



Tree nut allergy and anxiety related factors modulate food consumption behaviour in peanut-allergic patients: Results of the MIRABEL survey

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ABSTRACT

Background: In the absence of specific data on food consumption of allergic consumers, general population surveys are used for risk assessment. Most of allergy risk assessment's experts advise that an understanding of the food consumption habits of people with food allergies is crucial for correctly estimate the risk.

Objective: This study aims to detail the food consumption of patients with peanut allergy including products with precautionary allergen labelling (PAL) and to identify the factors influencing their consumption behaviour.

Methods: The MIRABEL study is a multi-center survey of peanut-allergic patients from France, Belgium and Luxembourg. It includes data on medical, socio-demographic, and consumption of different food categories, including products with PAL. Anxiety score and allergy severity level variables were constructed and studied as potential consumption determinants. To study the association of modulator variables with food consumption, a logistic regression model was built to test the association with food category and ingredient choice.

Results: 443 of the 785 patients from MIRABEL survey were included in the consumption study. Tree nut allergy, knowledge of threshold dose, label reading and anxiety score significantly influenced the consumption of products which may contain unintended traces of peanut. The direction of influence depended on food categories and ingredient choices. Diet advice by allergists, severity of the allergy and threshold dose determined by oral food challenge did not significantly impact consumption.

Conclusions: and clinical relevance: It showed, for the first time, that consumption of food products by peanut-allergic patients, including those with PAL, is modulated by factors related to anxiety such as label reading and knowledge of threshold and concomitant tree nut allergy. Knowledge of peanut-allergic food behaviours will make it possible to improve risk assessment and help allergists and risk managers to make diet advices.

1. Introduction

Peanut allergy is one of the most frequent food allergy, with a prevalence of 1.55% (95%CI: 1.18–1.93) in Europe for children estimated from oral challenges or convincing clinical history (Nwaru et al., 2014). In France, the lifetime prevalence of self-reported peanut allergy was of 0.6 (95%CI: 0.3–1) in 6–17 years old children (Rancé et al., 2005). To prevent the risk of reaction, peanut-allergic consumers avoid peanuts by carefully examining ingredient labels (Avery et al., 2003; Hefle et al., 2007; Pieretti et al., 2009; Sicherer et al., 2001). To protect allergic consumers, the European Directive 2003/89/EC mandates that the 14 major allergens must be identified on food labelling if they are used as intended ingredients. However, a risk still remains because

traces of peanut could be inadvertently present in a wide range of industrial food products, through cross-contact during as example processing on shared equipment or storage. In the absence of guidance and operational tools, the food industry have introduced precautionary allergen labelling (PAL), with indications such as “may contain traces”, or “manufactured in a facility”, even if the chance of contamination and its impact on health is negligible. However, the use of PAL on food labels is up to now entirely voluntary and the meaning of these PALs can be confusing for the consumers (Marchisotto et al., 2017). Consequently, risk assessments on the potential unintended presence of peanut residues (i.e. not an ingredient of the food product) will help to develop new, more informative labels for peanut-allergic consumers. Moreover, enhanced labelling efforts would improve the quality of life for peanut-

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Abbreviations

CI	Confidence interval
FAQLQ	Food Allergy Quality of Life Questionnaire
IQR	Interquartile range
OFC	Oral food challenge

OR	Odds ratio
OQALI	Observatory of Food Quality
PAL	Precautionary allergen labelling
RAV	Allergy Vigilance Network
RR	Rate ratio

allergic consumers, allowing them to make safe and informed decisions about what to eat and ensure that the range of products available to them is not unduly restricted.

Food risk assessments for chemical substances and food allergens generally assume that there is no link between the consumption of the products that may contain chemicals or allergens and allergy severity. Although this independency hypothesis is valid in most cases of chemical risk assessment, there is no confirmation that food allergies do not affect consumption behaviour (Crevel et al., 2014). For example, characteristics such as the history of severe reaction, the knowledge of the threshold dose, the diet advice from the physician, or the anxiety of the patients (or their parents) may influence food choices. Patients with severe allergy may be inclined to avoid or limit the frequency of consumption or intake of certain categories of products and ingredients associated with the presence of peanut. These questions have not been addressed to date due to the absence of food surveys specifically designed for food-allergy patients.

Most authors who have studied the risk assessment of unintended allergen intake suggest that an understanding of the food consumption habits of people with food allergies is crucial for correctly estimating the risk. They therefore recommend food consumption surveys focused on allergic populations (Crevel et al., 2014; Hattersley et al., 2014; Kruizinga et al., 2008; Madsen et al., 2009; Spanjersberg et al., 2007, 2010).

Using data from the MIRABEL project (Crépet et al., 2015), the purpose of this original study was first to describe in peanut-allergic patients the consumption of specific categories of food that may contain traces of peanut. The impact of peanut allergy characteristics, the diet advice from the allergists regarding PAL, the PAL reading by the patients, and their anxiety associated to food allergy were analysed.

2. Materials and methods

2.1. Study population

The MIRABEL study is an observational multi-center survey based on the voluntary participation of patients from mainland France, Belgium and Luxembourg, recruited from April 2012 to December 2013 during visits to their allergists (either office- and/or hospital-based), all members of the Allergy Vigilance Network (RAV). This study has been described in depth elsewhere (Crépet et al., 2015). The study was approved by the French Data Protection Authority (CNIL) (Authorization no. DE-2011-048). All patients or parents signed an informed consent form.

