30	1.24
Milk	4‡	1.30	0.08	0.08	0.03	-2.43	-2.27	-1.08	-	-1.00; 1.16	1.24	1.24
Tea	3§	0.86	0.07	0.20	0.05	-2.27	-1.89	-	-	-1.69; 2.09	1.18	1.14
Pasta dishes	3§	0.84	0.06	0.25	0.05	-1.67	-1.09	-	-	-0.83; 1.34	1.09	1.07
What is your opinion about ...												
The food you eat at home is healthy	3	2.09	0.14	0.92	0.04	-3.09	-1.14	-	-	-0.23; 2.07	0.84	0.83
Your diet is healthy	3	1.68	0.12	0.96	0.05	-2.92	-0.60	-	-	0.36; 1.57	0.89	0.89
You like the food your parents prepare at home	4¶	0.62	0.05	1.01	0.11	-5.55	-2.03	-0.94	-	-0.06; 1.95	0.96	0.97
You feel well informed about what are health foods	3	0.90	0.07	1.12	0.10	-4.47	-1.09	-	-	0.03; 2.22	0.95	0.95
You enjoy fruit and vegetables	4¶	0.53	0.05	1.75	0.26	-5.94	-3.45	-0.39	-	1.36; 2.15	0.94	0.94

N_{cat} , number of categories; α_i , discrimination parameter of item i ; SE, standard error; δ_i , location of item i on the attitude continuum; τ_{i1} , equal to zero for all items; τ_{i2} , difference between subjective categories from category 2; τ_{i3} , difference between subjective categories from category 3; τ_{i4} , difference between subjective categories from category 4; τ_{i5} , difference between subjective categories from category 5. Range = Delta \pm Tau of the last category.

*Very unhealthy; unhealthy; indifferent; healthy.

†Very unhealthy; unhealthy; indifferent; healthy; very healthy.

‡Unhealthy; indifferent; healthy; very healthy.

§Unhealthy; indifferent; healthy.

||Disagree; indifferent; agree.

¶Disagree; indifferent; slightly agree; moderately agree.

presented adequate IRT parameters and respective standard errors for the final Scale of evaluation of Food choices (SOFIE). The questions are displayed in online Supplemental Figure 2.

The IRT parameters (α_i , δ_i and τ_{ik}), range of scores, and values for outfit and infit of the remaining items are described in Table 1 in δ_i increasing order. The item 'What is your opinion about: the food you eat at home is healthy?' presented the highest value for discrimination parameter ($\alpha_i = 2.09$). Individuals who presented SOFIE scores between -0.23 and 2.07 were more likely to agree on this item. The item 'What is your opinion about: you enjoy fruit and vegetables?' presented the lowest value for discrimination parameter ($\alpha_i = 0.53$) and the highest value for δ_i (1.75). Individuals who presented SOFIE scores between 1.36 and 2.15 were more likely to agree moderately on this item. The characteristic curves for these two items are displayed in Figs 1 and 2, respectively.

The items presented adequate values for outfit (range 0.84–1.30) and infit (range 0.83–1.27). The adequate overall adjustment of the observed average values is shown in Fig. 3.

SOFIE was categorised into three levels, namely low (1), indifferent (2) and high (3). Level (1) includes items about how healthy the adolescents perceived chocolate milk, cheese products, sandwiches/toasts/panini, cereal bars, yoghurt/yoghurt products, bowl of cereal and juices. Level (2) includes items about how healthy the adolescents

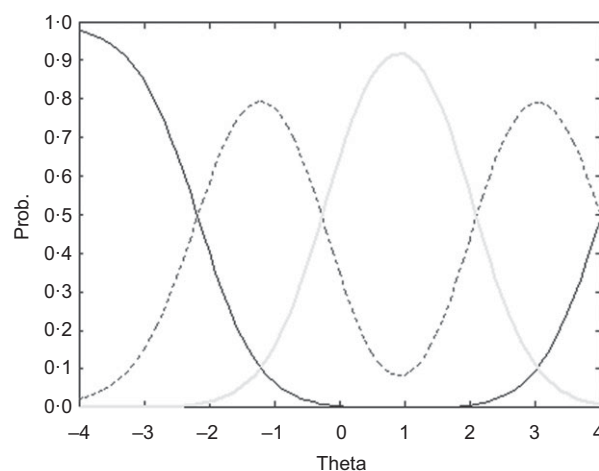


Fig. 1 Item characteristic curve for ('What is your opinion about the food you eat at home is healthy?') with the highest discrimination parameter ($\alpha_i = 2.09$) (*n* 2000). Prob., Probability; Theta, IRT scores; z0 (—), item characteristic curve from category 1; z1 (---), item characteristic curve from category 2; z2 (-.-), item characteristic curve from category 3

perceived bread/toast, milk, tea and pasta dishes. Level (3) includes items about the opinions about feed at home, individual diet, information about healthy foods and food preferences. So, individuals who moderately agreed on item 'What is your opinion about: you enjoy fruit and vegetables?' (those with scores between 1.36 and 2.15) were more

