Article

Association of Dietary Intake with Interoception and Gastric Myoelectric Activity in Women with Binge Eating Disorder and Bulimia Nervosa

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Abstract

Background: Women with binge eating disorder (BED) and bulimia nervosa (BN) usually consume high-calorie meals with variable macro- and micronutrient compositions and have a disturbed perception of gastric fullness. The association of dietary intake with gastric interoception and gastric myoelectric activity (GMA) is poorly studied. This study examined the link between GMA/interoception and dietary intake in women with eating disorders (ED) compared to age/body mass index (BMI)-matched controls.

Methods: A total of 18 women diagnosed with BED (n = 9) or BN (n = 9) and 18 age/BMI-matched controls (MC) group were enrolled in this study. Interoception was measured by measuring the volume of ingested water until the feeling of maximal fullness within 5 minutes (5 min water load test; 5 min WL). GMA was measured using transcutaneous electrogastrography (EGG) before and after water ingestion. Dietary intake was recorded using the multipath 24-hour recall of the two proceeding days. Then, food processor software was used to analyze the macro- and micronutrient composition of their diets. The volume of water load (WL) and the EGG's average dominant frequency (ADF) were correlated with macro- and micronutrient intakes.

Results: Compared to the matched controls, women with ED had a significantly higher consumption of total calories, fat, saturated fat, carbohydrate (CHO), fibers, and sugar, with further higher intakes of total calories and trans-fat in the BED compared to the BN subgroup ($p < 0.05$). Moreover, the BED group showed higher vitamin B1, copper, and iron intakes than the MC group (p-values were <0.05). The volume of 5 min WL was higher in the BN group than in the control group (697.50 ± 186.45 vs. 466.67 ± 120.44 mL; $p < 0.05$) and the BED group (697.50 ± 186.45 vs. 488.75 ± 152.17 mL; $p < 0.05$). In the BED group, ADF showed a significant positive correlation with CHO, sugar, and vitamin B12 intakes (r = 0.700, 0.719, and 0.766, respectively; $p < 0.05$). Additionally, the 5 min WL volume was negatively correlated with the fiber and sodium intake in the BN group (r = –0.710 and –0.724, respectively; $p < 0.05$).

Conclusion: Specific dietary approaches might be effective for women with BN and BED. Women with BN may benefit from diets that are higher in fiber and sodium. In contrast, those with BED may find diets rich in simple carbohydrates and vitamin B12 helpful for regulating their eating habits and gastric mobility. Future research is encouraged to test this finding prospectively.

Keywords

binge eating disorder; bulimia nervosa; dietary intake; gastric interoception; gastric myoelectric activity

Introduction

Eating disorders (EDs) are mental disorders characterized by disturbed eating behaviors in the form of ingestion of large or tiny amounts of food that can significantly impair physical, cognitive, and social health [1]. The WHO International Classification of Diseases (ICD-11) and the Diagnostic and Statistical Manual of Mental Disorders, fifth

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Table 1. Macronutrient contents of the diets of participants in the study groups.

Variables	MC group (n = 18) mean ± SD or median (IQR)	BN group (n = 9) mean ± SD or median (IQR)	BED group (n = 9) mean ± SD or median (IQR)	F/H values	*p*-value
Total calories (kcal/day)	1328.65 ± 272.87	1829.77 ± 305.52[a]	2276.87 ± 410.10[a, b]	26.27	<0.001
Protein intake (g/day)	61.62 ± 20.83	83.19 ± 31.26	97.76 ± 17.71[a]	7.46	0.002
CHO intake (g/day)	162.43 ± 40.33	225.74 ± 38.59[a]	278.01 ± 60.22[a]	19.22	<0.001
Total fiber (g/day)	10.32 (12.87)	22.99 (19.22)[a]	18.67 (8.37)[a]	8.93	0.012
Total sugar (g/day)	51.54 (23.46)	72.17 (23.31)[a]	76.47 (68.87)[a]	10.43	0.005
Added sugar (g/day)	9.36 (22.86)	36.80 (34.96)	42.39 (55.36)[a]	9.08	0.011
Fat intake (g/day)	49.20 (22.95)	66.72 (12.15)[a]	99.93 (51.32)[a]	15.34	<0.001
Saturated fat (g/day)	14.54 (8.54)	20.62 (16.66)[a]	26.19 (21.95)[a]	13.99	0.001
Monounsaturated fat (g/day)	8.55 (6.50)	7.58 (8.00)	13.47 (14.48)	1.89	0.388
Polyunsaturated fat (g/day)	5.09 (5.76)	4.98 (6.94)	10.39 (6.09)	2.51	0.284
Trans-fat (g/day)	0.01 (0.12)	0.01 (0.06)	0.20 (0.31)[b]	4.99	0.082

