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Food neophobia and its relationship with dietary variety and quality in Irish adults: Findings from a national cross-sectional study

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ABSTRACT

Food neophobia is characterised by a reluctance to eat novel or unfamiliar foods and has been linked to reduced dietary variety and quality. However, this link has been primarily studied in children. Therefore, we aimed to explore the relationship between food neophobia and dietary variety and quality in adults using a sub-sample of the National Adults Nutrition Survey collected between 2008 and 2010 (n = 1088). Food and nutrient intakes were assessed using a 4-day semi-weighed food diary. Food neophobia was measured using the Food Neophobia Scale (FNS). Dietary variety was assessed in three ways; Total Dietary Variety (TDV), Food-Group Variety (FGV) and Fruit and Vegetable Variety (FVV). Diet quality was assessed using the Mean Adequacy Ratio (MAR) and Nutrient-Rich Food Index (NRF9.3). A multivariate general linear model was used to assess the linear relationships between FNS score and all dietary measures, controlling for age, sex, education level, social class, location and BMI. Food neophobia was found to be inversely associated with TDV, FGV and FVV. In addition, food neophobia was negatively associated with vitamin C, magnesium and fruit and vegetable intakes and positively associated with percentage energy from free sugars. However, food neophobia was not significantly associated with all other nutrients, MAR and NRF9.3. While these results suggest food neophobia may not be a particularly important risk factor for poor nutrient status, adherence to certain dietary recommendations remains low within the Irish population and food neophobia may further inhibit the adaption of healthy and sustainable diets. Future research should seek to understand the implications of food neophobia on dietary behaviour change.

1. Introduction

Few foods contain all essential nutrients. Thus, humans must consume a variety of foods to meet their needs. In general, the more varied ones diet is, the more likely they are to meet their nutritional needs (Hatlùy et al., 1998; Murphy et al., 2006). The amount of variety required is determined by the foods consumed, with higher intakes of nutrient-dense foods reducing the demand for diversity. In addition, in an environment where high energy-dense foods are widely available, increased variety, particularly in the context of a single meal, may lead to overconsumption, increasing the risk of overweight and obesity (de Oliveira Otto et al., 2018; Salehi-Abargouei et al., 2016). For this reason, many dietary guidelines have moved away from the "eat a varied diet" message to only emphasise variety in the context of nutrient-dense foods like fruits and vegetables. One factor thought to influence dietary variety is food neophobia (Dovey et al., 2008).

Food neophobia is characterised by a reluctance to eat novel or unfamiliar foods (Pliner & Hobden, 1992). This hesitancy towards new foods is common among humans and other omnivorous animals (Rozin, 1976). In humans, food neophobia is highly heritable with estimates ranging between 58% and 78% (Cooke, 2018). Like most complex traits, food neophobia varies widely within and among populations. Part of this

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variation has been linked to differences in sociodemographic characteristics, including age, sex, education level, socioeconomic status, living region and body mass index (Dovey et al., 2008; Lafraire et al., 2016; Meiselman et al., 2010; Tuorila et al., 2001). Food neophobia has also been associated with other traits, including general neophobia, sensation seeking, anxiety and openness (Dovey et al., 2008; Knaapila et al., 2011; Lafraire et al., 2016).

Evolutionary, food neophobia is thought to have developed as an adaptive trait, helping to protect against the ingestion of toxins (Rozin, 1990). While it may have developed as a protective trait, today, where most foods are safe, food neophobia shows more maladaptive consequences. In children, food neophobia has been consistently shown to reduce both dietary variety and quality (Falciglia et al., 2000; Quick et al., 2014; Roßbach et al., 2016). Children with higher food neophobia tend to eat less fruits, vegetables, cereals and meat and more sugary and salty foods (Cooke et al., 2003, 2006; Dos Anjos et al., 2020; Galloway et al., 2003; Kozioł-Kozakowska et al., 2018). Moreover, studies in children have found higher food neophobia to be associated with lower protein and energy intakes (Alawi Kutbi et al., 2021; Cooke et al., 2006; Roßbach et al., 2016). Although some investigations have found the opposite effect, linking food neophobia with higher energy density and sugar intakes (Russell & Worsley, 2008).