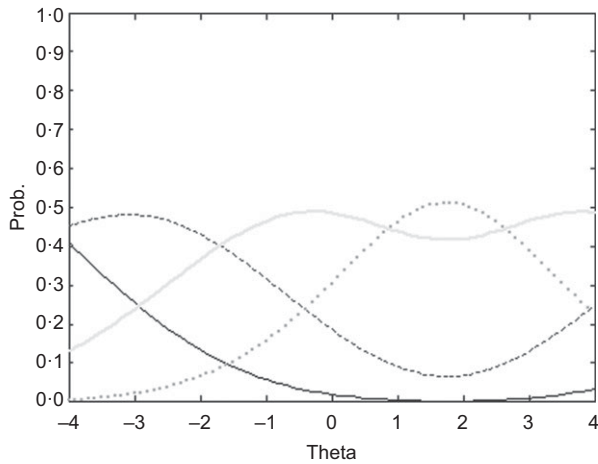


Fig. 2 Item characteristic curve for ('What is your opinion about enjoying fruits and vegetables?') with the lowest discrimination parameter ($\alpha_i=0.53$) and highest parameter of the location of the item ($\delta_i=1.75$) ($n=2000$). Prob., probability; Theta, IRT scores; z0 (—), item characteristic curve from category 1; z1 (---), item characteristic curve from category 2; z2 (— · —), item characteristic curve from category 3; z3 (· · · · ·), item characteristic curve from category 4

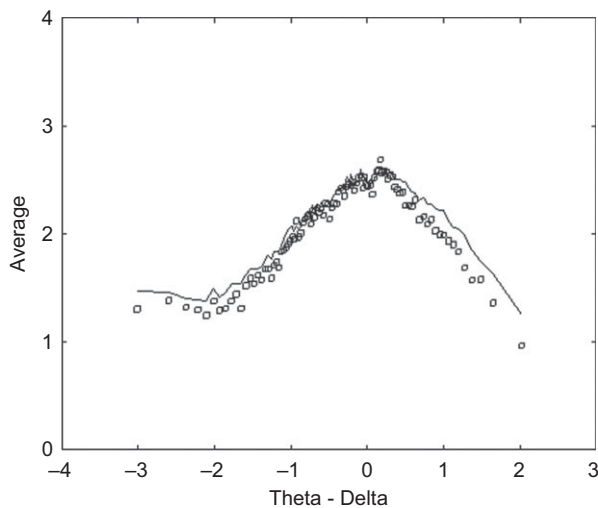


Fig. 3 Average observed *v* expected estimates of food choice scores ($n=2000$). Theta - Delta = IRT scores - parameter of the location of the item

likely to present high health motivation in choosing foods. Individuals who perceived tea as healthy (those with scores between -1.69 and 2.09) were more likely to present indifferent health motivation when choosing foods. SOFIE medium scores are less informative than those in the low and high levels (Fig. 4).

Demographic and socioeconomic characteristics of the participants on the three levels of SOFIE are displayed in Table 2. Girls and adolescents with a high Family Affluence Scale index and mothers with university education presented high health motivation when choosing foods.

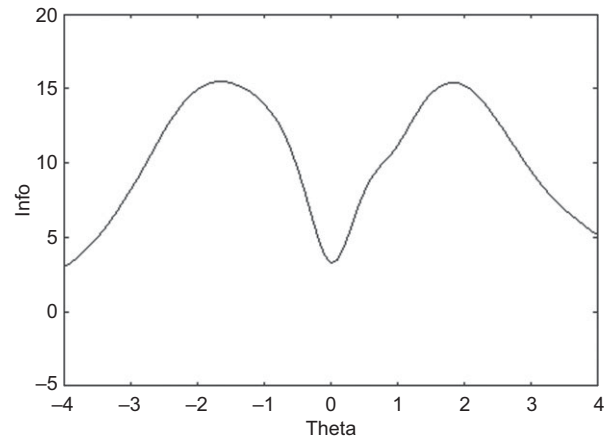


Fig. 4 Test information curve from Scale of Evaluation to Food Choices ($n=2000$)