MC, matched control; BN, bulimia nervosa; BED, binge eating disorder; IQR, interquartile range; CHO, carbohydrate; SD, standard deviation. Data are presented as means ± SD or median and IQR. According to the normality of the data, a one-way analysis of variance (ANOVA) or the Kruskal–Wallis test was used; [a] indicates significance versus the MC group and [b] indicates significance versus the BN group using Tukey's post hoc test or the Mann–Whitney U test; $p < 0.05$.

edition (DSM-5) text version classify EDs into three major types: anorexia nervosa (AN), bulimia nervosa (BN), and binge eating disorder (BED) [2]. The prevalence of EDs in females is about three times that in males, and the global point prevalence rate was about 7.8% between 2013 and 2018 [3]. The prevalence rates in Saudi Arabia were reported to be high, with a prevalence rate of 14.8% for BED and 8.7% for BN [4].

Previous reports showed that patients with AN and BED have postprandial disturbed gastrointestinal functions, which consequently affects the development of purging symptoms. Additionally, several reports have stated that patients with BN have delayed gastric emptying [5]. It has been reported that the slower the gastric emptying, the more frequent the vomiting in patients with BN [6]. However, some studies showed an insignificant difference between patients with BN and those without EDs, especially if there was no vomiting as a compensatory mechanism in BN [5,7]. From a physiological point of view, gastric distension and emptying play an essential role in the development of satiation, but gastric sensations might be disturbed in patients with EDs [8]. Interoception refers to the perception of afferent signals from gastrointestinal (GIT) organs, especially the stomach. Gastric distention during the ingestion of food or fluids stimulates mechanosensitive spinal and vagal afferent fibers, which transmit sensory signals from the stomach to specific areas in the brain responsible for the perception of satiety [9]. Blunted sensitivity to these afferent signals leads to excessive dietary intake due to delayed satiation. Gastric motility is also involved in the development of satiation [8]. Based on the previous scenario, abnormal interoception and gastric myoelectric activity play a role in the pathogenesis of BN and BED.

The water load test (WL test) is an objective, laboratory-based method for measuring gastric interoception. It involves drinking water until satiety and then to maximal fullness within 2 to 5 minutes [10,11]. Electrogastrography (EGG) records gastric myoelectric activity (GMA) through skin electrodes placed on the epigastrium. GMA is a slow wave rhythm and spike potential that originates from the pacemaker interstitial cells of Cajal [12]. Gastric interoception and GMA in patients with ED are infrequently studied in the literature. van Dyck *et al.* [8] found that patients with BED and BN had delayed satiety, as measured through the WL test and abnormal GMA. Another study stated that the percentage of normogastria in the ED group was less than in the healthy control, and the duration of the EDs was associated with the percentage of bradygastria [13].

Various dietary intakes significantly impact interoception, gastric emptying, and GMA. It was reported that the caloric density and physical characteristics of the ingested foods affect gastric emptying rates [14]. There has been little study on enteroception and GMA in relation to dietary intake in patients with BED and BN. Monitoring the GMA patterns associated with different dietary regimens may help in tailoring a diet that may normalize GMA and disturbed interoception. Taken together, this study aimed to examine the association of interoception and GMA of the stomach with different dietary intakes in patients with EDs and age/BMI-matched controls.

Table 2. Micronutrient contents of the diets of participants in the study groups.

