ORIGINAL CONTRIBUTION

A population-based study of macronutrient intake according to mental health status with a focus on pure and comorbid anxiety and eating disorders

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Abstract

Purpose Eating disorders (ED) and anxiety impact food choices. In addition, comorbid anxiety seems to increase ED symptoms and severity. However, the association between such comorbidity and dietary intake is unknown. This population-based, cross-sectional study aimed to assess macronutrient intake according to mental health status (i.e., no disorder, pure and comorbid anxiety and ED).

Methods The study included $N = 24{,}771$ participants (74% female, mean age $= 53.2 \pm 13.7$ years) in the NutriNet-Santé cohort, who completed once the trait subscale of the State-Trait Anxiety Inventory (STAI-T; high anxiety: ≥ 40 points) between 2013 and 2016 and the SCOFF questionnaire screening for ED in 2014. The Expali algorithm was applied to categorize ED (no ED; restrictive: RS; bulimic: BL; hyperphagic: HP; other ED). Participants were divided into ten groups by crossing their anxiety status (two groups: low or high) and their ED status (five groups). Macronutrient intakes were evaluated from ≥ 3 24-h dietary records. Analyses of covariance (ANCOVA) and Dunnett-Hsu tests (reference = no disorder) were performed.

Results Significant differences in macronutrient intake were seen between the pure and comorbid forms, especially for RS and HP. Compared to the "no disorder" group, a significantly higher percentage of energy from carbohydrates, higher intakes of total carbohydrates, simple sugars, and plant-based protein, lower intakes of total fat, saturated and monounsaturated fatty acids, and cholesterol were observed in the comorbid anxiety + RS group, but not in the pure RS group. In contrast, significantly lower intakes of added sugar and plant-based protein, and a higher intake of cholesterol were observed in the pure HP group, but not in the comorbid anxiety + HP group. For BL and other ED, similar results were observed between the pure and comorbid forms.

Conclusion This large epidemiological study provided some support for differences in macronutrient intake between individuals with pure or comorbid anxiety and ED. Differences in intake were largely dependent on ED type. Future prospective studies and studies using clinically defined anxiety and ED are needed to elucidate causality as well as potential effect modification of the observed associations.

Keywords Comorbidity · Trait anxiety · Eating disorders · Dietary intake · Macronutrients · Population-based study

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Abbreviations

AN	Anorexia nervosa
ANCOVA	Analysis of covariance
BED	Binge-eating disorders
BL	Bulimic eating disorders
BMI	Body mass index
ED	Eating disorders
HP	Hyperphagic eating disorders
LS mean	Least-squares mean value
MUFA	Monounsaturated fatty acids
PUFA	Polyunsaturated fatty acids
RS	Restrictive eating disorders
SFA	Saturated fatty acids
STAI-T	Trait subscale of the State-Trait Anxiety Inventory

Introduction

Despite their considerable deleterious impact on daily life, frequent comorbidity, and increasing share of the global disease burden [1], mental disorders continue to receive insufficient research attention [2]. Among nearly twenty disorder categories in the DSM-5, feeding and eating disorders (ED) are characterized by a long-term disturbance in eating-related behaviors that has a substantial effect on physical and psychosocial functioning [3]. Restrictive disorders, especially anorexia nervosa (AN), bulimic disorders, and binge-eating disorders (BED) are considered typical ED and have been the main focus of ED research [4]. An ED-related increased mortality risk in young adulthood has been reported [5]. Yet, ED prevalence in middle age is not uncommon [6, 7]. Moreover, individuals suffering from ED often present with mental comorbidity, especially anxiety disorders [3, 5], which occur more frequently in that subgroup than in the general population [8].

Comorbidity is defined as the presence/accumulation of ≥ 2 distinct health conditions (physical and/or mental) in the same individual; it is linked with increased symptom severity, poorer health outcomes [9] and reduced quality of life [10]. In the case of ED, comorbid anxiety has been associated with worse ED psychopathology and increased ED symptom severity relative to pure ED or to comorbid depression [11, 12]. Longitudinal evidence has shown that mental comorbidity in ED can predict poor outcomes, including greater risk for relapse and premature death [13].

Whereas by definition ED feature problematic dietary intake [3], anxiety status, especially trait anxiety, has also been shown to impact dietary intake [14–16]. Individuals with AN avoid high-energy food rich in sugar and fat [17, 18], whereas intake of such foods seems to be positively associated with BED [18–20]. As regards anxiety disorders, epidemiological studies suggest an inverse association between diet quality and

risk of anxiety, although nutritional interventions are needed to confirm this effect [16]. Recent research revealed a decrease in total caloric intake and an increase in sugar consumption among young adults self-reporting anxiety symptoms [21]. However, there is a paucity of research on the link between macronutrient intake and anxiety [14–16]. Despite reported associations between trait anxiety and food/nutrient intake [14, 15, 17, 19, 20], possible mediating and/or moderating effects of anxiety regarding ED [22–24], and the high ED-anxiety comorbidity [3], no study, to our knowledge, has investigated dietary/nutrient intake among individuals with such comorbidity. We hypothesized that individuals with anxiety and/or ED have different macronutrient intakes from people without these disorders, and that unfavorable dietary intake (underscored by reduced nutrient diversity) is more pronounced in the case of mental comorbidity. Therefore, the aim of this population-based cross-sectional study was to evaluate macronutrient intakes according to the presence of anxiety and/or ED in pure or comorbid form, in a large adult sample.