The results of the mixed model linear regression analyses with food group consumption as the dependent variable are shown in Table 3. SOFIE scores were positively associated with intakes of cereals, dairy products, meats and eggs, and fish, and were negatively associated with intakes of alcohol ($P < 0.05$). These results are similar when under-reporters were excluded from the analyses (online Supplemental Table S3). The only difference observed was that SOFIE scores were also negatively associated with intakes of nuts and seeds and savoury snacks ($P < 0.05$). Comparative analyses indicated that under-reporters had a lower intake of savoury snacks ($P < 0.05$) (data not shown).

The results of mixed model linear regression analyses with biomarkers as the dependent variable are displayed in Table 4. SOFIE scores were positively associated with the concentrations of vitamin C, β -carotene, *n*-3 fatty acids, cobalamin, holo-transcobalamin and folate (plasma and erythrocyte) ($P < 0.05$). These results are similar when the number of cigarettes was included as covariate and when under-reporters were excluded (online Supplemental Table S4).

Discussion

The present study developed a scale to assess health motivation influencing food choices (SOFIE), applying a generalised graded unfolding model of the IRT to the FCP questionnaire, among adolescents. Factor analysis indicated that more than one factor explained the total variance from the subsections analysed. Nineteen items from the subsections about opinions on food choices, preferences and healthy eating (1.1) and how healthy the adolescents perceived each of those foods and drinks (2.2) showed the unidimensionality assumption for GGUM^(11,29,30). Some previously developed questionnaires^(33,34) have evaluated the motivation influencing food choices based on multidimensional approaches. Our results indicate that

Table 2 Demographic and socioeconomic characteristics and BMI according to food choices among European adolescents (*n* 2000)

	<i>N</i>	%	Unhealthy		Indifferent		Healthy		<i>P</i> value
			<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	
			1053	52.7	639	32.0	308	15.4	
Age (years)									
12.5–13.99	602	30.1	315	29.9	188	29.4	99	32.1	0.971‡
14–14.99	517	25.8	263	25.0	181	28.3	73	23.7	
15–15.99	487	24.4	268	25.5	161	25.2	58	18.8	
16–17.49	394	19.7	207	19.7	109	17.1	78	25.3	
Sex									
Male	938	46.9	491	46.6	329	51.5	118	38.3	0.001*†
Female	1062	53.1	562	53.4	310	48.5	190	61.7	
FAS									
Low	834	44.0	476	47.9	256	42.3	102	34.1	<0.001*†
High	1063	56.0	517	52.1	349	57.3	197	65.9	
Maternal education									
Primary	139	7.3	87	8.6	42	6.9	10	3.4	0.001*†
Lower secondary	466	24.4	248	24.6	144	23.6	74	25.2	
Higher secondary	641	33.5	356	35.4	200	32.8	85	28.9	
University degree	665	34.8	316	31.4	224	36.7	125	42.5	
Centre									
Athens	208	10.4	125	11.9	74	11.6	9	2.9	<0.001*†
Dortmund	232	11.6	85	8.1	105	16.4	42	13.6	
Gent	191	9.6	122	11.6	52	8.1	17	5.5	
Heraklion	173	8.6	105	10.0	61	9.5	7	2.3	
Lille	190	9.5	112	10.6	54	8.5	24	7.8	
Pécs	162	8.1	120	11.4	36	5.6	6	1.9	
Rome	218	10.9	108	10.3	74	11.6	36	11.7	
Stockholm	202	10.1	75	7.1	34	5.3	93	30.2	
Vienna	300	15.0	144	13.7	99	15.5	57	18.5	
Zaragoza	124	6.2	57	5.4	50	7.8	17	5.5	
BMI									
Thinness	116	5.8	63	6.0	41	6.4	12	3.9	0.421‡
Normal	1420	71.0	720	68.4	481	75.3	219	71.1	
Overweight	355	17.8	205	19.5	93	14.6	57	18.5	
Obesity	109	5.4	65	6.2	24	3.8	20	6.5	

FAS, Family Affluent Scale; BMI, body mass index.

†Likelihood ratio.

‡Linear-by-linear association.