Variables	MC group (n = 18)	BN group (n = 9)	BED group (n = 9)	F/H values	*p*-value
	mean ± SD or median (IQR)	mean ± SD or median (IQR)	mean ± SD or median (IQR)		
Vitamin B1 (mg/day)	0.36 (0.33)	0.85 (0.31)	0.87 (0.17)[a]	6.94	0.031
Vitamin B2 (mg/day)	0.82 (0.49)	1.18 (0.59)	0.92 (0.87)	2.36	0.308
Vitamin B6 (mg/day)	0.90 (0.39)	0.98 (0.60)	0.73 (1.13)	1.45	0.485
Vitamin B12 (mcg/day)	1.84 (2.12)	1.70 (2.06)	1.88 (1.40)	0.04	0.978
Vitamin C (mg/day)	21.73 (58.61)	30.19 (50.20)	31.15 (37.16)	0.31	0.857
Vitamin D (IU/day)	44.32 (89.43)	93.04 (70.65)	78.27 (97.77)	0.93	0.629
Iron (mg/day)	7.86 ± 2.71	13.49 ± 3.07[a]	13.86 ± 3.96[a]	14.82	<0.001
Copper (mg/day)	0.42 (0.30)	0.51 (0.35)	0.78 (0.53)[a]	5.66	0.059
Sodium (mg/day)	1890 (1209)	2184 (918)	2574 (1608)	3.19	0.203
Potassium (mg/day)	1334.32 ± 401.33	1758.37 ± 427.09[a]	1627.55 ± 381.20	3.57	0.040
Zinc (mg/day)	4.08 ± 1.66	4.73 ± 1.36	5.24 ± 1.41	1.69	0.201

MC, matched control; BN, bulimia nervosa; BED, binge eating disorder. Data are presented as means ± SD or median and IQR. According to the normality of the data, a one-way ANOVA or the Kruskal–Wallis test was used; [a] indicates significance versus the MC group using Tukey's post hoc test or the Mann–Whitney U test; $p < 0.05$.

Materials and Methods

Study Participants

This study included 36 female participants (aged 18 to 60 years). The inclusion criterion was the absence of chronic diseases (for controls) or a diagnosis of BN or BED (for cases). Both controls and cases had no gastrointestinal (GIT) diseases or previous GIT surgeries and were not taking medication that affected GIT motility. Pregnant and lactating individuals who had undergone GI surgery such as bariatric surgery, those with an existing chronic disease or gastrointestinal illness, or those with psychotic disorders that could affect their participation in and commitment to the study were excluded. The participants were divided into an eating disorder (ED) group (n = 18) and a matched control (MC) group (n = 18), in which participants were matched in terms of age and body mass index. The study was conducted between February and December 2022 at the Nutrition Clinic, the College of Applied Medical Sciences, King Saud University. ED cases were known cases diagnosed with binge eating disorder (BED; n = 9) and bulimia nervosa (BN; n = 9) and recruited from the Psychiatric Clinic and the College of Medicine. The patients with EDs were diagnosed according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5), and were screened using version 6 of the Eating Disorder Examination (EDE-Q) 6.0 Questionnaire—Arabic validated version [15]. EDE-Q 6.0 is a self-reported questionnaire consisting of 24 items. It reflects the psychopathology of eating disorders on four subscales: restraint eating, eating concerns, shape concerns, and weight concerns. The psychiatric medications administered to the BN group included Fluoxetine (22.2%), Venlafaxine (11.1%), Risperidone (11.1%), Methylphenidate (11.1%), Escitalopram (11.1%), and Lamotrigine (11.1%); some patients were not administered any medication (66.6%) and some patients took more than one medication (33.4%). For the participants in the BED group, the medication included Fluoxetine (55.6%), Venlafaxine (11.1%), Natalizumab (11.1%), Vortioxetine (11.1%), and Methylphenidate (11.1%), as well as no medication (11.1%) and more than one medication (11.1%). The study protocol was conducted in accordance with the Declaration of Helsinki and reviewed and approved by The Institutional Review Board of the College of Medicine, King Saud University, on 18 January 2022 under reference number 22/0056/IRB. Each participant read and signed an informed consent form after the study objectives, procedures, and possible hazards were described to them in full.

Dietary Analysis

The dietary intake of all participants was determined through the multiple-pass 24-hour recall for two days preceding the EGG appointment day [16]. Dietary intake reports were analyzed using food processor software version 11.1 (ESHA Research, Salem, OR, USA), including a food composition table database based on the United States Department of Agriculture (USDA) Standard Reference [17]. Energy intake (Kcal/day) and macronutrients, such as protein (g/day), carbohydrate (CHO; g/day), fat (g/day), total fiber (g/day), total sugar (g/day), added sugar (g/day), saturated fat (g/day), monounsaturated fat (g/day), polyunsaturated fat (g/day), and trans-fat (g/day) contents, were used

Table 3. Interoception and GMA in the study groups.