Material and methods

The NutriNet-Santé web-cohort

NutriNet-Santé is a French ongoing prospective web-cohort launched in 2009. Details about its design, protocol, and main research goals can be found elsewhere [25]. Briefly, media announcements (e.g., television, radio, Internet, printed press) are used to recruit adults aged 18 years and older from the general population. Apart from age, the inclusion criteria pertain to comprehension of written French and ability to follow an Internet-based protocol (https://etude-nutrinet-sante.fr/). NutriNet-Santé was approved by the Institutional Review Board of the French Institute for Health and Medical Research and by the National Commission on Informatics and Liberty. The cohort is registered (# NCT03335644) at https://www.ClinicalTrials.gov. Interested volunteers provide informed consent before enrolling in the cohort.

At inclusion and yearly thereafter, participants are asked to fill out a set of five questionnaires (described below) gathering data on socio-demographic and lifestyle characteristics, anthropometrics, physical activity, diet, and health status. In addition, participants are asked to complete one nutrition- or health-related questionnaire per month, as part of the follow-up.

Measures

Dietary data

Macronutrient intake was the main outcome in this analysis. In NutriNet-Santé, dietary intake is evaluated at baseline

and every six months thereafter, each time using three non-consecutive 24-h dietary records. The dietary data collection tool has been validated against both dietitian interviews and various nutritional status biomarkers [26–28]. For each diet assessment day, participants were asked to report each food, beverage, and/or composite dish consumed, including the portion size/quantity, preparation method, and meal setting (place, time, etc.). Estimation of portion sizes is aided by validated photographs [29]. Next, NutriNet-Santé has its own food composition table that includes > 3500 items; it was used to estimate mean daily energy and nutrient intake [30]. All collected dietary data were weighted to respect the 5:7 and 2:7 ratios of weekdays and weekend days. For this analysis, each participant's dietary macronutrient intake was averaged across a minimum of three 24-h dietary records completed over a 2.5-year window around the anxiety assessment date (described below); it was energy-adjusted using the residual method [31]. Individuals with aberrant daily energy values (< 500 kcal [32]), with fewer than three 24-h records and pregnant females at any of the dietary assessment points, were excluded from the analysis. Likewise, individuals with prevalent or incident diabetes mellitus (type 1 or type 2) were ineligible for this study due to potential dietary specificities, especially regarding the intake of carbohydrates.

The following outcome variables related to macronutrient intake were selected: percentage energy in the total diet from carbohydrates, protein and fat, respectively; mean total carbohydrates (g/day); mean complex carbohydrates (g/day); mean simple sugars (g/day); mean added sugars (g/day); mean total protein (g/day); mean animal protein (g/day); mean plant-based protein (g/day); mean total fat (g/day); mean saturated fatty acids (SFA) (g/day); mean monoun-saturated fatty acids (MUFA) (g/day); mean polyunsaturated fatty acids (PUFA) (g/day); mean total cholesterol (mg/day); and mean total fiber (g/day).

Anxiety assessment

Anxiety was assessed during the period 2013–2016 by self-reports on the French version of the State-Trait Anxiety Inventory Form Y (STAI) which has been validated for use with general-population adults [33]. A total of 119,451 participants received the questionnaire, of whom 40,809 completed it once. STAI is one of the most widely used tools for the assessment of general anxiety proneness (as a state and as a trait), distinguishing it from depression [34]. State and trait anxiety are assessed by separate sets of 20 questions scored on a 4-point Likert scale from "Almost never" to "Almost always"; each set has its own psychometric evaluation. The higher the score, the greater the proneness to anxiety. Considering the objectives of this study and for purposes of consistency with prior research [14, 15], only the

trait-anxiety subscale (STAI-T) was used for this analysis. It evaluates trait anxiety, characterized by a relatively stable tendency to exhibit tension and anxiety (i.e., state anxiety) in a variety of situations. Trait anxiety measured by the STAI-T has been highly correlated with the generalized anxiety disorder [35]. As in prior studies, and given the lack of an established cut-off value, participants were considered as having "high trait anxiety" if their total score was ≥ 40 points or as having "low trait anxiety" if their total score was < 40 points [14].

ED assessment

Screening for ED took place in 2014 via the validated self-administered 5-item SCOFF questionnaire [36, 37]. In total, 125,279 enrollees received the SCOFF, of whom 51,073 returned a completed questionnaire. Participants who did not complete the SCOFF in 2014 but did so in 2017 were also included in the study. Each of the five items is a Yes/No question, with two or more positive responses indicating a strong likelihood of ED; the score has been shown to approximate actual ED point prevalence [38]. Next, the *Expali* validated algorithmic tool, based on the SCOFF score and Body mass index (BMI, kg/m²), was used to identify four ED types: restrictive (RS; including AN, atypical AN, and restrictive food intake disorder), bulimic (BL; including bulimia nervosa and low-frequency/short-duration bulimia nervosa), hyperphagic (HP; including BED and low-frequency/short-duration BED), and other (not otherwise specified) ED [39].

