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Crescent Journal of Medical and Biological Sciences
Vol. 5, No. 2, April 2018, 107–114
eISSN 2148-9696

The Association of Energy Intake and Expenditure, Macronutrients, Glycemic Index and Load, and General Characteristics With Postprandial Peptide YY 3-36 Serum Levels

Maryam Rahemi[1], Mohmmad Alizadeh[2*]

Abstract

Objectives: This study set out to determine the association between dietary intakes at lunch and postprandial peptide YY 3-36 (PYY3-36) 90-120 minutes after the consumption of lunch meal.

Materials and Methods: In the present cross-sectional study, the subjects (n=176) were asked to eat their lunch at work on the test day. The postprandial concentration of PYY3-36 was measured 1.5 to 2 hours after the consumption of lunch meal.

Results: The subjects within the age range of 25 to 39 and those with ages less than 25 ($P=0.005$) indicated the highest and the lowest levels of PYY3-36, respectively. Postprandial PYY3-36 had a direct significant association with fat content at lunch ($P=0.049$) and had an inverse association with cholesterol ($P=0.001$), docosahexaenoic acid (DHA) ($P=0.040$) and eicosapentaenoic acid (EPA) ($P=0.022$). Moreover, polyunsaturated fatty acids (PUFAs) and linoleic acid at lunch indicated a significant positive correlation with PYY3-36 (r=0.182, $P=0.016$ for both). Furthermore, a significant negative correlation was detected between energy intake at dinner and post-lunch PYY3-36 (r=-0.216, $P=0.004$). Protein (OR [odds ratio]=0.390, 95% CI: 0.160-0.950) and fat intake (OR=2.697, 95%CI: 1.103-6.594) at lunch, energy intake at dinner (OR=0.298, 95% CI: 0.127-0.702), and energy spent to perform physical activities after lunch (OR=0.411, 95% CI: 0.182-0.929) significantly predicted the serum concentration of post-lunch PYY3-36. No significant association was found between PYY3-36 and glycemic index and load.

Conclusions: There was a significant association between dietary intakes at lunch meal and post-lunch serum concentration of PYY3-36. Further large-scale cross-sectional researches and randomized controlled trials are needed to confirm the mentioned results.

Keywords: Diet, Glycemic index, Glycemic load, Meals, Peptide YY

Introduction

Many studies have been done assuming appetite regulatory system as obesity increases (1). Gastrointestinal peptide hormones are the main part of the appetite regulatory system and secreted in reaction to nutritional stimulants (2). Peptide YY (PYY) which is an appetite suppressing 36-amino acid gut hormone (3) is released from colon mucosa and ileum in response to eating food (4) and reaches its maximum almost 90 minutes (5) (60-120 minutes) after having a meal (6). PYY is probably crucial because of its impact in postponing the start of the next meal rather than putting an end to the current meal (7,8). PYY is present in the blood in 2 forms: PYY3-36 and PYY1-36 (9). PYY1-36 represents 40% of the circulating PYY which is cleaved by dipeptidyl peptidase IV (DPP-IV) (10). PYY3-36 crosses the blood-brain barrier via a nonsaturatable mechanism, PYY3-36 quenches the appetite, and enhances weight loss by hindering the secretion of an appetite-stimulating hormone, called neuropeptide Y (NPY), by presynaptic Y2 receptors (3,10,11). Postprandial PYY peak is dependent on the calorie value and composition of the meal (12). Essah et al showed that a high-fat and low-carbohydrate meal stimulates PYY release greater than a high-carbohydrate and low-fat diet in obese subjects (13). Two research studies revealed that high intake of protein resulted in the highest secretion of the anorectic PYY and satiety in obese and normal-weight individuals (14, 15). Helou et al showed that the protein and fat of a meal can cause a prolonged and an immediate rise in PYY3–36 (8). A low-glycemic load (GL) diet may decrease appetite (16). Studies have indicated that the suppression of appetite was

Received 2 May 2017, **Accepted** 15 September 2017, **Available online** 10 October 2017