Variable	MC group (n = 18)	BN group (n = 9)	BED group (n = 9)	F/H value	*p*-value
	mean ± SD or median (IQR)	mean ± SD or median (IQR)	mean ± SD or median (IQR)		
5 min WL volume (mL)	466.67 ± 120.44	697.50 ± 186.45[a]	488.75 ± 152.17[b]	7.36	0.002
Pre-P_BG (%)	52.33 ± 17.17	50.68 ± 15.99	51.11 ± 13.95	0.03	0.966
Pre-P_NG (%)	15.68 (16.70)	19.46 (10.42)	18.85 (21.05)	0.10	0.953
Pre-P_TG (%)	19.38 ± 9.11	21.88 ± 9.20	23.45 ± 9.56	0.59	0.560
Pre-P_RR (%)	6.28 (7.31)	6.23 (7.32)	4.67 (7.83)	0.22	0.896
E-Post-P_BG (%)	60.23 (19.94)	51.96 (22.95)	67.06 (27.44)	2.30	0.317
E-Post-P_NG (%)	14.54 (10.16)	18.99 (22.81)	11.22 (7.05)[b]	4.56	0.102
E-Post-P_TG (%)	19.00 (11.07)	16.61 (8.04)	15.79 (12.80)	0.89	0.641
E-Post-P_RR (%)	3.30 (6.65)	3.48 (3.01)	3.99 (12.04)	0.13	0.935
M-Post-P_BG (%)	53.91 ± 18.65	51.45 ± 15.79	57.68 ± 17.90	0.25	0.782
M-Post-P_NG (%)	18.79 ± 9.81	23.67 ± 18.13	23.71 ± 14.98	0.57	0.570
M-Post-P_TG (%)	21.54 ± 11.27	18.75 ± 9.29	15.83 ± 7.82	0.91	0.414
M-Post-P_RR (%)	2.91 (5.86)	3.82 (10.43)	2.13 (2.99)	0.81	0.668
L-Post-P_BG (%)	55.87 ± 18.68	40.58 ± 22.84	58.09 ± 16.24	2.15	0.133
L-Post-P_NG (%)	18.19 ± 13.18	24.80 ± 20.44	20.29 ± 10.88	0.56	0.577
L-Post-P_TG (%)	21.34 ± 10.31	22.19 ± 13.40	18.03 ± 9.95	0.34	0.716
L-Post-P_RR (%)	3.57 (3.85)	5.37 (8.32)	3.45 (3.66)	1.05	0.590
Pre-P ADF (CPM)	1.41 (1.13)	1.61 (1.13)	1.59 (0.96)	0.05	0.974
E-Post-P ADF (CPM)	1.60 (0.97)	1.61 (1.92)	1.57 (0.68)	0.32	0.852
M-Post-P ADF (CPM)	1.48 (0.76)	1.76 (1.55)	1.52 (0.92)	0.04	0.980
L-Post-P ADF (CPM)	1.39 (1.53)	1.03 (1.32)	1.07 (1.18)	3.43	0.180

BG, bradygasteria; NG, normogastria; TG, tachygastria; RR, respiratory rhythm; ADF, average dominant frequency; MC, matched control; BN, bulimia nervosa; BED, binge eating disorder; GMA, gastric myoelectric activity; WL, water load. Data are presented as means ± SD or median and IQR. According to the normality of the data, a one-way ANOVA or the Kruskal–Wallis test was used; [a] indicates significance versus the MC group and [b] indicates significance versus the BN group using Tukey's post hoc test or the Mann–Whitney U test; $p < 0.05$.

for analysis. Furthermore, the content of micronutrients such as vitamins B1, B2, B6, B12, C, and D; iron; copper; sodium; potassium; and zinc in the participants' diet was reported.

Measuring the GMA

Transcutaneous multichannel electrogastrography (EGG) was used to measure the GMA with a 5-minute water load test (3CPM Company, Sparks, MD, USA). Disposable skin electrodes of the EGG were positioned on the mid-clavicular line, two inches below the costochondral margins on both sides, and midway between the umbilicus and xiphoid on the midline [18,19]. The EGG recording was carried out for at least 10 minutes at the baseline after 8 hours of fasting (preprandial recording; Pre-P), and then the participants were instructed to drink as much plain water as they could from the measured bottles for up to 5 minutes until satiety. The volume of ingested water was recorded (5 min WL volume). Furthermore, the EGG recording was continued for 30 minutes after water load (postprandial recording). The postprandial recording was divided into three periods (each one was 10 minutes): (a) early (E-Post-P) recording for the first 10 minutes, (b) middle (M-Post-P) recording from the 10th to 20th minutes, and (c) late (L-Post-P), from the 20th to 30th minute of the record. The percentage of power in the frequency range from 0 to 15 cycles per minute (CPM) and average dominant frequency (ADF) were used for analysis. A frequency region from 1.0 to 2.5 CPM was considered bradygasteria (BG), that from 2.5 to 3.75 CPM was considered normogastria (NG), that from 3.75 to10 CPM was considered tachygastria (TG), and that from 10 to 15 CPM was considered respiratory rhythm (RR) [20].