2.2. Data collection

A medical questionnaire was filled out by the allergist and a food consumption questionnaire was completed by the peanut-allergic patients or their parents for children younger than 16 years old. The medical questionnaire focused on the history and the characteristics of the allergy in the patients. The questions included the accidental allergic reaction reported at the first visit, the exposure route, the type and amount of food triggering the accidental allergic reaction, the allergic co-morbidities, the association with tree nut allergy or other food allergies and the results of the allergy tests including the oral food challenge (OFC), if done. The medical data was detailed elsewhere

(Deschildre et al., 2016).

The dietary questionnaire provided socio-demographic data as well as detailed data related to food consumption. The food products included in the study were selected according to whether they may contain unintended peanut traces. Packaged food products for which the literature reveals the unintended presence of peanut (Rimbaud et al., 2013), and/or those that may be associated with a precautionary label such as “may contain traces” were included in the survey. The information on the PAL was available from the French Observatory of Food Quality (OQALI) database which centralizes, at the branded product level, all data provided on labels (such as the ingredients list and PAL) to monitor the quality of processed food (Menard et al., 2011). The 10 selected food product categories were: breakfast cereals, cereal bars, bread and bakery products, appetizer products, pizzas, cream desserts and fresh desserts, biscuits and pastries, chocolate tablets or spread, other chocolate products (e.g. chocolate bars, chocolate sweets and powdered chocolate) and ice cream and sorbets. For each of these packaged food product categories, allergic patients were questioned on their consumption frequency per day/week/month or year. If they indicated consumption, they were asked to describe the portion size using photographs and to describe the consumed products precisely by listing the brand, the product name and the ingredients.

Individuals were also questioned on their anxiety relating to their allergy, to their out-of-home consumption behaviour and to labelled/unlabelled product consumption. The consumption questionnaire comprised 11 questions adapted from the Food Allergy Quality of Life Questionnaires (FAQLQ) (Flokstra-de Blok et al., 2008; Flokstra-de Blok et al., 2009a, 2009b). A score summarizing this information was calculated following a method inspired from the SF-36 health effect questionnaire (McHorney et al., 1994; Ware and Sherbourne, 1992). To do so, an exploratory factor analysis for qualitative variables was performed and highlighted four principal components of anxiety related to: (i) out-of-home eating, (ii) PAL, (iii) inadvertent peanut consumption and risk of severe allergic reaction, and (iv) peanut allergy in general. The four types of response to each question (not worried, a little worried, somewhat worried, very worried) were attributed a value of 0, 33, 66 and 100, respectively. We then calculated the mean score for each principal component. Finally, the overall anxiety score was calculated from the mean of the four principal component scores and ranged from 0 to 100.

Finally, patients (or parents) were asked if they knew the threshold dose of peanut that would cause an allergic reaction and to give this quantity.

2.3. Study variables

From the medical and consumption questionnaires, the following variables were constructed:

1. Age: it was considered as a continuous variable after testing the linearity of the relationship between age and the logit of the probability of consumption.
2. Gender.
3. Severity of the allergy: patients were classified according to a previous cluster analysis of MIRABEL medical data detailed in Just et al. (2016): Cluster 1: “Severe peanut allergy with few allergic co-morbidities”; cluster 2: “Multiple allergic diseases with severe

peanut allergy”; cluster 3: “Mild peanut allergy”. For the present study, the severe clusters 1 and 2 were pooled.

4. Association with tree nut allergies identifying patients with one or more food allergies to cashew nut, pistachio, hazelnut, walnut, pecan nut, almond, brazil nut, chestnut and/or macadamia nut.
5. Threshold dose at the peanut oral food challenge (OFC). The threshold dose was defined as the cumulative dose of roasted crushed peanuts causing an objective reaction, converted into mg of peanut protein. The allergic patients who did not react during a complete OFC (absence of an objective sign for a cumulative dose > 7 g of peanut) were excluded from the study to focus only on confirmed allergic patients. We tested the linearity of the peanut threshold dose on the logit of the probability of consumption using a tendency test. Because the assumption of linearity was not rejected, the threshold dose of peanut was considered as a continuous variable and the measurement of association with consumption was estimated per 100 units of the peanut threshold dose.
6. Diet advice from the allergists: strict eviction (exclusion of peanut as an ingredient and products with PAL) and lax eviction (exclusion of peanut as an ingredient but tolerating products with PAL).
7. Knowledge of the threshold dose by the patient or the parent.
8. PAL reading of regularly consumed products. Two groups were distinguished: individuals who carefully read the PALs of the products they usually buy and the other individuals.
9. Anxiety. After testing the linearity of the anxiety score on the logit of the probability of consumption using a tendency test, the anxiety score was integrated as a continuous variable in the analysis. The measure of association with consumption was estimated per 10 units of anxiety score.

2.4. Method of analysis

We studied the statistical associations between medical variables and food consumption in peanut-allergic patients. Food consumption was the outcome variable and was defined in three ways: (i) as a binary variable depending on food category consumption (yes/no); (ii) as a weekly food category intake frequency; and (iii) as a binary variable depending on ingredients choice considering all food categories together (yes/no). Ingredients were defined as: chocolate only, (dried) fruit or tree nuts, fruit or tree nuts and chocolate, honey and caramel, plain and milk. The “fruit” category included products containing fresh fruit or dried fruit. In complementary analyses, we studied the consumption of two specific food subcategories susceptible to contain peanut traces: chocolate cereals and chocolate tablets with tree nuts.

The analyses were adjusted on (1) age and (2) gender variables. The following modulator factors were also considered: (3) diet advice (strict/lax eviction); (4) tree nut allergy (yes/no); (5) allergy severity (severe/mild allergy); (6) knowledge of threshold dose by the patient or the parents (yes/no); (7) label reading (yes/no); (8) threshold dose of peanut-allergic reaction for patients with a positive OC; and (9) anxiety score.