 **P* < 0.05.

Table 3 Mixed model analyses between food groups' intakes (g/d) and food choice scores among European adolescents adjusted by age, gender, maternal education, Family Affluent Scale and energy intake (*n* 1945)

Food groups' intake	β	95 % CI	<i>P</i> value
Vegetables	-14.45	-63.43, 34.52	0.56
Fruits	68.18	-12.01, 148.36	0.09
Vegetables and fruits	49.71	-41.17, 154.10	0.26
Sweets	-33.55	-289.34, 222.24	0.80
Cereals	100.59	32.79, 168.39	0.004*
Nuts and seeds	-5.53	-12.48, 1.43	0.12
Vegetable oils	2.90	-4.31, 10.12	0.43
Olives and avocado	-5.67	-11.27, -0.06	0.47
Alcohol	-104.94	-188.07, -21.81	0.01*
Dairy products	439.74	268.51, 610.96	<0.001*
Pulses	21.42	-0.18, 43.01	0.05
Water	54.66	-412.03, 521.35	0.82
Meats and eggs	111.75	48.92, 174.59	0.001*
Fish	44.79	25.40, 64.17	<0.001*
Savoury snacks	-9.72	-22.74, 3.29	0.14

EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

 **P* < 0.05. Centre used as the random intercept.

SOFIE covers one dimension of the continuum in the evaluation of health motivation for choosing foods.

Regarding the IRT analyses, the accuracy of the estimates of item parameters depends on the responses to each category⁽³⁵⁾. For these reasons, two items were excluded, because they presented a low frequency of response to the 'disagree' category and, therefore, higher standard errors: 'What is your opinion about: what you eat now will have a big impact on your future health?' and 'What is your opinion about: if there is the option to choose a whole grain version of a food, you will choose it?' The item 'How healthy you perceived water?' was excluded because it had a high frequency of response on the 'unhealthy' category and, therefore, it was not possible to apply re-categorisation of item responses. Sixteen items assessed health motivation influencing food choices accurately. Moreover, SOFIE does not present extreme values for the parameter of location of the item (δ_i), varying

Table 4 Mixed model analyses between biomarkers and food choice scores among European adolescents adjusted by age, gender, maternal education, Family Affluent Scale, BMI and energy intake (*n* 641)

Biomarkers	β	95% CI	<i>P</i> value
Vitamin C (mg/l)	11.34	6.17, 16.51	<0.001*
β -Carotene (ng/ml)	447.42	155.61, 739.22	0.003*
EPA + DHA (%)	4.54	2.43, 6.66	<0.001*
EPA + DHA (μ mol/l)	96.27	12.26, 180.28	0.025*
Holo-transcobalamin (pmol/l)	64.65	18.47, 110.83	0.006*
Cobalamin (pmol/l)	516.39	308.11, 724.68	<0.000*
Plasma folate (nmol/l)	42.50	26.71, 58.30	<0.001*
Erythrocyte folate (nmol/l)	1266.53	730.45, 1802.60	<0.001*
Trans-fatty acids (μ mol/l)	0.75	-0.42, 1.93	0.208

**P* < 0.05. Centre used as the random intercept.

from -0.11 to 1.75. No extreme values of τ_{ik} and δ_i can confirm the accuracy of the estimates⁽¹¹⁾.

The item 'What is your opinion about: you enjoy fruit and vegetables?' presented the lowest discrimination parameter (α_i) and the largest location (δ_i). However, this item remained in SOFIE because of its importance for evaluating health motivation influencing food choices in this specific population. Lowest discrimination (α_i) and largest location (δ_i) of this item indicate the difficulty to evaluate the food practices related to fruit and vegetable intakes. Some adolescents may think they have an adequate consumption of healthy foods⁽³⁶⁾ even if they are not reaching the corresponding dietary recommendation stated in g/d and daily number of servings⁽³⁷⁾. Another possibility is that adolescents' answers are influenced by social desirable responses⁽³⁸⁾. Furthermore, the current study failed to find an association between fruit and vegetable intakes and SOFIE scores (*P* > 0.05), confirming the difficulty in evaluating the food practices related to these intakes. A recent study indicated that adolescents have a greater motivation to choose unhealthy snacks even when they have eaten healthy foods or when there is a high availability of healthy foods at home⁽³⁹⁾.