Statistical Analysis

A statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, version 23, IBM Statistics, Chicago, IL, USA). The study parameters are presented as means ± standard deviation (SD) or median and interquartile range (IQR) according to the normality of data. Normality was tested using the Shapiro–Wilk test. A one-way analysis of variance (ANOVA) with

Table 4. Correlation between gastric myoelectrical activity and nutrient intakes in the MC group (n = 18).

Variables	5 min WL	Pre-P ADF	E-Post-P ADF	M-Post-P ADF	L-Post-P ADF
Total calories (kcal/day)	r = –0.042	r = –0.628**	r = –0.181	r = 0.148	r = 0.129
Protein intake (g/day)	r = 0.117	r = –0.387	r = 0.072	r = 0.298	r = 0.157
CHO intake (g/day)	r = –0.315	r = –0.164	r = –0.076	r = –0.250	r = –0.009
Total fiber (g/day)	r = –0.089	r = 0.039	r = 0.232	r = –0.465	r = 0.125
Total sugar (g/day)	r = –0.196	r = 0.066	r = –0.009	r = –0.370	r = –0.017
Added sugar (g/day)	r = 0.143	r = –0.013	r = 0.082	r = –0.220	r = –0.108
Fat intake (g/day)	r = 0.060	r = –0.726**	r = –0.344	r = 0.337	r = 0.258
Saturated fat (g/day)	r = –0.097	r = –0.637**	r = –0.428	r = 0.443	r = 0.162
Vitamin B1 (mg/day)	r = 0.049	r = –0.294	r = –0.069	r = –0.246	r = 0.215
Vitamin B2 (mg/day)	r = –0.413	r = –0.164	r = –0.122	r = –0.053	r = 0.152
Vitamin B6 (mg/day)	r = 0.017	r = –0.196	r = 0.365	r = –0.234	r = 0.016
Vitamin B12 (mcg/day)	r = –0.330	r = –0.075	r = 0.076	r = 0.217	r = 0.333
Vitamin C (mg/day)	r = 0.186	r = –0.007	r = 0.032	r = –0.019	r = –0.003
Vitamin D (IU/day)	r = –0.042	r = 0.272	r = 0.121	r = 0.278	r = 0.291
Iron (mg/day)	r = –0.198	r = –0.155	r = 0.261	r = –0.251	r = 0.378
Copper (mg/day)	r = 0.026	r = –0.218	r = 0.085	r = –0.536*	r = 0.117
Sodium (mg/day)	r = –0.052	r = –0.537*	r = –0.360	r = 0.188	r = 0.336
Potassium (mg/day)	r = 0.236	r = –0.235	r = 0.310	r = –0.036	r = 0.046
Zinc (mg/day)	r = –0.088	r = –0.373	r = 0.173	r = –0.077	r = 0.364

5 min WL, the volume of ingested water within 5 minutes until satiety; Pre-P, preprandial; ADF, average dominant frequency; E-Post-P, early postprandial; M-Post-P, middle postprandial; L-Post-P, late postprandial; *, correlation is significant at the 0.05 level (two-tailed); **, correlation is significant at the 0.01 level (two-tailed).

Tukey's post hoc test or the Kruskal–Wallis test followed by the Mann–Whitney U test was used to compare the results among the three groups (MC, BED, and BN) according to the normality of the tested variable. For example, for non-parametric data, the statistical significance among the three groups was tested using the Kruskal–Wallis test, and the *p*-values are presented in tables. Then, intergroup comparisons (between MC and BN, MC and BED, and BN and BED) were performed using the Mann–Whitney U test. Any significant difference between the BN or BED group and the MC group is indicated by ([a]), while any significant difference between BN and BED is indicated by ([b]). Moreover, the Spearman correlation was used to test the GMA's correlation with the main dietary composition parameters. Comparisons were considered significant if the *p*-value was <0.05.