2.5. Statistical analysis

Characteristics of the study population were described as percentages or median values with interquartile ranges (IQR). A logistic regression model was used to study the association of modulator variables with food category and ingredients choice expressed as a binary variable (yes/no). The associations were estimated as odds ratios (OR) with corresponding 95% confidence intervals (CI). To account for over-dispersion, a negative binomial regression model was used to evaluate the determinants of the weekly frequency of food category consumption (Agresti, 1990). The associations in this latter model were estimated as rate ratios (RR) with 95% CI. To be explicit in the interpretation of the odds ratios and rate ratios, a value higher than one means that the probability to consume (binary or weekly frequency) is higher for

Table 1

Characteristics of the study population.

No. of subjects (n)	443
Gender, females/males (% males)	179/264 (60)
Age ^a (y), median (IQR ^b) (n)	10 (7–14) (443)
Diet advice, strict eviction/lax (% lax) (n)	211/183 (46) (394)
Tree nut allergy, yes/no (% no) (n)	233/210 (47) (443)
Allergy severity n (%)	369 (100)
Severe with some or a few co-morbidities	261 (73)
Mild	98 (27)
NA ^c	84
Knowledge of threshold dose, no/yes (% yes) (n)	264/179 (40) (443)
Label reading, yes/no (% no) (n)	192/207 (52) (399)
Median threshold dose ^d (IQR ^b) (n)	54.40 (16.44–242.88) (117)
Anxiety score, median (IQR ^b) (n)	53.5 (38.9–67.4) (443)

^a Age at recruitment in the study.

^b IQR, Interquartile range.

^c Missing data (not known).

^d From positive oral food challenge, in mg of peanut protein.

individuals not included in the reference group compared to the reference group. Both unadjusted and adjusted analyses were carried out. A P value of less than 0.05 was considered as significant. The statistical analysis was performed using SAS software version 9.2.

3. Results

3.1. Study population

Of the 785 patients included in the MIRABEL survey via 70 allergists, a complete consumption questionnaire was available for 443 peanut-allergic patients. Their characteristics are presented in Table 1. The mean age at recruitment was 11 years and 85% of the patients were aged less than 16 years. Almost half (46%) of the patients were recommended to follow lax eviction by their allergist and 53% had a concomitant tree nut allergy. The severe allergy cluster included 73% of the peanut-allergic patients. In addition, 40% of the patients knew the quantity of peanuts that causes an allergic reaction. Half of the patients (48%) carefully read the labels on the product packages they usually buy and the median anxiety score was of 53.5 on 100.

3.2. Consumption in MIRABEL patients

The description of consumption in the 10 categories in terms of binary consumption choice, weekly frequency and maximum intake is presented in Table 2. From a general point of view, almost all of the patients consumed every food category except for cereal bars and pizza that are consumed by few patients, 21% and 47% respectively. When consumed, the most frequently consumed categories were breakfast cereals (3.25 times per week), chocolate tablets or spread (3.5 times per week), biscuits and pastries (4 times per week), other chocolate products (5.9 times per week) and bread and bakery products (7 times per week). The most consumed food categories in terms of maximum intake per meal were pizza and cream desserts.

The description of the consumption according to ingredients is presented in Table 3 and showed that chocolate and plain or milk ingredients were the most consumed ingredients with 91% and 90% of consumers, respectively.

3.3. Associations between food consumption and medical characteristics, label reading, diet advice and anxiety score

Unadjusted and adjusted associations are presented in Table 4 for binary consumption choice by food category and subcategory, in Table 5 for weekly frequency by food category and in Table 6 for binary consumption by ingredient choice. Results for adjusted analyses are commented below. Ones are results related to peanut allergy

Table 2

Description of the 10 consumption categories among MIRABEL cases (The consumption is described in terms of binary consumption choice, weekly frequency and maximum intake variables).

Food categories	Consumption									
	Binary choice		Weekly frequency (n)							
	Yes, n (%)	NA ^b (n)	1p ^a	2.5p ^a	5p ^a	Med ^a	Mean ^a	95p ^a	97.5p ^a	99p ^a
Breakfast cereals	320 (73)	9	0.04	0.06	0.12	3.25	5.33	14.25	21.12	35
Cereal bars	94 (21)	7	0.06	0.08	0.10	1	2.07	7	9	30
Bread and bakery products	384 (88)	11	0.08	0.25	0.5	7	8.55	25	31	42.29
Appetizer products	328 (77)	3	0.06	0.10	0.19	1	1.60	4.75	6	8
Pizza	199 (47)	2	0.04	0.04	0.06	0.5	0.68	2	2	5
Cream desserts	334 (80)	20	0.06	0.10	0.19	2.5	4.94	16	28	42
Biscuits and pastries	340 (83)	6	0.06	0.10	0.25	4	6.53	21	28	50.5
Chocolate tablets or spread	325 (79)	6	0.08	0.17	0.25	3.5	5.37	16	18.25	23.75
Other chocolate products	250 (62)	6	0.04	0.08	0.10	5.88	6.14	15.44	21.25	27
Ice cream and sorbets	313 (77)	12	0.04	0.06	0.09	0.58	1.31	4	6	9.25

Maximum intake (g/meal)										
Breakfast cereals	11	15	15	15	45	44.18	90	120	120	
Cereal bars	33	18	20	20	25	30.44	64	90	100	
Bread and bakery products	23	8	15	25	70	84.79	188	210	325	
Appetizer products	36	12	17	20	50	74.70	200	300	500	
Pizza	24	61	61	83	211	261.43	648	648	1296	
Cream desserts	26	80	90	100	100	129.35	230	360	400	
Biscuits and pastries	24	25	25	25	75	96.02	250	250	300	
Chocolate tablets or spread	21	10	10	10	30	47.04	120	156	250	
Other chocolate products	33	5	5	10	33	49.96	174	200	225	
Ice cream and sorbets	38	25	25	25	90	97.46	206	222	360	

^a Percentiles are calculated among consumers.