The influence of food neophobia on dietary choices is seen across all ages. Although mostly studied in children, evidence linking food neophobia to detrimental dietary intakes in adults is beginning to emerge. As with children, higher food neophobia in adults is associated with lower dietary variety and reduced intakes of certain food groups (Jaeger et al., 2017; Nicklaus et al., 2005). Adults with higher food neophobia tend to consume lower amounts of nutrient-dense foods like fruits and vegetables and fish (Costa et al., 2020; Jaeger et al., 2017; Knaapila et al., 2015; Siegrist et al., 2013; Zickgraf & Schepps, 2016). Whereas, intakes of energy-dense, salty and sugar-rich foods either show no association or are positively associated with higher food neophobia (Costa et al., 2020; Knaapila et al., 2011). These differing food preferences may make food neophobic individuals less likely to meet dietary recommendations, increasing their risk of diet-related chronic diseases.

To date, only a few studies have examined the effect of food neophobia on total diet quality in adults. Two studies in Finnish adults found higher food neophobia was associated with lower overall diet quality (Knaapila et al., 2015; Sarin et al., 2019). In addition, Knaapila et al. found participants with higher food neophobia had significantly higher BMI and Sarin et al. found higher food neophobia was negatively associated with several health-related biomarkers and individuals with higher neophobia had a small increased risk of type 2 diabetes after ~8 years follow-up. Similarly, a recent study in Italian adults found higher food neophobia was negatively associated with adherence to the Mediterranean diet (Predieri et al., 2020). However, a study in Portuguese adults did not find a significant relationship between diet quality or nutrient intakes and food neophobia (Costa et al., 2020). Most of the evidence in this areas has measured food consumption using food frequency questionnaires (FFQs) which are less sensitive at capturing daily food and nutrient intakes compared with other methods, such as food diaries (Thompson & Subar, 2017). This has limited the ability of previous studies to assess adherence to certain dietary recommendations, particularly those of nutrients. In addition, few investigations have used representative population samples which may further limit their generalisability. Therefore, there is a need for further exploration into the effects of food neophobia on diet quality and nutrient intakes using more detailed dietary assessment tools. In addition, given the geographic differences in both food neophobia (Rabadán & Bernabéu, 2021) and diet quality (Imamura et al., 2015), the influence of food neophobia on achieving dietary recommendations may differ across countries. Thus, to assess the influence of food neophobia on a population, country specific research may be required.

A better understanding of how food neophobia influences adherence to dietary recommendations may assist public health initiative to encourage healthier food choices. People with higher food neophobia are often less willingness to try both new foods and healthy and sustainable alternatives to familiar products (Hartmann & Siegrist, 2017; Schickenberg et al., 2008; Tuorila et al., 2001). This reluctance to adopt to new dietary habits may mean more targeted approaches to dietary change are required. In order to extend our understanding of how food neophobia influences dietary intakes in adults, this study aimed to explore the relationship between food neophobia and dietary variety, diet quality, nutrient intakes and fruit and vegetable intakes in a nationally representative sample of Irish adults. Importantly, food intakes were captured using a 4-day semi-weighed food diary which allowed both macronutrient and micronutrient adequacy to be assessed.

2. Methods

2.1. Survey details

The National Adult Nutrition Survey (NANS) is a nationally representative cross-sectional survey of food and beverage consumption, nutrient intakes, anthropometric measurements, lifestyle factors and food-related attitudes in Irish adults aged 18 years and over. A more detailed description of the survey methods has been previously reported (IUNA, 2011).

In summary, the survey was conducted between 2008 and 2010 in the Republic of Ireland on a nationally representative sample of 1500 adults (740 male, 760 females) aged between 18 and 90 years. The response rate for participation was 59.6%. Participants were recruited using a database held by Data Ireland (National Postal Service), which randomly selected people from 20 geographical clusters across Ireland. The final sample was representative of the Irish population with respect to age, sex, social class and location (urban/rural). Ethical approval was obtained from University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospitals and the Human Ethics Research Committee of University College Dublin (ECM 3(p), September 4, 2008).

2.2. Sociodemographic characteristics

Participants completed questionnaires on Health and Lifestyle, Physical Activity and Food Choice Attitudes. The Health and Lifestyle questionnaire gathered information on participants sociodemographics, supplement use, usual alcohol intake and smoking status. Anthropometric measurements were carried out in the participants' homes by a trained researcher. Body mass was measured using a Tanita BC-420MA Body Composition Analyzer (Tanita Corporation, Tokyo, Japan) and height was assessed using a Leicester portable height measure to the nearest 0.1 cm. Body mass index (BMI) was calculated by dividing body mass (kg) by height (m^2).