[1]Student Research Committee, Urmia University of Medical Sciences, Urmia, Iran. [2]Department of Nutrition, Food and Beverages Safety Research Center, Faculty of Medicine, Urmia University of Medical Sciences, Urmia, Iran.
*Corresponding Author: Mohammad Alizadeh, MSc, Ph.D; Tel: +984432752372, Fax: +984432780800, Email: alizadeh.m@umsu.ac.ir

due to the consumption of a low-GL meal rather than the consumption of a high-GL meal in obese individuals (17-19); however, one of the studies showed that secretion of postprandial PYY is not influenced by GL (16). According to the obesity crisis in the world, accurate information on the mechanisms regulating body weight and appetite is needed to improve effective management of obesity.

This study set out to determine the association of dietary intakes including macronutrients, fatty acids, fibers, glycemic index (GI) and load, and energy intake, and expenditure 90 to 120 minutes after the consumption of lunch meal with the postprandial serum concentration of PYY3-36 in the staff of Urmia University, Iran.

Materials and Methods

Subjects

From 403 university staff, 194 did not accept to participate in the study and 24 were excluded due to thyroid disease, diabetes, recent weight loss, special diets, and lactation. Furthermore, 9 individuals did not complete the study. Hence, the present study included 176 healthy staff volunteers consisting of 107 female and 69 male subjects within the age range of 19 to 58 and the mean age of 28.67 ± 8.82 years. The changes of body weight of all subjects were ≤5% in the last 3 months (mean body mass index [BMI]: 24.91 ± 4.71 kg/m^2; range: 16-40.30). The exclusion criteria were pregnancy, lactation, any history of chronic diseases like cardiovascular disease, diabetes, thyroid disease, and so on and also the use of medications recognized to affect the appetite. Moreover, the subjects with significant side effects of weight change and those following weight loss or special diets were excluded. Informed consent was gained from all participants.

The Study Design

In this cross-sectional study, simple sampling method was used. Recruitment lasted from April 27 to June 4, 2016. The subjects were asked to eat their lunch at work on the test day and 1.5 to 2 hours after consumption of the lunch meal, 3 mL of blood sample was obtained from hand vein while the subjects were in a sitting position. Venous blood samples were collected in tubes and kept for 1 to 2 hours to form clots. Then, the separation of serum was done via centrifugation at 3000 rpm for 10 minutes, and then it was kept at -80°C until analysis. Serum levels of PYY3-36 were measured using human PYY3-36 ELISA kit (CUSABIO kit, China). The inter- and intra-assay variation coefficients were <10% and <8%, respectively. Energy intake, dietary intake, and energy expenditure were determined**.** Physical activity and dietary intake on the test day were determined using a dietary and physical activity recall questionnaire. Researchers recorded the consumed foods at lunch using the recall method. Moreover, details of subjects' afternoon snacks, their dinner and evening snacks at night were recorded by calling the subjects or by conducting face-to-face interviews the next day. Household measures such as tablespoons and glasses were used to help food recall. Subjects were interviewed to recall the type and duration of their physical activities on the test day from wake-up time until blood sampling time and then from blood sampling time until sleep time. The amount of caloric expenditure during physical activities was calculated considering the table of physical activity and calories expended per hour (20). Usual energy expenditures in physical activities were calculated by summing the hours of different physical activities per week. GL and GI of a lunch meal were calculated using a formula (21). General information was collected using a general information questionnaire. Weight and height were also measured (InBody 770, Korea). Moreover, BMI was measured by the formula as follows: (weight per kg) / (height per meter)^2.