Results

Thirty-six women completed all procedures of this study. Eighteen subjects had an ED (BED = 9 and BN = 9), and there were eighteen matched controls. The mean age of the ED and MC groups were 24.00 ± 4.50 and 23.33 ± 3.09 years, respectively ($p < 0.05$), and their mean BMI was 26.98 ± 6.98 and 26.78 ± 5.98 Kg/m^2, respectively ($p < 0.05$).

Dietary Intake among Study Groups

The BN and BED groups had significantly higher total calorie, CHO, total fiber, total sugar, fat, and saturated fat intakes than the MC group (Table 1). The BED group had significantly higher total calorie and trans-fat intakes than the BN group (*p*-value trend <0.05). The BED group had significantly higher protein and added sugar intake than the MC group, which was not the case in the BN group. Iron intake was significantly higher in the BN and BED groups than in the MC group ($p < 0.01$ in both comparisons) (Table 2), with no further difference in iron intake between BED and BN ($p > 0.05$). Vitamin B1 and copper intakes were significantly higher in the BED than in the MC group (*p*-values < 0.05).

Interoception and Gastric Myoelectric Activity in Study Groups

Compared to the MC group, the BN group ingested a significantly higher volume of water until satiety during the 5-minute drinking test ($p < 0.05$). However, participants in the BED group ingested significantly less water than those in the BN group ($p < 0.05$) (Table 3). In the BED group, the percentage of normogastria was significantly less than in the BN group during the early postprandial period (*p*-value < 0.05 obtained via the Mann–Whitney U test).

Table 5. Correlation between gastric myoelectrical activity and nutrient intake in the BN study groups (n = 9).

Variables	5 min WL	Pre-P ADF	E-Post-P ADF	M-Post-P ADF	L-Post-P ADF
Total calories (kcal/day)	r = –0.246	r = 0.262	r = –0.238	r = –0.095	r = 0.488
Protein intake (g/day)	r = –0.503	r = –0.286	r = –0.190	r = 0.333	r = 0.366
CHO intake (g/day)	r = 0.258	r = 0.571	r = –0.190	r = –0.571	r = 0.268
Total fiber (g/day)	r = –0.710*	r = –0.095	r = –0.095	r = 0.143	r = 0.049
Total sugar (g/day)	r = –0.503	r = 0.548	r = 0.214	r = –0.595	r = –0.122
Added sugar (g/day)	r = –0.160	r = –0.310	r = –0.262	r = 0.119	r = 0.220
Fat intake (g/day)	r = –0.307	r = 0.405	r = 0.143	r = –0.619	r = –0.122
Saturated fat (g/day)	r = –0.344	r = 0.405	r = 0.001	r = –0.381	r = 0.244
Vitamin B1 (mg/day)	r = –0.270	r = 0.024	r = –0.405	r = 0.500	r = 0.537
Vitamin B2 (mg/day)	r = –0.626	r = –0.190	r = –0.143	r = 0.190	r = 0.268
Vitamin B6 (mg/day)	r = 0.049	r = –0.214	r = –0.500	r = 0.881**	r = 0.586
Vitamin B12 (mcg/day)	r = –0.626	r = –0.595	r = –0.095	r = 0.429	r = 0.073
Vitamin C (mg/day)	r = –0.295	r = 0.095	r = 0.119	r = 0.595	r = 0.098
Vitamin D (IU/day)	r = –0.636	r = 0.071	r = 0.036	r = –0.179	r = 0.366
Iron (mg/day)	r = –0.209	r = –0.143	r = –0.310	r = 0.690	r = 0.366
Copper (mg/day)	r = 0.135	r = 0.405	r = 0.405	r = –0.548	r = –0.268
Sodium (mg/day)	r = –0.724*	r = 0.048	r = 0.714*	r = –0.476	r = –0.366
Potassium (mg/day)	r = –0.344	r = –0.476	r = 0.071	r = 0.167	r = 0.098
Zinc (mg/day)	r = 0.086	r = –0.381	r = 0.595	r = –0.167	r = –0.366

5 min WL, the volume of ingested water within 5 minutes until satiety; Pre-P, preprandial; ADF, average dominant frequency; E-Post-P, early postprandial; M-Post-P, middle postprandial; L-Post-P, late postprandial; *, correlation is significant at the 0.05 level (two-tailed); **, correlation is significant at the 0.01 level (two-tailed).