2.3. Food neophobia questionnaire

Out of the 1500 participants, 1263 completed the food choice attitudinal questionnaire. This questionnaire included measures of food choice motives, healthy eating habits, food-related resources, satisfaction with food-life, healthy eating identity and food neophobia.

Food neophobia was measured using the Food Neophobia Scale (FNS) developed by Pliner and Hobden (1992). The FNS is a ten-item questionnaire with five food neophobic statements (e.g. "I don't trust new foods") and five food neophilic statements (e.g. "I will eat almost anything"). Each item is scored on a 7-point agreement scale, ranging from 1 = strongly disagree to 7 = strongly agree. All food neophilic statements were reversed scored so that higher scores indicated greater food neophobia (Supplementary Table 1). Of the 1263 participants who completed the food choice attitudinal questionnaire, 1191 completed all 10 items of the FNS and 1088 of those had complete sociodemographic data and were included in the final analysis (Supplementary Fig. 2). All items were summed to give a total FNS score. The final score had a

possible range of 10–70.

2.4. Food and nutrient intake

Food, beverage and supplement intake was measured using a four-day semi-weighed food diary. Participants were advised to collect all packaging from food and beverages consumed over the four-day period. A portable food scale (Tanita, Japan) was given to each participant and detailed instructions on its use were provided by a trained researcher. This method was used to quantify 46% of foods and drinks consumed. The remaining food quantities were estimated using weights derived from food packaging (10%), portion size estimates using a photographic atlas (Nelson et al., 1997) (16%) or food portion sizes guide (Ministry of Agriculture, 1997) (11%), using household measures (e.g. teaspoons etc. 11%), through average portions weights from previous national surveys (4%) or based on the researchers knowledge of respondents general eating habits (2%). The nutritional composition of foods and beverages was assessed using WISP V3.0 (Tinuviel Software, Anglesey, UK). WISP derived food composition using data from McCance and Widdowson's The Composition of Foods (5th and 6th editions) plus all nine supplemental volumes (Food Standards Agency, 2002). Additional information on the composition of generic Irish foods, supplements and composite dishes was added using the Irish Composition Database (Black et al., 2011). Free sugars were not available from the composition tables and were calculated using a systematic approach by Louie et al. (2015). As we were primarily interested in whether food neophobia influenced nutrient intake from foods we evaluated intakes excluding those from supplements.

Mean daily fruit and vegetable intake (g/day) was estimated by averaging the sum of all fruits and vegetables consumed on each survey day. Composite dishes were broken down into their ingredients using recipes books from composite tables (Food Standards Agency, 2002) and their fruit and vegetable components were added to the final estimate.

2.5. Dietary variety

Dietary variety was measured in three different ways, total dietary variety (TDV), food group variety (FGV) and fruit and vegetable variety (FVV). TDV was measured using a method outlined by Bernstein et al. (2002) and involved counting the total number of different foods reported over the four survey days. Foods consumed on multiple occasions only counted as one item. All foods were counted regardless of the quantity consumed. A food-based approach was used which meant all drinks (except for fruit juices, smoothies and milk), herbs, spices, and condiments were excluded. Composite dishes (e.g. chicken pie) were counted as one item and were not broken down into individual ingredients.

FGV was measured using a modified version of the 20 food group measure outlined by Quick et al. (2014). Food groups were modified to align with the 2016 Irish Dietary Guideline (Department of Health, 2016). Foods were divided into 6 groups based on the tiers of the Irish Food Pyramid and were further divided into a total of 20 sub-groups (see Supplementary Table 3 for details). Foods were only included where a minimum of half a serving or more was consumed over the four survey days (i.e. 0.125 serving per day). Composite dishes were included in the group which reflected their main ingredient (e.g. chicken curry = white meat). As the consumption of processed meat (e.g. ham, bacon, sausage) is discouraged in the Irish Dietary Guidelines these foods were excluded from all meat sub-groups. The serving sizes for each food group can be found in Supplementary Table 4.

FVV was measured using an approach outlined by Bernstein et al. (2002) and involved counting the total number of different fruits and vegetables consumed over the four days. Fruit and vegetables consumed on multiple occasions were only counted as one item. As with TFV, items were counted regardless of the quantity consumed. Fruits and vegetables from composite dishes were excluded from this score.