Mental health status with regard to anxiety and ED

Mental health status (i.e., no disorder, pure or comorbid ED and anxiety) was the main exposure in this analysis. Participants were divided into ten groups by cross-tabulating their anxiety status (low or high) and their ED status (no disorder, RS, BL, HP, or other ED). Therefore, the following ten groups were modeled as the exposure: no disorder; pure anxiety; pure RS; anxiety + RS; pure BL; anxiety + BL; pure HP; anxiety + HP; other ED only; and anxiety + other ED.

Covariate data

A validated socio-demographic questionnaire was used to collect self-reported data on age, sex, educational level, socio-professional category, marital status, alcohol use, and smoking status [40]. The International Physical Activity Questionnaire assessed physical activity levels based on an established scoring protocol [41]. Self-reported height and weight data were collected using a validated anthropometrics questionnaire [42], which allowed the calculation of BMI and its main categories (underweight: < 18.5, normal weight:

18.5–24.9, overweight: 25.0–29.9, and obese: ≥ 30.0). As all of the above questionnaires are administered at baseline and annually thereafter; in the present analysis we used covariate data collected within a 2.5-year window around the STAI-T completion date.

Statistical analysis

Descriptive characteristics across mental health status reflect number (percent) from chi-squared tests (categorical variables) and mean ($\pm$ SD) from ANOVA (continuous variables). The associations between mental health status (exposure) and macronutrient intake (outcome) were assessed using analyses of covariance (ANCOVA) adjusted for age (years, continuous scale), sex, alcohol consumption (g ethanol/day, continuous scale), smoking status (never, former, current smoker), physical activity level (low, moderate, high), educational level (less than high school, high school diploma or equivalent, college/undergraduate degree, graduate degree), socio-professional category (homemaker/disabled/unemployed, student, manual/blue collar worker, office work/administrative staff, professional/executive staff, retired), marital status (living alone or married/cohabiting), and number of 24-h dietary records (continuous scale). The underlying assumptions of the ANOVA/ANCOVA were checked and interpretation of the results was guided by published empirical evidence [43, 44]. Next, many-to-one comparisons applying the Dunnett-Hsu's method (reference = no disorder) were performed. The main tests were two-sided and $p < 0.050$ was considered as evidence for statistical significance. SAS version 9.4 (SAS Institute, Inc., Cary NC, USA) was used for all statistical analyses.

Results

Description of sample

In total, 35,472 participants completed both the STAI-T and SCOFF questionnaires ($n = 33,193$ with SCOFF in 2014; $n = 1559$ with SCOFF in 2017). Among them, those with fewer than three 24-h dietary records, with aberrant energy intake values and/or pregnant females ($n = 7222$) were excluded from the analysis. Next, participants with diabetes mellitus ($n = 1171$) and those lacking complete covariate data ($n = 2308$) were also excluded. Thus, 24,771 participants were included in the analysis (Fig. 1) (74.0% female; mean age = 53.2 ± 13.7 years). Participants included in the analysis were generally older, more likely to be retired, to report higher levels of physical activity, and were less likely to be obese or current smokers compared to those who were excluded from the analysis (all $p < 0.001$; data not tabulated). The individuals in our sample were divided into ten groups
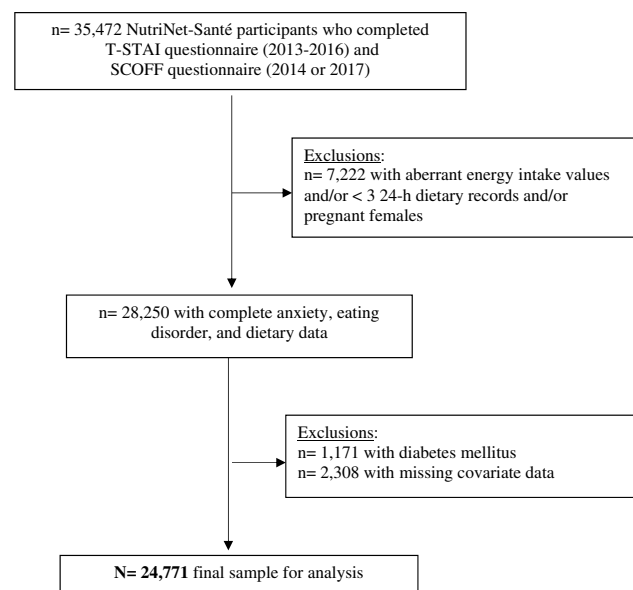

Fig. 1 Participant flowchart

according to their mental health status, as follows: no disorder $n = 13,881$; pure anxiety $n = 7977$; pure RS $n = 55$; anxiety + RS $n = 152$; pure BL $n = 236$; anxiety + BL $n = 461$; pure HP $n = 631$; anxiety + HP $n = 974$; other ED $n = 181$; and anxiety + other ED $n = 223$.

Descriptive characteristics across mental health status are presented in Table 1. In general, individuals with a mental health disorder (anxiety or ED) were more likely to be female, younger (except for HP and other ED), current smokers (except for HP), to live alone, and to consume less alcohol compared to those without a disorder (all $p < 0.001$). In the full sample, the mean number of 24-h dietary records was 8.8 ± 3.5. Overall, individuals with RS had the lowest caloric intake, which was 1595.1 (± 495.9) Kcal/day in the case of pure RS and 1438.7 (± 385.1) Kcal/day in the case of comorbid RS.