^b Missing data for the weekly frequency and the maximum intake consumption variables.

Table 3

Description of the ingredient choice (yes/no) among MIRABEL cases.

Ingredient categories	Binary consumption choice Yes, n (%)
Chocolate	401 (91) ^a
Fruit or tree nuts	212 (48) ^a
Honey or caramel	294 (67) ^a
Plain or milk	396 (90) ^a
Fruit or tree nuts and chocolate	249 (57) ^a

^a Missing data for the consumption by ingredient choice (n = 3).

characteristics and the others are related to the patient characteristics.

The severity of peanut allergy seemed to not modulate binary consumption choice, the weekly frequency consumption of the 10 categories, or ingredient choice (Tables 4–6).

Tree nut allergy was associated with a lower proportion of peanut-allergic patients consuming chocolate tablets or spreads (OR = 0.47 [0.26–0.88], $p < 0.05$) (Table 4). We observed the same association for the subcategory chocolate tablets with tree nuts (OR = 0.34 [0.15–0.77], $p < 0.05$) (Table 4). Nevertheless, among chocolate tablets or chocolate spread consumers, tree nut allergy was associated with a greater weekly frequency of consumption of chocolate tablets or spreads (Table 5) with an RR = 1.33 [1.03–1.71] ($p < 0.05$). Tree nut allergy did not modulate ingredient choice (Table 6) except the fruit or tree nut and chocolate ingredients for which the tree nut allergy was associated with a lower consumption (OR = 0.42 [0.26–0.70], $p < 0.0001$).

The threshold doses for patients with a positive OFC did not modulate either the proportion of consumers of food categories, subcategories, ingredients, or the weekly frequency of consumption (Tables 4–6).

Finally, the diet advised by the allergist did not modulate the consumption in terms of proportion of peanut-allergic consumers or weekly frequency of consumption of the 10 categories, the 2 subcategories and of the different ingredients (Tables 4–6).

The knowledge by the patient of the threshold dose was significantly associated with a higher proportion of peanut-allergic consumers (Table 4) and higher weekly frequency consumption of bread and bakery products (Table 5) (OR = 2.47 [1.09–5.63], $p < 0.05$; RR = 1.48 [1.17–1.87], $p < 0.01$ respectively) and with a lower weekly consumption frequency of ice cream and sorbets (Table 5) (RR = 0.49 [0.34–0.72], $p < 0.01$). The knowledge of threshold dose did not influence ingredient choices (Table 6).

PAL reading was significantly associated with a lower proportion of peanut-allergic consumers of other chocolate products (Table 4) (OR = 0.57 [0.34–0.93], $p < 0.05$). However, label reading did not influence the weekly frequency consumption of the 10 product categories or ingredient choice (Tables 5 and 6).

Finally, anxiety score did not influence the proportion of peanut-allergic consumers of the different food categories (Table 4). Nevertheless, the anxiety score was associated with higher weekly frequencies of consumption of appetizer products and cream desserts (RR = 1.08 [1.01–1.17], $p < 0.05$; RR = 1.14 [1.01–1.28], $p < 0.01$ respectively) (Table 5). Moreover, the anxiety score negatively influenced the consumption of products with “fruit or tree nuts and chocolate” (OR = 0.98 [0.97–1.00], $p < 0.05$) (Table 6).

4. Discussion

MIRABEL is the first survey to produce specific data on intake and frequency of specific food categories liable to contain unintended traces of peanut in allergic patients from France, Belgium and Luxembourg. This data made it possible to evaluate the intake and consumption frequency of those products. This information can be directly used to refine risk assessment for peanut-allergy sufferers. Moreover, this data made it possible to characterize food consumption behaviour of food potentially containing peanut traces in regard to specific factors. Our results suggest that modulator factors involve individual perception of the allergy rather than the characteristics of the allergy themselves.

We observed that concomitant tree nut allergy, knowledge of

Table 4
Unadjusted (unadj) and adjusted (adj) associations (OR [$CI_{95\%}$]) of predictor variables with consumption choice (yes/no) by category and subcategory.