Correlation of 5 Min WL and GMA Parameters with Dietary Intake in the Study Groups

In the MC group, 5 min WL showed no significant correlation with the tested dietary intake parameters ($p >$ 0.05). Baseline ADF showed significant inverse correlations with total calorie, total fat, saturated fat, and sodium intake (Table 4). Moreover, copper intake showed an inverse correlation with the middle postprandial ADF ($p <$ 0.05).

In the BN group, 5 min WL showed significant inverse correlations with total fiber and sodium intake (r = –0.710 and –0.724, respectively; $p < 0.05$) (Table 5). Early postprandial ADF showed a positive correlation with sodium intake (r = 0.714, $p < 0.05$), and middle postprandial ADF showed a positive correlation with vitamin B6 intake (r = 0.881, $p < 0.01$).

As shown in Table 6, the BED group showed a significant positive correlation of preprandial ADF with fat and iron intake (r = 0.714 and 0.810, respectively; $p < 0.05$). The middle postprandial recording showed a positive correlation with sodium intake (r = 0.786, $p < 0.05$), while the late postprandial ADF correlated positively with total CHO, total sugar, and vitamin B12 intake (r = 0.700, 0.719, and 0.766, respectively; $p < 0.05$).

Discussion

This study examined the dietary intake of patients with BN and BED compared to matched controls and the association of dietary intake with interoception and GMA parameters. Patients with BN and BED consumed more total daily calories and higher amounts of protein, CHO, total sugar, and fat than those in the control group. Moreover, participants in the BED group ingested more total daily calories, CHO, fat, and trans-fat than those in the BN group. In line with our results, Wiklund *et al.* [21] found that women with BED had a higher mean total daily caloric intake compared with controls and a higher intake than the recommended daily allowance. A Brazilian study reported insignificant differences between patients with BED and BN regarding total daily caloric consumption and protein and fat intakes, and participants with BN ingested more sugar-sweetened beverages than those with BED [22]. Regarding micronutrient intakes, our results showed that participants in the BED group had higher vitamin B1 and iron intakes than those who matched the control group. However, Wiklund *et al.* [21] reported that women had significantly higher intakes of vitamins A and B6, folate, iron, potassium, and copper but lower intakes of vitamins D, B1, B3, and B12 and sodium compared with a control group. The differences

Table 6. Correlation between gastric myoelectrical activity and nutrient intake in the BED groups (n = 9).

Variables	5 min WL	Pre-P ADF	E-Post-P ADF	M-Post-P ADF	L-Post-P ADF
Total calories (kcal/day)	r = –0.720	r = 0.476	r = –0.071	r = 0.548	r = 0.659
Protein intake (g/day)	r = –0.240	r = –0.333	r = –0.452	r = 0.452	r = 0.156
CHO intake (g/day)	r = –0.252	r = 0.310	r = 0.095	r = 0.333	r = 0.700*
Total fiber (g/day)	r = 0.228	r = 0.310	r = 0.286	r = 0.095	r = 0.132
Total sugar (g/day)	r = –0.180	r = 0.452	r = 0.095	r = 0.167	r = 0.719*
Added sugar (g/day)	r = 0.443	r = 0.667	r = 0.476	r = –0.262	r = 0.479
Fat intake (g/day)	r = 0.371	r = 0.714*	r = 0.190	r = 0.262	r = 0.228
Saturated fat (g/day)	r = 0.587	r = 0.667	r = 0.167	r = 0.167	r = –0.036
Vitamin B1 (mg/day)	r = 0.024	r = –0.167	r = 0.524	r = –0.429	r = –0.503
Vitamin B2 (mg/day)	r = –0.371	r = 0.095	r = –0.238	r = –0.024	r = –0.156
Vitamin B6 (mg/day)	r = –0.720	r = 0.571	r = 0.024	r = 0.143	r = 0.659
Vitamin B12 (mcg/day)	r = –0.048	r = 0.595	r = 0.190	r = 0.095	r = 0.766*
Vitamin C (mg/day)	r = 0.072	r = 0.190	r = –0.071	r = 0.262	r = –0.575
Vitamin D (IU/day)	r = –0.491	r = 0.262	r = 0.357	r = –0.310	r = 0.587
Iron (mg/day)	r = 0.323	r = 0.810*	r = 0.310	r = –0.310	r = 0.048
Copper (mg/day)	r = –0.371	r = 0.214	r = 0.071	r = –0.310	r = –0.299
Sodium (mg/day)	r = 0.479	r = 0.357	r = –0.429	r = 0.786*	r = 0.072
Potassium (mg/day)	r = 0.252	r = 0.643	r = 0.310	r = –0.048	r = 0.347
Zinc (mg/day)	r = 0.048	r = 0.476	r = 0.167	r = –0.452	r = –0.263

5 min WL, the volume of ingested water within 5 minutes until satiety; Pre-P, preprandial; ADF, average dominant frequency; E-Post-P, early postprandial; M-Post-P, middle postprandial; L-Post-P, late postprandial; *, correlation is significant at the 0.05 level (two-tailed).

in the dietary pattern, socioeconomic and demographic factors, and the tool used for food composition analysis cause this discrepancy in results between the studies.