Association between mental health status and macronutrient intake

The main results in the form of least-squares (LS) means (standard error) are summarized in Table 2. Overall, ANCOVA revealed significant differences in mean intake across the ten groups for all macronutrients ($p < 0.001$) except for PUFA ($p > 0.185$). The detailed results from the main analysis are presented in Supplementary Figs. S1 to S16.

We observed that the anxiety + RS group had a significantly higher percentage of energy from carbohydrates (LS mean $\Delta = +4.6\%$/day, $p < 0.001$), higher intakes of total carbohydrates (LS mean $\Delta = +14.2$ g/day, $p < 0.001$),

Table 1 Descriptive characteristics of participants (N=24,771, NutriNet-Santé Study, France)

	No disorder		Pure anxiety		Pure restrictive disorder		Anxiety + restrictive disorder		Pure bulimic disorder		Anxiety + bulimic disorder		Pure hyperphagic disorder		Anxiety + hyperphagic disorder		Other eating disorders		Anxiety + other eating disorders	
	n=13,881		n=7977		n=55		n=152		n=236		n=461		n=631		n=974		n=181		n=223	
Sex																				
Female	9442	(68.0)	6406	(80.3)	47	(85.5)	149	(98.0)	205	(86.9)	425	(92.2)	484	(76.7)	852	(87.5)	134	(74.0)	187	(83.9)
Male	4439	(32.0)	1571	(19.7)	8	(14.6)	3	(2.0)	31	(13.1)	36	(7.8)	147	(23.3)	122	(12.5)	47	(26.0)	36	(16.1)
Age, years, mean (SD)	54.8	(13.4)	51.4	(13.8)	46.6	(15.1)	40.6	(12.5)	49.1	(13.8)	44.9	(13.0)	55.6	(11.9)	51.7	(12.9)	55.5	(13.7)	49.8	(14.1)
Age category																				
18–39 years	2295	(16.5)	1904	(23.9)	21	(38.2)	84	(55.3)	67	(28.4)	185	(40.1)	75	(11.9)	202	(20.7)	29	(16.0)	58	(26.0)
40–65 years	7533	(54.3)	4453	(55.8)	24	(43.6)	60	(39.5)	130	(55.1)	236	(51.2)	392	(62.1)	604	(62.0)	94	(51.9)	126	(56.5)
≥65 years	4053	(29.2)	1620	(20.3)	10	(18.2)	8	(5.3)	39	(16.5)	40	(8.7)	164	(26.0)	168	(17.3)	58	(32.0)	39	(17,5)
Educational level																				
≤High school	4652	(33.5)	2632	(33.0)	16	(29.1)	38	(25.0)	76	(32.2)	148	(32.1)	254	(40.3)	419	(43.0)	89	(49.2)	105	(47.1)
>High school	9229	(66.5)	5345	(67.0)	39	(70.9)	114	(75.0)	160	(67.8)	313	(67.9)	377	(59.7)	555	(57.0)	92	(50.8)	118	(52.9)
Employment status[a]																				
Without professional activity	982	(7.1)	902	(11.3)	6	(10.9)	32	(21.1)	24	(10.2)	57	(12.4)	40	(6.3)	126	(12.9)	11	(6.1)	36	(16,1)
With professional activity	7052	(50.8)	4597	(57.6)	34	(61.8)	106	(69.7)	146	(61.9)	336	(72.9)	311	(49.3)	552	(56.7)	84	(46.4)	125	(56,1)
Retired	5847	(42.1)	2478	(31.1)	15	(27.3)	14	(9.2)	66	(28.0)	68	(14.8)	280	(44.4)	296	(30.4)	86	(47.5)	62	(27.8)
Marital status																				
Living alone	3037	(21.9)	2140	(26.8)	15	(27.3)	68	(44.7)	64	(27.1)	126	(27.3)	153	(24.3)	278	(28.5)	43	(23.8)	52	(23.3)
Married/cohabiting	10,844	(78.1)	5837	(73.2)	40	(72.7)	84	(55.3)	172	(72.9)	335	(72.7)	478	(75.8)	696	(71.5)	138	(76.2)	171	(76.7)
Physical activity[b]																				
Low	2635	(19.0)	2002	(25.1)	10	(18.2)	31	(20.4)	54	(22.9)	119	(25.8)	152	(24.1)	287	(29.5)	40	(22.1)	55	(24.7)
Moderate	5633	(40.6)	3386	(42.4)	25	(45.5)	74	(48.7)	78	(33.1)	186	(40.4)	255	(40.4)	397	(40.8)	61	(33.7)	86	(38.6)
High	5613	(40.4)	2589	(32.5)	20	(36.4)	47	(30.9)	104	(44.1)	156	(33.8)	224	(35.5)	290	(29.8)	80	(44.2)	82	(36.8)
Body mass index (BMI, kg/m², mean (SD)	23.9	(3.8)	23.4	(4.1)	20.1	(3.1)	17.9	(2.7)	22.9	(2.9)	22.8	(3.7)	27.5	(5.1)	27.9	(5.8)	26.9	(5.4)	25.6	(5.2)

Table 1 (continued)