2.6. Diet quality

Diet quality was assessed using the Mean Adequacy Ratio (MAR) previously described by Hatlùy et al. (1998) and the Nutrient Rich Food Index 9.3 (NRF9.3) (Fulgoni et al., 2009). The MAR was used to assess the influence of food neophobia on achieving micronutrient adequacy. Firstly, a Nutrient Adequacy Ratio (NAR) was calculated for a selection of 18 micronutrients by dividing the intake by the Average Requirement for each subject's sex and age specified by the European Food Safety Authority (European Food Safety Authority, 2017). Adequate Intakes (AI) were used when ARs were unavailable. All NAR scores were capped at 1 to avoid overvaluing intakes of single nutrients. The final MAR was then calculated by summing all NAR scores and dividing them by the total number of nutrients assessed. All ARs and AIs used can be found in Supplementary Table 5. The final MAR included a total of 15 micronutrients (thiamin, niacin and phosphorus were excluded as they were adequately consumed by all participants). MAR was also calculated with intakes from supplements included.

The NRF9.3 was used to give a measure of total nutrient density for all foods and beverages consumed. It is calculated from the ratio of recommended daily values of 9 nutrients to encourage (NR: protein, dietary fibre, vitamins A, C, and E, calcium, iron, potassium and magnesium) and 3 nutrients to limit (LIM: saturated fat, total sugar, and sodium) relative to energy intake. First, NR and LIM were calculated per 100 kcal for each food and beverage consumed. Then NRF9.3 scores for each item were calculated by subtracting the LIM scores from the NR scores. These scores were then converted into individual scores by summing all NRF9.3 food and beverage scores for each subject and dividing by the number of 100 kcal units of participants' total energy intake. The recommended daily values and equations used in the calculation are outlined in Supplementary Tables 6 and 7

Under-reporters were defined as individuals with an energy intake to basal metabolic rate ratio (EI: BMR) of less than 1.1 (McGowan et al., 2001). BMR was estimated by age, weight and sex using Schofield's equation (FAO/WHO/UNU, 2001). All diet and nutrient analyses were run with and without under-reporters included.

2.7. Statistical analysis

All statistical analyses were carried out using SPSS® for Windows™ statistical software package version 26 (SPSS Inc., Chicago. IL, USA). Internal consistency of the FNS was assessed using Cronbach's alpha and the Shapiro-Wilk test was used to assess the normality of the distribution. As the Shapiro-Wilk test showed a significant departure from normality ($W(1088) = 0.980$, $P < 0.001$), a U Mann-Whitney test (for variables with 2 groups) and Kruskal-Wallis analysis of variance (for variables with more than 2 groups) were used to compare FNS scores across participants sociodemographic characteristics (sex, age group, education level, social class, location), BMI category and between under and valid reporters. A multivariate general linear model was used to calculate parameter estimates (beta coefficients and 95% confidence intervals) to explore the associations between FNS scores and all dietary measures. As each dietary measure was deemed a separate outcome of food neophobia, each variable was assessed using a separate model, resulting in a total of 36 models. Age, sex, BMI, education level, social class and location were considered potential confounders and were adjusted for in all models. A complete case analysis approach was used for all analyses (Supplementary Fig. 2). The standard criteria for statistical significance ($P < 0.05$) was adjusted for multiple comparisons using the Bonferroni correction and $P < 0.001$ (0.05/37) was considered statistically significant for all dietary analyses.

3. Results

3.1. Food Neophobia Scale

Internal consistency of the FNS was found to be high (α = 0.908). The mean, median and standard deviation of FNS scores for the 1088 study sample was 34.35, 33.00 and 13.33, respectively. FNS scores ranged from 10 to 68 (possible range 10–70). The frequency distribution of FNS scores can be seen in Supplementary Fig. 1. The FNS scores across sociodemographic characteristics are shown in Table 1. Significant differences ($P < 0.05$) were observed across age, education, social class and location. FNS scores increased in age groups 52–64 and 65+ (H(3) = 47.082, $P < 0.001$). Subjects with higher education levels showed lower FNS scores (H(3) = 32.258, $P < 0.001$). Participants in the semi-skilled/unskilled social class had higher FNS scores compared to upper classes and students (H(4) = 27.196, $P < 0.001$). Participants living in urban areas showed slightly lower FNS scores compared to rural (U = 115409, $P = 0.013$). FNS scores were not significantly different across sexes (U = 146813, $P = 0.825$) or BMI categories (H(2) = 4.693, $P = 0.096$). The prevalence of under-reporting (i.e. EI: BMR <1.1) for the sample population was 34.0%. FNS scores did not differ between valid and under-reporters (U = 132208, P = 0.899).