Statistical Analysis

Demographic parameters like weight, height, gender, age, BMI, stable weight, supplement and drugs use, smoking, and PYY3-36 were described. The information provided by dietary recall questionnaire was converted into grams per meal by measures of household (22). Moreover, trends in the intake of energy and macronutrients were determined by Nutritionist IV software (First DataBank Division, The Hearst Corporation, 1111 Bayhill Drive, San Bruno, CA 94066) which was modified for Iranian food. One-sample Kolmogorov-Smirnov test was used to evaluate normal or non-normal distribution of the variables. The data were analyzed using non-parametric tests due to non-normal distribution of the variables. Quantitative variables were stratified into medians or tertiles. PYY3-36 as the dependent variable was stratified into 2 medians, and other variables were stratified into the medians or tertiles. Correlations between variables were specified using Spearman correlation test. Chi-square analysis was used to compare the frequency of variables between low and high levels of PYY3-36 based on cross-tabulation analysis. The analysis of logistic regression was applied to evaluate the relationship between the variables and PYY3-36 in 2 crudes (model 1) and adjusted models (model 2). In model 2, the association was adjusted for confounding factors such as age, gender, smoking, supplement use, and stable weight. The confounding factors entered into the adjusted model had shown a P<0.3 in the assessment of their relationships with PYY3-36 in chi-square tests. Logistic regression was employed to estimate the PYY3-36 values higher than the median. Due to the high correlation observed between energy sub-types, an exploratory factor analysis was also used to reduce the dimensionality of the energy expenditure and intake. Therefore, 2 dimensions were identified including factors 1 and 2. Factor 1 included usual energy expenditure and energy spent before and after blood sampling over physical activity and factor 2 included energy intake at different snacks and meals (lunch, afternoon, dinner, and bedtime). Sample adequacy for factor analysis was confirmed by Kaiser-Meyer-Olkin

(KMO) and Bartlett test. All the analyses were done by the Statistical Package for Social Sciences (SPSS version 23.0). $P \leq 0.05$ was assumed statistically significant.

Results

The association between general characteristics and PYY3-36 has been outlined in Table 1. A significant association was observed between PYY3-36 and age ($P=0.005$). Thirty-six point eight percent and 63.2% of participants aged less than 25 years old presented PYY3-36 serum level of higher and lower than the median split, respectively. The percentages of subjects within the age range of 25 to 39 indicating PYY3-36 serum level of higher and lower than the median split were 62.8% and 37.2%, respectively. The association between PYY3-36 and energy intake and expenditure is presented in Table 2. The results of chi-square test revealed a significant opposite association between post-lunch PYY3-36 level and the amount of energy consumed at the following dinner meal. In the high PYY3-36 group, the frequency of subjects placed in higher tertiles of energy was decreased ($P=0.012$); conversely, in the low PYY3-36 group, the frequency of subjects placed in higher tertiles was increased. A significant inverse association was found between post-lunch PYY3-36 level and the amount of physical activity energy expenditure after obtaining the blood samples. In the high PYY3-36 group, the majority of the subjects (62.1%) were found to be in the lowest tertile of energy; while in low PYY3-36 group, the majority of the subjects (61.7%) were placed in the second tertile.

The association of macronutrients, fatty acids, fibers, GI, and GL with PYY3-36 is indicated in Table 3. A significant association was observed between eicosapentaenoic acid (EPA), fat, cholesterol, and docosahexaenoic acid (DHA) content of lunch and PYY3-36. In the high PYY3-36 group, the majority of the subjects were placed in the maximum tertile of fat and the minimum tertile of cholesterol (62.1 and 63.8, respectively). In the high PYY3-36 group, the frequency of subjects consuming EPA and DHA more than the median value (31% and 36.6%, respectively) was significantly ($P=0.022$ and $P=0.040$, respectively) lower than the frequency of those consuming EPA and DHA less than the median value (53.5% and 53.85, respectively).

The Spearman correlation coefficient showed a significant linear correlation of polyunsaturated fatty acids (PUFAs) and linoleic acid of lunch and energy intake in dinner with post-lunch PYY3-36 (Figure 1). A significant inverse linear correlation was detected between dinner energy intake and post-lunch PYY3-36 ($r=-0.216$, $P=0.004$). Moreover, a positive significant correlation of PUFAs and linoleic acid with PYY3-36 was specified in the study (r=0.182, $P=0.016$ for both). No significant correlation was observed between PYY3-36 and other variables (data not presented).