	No disorder		Pure anxiety		Pure restrictive disorder		Anxiety+restrictive disorder		Pure bulimic disorder		Anxiety+bulimic disorder		Pure hyperphagic disorder		Anxiety+hyperphagic disorder		Other eating disorders		Anxiety+other eating disorders	
	n=13,881		n=7977		n=55		n=152		n=236		n=461		n=631		n=974		n=181		n=223	
BMI category																				
Underweight and normal weight (<24.9)	9469	(68.2)	5690	(71.3)	55	(100.0)	152	(100.0)	211	(89.4)	414	(89.8)	191	(30.3)	300	(30.8)	77	(42.5)	118	(52.9)
Overweight and obese (≥25.0)	4412	(31.8)	2287	(28.7)	0	(0.0)	0	(0.0)	25	(10.6)	47	(10.2)	440	(69.7)	674	(69.2)	104	(57.5)	105	(47.1)
Smoking status																				
Non-smoker (including former smokers)	12,616	(90.9)	7146	(89.6)	42	(76.4)	126	(82.9)	214	(90.7)	400	(86.8)	581	(92.1)	858	(88.1)	162	(89.5)	191	(85.7)
Smoker	1265	(9.1)	831	(10.4)	13	(23.6)	26	(17.1)	22	(9.3)	61	(13.2)	50	(7.9)	116	(11.9)	19	(10.5)	32	(14.3)
Alcohol use, g ethanol/day, mean (SD)	7.7	(10.2)	6.6	(9.3)	6.0	(11.2)	3.8	(6.6)	6.5	(8.5)	5.6	(8.0)	7.0	(9.9)	5.9	(8.9)	7.8	(11.5)	6.7	(9.7)
Total energy intake, Kcal/day, mean (SD)	1821.4	(486.9)	1779.1	(461.8)	1595.1	(495.9)	1438.7	(385.1)	1701.8	(468.2)	1651.5	(432.4)	1713.1	(494.1)	1688.0	(490.1)	1722.0	(546.7)	1650.1	(468.7)
Number of 24-h dietary records, mean (SD)	9.0	(3.5)	8.6	(3.5)	8.3	(3.6)	8.8	(3.4)	8.7	(3.7)	7.9	(3.4)	8.9	(3.6)	8.3	(3.6)	8.4	(3.8)	8.1	(3.3)

Values refer to number (%) except when noted otherwise, derived from chi-squared tests or ANOVA, as appropriate, and rounded off to one decimal place; all P values < 0.001

ANCOVA analysis of covariance

[a] "Without professional activity" includes "homemaker/disabled/unemployed" and "student"

[b] Assessed with the International Physical Activity Questionnaire-Short Form according to established scoring criteria

Table 2 Macronutrient intake according to mental health status ($N=24,771$, NutriNet-Santé Study, France)