The item 'What is your opinion about: the food you eat at home is healthy?' presented the highest value for discrimination parameter ($\alpha_i = 2.09$). This item is important to the continuum of motivation influencing food choices. Individuals who agreed on this item were more likely to choose healthy food options. With respect to foods eaten at home, the literature indicates that the more frequent the family meals, the better the diet quality, and this may be associated with a healthy nutritional status of the youth⁽⁴⁰⁾. In this regard, adolescents with the best socioeconomic status and maternal education also presented high health motivation when choosing foods.

SOFIE scores presented an adequate adjustment with more accurate estimates in the low and high levels (Figs 3 and 4). Therefore, IRT analyses improved the assessment of health motivation influencing food choices. The formerly used approaches were restricted to the

classical test theory^(8,41). IRT has some advantages in comparison with the classical approach, which only assess the percentage of responses for each item. Although the current analysis indicated differences on demographic and socioeconomic characteristics across the SOFIE levels, the IRT parameters and scores were independently estimated of the sample characteristics⁽⁴²⁾. Moreover, IRT distributes items based on the continuum of motivation influencing food choices, which allows categorising responses on low or high motivation⁽⁴²⁾. In this context, SOFIE allows to know the food attitudes influenced by adolescents' health motivation.

The assessment of associations between SOFIE scores and other determinants of health may improve our understanding when evaluating the rationale behind adolescents' food choices. In the current study, mixed model linear regression analyses indicated that SOFIE scores were positively associated with the intakes of cereals, dairy products, meat and eggs and fish, and with the concentrations of vitamin C, β -carotene, *n*-3 fatty acids, cobalamin, holo-transcobalamin and folate. An increase of one unit in SOFIE score is associated with an increase of fish consumption of 46 g/d. Similarly, an increase of one unit in SOFIE score is associated with a 4.7% increase in EPA and DHA concentrations in blood. SOFIE scores were positively associated with all biomarkers analysed, but only with a few food groups. In the study sample, intakes of fruits, vegetables and fish were also correlated with the blood concentrations of vitamin C, β -carotene and *n*-3 fatty acids⁽²⁰⁾. Despite the associations between SOFIE scores and nutritional biomarkers as well as food intakes, it was not possible to confirm that adolescents who have health-motivated food choices will have healthier food consumption. On the other hand, it seems that health motivations are influencing food choices, which may guide health professionals to improve the efficiency of their actions.

Based on the sensitivity analyses to assess how SOFIE scores performed excluding under-reporters, we observed that SOFIE scores were negatively associated with intakes of nuts and seeds and savoury snacks (*P* < 0.05). The intakes of savoury snacks (*P* < 0.05) were lower for adolescents who underreported compared with the whole sample. Therefore, caution should be taken when interpreting these results. This may indicate that other factors may motive food choices rather than health.

As previously reported, hunger and taste are some of the most important motivations at breakfast⁽⁸⁾. Moreover, it has been established that the reasons why adolescents choose the first food to eat in the morning may vary. For school lunch, adolescents prefer taste over healthy options at the first selected food (59%), although taste motivation reduces at the selection of the third food (41%). In contrast, the motivation to select foods for reasons related to health increased from the first selected food (8%) to the third selected food (24%)⁽⁵⁾. Health may not be the main motivation when adolescents choose what they eat. It is



necessary to highlight the importance of assessing accurately the health motivation influencing food choices when developing public health policies. SOFIE may help identify individuals with lower health motivation when choosing foods and guide interventions.

Limitations and strengths

Limitations of this study include the inherent limitation of the GGUM 2004 software, regarding the maximum number of respondents allowed for analysis, which is 2000. In addition, the cross-sectional nature of our study cannot be used to establish causation between food intakes and/or nutritional biomarkers with motivation influencing food choices or vice versa. The study has also several strengths. The estimation of item parameters and scores presented low standard errors. The use of IRT analysis allowed including new items in SOFIE based on the items' parameters calculated in the present analyses. GGUM may provide new insights to evaluate motivation influencing food choices, and SOFIE can be presented as a new approach to evaluate health motivation.

Conclusions

SOFIE scores, obtained using GGUM, can improve the assessment of motivation influencing food choices. The items in SOFIE showed the best discrimination performance in investigating the attitudes presented by individuals with low, indifferent or high health motivation. The associations between SOFIE scores and food intakes and nutritional biomarkers indicated that health motivation may influence healthy food intakes. This is very important for planning public policies to promote healthy food choices. SOFIE is proposed as a new measure to further study health motivation influencing food choices.

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by the responsible institution in each of the participating countries. Written informed consent was obtained from all subjects/patients.

Supplementary material

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Appendix

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