The results of logistic regression are presented in Table 4. Regarding the protein intake, subjects presented in tertile 2 in the crude model had 60.4% less chances (odds ratio [OR]=0.396, 95% CI: 0.173-0.907, $P=0.028$) and 61% less chances in the adjusted model to present higher than the median range of PYY3-36 in comparison with subjects in tertile 1 (OR=0.390, 95% CI: 0.160-0.950, $P=0.038$).

Fat consumption significantly predicted higher levels of PYY3-36 (Crude model: T3 vs. T1 OR=2.827, 95% CI: 1.218-6.562, $P=0.016$, P-trend=0.009; adjusted model:

Table 1. Association of General Characteristics With Low and High Levels of Peptide YY 3-36[a]

Variables	Sub groups	PYY3-36		*P*
		No. (%) of lower than median	No. (%) of higher than median	
Gender	Female	51 (47.2)	57 (52.8)	0.168*
	Male	38 (55.9)	30 (44.1)	
Marital status	Married	28 (48.3)	30 (51.7)	0.395*
	Single	61 (51.7)	57 (48.3)	
Smoking	Yes	9 (34.6)	17 (65.4)	0.060*
	No	80 (53.3)	70 (46.7)	
Drug use	Yes	10 (43.5)	13 (56.5)	0.307*
	No	79 (51.6)	74 (48.4)	
Supplement use	Yes	7 (43.8)	9 (56.3)	0.379*
	No	82 (51.3)	78 (48.8)	
Stable weight in past 3 months	Yes	64 (52.9)	57 (47.1)	0.226*
	No	25 (45.5)	30 (54.5)	
Age	< 25	48 (63.2)	28 (36.8)	0.005**
	25-39	29 (37.2)	49 (62.8)	
	≥40	12 (54.5)	10 (45.5)	
Menstrual cycle	Man	38 (55.9)	30 (44.1)	0.374**
	Follicular phase	23 (46.0)	27 (54.0)	
	Luteal phase	23 (53.5)	20 (46.5)	
	Irregular menstrual cycles/postmenopausal	5 (33.3)	10 (66.7)	

[a] PYY3-36 concentrations were stratified into two medians (Lower than median and higher than median). *Fisher's exact test, **Pearson's chi-squared test.

Table 2. Association Between Tertiles or Medians[a] of Energy Subtypes Per kcal With Low and High Levels of Peptide YY 3-36 (PYY3-36)[b]

Energy Subtypes	Tertiles or Medians	PYY3-36		*P*
		No. (%) of Lower Than Median	No. (%) of Higher Than Median	
Energy intake in lunch	T1	29 (50.0)	29 (50.0)	0.802*
	T2	32 (54.2)	27 (45.8)	
	T3	28 (48.3)	30 (51.7)	
Energy of afternoon snack	T1	32 (54.2)	27 (45.8)	0.302*
	T2	25 (42.4)	34 (57.6)	
	T3	32 (55.2)	26 (44.8)	
Energy intake in dinner	T1	21 (36.2)	37 (63.8)	0.012*
	T2	31 (51.7)	29 (48.3)	
	T3	37 (63.8)	21 (36.2)	
Energy spent in physical activity before blood sampling	T1	25 (43.1)	33 (56.9)	0.324*
	T2	31 (51.7)	29 (48.3)	
	T3	33 (56.9)	25 (43.1)	
Energy spent in physical activity after blood sampling	T1	22 (37.9)	36 (62.1)	0.035*
	T2	37 (61.7)	23 (38.3)	
	T3	30 (51.7)	28 (48.3)	
Usual Energy expenditures in physical activities	T1	27 (46.6)	31 (53.4)	0.745*
	T2	32 (53.3)	28 (46.7)	
	T3	30 (51.7)	28 (48.3)	
Factor1[c]	T1	28 (48.3)	30 (51.7)	0.721*
	T2	29 (49.2)	30 (50.8)	
	T3	32 (55.2)	26 (44.8)	
Factor 2[d]	T1	24 (41.4)	34 (58.6)	0.202*
	T2	32 (54.2)	27 (45.8)	
	T3	33 (56.9)	25 (43.1)	
Energy of bedtime snack	Median 1	41 (46.6)	47 (53.4)	0.183**
	Median 2	48 (54.5)	40 (45.5)	