The 5-minute WL volume was the highest in the BN group, with a statistically significant increase compared to the BED and MC groups. This indicates that patients with BN may have a delay in gastric sensing for satiety, which may facilitate the ingestion of larger quantities of foods/fluids. van Dyck *et al*. [8] reported that volumes of water load until satiation were higher in patients with EDs (a mixture of BN and BED) than in normal controls. A study measured gastric capacity and intragastric pressure after overnight fasting using a gastric balloon and filling it with water at a rate of 100 mL/min. The gastric capacity of the subjects with BN was the largest compared to those without EDs and those with obesity [23]. It was reported that patients with BN may present with acute gastric dilatation, gastric perforation, and self-induced vomiting, predisposing them to gastroesophageal reflux, dental caries, salivary gland enlargement, and electrolyte disturbances [24].

This study measured the GMA using a clinically valid EGG device and reported a lower percentage of normogastria in the BED group than in the BN and MC groups during the early postprandial period. Ogawa *et al*. [13] found that the percentage of normal GMA power was significantly smaller in patients with EDs. This finding was also reported in van Dyck *et al*.'s study [8]. However, both studies used a mixture of patients with BN and BED, while our study divided the ED group and compared those with BN and BED.

The association of dietary intake with interoception and ADF of the stomach is not addressed frequently in the literature. We suggest that certain diets might help normalize gastric interoception and GMA. In the BN group, the volume of water load is inversely correlated with total fiber and sodium intakes. This might indicate that dietary regimens high in fiber and sodium may be beneficial as they are associated with lower gastric volumes. Moreover, sodium and vitamin B6 were positively correlated with ADF during the early to middle periods of postprandial recording. The higher the fat and iron intake in the BED group, the greater the baseline ADF. In addition, carbohydrate, sugar, and vitamin B12 intakes were correlated positively with late postprandial ADF. Our previous work in cases with obesity showed that the total caloric intake of carbohydrates, fiber, and fat was positively correlated with the ADF in the early postprandial EGG recording [25]. The hypothesis that changes in gastric interoceptive sensitivity can be induced through dietary modification in patients with eating disorders is frequently tested, especially by combining new technologies with clinical interventions [26]. One example of this is using a Western-style dietary intervention for four days to reduce interoceptive sensitivity, hippocampal-dependent learning, and memory [27].

Despite its many strengths, this study has some limitations, such as a relatively small sample (despite statistical calculation) and the subjective nature of the dietary assessment method. It also only includes female cases due to the prevalence of EDs in women compared to men. Moreover, the study design cannot determine a cause-and-effect relationship.

Conclusion

In conclusion, the associations found in this study between dietary intake and gastric interoception/GMA may provide a basis for a possible modulation of gastric interoception, volume, and GMA through dietary management for women with BN and BED. Moreover, in addition to treating the disorder through pharmacotherapy, tailored diets for individuals with EDs may result in better outcomes in managing their dietary habits and improving their gastric functions. For example, in women with BN, consuming a diet containing more fiber and sodium may be associated with the development of smaller gastric volumes, and those with BED might benefit from diets rich in CHO, sugar, and vitamin B12. Future research should assess this finding by using these dietary interventions in a prospective study. Further research is required to overcome the identified limitations and provide a more thorough analysis of the topic.

Availability of Data and Materials

The data used to support the findings of this study are available from the corresponding author on reasonable request.

Author Contributions

MMAA, AHA, and SHA designed the research study; AA, and HMA, AHA participated in the patient recruitment and sorting of data; DA and AA analyzed the data; MMAA and DA do writing and revision. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board at King Saud University, Riyadh, Saudi Arabia, under reference number 22/0056/IRB, dated 18 January 2022. Each participant signed an informed consent form after fully illustrating the study objectives, procedures, and possible hazards.

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Conflict of Interest

The authors declare no conflict of interest.

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