Table 1
Mean Food Neophobia Scale (FNS) scores (possible range 10–70) across sociodemographic characteristics for the total sample population (n = 1088).

	Mean (SD)	Median	Range	*n* (%)	*P*-value
FNS score	34.4 (13.3)	33.0	10–68	1088 (100)	
Gender					
Male	34.5 (13.6)	33.0	10–67	539 (49.5)	0.825
Female	34.2 (13.1)	33.0	10–68	549 (50.5)	
Age					
18 - 35	32.0 (13.1)	30.0	10–68	441 (40.5)	<0.001
36 - 51	34.0 (13.3)	33.0	10–67	358 (32.9)	
52 - 64	36.9 (12.8)	36.0	10–68	179 (16.5)	
65+	40.8 (12.4)	42.5	15–67	110 (10.1)	
Education Level					
Primary	39.7 (12.5)	39.5	10–64	66 (6.1)	<0.001
Intermediate	35.9 (14.0)	35.0	10–68	200 (18.4)	
Secondary	36.2 (13.0)	35.0	10–67	262 (24.1)	
Tertiary	32.3 (13.0)	30.0	10–68	560 (51.5)	
Social Class					
Professional	33.4 (12.9)	32.0	10–67	534 (49.1)	<0.001
Non-manual skilled	36.5 (13.9)	37.0	10–68	198 (18.2)	
Manual skilled	35.2 (13.9)	35.0	10–63	138 (12.7)	
Semi-skilled/ unskilled	39.0 (12.5)	38.0	10–68	81 (7.4)	
Student	31.4 (13.2)	29.0	10–67	137 (12.6)	
Location					
Rural	35.8 (13.2)	35.0	10–67	341 (31.3)	0.013
Urban	33.7 (13.3)	33.0	10–68	747 (68.7)	
BMI					
Normal weight	33.3 (13.1)	31.5	10–68	422 (38.8)	0.096
Overweight	34.8 (13.7)	34.0	10–68	428 (39.3)	
Obese	35.3 (13.1)	34.5	10–65	238 (21.9)	
Under-reporting					
Valid reporting	34.4 (13.2)	33.0	10–68	718 (66.0)	0.899
Under-reporting	34.3 (13.5)	33.5	10–68	370 (34.0)	

Rural, population <10,000, Urban, population >10,000. BMI category defined using WHO standards: normal weight, BMI<25·0 kg/m^2; overweight, BMI = 25·0–29·9 kg/m^2; obese, BMI≥30·0 kg/m^2. *P*-value from U Mann-Whitney test (for variables with 2 groups) and Kruskal-Wallis analysis of variance (for variables with more than 2 groups).

3.2. Dietary variety, diet quality and fruit and vegetable intake

TDV, FGV, and FVV all showed significant ($P < 0.001$) inverse associations with FNS scores (Table 2). A small negative association was observed between food neophobia and MAR and NRF9.3, although these were not significant after Bonferroni correction (Table 2). In addition, total fruit and vegetable intakes showed a small significant inverse association with food neophobia. Similar relationships were observed when under-reporters were included (Supplementary Table 8).

3.3. Nutrient intakes

For individual nutrients, higher food neophobia was found to have a significant positive association with percentage energy from free sugars and a significant negative association with vitamin C and magnesium intake (Table 3). When under-reporters were included significant positive associations were observed for percentage energy from carbohydrates and free sugars and significant negative associations were observed for vitamin C and NRF9.3 (Supplementary Table 9).

4. Discussion

The results of this study suggest that higher food neophobia is associated with lower total dietary variety as well as a lower variety of recommended foods. In addition, higher food neophobia was found to have a positive association with percentage energy from free sugars and a small negative association with vitamin C, magnesium and fruit and vegetable intake. However, food neophobia was not significantly

Table 2
Mean dietary variety, diet quality and fruit and vegetable intake and their parameter estimates with FNS score as the independent variable in a multivariate linear model[a], excluding under-reporters (n = 718).