[a] Energy of bedtime snack was stratified into two medians and others were stratified into 3 tertiles.
[b] PYY3-36 concentrations were stratified into two medians (lower than median and higher than median).
[c] Factor 1 included usual energy expenditure and energy spent before and after blood sampling over physical activity.
[d] Factor 2 included energy intake in different snacks and meals (lunch, afternoon, dinner, and bedtime).
* Pearson chi-squared test.
** Fisher exact test, T1: tertile 1, T2: tertile 2, T3: tertile 3.

T3 vs. T1 OR=2.697, 95% CI: 1.103-6.594, $P=0.030$, P-trend=0.005). Energy intake in dinner significantly predicted post-lunch PYY3-36 levels (P-trend=0.015 in crude model and P-trend=0.021 in adjusted model). Comparing the participants in the minimum tertile, subjects placed in the highest tertile of dinner energy intake had 68% (in the crude model) and 70.2% (in the adjusted model) less odds to be in higher PYY3-36 group (Crude model: T3 vs. T1 OR=0.320, 95% CI: 0.147-0.696, $P=0.004$; adjusted model: T3 vs. T1 OR=0.298, 95% CI: 0.127-0.702, $P=0.006$). In comparison with subjects in tertile 1, subjects who were in tertile 2 of the energy spent to perform physical activities after obtaining blood sampling had 63.9% (in crude model) or 58.9% (in adjusted model) less chances to have PYY3-36 levels higher than the median value (Crude model: T2 vs. T1 OR=0.361, 95% CI: 0.168-0.777, $P=0.009$; adjusted model: T2 vs. T1 OR=0.411, 95% CI: 0.182-0.929, $P=0.033$).

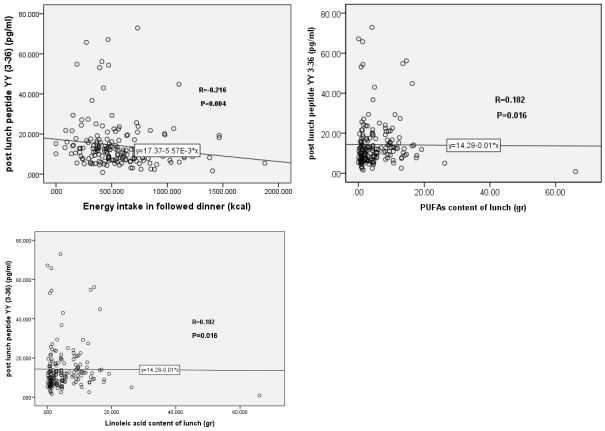

Figure 1. Correlations Between PUFAs (Polyunsaturated Fatty Acids) and Linoleic Acid From Lunch and Energy Intake at the following Dinner (kcal) With Post Lunch Serum Concentration of Peptide YY 3-36.

Discussion

This study indicated a direct significant association between fat content of lunch and PYY3-36; nevertheless, no significant association was observed between intake of protein and PYY3-36. Moreover, fat intake significantly predicted higher levels of PYY3-36. For the first time, Adrian et al reported that dietary fat elicited the greatest PYY response (23), and several studies showed that protein induced maximum response of PYY (14,15).