	No disorder		Pure anxiety		Pure restrictive disorder		Anxiety+restrictive disorder		Pure bulimic disorder		Anxiety+bulimic disorder		Pure hyperphagic disorder		Anxiety+hyperphagic disorder		Other eating disorders		Anxiety+other eating disorders	
	$n=13,881$		$n=7977$		$n=55$		$n=152$		$n=236$		$n=461$		$n=631$		$n=974$		$n=181$		$n=223$	
Energy from carbohydrates (%)	41.0	(0.1)	**41.4**	(0.1)	41.8	(0.8)	**45.6**	(0.5)	41.4	(0.4)	41.2	(0.3)	**39.7**	(0.3)	**40.3**	(0.2)	40.4	(0.4)	40.3	(0.4)
Energy from protein (%)	16.7	(0.1)	**16.5**	(0.1)	**18.2**	(0.4)	**17.6**	(0.3)	17.0	(0.2)	**17.4**	(0.1)	**18.0**	(0.1)	**17.6**	(0.1)	**17.4**	(0.2)	**17.5**	(0.2)
Energy from fat (%)	38.8	(0.1)	38.8	(0.1)	**36.5**	(0.7)	**33.5**	(0.5)	38.1	(0.4)	**38.0**	(0.3)	38.7	(0.2)	38.7	(0.2)	38.7	(0.4)	38.9	(0.4)
Total carbohydrates (g/day)	195.6	(0.5)	**196.7**	(0.5)	196.9	(3.6)	**209.8**	(2.2)	196.5	(1.8)	196.7	(1.3)	**189.6**	(1.1)	**192.8**	(0.9)	191.7	(2.0)	192.8	(1.8)
Complex carbohydrates (g/day)	104.4	(0.4)	**105.6**	(0.4)	102.0	(3.0)	105.5	(1.8)	102.6	(1.5)	104.4	(1.1)	101.9	(1.0)	103.6	(0.8)	102.9	(1.7)	100.8	(1.5)
Simple sugars (g/day)	90.6	(0.4)	90.6	(0.4)	94.3	(2.9)	**103.5**	(1.8)	93.3	(1.4)	91.7	(1.0)	**87.2**	(0.9)	**88.5**	(0.8)	88.1	(1.6)	91.3	(1.5)
Added simple sugars (g/day)	37.1	(0.3)	**38.0**	(0.3)	37.3	(2.1)	35.4	(1.3)	35.6	(1.0)	36.6	(0.8)	**35.1**	(0.7)	36.3	(0.5)	35.3	(1.2)	37.0	(1.1)
Protein (g/day)	77.4	(0.2)	**76.9**	(0.2)	81.3	(1.6)	78.0	(1.0)	78.2	(0.8)	**79.3**	(0.6)	**81.7**	(0.5)	**80.5**	(0.4)	79.6	(0.9)	**80.1**	(0.8)
Animal protein (g/day)	52.2	(0.2)	51.9	(0.2)	55.1	(1.8)	49.7	(1.1)	51.5	(0.9)	53.2	(0.7)	**57.2**	(0.6)	**55.7**	(0.5)	**55.2**	(1.0)	**55.5**	(0.9)
Plant-based protein (g/day)	25.2	(0.1)	25.1	(0.1)	26.1	(0.7)	**28.3**	(0.4)	**26.7**	(0.4)	**26.1**	(0.3)	**24.5**	(0.2)	24.7	(0.2)	24.5	(0.4)	24.7	(0.4)
Fat (g/day)	82.6	(0.2)	82.5	(0.2)	79.9	(1.5)	**76.0**	(0.9)	81.8	(0.7)	81.4	(0.5)	83.0	(0.5)	82.8	(0.4)	83.2	(0.8)	83.0	(0.7)
SFA (g/day)	34.1	(0.1)	34.2	(0.1)	33.1	(0.9)	**30.6**	(0.5)	**32.6**	(0.4)	**32.9**	(0.3)	34.1	(0.3)	34.1	(0.2)	34.1	(0.5)	34.5	(0.4)
MUFA (g/day)	30.9	(0.1)	30.8	(0.1)	29.6	(0.8)	**28.1**	(0.5)	31.0	(0.4)	30.6	(0.3)	31.1	(0.2)	31.0	(0.2)	31.4	(0.4)	30.8	(0.4)
PUFA (g/day)	11.5	(0.1)	11.5	(0.1)	11.2	(0.4)	11.6	(0.3)	12.1	(0.2)	11.7	(0.2)	11.5	(0.1)	11.6	(0.1)	11.5	(0.2)	11.6	(0.2)
Cholesterol (mg/day)	320.6	(1.6)	317.1	(1.7)	328.6	(12.4)	**273.7**	(7.6)	314.5	(6.1)	317.0	(4.5)	**340.3**	(3.9)	327.6	(3.2)	334.1	(6.9)	327.0	(6.3)
Fiber (g/day)	19.7	(0.1)	**19.5**	(0.1)	22.1	(0.7)	**24.6**	(0.4)	**22.0**	(0.4)	**21.1**	(0.3)	19.3	(0.2)	19.4	(0.2)	19.1	(0.4)	19.8	(0.4)

Values refer to least-squares means (standard error). ANCOVA models adjusted for age, sex, BMI, smoking status, physical activity level, socio-professional category, marital status, alcohol consumption, and number of 24-h dietary records. $p < 0.001$ for all tests/variables except for PUFA ($p > 0.185$)

Least-squares means significantly different from the reference category (=no disorder) in the Dunnett-Hsu's tests presented in bold

Anxiety evaluated by Spielberger Trait Anxiety Inventory (STAI-T) form Y with threshold of 40 points; score range between 20 and 80 points, with higher scores reflecting higher proneness to anxiety. Types of eating disorders categorized using the *Expali* algorithm applied to SCOFF questionnaire data. Values are rounded off to one decimal place

ANCOVA analysis of covariance, *BMI* body mass index, *MUFA* monounsaturated fatty acids, *PUFA* polyunsaturated fatty acids, *SFA* saturated fatty acids

simple sugars (LS mean $\Delta = +12.9$ g/day, $p < 0.001$), plant-based protein (LS mean $\Delta = +3.1$ g/day, $p < 0.001$), lower intakes of total fat (LS mean $\Delta = -6.6$ g/day, $p < 0.001$), SFA (LS mean $\Delta = -3.6$ g/day, $p < 0.001$), MUFA (LS mean $\Delta = -2.8$ g/day, $p < 0.001$), and cholesterol (LS mean $\Delta = -46.8$ mg/day, $p < 0.001$) in comparison with the "no disorder" group, whereas the results for the pure RS group were not significant. Both the pure RS and anxiety + RS groups had a significantly higher percentage of energy from protein (LS mean $\Delta = +1.5$%/day, $p < 0.002$; LS mean $\Delta = +0.9$%/day, $p < 0.004$, respectively), a lower percentage of energy from fat (LS mean $\Delta = -2.3$%/day, $p < 0.017$; LS mean $\Delta = -5.3$%/day, $p < 0.001$, respectively), and a higher intake of fiber (LS mean $\Delta = +2.4$ g/day, $p < 0.008$; LS mean $\Delta = +4.9$ g/day, $p < 0.001$, respectively) compared to the "no disorder" group.