Food categories	OR [$CI_{95\%}$]	Diet advice (Ref = lax)	Tree nut allergy (ref = no)	Allergy severity (ref = severe allergy)	Knowledge of threshold dose (ref = no)	Label reading (ref = never)	Threshold doses for positive OFC ^b /100	Anxiety score/10
Breakfast cereals	OR unadj	0.88 [0.56–1.37]	0.94 [0.62–1.44]	0.92 [0.55–1.54]	1.19 [0.77–1.83]	0.66 [0.42–1.04]	1.06 [0.95–1.17]	0.94 [0.84–1.04]
	OR adj ^a	0.93 [0.56–1.06]	0.75 [0.45–1.26]	0.99 [0.56–1.76]	1.11 [0.66–1.87]	0.81 [0.47–1.38]	1.04 [0.90–1.21]	1.04 [0.90–1.20]
	OR unadj	1.08 [0.67–1.75]	0.81 [0.51–1.28]	1.13 [0.65–1.97]	0.96 [0.60–1.53]	1.10 [0.68–1.77]	1.02 [0.94–1.10]	1.03 [0.92–1.16]
Cereal bars	OR adj ^a	1.34 [0.76–2.35]	0.60 [0.34–1.05]	1.12 [0.60–2.09]	0.91 [0.52–1.59]	1.32 [0.74–2.36]	1.08 [0.96–1.21]	1.03 [0.88–1.21]
	OR unadj	0.59 [0.31–1.11]	2.01 [1.12–3.62] *	1.20 [0.55–2.65]	1.70 [0.91–3.15]	0.67 [0.37–1.21]	1.00 [0.88–1.14]	0.90 [0.78–1.04]
	OR adj ^a	0.82 [0.39–1.74]	1.78 [0.83–3.81]	1.28 [0.55–2.99]	2.47 [1.09–5.63] *	0.68 [0.32–1.48]	0.98 [0.79–1.23]	0.92 [0.74–1.14]
Appetizer products	OR unadj	0.79 [0.49–1.27]	0.93 [0.60–1.46]	1.05 [0.60–1.84]	1.32 [0.83–2.10]	0.55 [0.34–0.87] *	0.99 [0.90–1.10]	0.87 [0.77–0.97] *
	OR adj ^a	0.86 [0.50–1.49]	0.80 [0.47–1.38]	1.14 [0.62–2.09]	1.55 [0.89–2.72]	0.74 [0.42–1.30]	0.93 [0.80–1.09]	0.91 [0.78–1.06]
	OR unadj	0.95 [0.63–1.43]	0.85 [0.58–1.24]	0.90 [0.56–1.44]	1.36 [0.92–2.01]	0.56 [0.37–0.83] **	0.97 [0.90–1.05]	0.89 [0.81–0.98] *
Pizza	OR adj ^a	0.94 [0.59–1.52]	0.91 [0.57–1.46]	0.84 [0.49–1.43]	1.16 [0.72–1.86]	0.63 [0.39–1.03]	0.99 [0.89–1.10]	0.98 [0.86–1.12]
	OR unadj	0.62 [0.36–1.05]	0.95 [0.59–1.54]	0.83 [0.46–1.49]	1.51 [0.91–2.50]	0.83 [0.51–1.35]	0.94 [0.87–1.02]	0.84 [0.74–0.95] **
	OR adj ^a	0.69 [0.38–1.24]	0.95 [0.53–1.71]	0.86 [0.45–1.62]	1.50 [0.83–2.74]	1.31 [0.72–2.39]	0.89 [0.77–1.04]	0.88 [0.75–1.04]
Biscuits and pastries	OR unadj	0.58 [0.33–1.02]	0.90 [0.54–1.50]	1.40 [0.70–2.81]	1.19 [0.71–2.02]	0.60 [0.35–1.02]	0.99 [0.90–1.10]	0.83 [0.72–0.94] **
	OR adj ^a	0.73 [0.38–1.41]	0.97 [0.51–1.84]	1.56 [0.73–3.33]	1.02 [0.53–1.94]	0.84 [0.43–1.63]	1.01 [0.82–1.23]	0.87 [0.73–1.05]
	OR unadj	0.64 [0.38–1.09]	0.59 [0.36–0.97] *	0.53 [0.29–0.93] *	1.34 [0.81–2.21]	0.89 [0.55–1.45]	1.04 [0.92–1.16]	0.83 [0.74–0.94] **
Chocolate tablets or spreads	OR adj ^a	0.86 [0.47–1.59]	0.47 [0.26–0.88] *	0.72 [0.39–1.36]	1.09 [0.59–1.99]	1.18 [0.63–2.21]	1.06 [0.90–1.24]	0.88 [0.74–1.04]
	OR unadj	1.19 [0.77–1.82]	1.26 [0.84–1.88]	0.94 [0.58–1.54]	0.86 [0.57–1.29]	0.62 [0.42–0.94] *	0.97 [0.90–1.05]	0.90 [0.81–1.00] *
	OR adj ^a	1.26 [0.78–2.04]	1.48 [0.91–2.39]	0.90 [0.53–1.53]	0.75 [0.46–1.20]	0.57 [0.34–0.93] *	1.01 [0.91–1.13]	0.96 [0.84–1.10]
Ice cream and sorbets	OR unadj	1.02 [0.63–1.66]	1.17 [0.74–1.86]	1.15 [0.64–2.05]	1.19 [0.73–1.91]	0.84 [0.53–1.34]	0.91 [0.84–0.99] *	0.91 [0.81–1.02]
	OR adj ^a	1.23 [0.71–2.14]	1.14 [0.66–1.98]	1.11 [0.59–2.08]	1.00 [0.57–1.74]	1.22 [0.69–2.16]	0.87 [0.75–1.01]	0.91 [0.78–1.06]
Food subcategories								
Chocolate cereal	OR unadj	0.90 [0.60–1.34]	0.69 [0.47–1.01]	0.69 [0.43–1.11]	1.04 [0.71–1.53]	0.61 [0.41–0.91] *	1.03 [0.95–1.11]	0.88 [0.80–0.97] *
	OR adj ^a	0.96 [0.60–1.53]	0.68 [0.42–1.08]	0.72 [0.43–1.21]	0.97 [0.60–1.53]	0.71 [0.44–1.16]	1.08 [0.94–1.23]	0.98 [0.85–1.12]
	OR unadj	0.90 [0.47–1.72]	0.34 [0.18–0.66] **	0.88 [0.40–1.94]	1.34 [0.73–2.46]	0.70 [0.38–1.30]	0.87 [0.65–1.15]	0.89 [0.77–1.04]
Chocolate tablets with tree nuts	OR adj ^a	1.09 [0.52–2.30]	0.34 [0.15–0.77] *	1.18 [0.50–2.78]	1.10 [0.52–2.29]	1.04 [0.48–2.26]	0.89 [0.62–1.27]	0.96 [0.78–1.18]

Note: ***, significant at 0.1%; **, significant at 1%; *, significant at 5%.

^a Associations adjusted for age at recruitment, gender and the other predictor variables.

^b Among patients with a positive OFC (n = 117), association adjusted for age at recruitment, gender and the other predictor variables.

Table 5
Unadjusted (unadj) and adjusted (adj) associations of predictor variables with the weekly frequency of consumption by category.