Table 3. Association Between Macronutrients, Fatty Acids, Fibers, GI and GL With Low and High Levels of Peptide YY 3-36[a]

Variables	Tertiles or Medians	PYY3-36		*P*	Variables	Tertiles or Medians	PYY3-36		*P*
		No. (%) of Lower Than Median	No. (%) of Higher Than Median				No. (%) of Lower Than Median	No. (%) of Higher Than Median	
GI	T1	28 (48.3)	30 (51.7)	0.855*	GL	T1	27 (45.8)	32 (54.2)	0.263*
	T2	32 (53.3)	28 (46.7)			T2	36 (59.0)	25 (41.0)	
	T3	29 (50.0)	29 (50.0)			T3	26 (46.4)	30 (53.6)	
PRO (g)	T1	24 (41.4)	34 (58.6)	0.199*	PRO	T1	26 (46.4)	30 (53.6)	0.196*
	T2	34 (57.6)	25 (42.4)			T2	27 (45.0)	33 (55.0)	
	T3	31 (52.5)	28 (47.5)			T3	36 (60.0)	24 (40.0)	
CHO (g)	T1	29 (50.0)	29 (50.0)	0.649*	CHO	T1	29 (51.8)	27 (48.2)	0.960*
	T2	28 (46.7)	32 (53.3)			T2	29 (49.2)	30 (50.8)	
	T3	32 (55.2)	26 (44.8)			T3	31 (50.8)	30 (49.2)	
Fat (g)	T1	31 (53.4)	27 (46.6)	0.049*	Fat	T1	34 (58.6)	24 (41.4)	0.315*
	T2	36 (60.0)	24 (40.0)			T2	26 (44.8)	32 (55.2)	
	T3	22 (37.9)	36 (62.1)			T3	29 (49.2)	30 (50.8)	
Dietary fiber (g)	T1	32 (54.2)	27 (45.8)	0.381*	Crude fiber (g)	T1	29 (50.0)	29 (50.0)	0.646*
	T2	32 (54.2)	27 (45.8)			T2	32 (55.2)	26 (44.8)	
	T3	25 (43.1)	33 (56.9)			T3	27 (46.6)	31 (53.4)	
Cholesterol (mg)	T1	21 (36.2)	37 (63.8)	0.001*	Oleic acid (g)	T1	27 (47.4)	30 (52.6)	0.565*
	T2	40 (69.0)	18 (31.0)			T2	33 (55.9)	26 (44.1)	
	T3	27 (46.6)	31 (53.4)			T3	27 (47.4)	30 (52.6)	
SFA (g)	T1	30 (51.7)	28 (48.3)	0.742*	Linoleic acid (g)	T1	35 (60.3)	23 (39.7)	0.163*
	T2	27 (46.6)	31 (53.4)			T2	28 (48.3)	30 (51.7)	
	T3	31 (53.4)	27 (46.6)			T3	25 (43.1)	33 (56.9)	
MUFAs (g)	T1	31 (53.4)	27 (46.6)	0.742*	Linolenic acid (g)	T1	35 (48.6)	37 (51.4)	0.759*
	T2	30 (51.7)	28 (48.3)			T2	19 (45.2)	23 (54.8)	
	T3	27 (46.6)	31 (53.4)			T3	28 (52.8)	25 (47.2)	
PUFAs (g)	T1	35 (60.3)	23 (39.7)	0.163*	Soluble fiber (g)	Median1	63 (51.2)	60 (48.8)	0.461**
	T2	28 (48.3)	30 (51.7)			Median2	25 (49.0)	26 (51.0)	
	T3	25 (43.1)	33 (56.9)						
EPA (g)	Median1	67 (46.5)	77 (53.5)	0.022**	DHA (g)	Median1	61 (46.2)	71 (53.8)	0.040**
	Median2	20 (69.0)	9 (31.0)			Median2	26 (63.4)	15 (36.6)	

[a]PYY3-36 concentrations were stratified into two medians (lower than median and higher than median); * Pearson chi-squared test; ** Fisher exact test; PYY3-36, peptide YY 3-36;PRO, protein; CHO, carbohydrate; SFA, saturated fatty acid; MUFAs, mono unsaturated fatty acids; PUFAs, Polyunsaturated fatty acids, EPA; Eicosapentaenoic acid, DHA; Docosahexaenoic acid, GI; glycemic index, GL; glycemic load; T1, tertile 1; T2, tertile 2; T3, tertile3.