The anxiety + BL group had a significantly higher percentage of energy from protein (LS mean $\Delta = +0.7$%/day, $p < 0.001$), a lower percentage of energy from fat (LS mean $\Delta = -0.8$%/day, $p < 0.020$), and a higher intake of protein (LS mean $\Delta = +1.9$ g/day, $p < 0.001$) than the "no disorder" group, whereas the results for the pure BL were not significant. Both pure and comorbid BL had significantly higher intakes of plant-based protein (LS mean $\Delta = +1.5$ g/day, $p < 0.001$; LS mean $\Delta = +0.9$ g/day; $p < 0.005$, respectively), fiber (LS mean $\Delta = +2.3$ g/day; $p < 0.001$, LS mean $\Delta = +1.4$ g/day; $p < 0.001$, respectively), and a lower intake of SFA (LS mean $\Delta = -1.6$ g/day, $p < 0.003$; LS mean $\Delta = -1.2$ g/day, $p < 0.001$, respectively) compared to the "no disorder" group.

Next, the pure HP group had significantly lower intakes of added sugars (LS mean $\Delta = -2.0$ g/day, $p < 0.011$), plant-based protein (LS mean $\Delta = -0.7$ g/day, $p < 0.013$), and a higher intake of cholesterol (LS mean $\Delta = +19.8$ mg/day, $p < 0.001$) in comparison with the "no disorder" group. Both pure and comorbid HP were associated with significantly lower percentage of energy from carbohydrates (LS mean $\Delta = -1.3$%/day, $p < 0.001$; LS mean $\Delta = -0.7$%/day, $p < 0.004$, respectively), higher percentage of energy from protein (LS mean $\Delta = +1.3$%/day, $p < 0.001$; LS mean $\Delta = +0.9$%/day, $p < 0.001$, respectively), lower intakes of total carbohydrates (LS mean $\Delta = -6.0$ g/day, $p < 0.001$; LS mean $\Delta = -2.9$ g/day, $p < 0.002$, respectively), simple sugars (LS mean $\Delta = -3.4$ g/day, $p < 0.001$; LS mean $\Delta = -2.1$ g/day, $p < 0.030$, respectively), higher intakes of total protein (LS mean $\Delta = +4.3$ g/day, $p < 0.001$; LS mean $\Delta = +3.1$ g/day, $p < 0.001$, respectively), and animal protein (LS mean $\Delta = +5.0$ g/day, $p < 0.001$; LS mean $\Delta = +3.5$ g/day, $p < 0.001$, respectively) compared to the "no disorder" group.

The anxiety + other ED group had a significantly higher intake of protein (LS mean $\Delta = +2.7$%/day, $p < 0.006$), whereas the results for the other ED group were not significant. Both pure and comorbid other ED had higher % protein (LS mean $\Delta = -0.7$%/day, $p < 0.020$; LS mean $\Delta = -0.8$%/day, $p < 0.001$, respectively), and higher intakes of animal protein (LS mean $\Delta = +3.0$ g/day, $p < 0.031$; LS mean $\Delta = +3.3$ g/day, $p < 0.004$, respectively) compared to the "no disorder" group.

Finally, the pure anxiety group had a significantly higher percentage of energy from carbohydrates (LS mean $\Delta = +0.6$%/day, $p < 0.001$), a lower percentage of energy from protein (LS mean $\Delta = -0.2$%/day, $p < 0.002$), higher intakes of total carbohydrates (LS mean $\Delta = +1.1$ g/day, $p < 0.033$), complex carbohydrates (LS mean $\Delta = +1.2$ g/day, $p < 0.003$), added sugars (LS mean $\Delta = +0.9$ g/day, $p < 0.001$), lower intakes of protein (LS mean $\Delta = -0.5$ g/day, $p < 0.033$), and fiber (LS mean $\Delta = -0.2$ g/day, $p < 0.014$) compare to the "no disorder" group.

Discussion

This large population-based cross-sectional study revealed some significant differences in macronutrient intake according to mental health status regarding anxiety and ED. The observed differences largely depended on ED type.

Our main hypotheses that individuals with anxiety and/or ED would display different macronutrient intake compared to their counterparts without mental disorders and that unfavorable dietary intake (*e.g.*, reduced diversity) would be more pronounced in the case of comorbidity were only partially supported. The strongest support for our hypotheses was found for RS. Generally, the difference in macronutrient intake between pure and comorbid forms seemed to be well pronounced in RS and much less pronounced in BL and other ED. Even though macronutrient intake exhibited similar trends across pure and comorbid ED, we observed a number of differences in terms of significance levels and absolute values in comparison with the "no disorder" group.

To our knowledge, this is the first epidemiological study investigating dietary intake across pure and comorbid anxiety-ED conditions among adults recruited from the general population. Prior research has reported that individuals with depression and anxiety, especially in the case of comorbidity, have a lower dietary quality than healthy controls [45]. Another previous study—based on a sample of 27,111 middle-aged male smokers—reported dietary intake according to the presence of pure or comorbid mental disorders [46]. These authors studied depression, anxiety, insomnia, and the comorbidity of all three disorders and did not find marked differences in micro- or macronutrient intake according to mental health status [46].