Food categories	RR [CI _{95%}]	Diet advice (ref = lax)	Tree nuts allergy (ref = no)	Cluster severity (ref = severe allergy)	Knowledge of threshold dose (ref = no)	Label reading (ref = never)	Threshold doses for positive OFC ^a /100	Anxiety score/10
Breakfast cereals	RR unadj RR adj ^a	1.03 [0.77–1.37] 1.16 [0.85–1.59]	0.90 [0.69–1.17] 0.90 [0.66–1.22]	0.83 [0.61–1.14] 1.17 [0.84–1.64]	0.80 [0.61–1.04] 0.80 [0.59–1.09]	0.88 [0.67–1.15] 1.00 [0.74–1.37]	0.99 [0.94–1.03] 0.96 [0.90–1.02]	1.03 [0.96–1.10] 0.98 [0.90–1.08]
Cereals bars	RR unadj RR adj ^a	1.82 [0.87–3.81] 1.24 [0.58–2.66]	0.57 [0.30–1.11] 0.59 [0.29–1.19]	0.81 [0.34–1.92] 0.97 [0.45–2.09]	0.69 [0.35–1.37] 0.87 [0.43–1.77]	0.64 [0.31–1.33] 0.66 [0.31–1.39]	0.89 [0.76–1.05] 0.95 [0.83–1.08]	1.12 [0.93–1.34] 1.03 [0.83–1.27]
Bread and bakery products	RR unadj RR adj ^a	0.84 [0.68–1.03] 0.82 [0.65–1.04]	1.19 [0.98–1.45] 1.26 [0.99–1.59]	0.92 [0.72–1.17] 1.12 [0.86–1.45]	1.35 [1.11–1.65] ** 1.48 [1.17–1.87] **	0.95 [0.77–1.16] 0.90 [0.71–1.48]	1.00 [0.96–1.04] 1.02 [0.97–1.07]	0.98 [0.94–1.03] 1.00 [0.94–1.07]
Appetizer products	RR unadj RR adj ^a	1.08 [0.85–1.38] 1.02 [0.78–1.32]	0.98 [0.78–1.22] 1.00 [0.77–1.30]	1.22 [0.91–1.63] 0.75 [0.55–1.02]	1.00 [0.80–1.26] 1.08 [0.83–1.41]	0.84 [0.67–1.06] 0.98 [0.75–1.29]	0.96 [0.91–1.02] 1.01 [0.94–1.08]	1.07 [1.01–1.13] * 1.08 [1.01–1.17] *
Pizzas	RR unadj RR adj ^a	0.83 [0.61–1.14] 0.80 [0.57–1.11]	0.90 [0.66–1.22] 0.84 [0.61–1.15]	0.76 [0.54–1.09] 1.19 [0.83–1.70]	1.39 [1.01–1.90] * 1.27 [0.92–1.76]	0.76 [0.56–1.04] 0.74 [0.52–1.04]	1.05 [0.98–1.13] 1.06 [0.95–1.18]	1.00 [0.92–1.08] 0.99 [0.90–1.08]
Cream desserts	RR unadj RR adj ^a	1.05 [0.71–1.55] 1.04 [0.67–1.60]	1.04 [0.73–1.49] 1.00 [0.64–1.57]	0.95 [0.60–1.51] 0.92 [0.55–1.52]	0.93 [0.64–1.34] 0.88 [0.57–1.36]	0.73 [0.50–1.06] 0.81 [0.51–1.26]	0.93 [0.85–1.02] 0.99 [0.89–1.09]	1.12 [1.01–1.23] * 1.14 [1.01–1.28] *
Biscuits and pastries	RR unadj RR adj ^a	1.04 [0.74–1.48] 0.97 [0.69–1.37]	0.82 [0.60–1.13] 0.69 [0.49–0.97] *	1.10 [0.73–1.66] 0.80 [0.55–1.17]	0.91 [0.66–1.25] 0.92 [0.66–1.29]	0.69 [0.51–0.94] 0.79 [0.55–1.14]	1.00 [0.93–1.07] 1.02 [0.93–1.11]	1.11 [1.02–1.20] * 1.07 [0.97–1.18]
Chocolate tablets or spreads	RR unadj RR adj ^a	1.12 [0.88–1.42] 1.08 [0.83–1.39]	1.33 [1.07–1.65] ** 1.33 [1.03–1.71] *	1.08 [0.81–1.44] 0.96 [0.72–1.29]	1.09 [0.87–1.36] 1.07 [0.83–1.38]	1.12 [0.89–1.41] 1.21 [0.93–1.58]	0.98 [0.94–1.02] 0.98 [0.90–1.07]	1.04 [0.98–1.10] 1.03 [0.96–1.11]
Other chocolate products	RR unadj RR adj ^a	1.15 [0.91–1.46] 1.14 [0.87–1.50]	0.83 [0.65–1.06] 0.95 [0.72–1.24]	1.27 [0.96–1.67] 0.79 [0.58–1.06]	0.84 [0.65–1.07] 0.87 [0.67–1.14]	0.98 [0.76–1.26] 1.05 [0.78–1.40]	0.97 [0.92–1.01] 0.99 [0.92–1.05]	0.99 [0.93–1.06] 1.01 [0.93–1.09]
Ice cream and sorbets	RR unadj RR adj ^a	1.31 [0.80–2.15] 1.15 [0.78–1.69]	1.31 [0.85–2.03] 1.13 [0.76–1.69]	1.84 [1.02–3.30] * 0.66 [0.41–1.06]	0.50 [0.34–0.74] *** 0.49 [0.34–0.72] ***	0.74 [0.48–1.14] 0.95 [0.62–1.44]	0.91 [0.79–1.04] 0.98 [0.85–1.12]	1.11 [1.00–1.24] 1.12 [1.00–1.25]

Note: ***; significant at 0.1%; **, significant at 1%; *, significant at 5%.