Ullrich et al showed that subjects had 90-minute protein and lipid intraduodenal infusions. The results showed that in comparison with protein infusion, 30 and 90 min after the beginning of lipid intraduodenal infusion, PYY was substantially more stimulated, and the reaction to protein was low in the infusion (24). Both fat and protein possibly cause a higher postprandial PYY response in comparison with carbohydrates (8,9). The type of fat, carbohydrate, or protein, obesity, gender, weight status, and age may possibly affect the PYY response value (9). The results of our study revealed a significant association between age and PYY3-36. In contrast, a number of studies found no association between age and fasting or postprandial PYY (25,26). There was only a marginally significant association between smoking and PYY3-36. Cahill et al (27) indicated that smoking, medication use, age, and menopause were associated with women's PYY levels, but not men's. The mentioned results accentuate the significance of conducting further investigations in this regard. There was an inverse significant linear correlation between post-lunch PYY3-36 level and energy consumed at the following dinner meal. Moreover, energy intake at dinner significantly predicted post-lunch PYY3-36 levels. In addition, Batterham et al showed that infusion of PYY3-36 at normal postprandial concentrations in humans considerably reduced food intake and appetite by 33% over 24 hours (3). Therefore, the present study confirmed that high level of PYY3-36 could decrease the intake of energy in the following meal.

The present study indicated a significant positive correlation of PUFAs and linoleic acid with PYY3-36. It was found for the first time that in the high PYY3-36 group, the frequency of subjects who consumed EPA and DHA more than median value was significantly lower than the frequency of subjects who consumed EPA and DHA lower than the median value. Furthermore, in the high PYY3-36 group, the majority of the subjects were in the lowest tertile of cholesterol. Fatty acids are absorbed by incorporation into micelles. Then, fatty acids are transported to the epithelial surface (28), where sensing and subsequent absorption of them takes place (29). Unsaturated fatty acids are highly accessible for sensing

Table 4. Association[a] Between Tertiles or Medians[b] of Macronutrients, Energy Intake and Expenditure, Extracted Factors of Energy, GI and GL With PYY3-36 Levels[c]

Variables	T or M	Model 1[f]			Model 2[g]		
		B±SE	OR (95%CI)	*P*[*]	B±SE	OR (95%CI)	*P*[*]
GI	T1			0.824			0.425
	T2	-0.185±0.372	0.831 (0.401-1.723)	0.618	-0.059±0.400	0.943 (0.430-2.067)	0.883
	T3	-0.261±0.489	0.770 (0.295-2.010)	0.594	-0.672±0.529	0.511 (0.181-1.441)	0.204
GL	T1			0.257			0.294
	T2	-0.512±0.373	0.599 (0.289-1.244)	0.169	-0.264±0.416	0.768 (0.340-1.735)	0.525
	T3	0.098±0.508	1.103 (0.408-2.985)	0.846	0.520±0.574	1.682 (0.546-5.182)	0.365
PRO (g)	T1			0.069			0.096
	T2	-0.927±0.423	0.396 (0.173-0.907)	0.028	-0.941±0.454	0.390 (0.160-0.950)	0.038
	T3	-0.840±0.442	0.432 (0.182-1.027)	0.058	-0.642±0.485	0.526 (0.203-1.362)	0.176
CHO (g)	T1			0.470			0.755
	T2	0.294±0.405	1.342 (0.607-2.967)	0.467	0.208±0.438	1.231 (0.521-2.905)	0.636
	T3	-0.186±0.431	0.830 (0.356-1.934)	0.666	-0.106±0.499	0.900 (0.338-2.392)	0.832
Fat (g)	T1			0.009			0.005
	T2	-0.158±0.394	0.854 (0.394-1.848)	0.688	-0.480±0.459	0.619 (0.252-1.519)	0.295
	T3	1.039±0.430	2.827 (1.218-6.562)	0.016	0.992±0.456	2.697 (1.103-6.594)	0.030
Factor 1[d]	T1			0.560			0.584
	T2	-0.023±0.374	0.977 (0.470-2.032)	0.950	0.043±0.395	1.043 (0.482-2.261)	0.914
	T3	-0.368±0.381	0.692 (0.328-1.460)	0.334	-0.364±0.422	0.695 (0.304-1.589)	0.388
Factor 2[e]	T1			0.161			0.434
	T2	-0.585±0.380	0.557 (0.264-1.175)	0.124	-0.332±0.405	0.718 (0.324-1.588)	0.413
	T3	-0.673±0.381	0.510 (0.242-1.075)	0.077	-0.555±0.436	0.574 (0.244-1.350)	0.203
Energy intake in dinner (kcal)	T1			0.015			0.021
	T2	-0.667±0.387	0.513 (0.240-1.095)	0.085	-0.650±0.413	0.522 (0.233-1.173)	0.116
	T3	-1.141±0.397	0.320 (0.147-0.696)	0.004	-1.210±0.437	0.298 (0.127-0.702)	0.006
Energy spent in physical activity after blood sampling (kcal)	T1			0.381			0.101
	T2	-1.018±0.391	0.361 (0.168-0.777)	0.009	-0.889±0.416	0.411 (0.182-0.929)	0.033
	T3	-0.535±0.392	0.586 (0.272-1.263)	0.173	-0.486±0.418	0.615 (0.271-1.395)	0.245
Energy of bedtime snack (kcal)	M2	-0.278±0.317	0.757 (0.406-1.410)	0.381	-0.247±0.334	0.781 (0.406-1.503)	0.459