	Mean (SD)	B (95% CI)	*P*-value
Dietary Variety			
TDV	33.4 (8.9)	−0.123 (−0.171; −0.074)	<0.001
FGV	11.0 (2.7)	−0.036 (−0.050; −0.021)	<0.001
FVV	7.2 (4.2)	−0.054 (−0.077; −0.032)	<0.001
Diet Quality			
MAR	0.6 (0.2)	−0.001 (−0.002; −0.000[b])	0.044
MAR (inc. sup)	0.7 (0.2)	−0.001 (−0.002; 0.000[c])	0.090
NRF9.3	30.5 (10.7)	−0.060 (−0.107; −0.013)	0.012
F&V intake			
F&V (g/day)	325.4 (183.6)	−2.633 (−3.632; −1.634)	<0.001

[a] All models were adjusted for age, sex, BMI, social class (Dummy coded with Professional classified as the baseline/control variable), education level (Dummy coded, with Primary classified as the baseline/control variable) and location.
[b] 0.00003.
[c] 0.0002. TDV, total dietary variety. FVV, fruit and vegetable variety. FGV, food group variety (potential range of 0–20). F&V, fruit and vegetable. MAR, mean adequacy ratio. Inc. sup, including supplements. NRF 9.3, Nutrient Rich Food Index 9.3. Results including under-reporters can be found in Supplementary Table 8. $P < 0.0014$ was considered statistically significant after adjusting α = 0.05 for 36 tests using the Bonferroni correction.

Table 3
Mean macro and micronutrient intakes and their parameter estimates with FNS score as the independent variable in a multivariate linear model[a], excluding under-reporters (n = 718).

	Mean (SD)	B (95% CI)	*P*-value
Macronutrients			
Energy (kcal/day)	2312.6 (554.2)	0.066 (−2.316; 2.449)	0.956
Total fat (% E)	34.3 (5.7)	0.004 (−0.029; 0.037)	0.811
Saturated fat (% E)	13.3 (3.2)	0.005 (−0.013; 0.024)	0.568
MUFA (% E)	12.5 (2.5)	−0.002 (−0.017; 0.012)	0.755
PUFA (% E)	6.0 (1.9)	−0.000[b] (−0.011; 0.010)	0.960
Protein (% E)	16.4 (3.0)	−0.015 (−0.032; 0.003)	0.094
Carbohydrate (% E)	44.0 (6.6)	0.052 (0.014; 0.090)	0.008
Free sugars (% E)	9.6 (5.1)	0.057 (0.029; 0.086)	<0.001
Alcohol (% E)	5.9 (7.2)	−0.040 (−0.080; 0.000[c])	0.051
Fibre (g/day)	21.7 (8.0)	−0.039 (−0.083; 0.005)	0.085
Micronutrients			
Vitamin A (μg)	1114.7 (791.5)	0.230 (−4.207; 4.667)	0.919
Vitamin D (μg)	4.4 (3.0)	−0.004 (−0.021; 0.012)	0.601
Vitamin E (mg)	11.1 (5.0)	0.002 (−0.026; 0.030)	0.910
Vitamin C (mg)	91.7 (55.2)	−0.524 (−0.836; −0.212)	0.001
Thiamin (mg)	2.0 (2.8)	−0.000[e] (−0.016; 0.016)	0.968
Riboflavin (mg)	2.2 (0.8)	−0.001 (−0.006; 0.003)	0.631
Niacin (mg)	46.0 (15.4)	−0.067 (−0.138; 0.005)	0.066
Vitamin B6 (mg)	3.0 (1.2)	0.003 (−0.003; 0.010)	0.302
Vitamin B12 (μg)	5.1 (3.3)	−0.001 (−0.019; 0.018)	0.949
Folate (μg)	419.5 (217.7)	0.599 (−0.595; 1.792)	0.325
Biotin (μg)	42.5 (18.2)	−0.045 (−0.144; 0.054)	0.376
Pantothenate (mg)	6.6 (2.3)	−0.000[d] (−0.012; 0.012)	0.988
Calcium (mg)	1029.5 (363.5)	0.791 (−1.170; 2.751)	0.429
Iron (mg)	13.7 (5.2)	−0.024 (−0.052; 0.003)	0.082
Magnesium (mg)	324.8 (97.7)	−0.882 (−1.381; −0.383)	<0.001
Zinc (mg)	10.6 (3.4)	−0.014 (−0.032; 0.004)	0.116
Phosphorous (mg)	1564.3 (425.8)	−2.072 (−4.153; 0.009)	0.051
Potassium (mg)	3448.1 (902.2)	−5.331 (−9.954; −0.708)	0.024
Sodium (mg)	2823.2 (872.6)	−0.323 (−4.480; 3.834)	0.879