^a Associations adjusted for age at recruitment, gender and the other predictor variables.

^b Among patients with a positive OFC (n = 117), association adjusted for age at recruitment, gender and the other predictor variables.

Table 6
Unadjusted (unadj) and adjusted (adj) associations of predictor variables with the ingredient consumption choice (yes/no), regardless of food category.

Ingredient categories	OR [CI _{95%}]	Diet advice (ref = lax)	Tree nut allergy (ref = no)	Allergy severity (ref = severe allergy)	Knowledge of threshold dose (ref = no)	Label reading (ref = never)	Threshold doses for positive OFC ^b /100	Anxiety score/10
Chocolate	OR unadj OR adj ^a	1.25 [0.61–2.55] 0.67 [0.19–2.42]	0.59 [0.30–1.16] 0.73 [0.22–2.48]	0.58 [0.21–1.58] 1.04 [0.29–3.74]	0.78 [0.40–1.50] 0.69 [0.21–2.25]	0.76 [0.32–1.81] 1.81 [0.51–6.43]	0.94 [0.86–1.03] 1.87 [0.15–23.95]	0.79 [0.67–0.93]** 0.78 [0.54–1.11]
Fruit or tree nuts	OR unadj OR adj ^a	0.91 [0.61–1.36] 0.94 [0.59–1.49]	0.81 [0.56–1.18] 0.87 [0.55–1.37]	1.11 [0.70–1.77] 0.81 [0.48–1.37]	0.80 [0.55–1.18] 0.86 [0.54–1.36]	0.85 [0.57–1.25] 1.13 [0.70–1.83]	0.98 [0.91–1.06] 0.99 [0.89–1.10]	0.86 [0.78–0.94]** 0.91 [0.80–1.04]
Fruit or tree nuts & chocolate	OR unadj OR adj ^a	1.00 [0.67–1.49] 1.09 [0.66–1.80]	0.47 [0.32–0.69]*** 0.42 [0.26–0.70]***	1.55 [0.97–2.47] 0.74 [0.43–1.26]	1.32 [0.90–1.95] 1.38 [0.83–2.29]	0.73 [0.49–1.10] 0.95 [0.57–1.60]	1.01 [0.94–1.09] 1.02 [0.91–1.15]	0.83 [0.76–0.92]** 0.98 [0.97–1.00]*
Honey or caramel	OR unadj OR adj ^a	1.08 [0.71–1.65] 0.95 [0.58–1.57]	1.10 [0.74–1.64] 1.10 [0.67–1.82]	1.20 [0.74–1.94] 0.63 [0.36–1.09]	1.14 [0.76–1.71] 1.29 [0.78–2.13]	0.76 [0.50–1.17] 0.96 [0.57–1.62]	1.01 [0.93–1.10] 1.01 [0.89–1.14]	0.96 [0.87–1.06] 1.06 [0.92–1.23]
Plain or Milk	OR unadj OR adj ^a	1.31 [0.68–2.52] 1.10 [0.47–2.58]	1.50 [0.80–2.81] 1.67 [0.71–3.95]	1.02 [0.47–2.21] 0.57 [0.24–1.37]	0.88 [0.47–1.66] 1.18 [0.50–2.75]	0.70 [0.34–1.45] 0.52 [0.21–1.29]	0.94 [0.85–1.03] 0.82 [0.58–1.17]	0.91 [0.78–1.06] 1.05 [0.83–1.34]

Note: ***, significant at 0.1%; **, significant at 1%; *, significant at 5%.

^a Associations adjusted for age at recruitment, gender and the other predictor variables.^b Among patients with a positive OFC (n = 117), association adjusted for age at recruitment, gender and the other predictor variables.

threshold dose by the patient, label reading and the anxiety score significantly modulated food consumption, especially products with PAL. The associations varied with food category and ingredient and with the way the consumption was defined (binary choice/frequency). However, the general trend was that concomitant tree nut allergy, label reading and anxiety score are negatively associated with food consumption whereas knowledge of threshold dose is positively associated. The other tested variables (diet advised by allergists, allergy severity and threshold dose) were not significantly associated with food consumption in our study.

4.1. Medical characteristics and consumption of specific products

MIRABEL is one of the first surveys studying food consumption of peanut-allergic patients and the link with their medical characteristics. These latter including allergy severity and the threshold dose with OFC which appeared to not influence food consumption behaviours. Therefore, it seems there is no need to integrate a relationship between the threshold dose and the food consumption in risk assessments. This absence of relationship must be tested in further work by estimating the risk in both ways: using the individual threshold or randomly selecting it in the dose-response distribution. However, a recent survey lead in US and Canada concluded that previous severe allergic reaction decreased the odds of purchasing foods using PAL (Marchisotto et al., 2017).

In our study, concomitant tree nut allergy negatively influenced food consumption behaviours. It was focused on tree nuts because they are mainly involved in peanut allergic patients (Maloney et al., 2008; Sasaki et al., 2018). However, patients may have other food allergies which could impact food consumption of studied products.; Anxiety score, label reading and food consumption of specific products.