[a] Analyzed by logistic regression.

[b] Energy intake in bedtime snack was stratified into two medians and other variables were stratified into three tertiles.

[c] PYY3-36 concentrations were stratified into two medians.

[d] Factor 1 included usual energy expenditure and energy spent before and after blood sampling over physical activity.

[e] Factor 2 included energy intake in different snacks and meals (lunch, afternoon, dinner, and bedtime).

[f] Unadjusted (crude) model.

[g] Adjusted with age, gender, smoking, supplements use, and stable weight, PYY3-36: peptide YY 3-36, GI: Glycemic index, GL: Glycemic load, T: tertile, M: median, tertile 1 was set as reference and other tertiles were compared with it.

[*] $P \leq 0.05$ was considered significant.

and absorption as the ease of micelle formation rises with the unsaturated degree of fat (30), consequently increasing satiety and hormone release (29). On the other hand, absorption efficiency decreases in response to chain elongation (31,32), and this feature probably caused reverse association of EPA and DHA with PYY3-36 in the present study. There were several limitations regarding the present research. The main constraint of the study was its small sample size. Secondly, other peptides such as NPY were not measured due to high costs. Thirdly, subjects' work-related stress was not controlled.

Conclusions

In this cross-sectional study, a direct significant correlation between PUFAs and linoleic acid with PYY3-36 and an inverse significant association between the amounts of energy spent to perform physical activities after obtaining blood sampling and PYY3-36 were indicated. The PYY3-36 levels after lunch consumption were related inversely to energy intake at the following dinner. Moreover, high levels of PYY3-36 reduced energy intake at the following dinner meal. Protein and fat intake at lunch, energy intake at dinner, and energy spent to perform physical activities after lunch significantly predicted the level of post-lunch PYY3-36. GI and GL had no effect on PYY3-36. The results of the present study suggest conducting studies with larger sample sizes. Furthermore, measurement of postprandial PYY3-36 at several times and examination of the effects of type of carbohydrate, protein, or amino acids on PYY3-36 may shed more light in this regard.

Conflict of Interests

The authors of this article declare that there is no conflict of interests in this research.

Ethical Issues

The protocol of the study was confirmed by the Ethics Committee of Urmia University of Medical Sciences.

Financial Support

This article is supported by Urmia University of Medical Sciences and is extracted from a master's thesis in nutrition.

Acknowledgements

We acknowledge the contributions of the participants to the present study. We greatly appreciate Dr. Rasoul Zarrin, the manager of Imam Khomeini hospital of Urmia, for his great assistance and support and Dr. Farzad Ebrahimzadeh for data analysis.

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