[a] All models were adjusted for age, sex, BMI, social class (Dummy coded with Professional classified as the baseline/control variable), education level (Dummy coded, with Primary classified as the baseline/control variable) and location.
[b] 0.0003.
[c] 0.0001.
[d] 0.0003.
[e] 0.00009. % E, percentage total daily energy Folate, dietary folate equivalence, vitamin A, retinol equivalence, niacin, niacin equivalence. Sodium excludes discretionary salt. CI, confidence intervals. Inc. sup, includes supplements. Results including under-reporters can be found in Supplementary Table 9. P < 0.0014 was considered statistically significant after adjusting α = 0.05 for 36 tests using the Bonferroni correction.

associated with intakes of other macro and micronutrients as well as MAR and NRF9.3.

These results are consistent with previous findings in children (Falciglia et al., 2000), adolescents (Quick et al., 2014) and adults (Jaeger et al., 2017; Zickgraf & Schepps, 2016) that increased food neophobia associates with lower dietary variety. This suggests that food neophobia limits dietary variety throughout the life course. In addition to lower fruit and vegetable variety, higher food neophobia was also linked to reduced overall intakes. This is consistent with other findings in both children (Cooke et al., 2006; Dos Anjos et al., 2020; Falciglia et al., 2000) and adults (Costa et al., 2020; Jaeger et al., 2017; Knaapila et al., 2015; Zickgraf & Schepps, 2016), suggesting an aversion to fruit and vegetables is a common characteristic among food neophobic individuals. Interestingly, despite observing an inverse association with dietary variety, food neophobia was not significantly associated with diet quality measured by MAR and NRF 9.3 after Bonferroni correction when under-reporters were excluded. When under-reporters were included NRF 9.3 was found to be significantly lower. However, due to the nature of the NRF 9.3 score under-reporting may lead to higher scores which may not reflect actual intakes. These results partially support previous findings in children (Cole et al., 2017) and adults (Rabadán & Bernabéu, 2021) linking food neophobia to reduced diet quality. However, as few investigations use the same measure of diet quality or method of dietary collection it is difficult to make direct comparisons with other studies. It is possible that if a different measure of diet quality were used the effect of food neophobia may have been more pronounced, particularly if fruit and vegetable and free sugars intakes made up components of the score. Despite this, among most research reported to date, the overall effect size of food neophobia on diet quality in adult populations appears modest.

When we looked at individual nutrients, we found that higher food neophobia had a positive association with the percentage of energy from free sugars. These results confirm previous studies in children (Dos Anjos et al., 2020; Russell & Worsley, 2008) but evidence in adults is mixed. Studies that looked directly at free sugar intake have not found associations with food neophobia in adolescence (Quick et al., 2014; Roßbach et al., 2016) or adults (Costa et al., 2020). However, indirect evidence looking at food intake have linked higher food neophobia with increased intakes of sugar-rich foods, like soft drinks, sweets and desserts (Jaeger et al., 2017; Predieri et al., 2020; Zickgraf & Schepps, 2016). These studies also find that higher food neophobia has a negative relationship with many recommended foods, including fruits, vegetables, fish, and whole-grain bread (Jaeger et al., 2017; Predieri et al., 2020; Zickgraf & Schepps, 2016). This suggests food neophobia may have a compensatory effect on food selection, decreasing intakes of beneficial food like fruits and vegetables and increasing intakes of sugar-rich foods. The mechanism by which this occurs is not fully understood but may be partly explained by food neophobic individuals heightened taste sensitivity which drives a preference for simple sweet foods over more complex flavours profiles (Dematte et al., 2014).