Several case–control studies have reported that compared to healthy controls, people with AN (i.e., the most common form of RS) were less likely to prefer/consume

fat, animal protein, and were more likely to consume plant-based protein [17, 18] and vegetables [47, 48], which is consistent with the results of our study. We found that fiber intake was higher in both pure and comorbid RS, whereas the pure anxiety group had a significantly lower fiber intake in comparison with the "no disorder" group. It has been evoked that a high-fiber diet might be used by individuals suffering from AN to alleviate symptoms of gastroparesis [49]. In addition, the inverse association between dietary fiber intake and anxiety reported in some studies [50] might not be universal but rather dependent on sex and obesity status [51]. Moreover, we found that the restrictive eating behaviors and reduced dietary diversity that are typical of AN were more pronounced in comorbid than in pure RS. The lower intake of total fat, SFA, MUFA, and dietary cholesterol and the higher intake of plant-based protein observed only in the group with anxiety-RS comorbidity but not in pure RS group, suggested that dietary homogeneity (*e.g.,* exclusion of red meat and meat products) is more pronounced in the case of comorbidity. A literature review reported that the more anxious individuals with AN were, the more likely they were to engage in restrictive eating behaviors to avoid weight gain [52]. Also, the observed higher intake of simple sugars, but not added sugars, among those with anxiety-RS comorbidity may reflect their preference for plant-based foods such as fruit (i.e., a source of fructose).

In our study, the highest intake of cholesterol was seen in those with pure HP; it was nearly 20 mg/day higher than that observed in the "no disorder" group. Findings based on a nationally-representative sample of U.S. adults indicated that among the three main ED types, only BED (*i.e.*, the most common form of HP) was associated with high cholesterol intake [53], which is consistent with our results. Interestingly, unlike pure HP, cholesterol intake in the anxiety + HP group was not significantly different from that in the "no disorder" group. Likewise, the differences from the "no disorder" group in added sugar intake were −0.8 g/day ($p > 0.618$) and −2.0 g/day ($p < 0.011$) for comorbid and pure HP, respectively. These results suggest that comorbidity might not have a harmful impact on dietary intake among individuals suffering from HP. Research with obese females revealed that BED mediated the association between anxiety and caloric intake [54]. A community-based study also reported that anxiety status partly explained the variance of binge-eating symptoms, which suggested that anxiety might have a role in the development and maintenance of BED [24]. However, these authors indicated that binge-eating might attenuate anxiety symptoms [24], which could help explain the present findings. As regards BL, the fact that individuals could also present AN and BED-like behaviors [18] might obscure any substantial differences between the pure and comorbid forms.

In terms of potential psychosocial mechanisms of the observed associations, the results of network analyses have suggested that ED and anxiety (measured with STAI-T) might be linked through avoidance of social eating and low self-esteem [55]. It has also been shown that anxiety disorders were more closely linked with the severity of ED symptoms than were affective or substance-related disorders [56]. Regarding physiological mechanisms, there is a growing body of diet-mental health research exploring disruptions in circadian rhythm, gut-brain axis regulation, and hormonal homeostasis, leading to systemic and neuro-inflammation and oxidative stress [57, 58].

This study is subject to some limitations. First, the cross-sectional design does not allow for causal or chronological inference. Prior research has shown that dietary intake and mental health status can mutually impact each other [14, 15, 58, 59]. Future prospective research in this domain is needed to shed light not only on causality but also on the potential bidirectional association between macronutrient intake and comorbidity of anxiety and ED. Even though the present cross-sectional data did not permit the establishment of the chronological sequence of anxiety and ED onset, it appears that anxiety is more likely to precede ED than vice versa [60, 61]. Second, our study is based on trait anxiety which is regarded as a relatively stable personality characteristic. Even though trait anxiety and ED were assessed with validated tools, neither one could be considered as representing a clinical diagnosis. The proportion of participants with high anxiety proneness or with ED in our study was somewhat higher than the respective proportions reported by recent literature reviews [62, 63]. Yet, it should be kept in mind that these disorders are likely under-diagnosed in the general population [4, 5, 64]. Next, categorizing participants into ten groups according to their mental health status resulted in several groups with a relatively small number of individuals (e.g., pure RS: $n = 55$), which may have had an impact on the available statistical power. Further, in spite of the large number of covariates used for statistical adjustment, residual unmeasured confounding (e.g., ethnoracial status, family history of anxiety or ED) could not be excluded. Finally, as with any epidemiological cohort, NutriNet-Santé relies on voluntary participation, which might introduce selection bias and might limit generalizability, as it includes a higher proportion of females and individuals of higher socio-economic status compared to the respective proportions found in the general French population [65]. Likewise, dietary intake in the cohort exhibited some differences compared to that found in a representative sample of the French population [66].

Despite these limitations, the study presents several important strengths. To our knowledge, it is the first epidemiological study to reveal associations between comorbidity of anxiety-ED and macronutrient intake. All data

were collected with validated questionnaires, using a very large and diverse sample of adults recruited from the general population. Moreover, macronutrient intakes were estimated based on a mean of nearly nine 24-h dietary records, validated against dietitian interviews and various biomarkers of nutritional status [26–28]. Given the high prevalence of mental comorbidity, the results of our study can be used for public health needs assessment. Our findings could help guide future epidemiological research, interventions, and policy development in the field of mental health, which is attracting attention in the Covid-19 pandemic context [67] yet is still far from being a public health priority [2].

Conclusions

This large population-based epidemiological study found some support for differences in macronutrient intake among individuals with pure or comorbid anxiety and ED and those without either disorder; these differences depended primarily on the ED type. Future prospective studies using clinically defined anxiety and ED featuring mediation and moderation analyses are needed to elucidate causality as well as potential effect modification of the observed associations.

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