Anxiety score and reading labels at each act of purchase, which could translate a form of anxiety, has a negative influence on food choices in MIRABEL patients. Studies have demonstrated that food allergy affects the quality of life of patients and their relatives and is associated with anxiety (Birdi et al., 2016; Saleh-Langenberg et al., 2015; Wassenberg et al., 2012). Food allergy is also linked with an increased risk of clinically relevant symptoms of anxiety in adolescents (Ferro et al., 2016). Furthermore, the willingness of MIRABEL patients to pay for different types of labels and especially for products guaranteed to be free of peanut traces was studied (Marette et al., Submitted). The level of anxiety is positively and significantly associated with the choice of the peanut-free label. In our study, label reading affects only the binary consumption choice of “other chocolate products”. Overall, 95% of MIRABEL patients read the label when they buy new products that they usually do not buy. This percentage decreases to 48% for products they usually buy (not shown). These results confirm the need to clearly list on the front of the package any change in the product (Cochrane et al., 2013). The fact that consumers may take a risk when ignoring PAL has already been reported (DunnGalvin et al., 2015; Hefle et al., 2007). In MIRABEL, 29.7% of the consumed products were products with PAL (Elegbede et al., 2015). One study showed that only 9 of the 899 products (1%) collected in MIRABEL on the French market were contaminated by peanut and 7 had PAL (Zagon et al., 2015). Six samples had a content of total peanut protein < 5 mg/kg, two samples contained between 8 and 10 mg/kg and one sample a maximum of about 20 mg/kg. These results raise the question of the real allergic risk linked to the consumption of those products, and the consequence on diet advice. Actions must be taken to make labels clearer and reflect actual risk. Moreover, a recent analysis on diet advice and PAL concluded that healthcare professionals remain confused about the interpretation and value of the current PAL system because it is unclear whether foods with no advisory labels are safe to consume (Zurzolo et al., 2016). This confusion regarding PAL for patients and physicians may explain why diet advice did not influence the consumption of the different food categories and ingredients. Knowledge of threshold dose by the patient positively influenced food consumption, suggesting that

individuals who know their threshold dose are less afraid to consume products with PAL and thus potential peanut traces.

4.2. Consumption of peanut-allergic patients: most affected products

Chocolate tablets and spreads, fruit or tree nuts and chocolate, and chocolate tablets with tree nuts are the products most affected by the modulator factors. These associations can be attributed to the fact that chocolate and tree nuts are known to be vectors of peanut contamination in the food industry. Thus, allergic consumers are more careful regarding those products. Another reason is that peanut allergy is frequently associated with tree nut allergy, thereby influencing the consumption of certain food products included in our study. In MIRABEL, 53% of the individuals declared a concomitant tree nut allergy. However, only 37% were declared tree nut-allergic by an allergist.

4.3. Limitations

These results must be analysed considering some limitations. The study population included only the population that consults allergists. This may result in overlooking peanut-allergic individuals with severe allergies, and therefore in an overestimation of the prevalence of severe symptoms and/or of low threshold doses. However, the participation of both office- and hospital-based allergists limits this bias. This recruitment strategy also made it possible to recruit a high number of peanut-allergic patients throughout France, Belgium and Luxembourg, and therefore cover peanut allergy and food behaviour variability. Around 11% of the population was diagnosed less than 1 year ago. Given that their food allergy was relatively new, these individuals may not have changed their food habits when the questionnaire had been administered, or in contrast, they may have changed all their habits before observing that they can consume some products. Moreover, 85% of the patients were younger than 16 years old and thus the questionnaire was filled by the parents. Maybe, the results would change if children had answered, especially for food consumed outside home when parents are not present. Also, even if dietary record is supposed to produce fairly accurate food intake, habitual eating pattern may be influenced by recording process and the reliability of records decrease over time (Biro' et al. (2002)). Moreover, it is well known that FFQs usually overestimated food intake compared to other nutritional assessment methods (Thompson and Byers, 1994). Indeed, as FFQ gives the possibility of choosing several foods in a given category e.g. appetizers, the larger the number of foods in the category the higher the probability of over estimating intake. Moreover, as individuals are surveyed only on a short period, dietary records do not catch the whole consumption, especially products occasionally consumed. Thus, some underestimation of certain food categories like seasonal or festival products could occur. Finally, this work reflects the difficulty and complexity inherent to the analysis of food consumption.

When the project MIRABEL was designed, the French version of the FAQLQ was not available. Therefore, we built a questionnaire with the aim to focus on anxiety linked to food allergy. We translated the four questions of the FAQLQ evaluating emotional impact and related to frightness and apprehension. We added other questions on the anxiety when eating products with the different labels (“guarantee without”, “may contain peanut”, “may contain other allergens”) or when products do not have PAL, and also when eating outside home (school canteen, restaurant, family/friends home). We are aware that this questionnaire is not validated and it could impact the measure of anxiety.

To conclude, this is the first survey on the consumption of specific food categories by peanut-allergy sufferers. The results showed that food consumption in MIRABEL patients is modulated by factors related to anxiety such as label reading, knowledge of threshold and concomitant allergies to tree nuts. Factors related to allergy characteristics and diet advice, do not influence food choices. These results must be confirmed by other consumption surveys on allergy sufferers and

compared with those of the general population. Waiting for, using the consumption data will directly improve risk assessment of peanut allergic individuals and findings will help allergists and risk managers to make diet advices.

Contributors

Alexandra Papadopoulos: involvement in developing the MIRABEL project, in statistical analysis and interpretation of the data, and in writing the manuscript.

Chabi Fabrice Elégbédé: involvement in data management and substantial involvement in revising the manuscript prior to submission.

Sarra Ait-Dahmane: involvement in the data collection and management.

Carine Dubuisson: involvement in the data collection and substantial involvement in revising the manuscript prior to submission.

Antoine Deschildre: involvement in the data collection, and substantial involvement in writing the manuscript.

Amélie Crépet: leader in the development and design of the MIRABEL project, involvement in the formulation of hypotheses, and in the acquisition, statistical analysis and interpretation of the data and in writing the manuscript.

Conflicts of interest

All the authors have approved the final version of the article and declare no conflict of interest.

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