Although many studies suggest food neophobia reduces dietary variety, few have looked at whether this leads to detrimental micronutrient intakes. Of the 19 micronutrients assessed, only intakes of vitamin C and magnesium showed a small negative association with food neophobia. A small study in adults confirmed the present finding that higher food neophobia associates with lower magnesium intake (Capiola & Raudenbush, 2012). However, unlike the present study, they also found higher food neophobia to be associated with lower energy intake and 18 other nutrients (Capiola & Raudenbush, 2012). Previous research in children has linked higher food neophobia to lower intakes of vitamin C (Kozioł-Kozakowska et al., 2018). As with the present study, the lower vitamin C was likely the result of reduced fruit and vegetable intakes (Kozioł-Kozakowska et al., 2018). Besides the small associations with vitamin C and magnesium, higher food neophobia was not associated with achieving micronutrient adequacy. This has also been observed in children, with one study finding a significant reduction in dietary variety but not with micronutrient adequacy, except vitamin E (Falciglia et al., 2000). Thus, while food neophobia tends to reduce dietary variety, the effect may be too small to lead to significant micronutrient deficiencies. Nowadays, in most developed countries, people will be exposed to a wide variety foods throughout their lives. This continued exposure to diverse sources of food may lead even highly food neophobic individuals to develop a large enough repertoire of acceptable foods to evade substantial micronutrient deficiencies.

While the positive association with free sugars and lower intakes of fruit and vegetables are of concern for individuals with higher food neophobia, overall, the effects were small, suggesting food neophobia may not be a strong predictor of diet quality. Despite this, diet quality for many participants remains below recommended levels, with many exceeding dietary recommendations for saturated fat, free sugars, sodium and dietary fibre (IUNA, 2011). While high food neophobia is unlikely to be the primary driver of unhealthy food choices, it may make it more difficult to change dietary behaviours. Food neophobic individuals show a higher resistance to try new foods (Tuorila et al., 2001) and have a lower willingness to try healthy alternatives (Schickenberg et al., 2008) and sustainable protein sources (Hartmann & Siegrist, 2017). This resistance may be partly explained by differences in food

choice motives. When making food choices people with higher food neophobia prioritise familiarity and convenience over health, natural content, environmental impact and social justice (Jaeger et al., 2020). Moreover, one recent study investigating the impact of the COVID-19 pandemic on dietary change found that participants with higher food neophobia were less likely to report positive changes in dietary habits (Jaeger et al., 2021). Thus, food neophobia may act as a potential gatekeeper to dietary change, inhibiting efforts to promote healthy and sustainable diets. Further research is needed to understand how food neophobia influences dietary behaviour change.

This study has both strengths and limitations. The strengths of this study are the large nationally representative sample and comprehensive dietary assessment method. The limitations of this study include its cross-sectional design which limits the ability to make direct causal inferences on the effects of food neophobia on food or nutrient intakes. As with most nutritional epidemiological studies, we relied on self-reported dietary measures to estimate food and nutrient intakes. Although food records are more reliable than other dietary assessment methods, all self-reported measures are prone to misreporting (Poslusna et al., 2009). We tried to adjust for this by excluding under-reporters in our analyses but this approach has some limitations (Black, 2000). In addition, when under-reporters were excluded the proportion of obese participants was significantly reduced (Supplementary Table 1). As people with obesity tend to exhibit lower diet quality (Asghari et al., 2017) this may have influenced the effect observed when under-reporters were excluded.

5. Conclusion

The findings of this study provide further evidence that higher food neophobia is associated with a lower dietary variety and indicate higher levels reduce intakes of vitamin C, magnesium and fruit and vegetable intake and increase intakes of free sugars. However, food neophobia was not significantly associated with overall diet quality. While these results suggest food neophobia may not be a particularly important risk factor for poor nutrient status, overall adherence to dietary recommendations remains low within the Irish population and food neophobia may further inhibit the adaption of healthy and sustainable diets. Future research should seek to understand the implications of food neophobia on dietary behaviour change.

Author contributions

DH conceived the current research questions, carried out the data analysis and wrote the first draft. JMK, MS, SMC contributed to the design of the study, data analysis and study review. AF, JW, SMC and BMN contributed to the design and execution of the National Adults Nutrition Survey and provided expert advice throughout. All authors critically reviewed the manuscript and approved the final version submitted for publication.

Ethical statement

Ethical approval was obtained from University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospitals and the Human Ethics Research Committee of University College Dublin (ECM 3 (p), September 4, 2008).

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Declaration of competing interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2021.105859.

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