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Original Article

Association of non-nutritive sweeteners intake with body weight, daily food consumption and appetite in an adult population

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SUMMARY

Background: Non-nutritive sweetener (NNS) is a substitute to sugar or nutritive sweetener, those that imitate the flavor of sugar but with less calories. This study evaluated the impact of NNS consumption on daily food intake, appetite and weight control among adults in Mount Lebanon.

Methods: An online survey was conducted among 553 adults aged 18–55 years in a low socioeconomic district Mount Lebanon. A cross-sectional study design, and snowballing sampling with sample size 553 were used in the study. Chi-squared test and t test for tetrachoric correlation were used for bivariate analysis, while partial proportional odds logistic, polychotomous logistic and multiple linear models were used for multivariate analysis.

Results: Compared to those not consuming NNS, the odds of grains, bread, artificially sweetened non-alcoholic beverages, snacks consumptions were significantly lower for those consuming NNS 'once a day' and '2–3 times a day'; '2–3 times a day' and '4–5 times a day'; '4–5 times a day'; '3–4 times a day' and '5 or more times a day'. NNS consumers did not significantly have lower odds of high frequency meals and appetite respectively than non-consumers. There was no evidence of difference in BMI between NNS consumers versus non-consumers.

Conclusion: NNS is associated with grains, bread, artificially sweetened non-alcoholic beverages and snacks but not with meals

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when it is taken in combination with the item. This study provides the basis for future research on NNS consumption in Lebanon.

Introduction

Diets high in sugar or having added sugar assume a significant contributing part in the expanded prevalence of many diseases [1]. Added sugar includes sucrose, fructose, glucose, dextrose, table sugar, starch hydrolysates (glucose syrup, high-fructose syrup), and other isolated sugar preparations which are added during food preparation and manufacturing [2]. High weight gain level related mortality has brought about an overflow of weight reduction diets and items containing nonnutritive sweetener (NNS) [3]. Sweeteners are considered an alternative to added sugars and are comprised of both caloric sweeteners that provide energy and non-nutritive sweeteners (NNSs) that do not provide energy [4,5]. NNSs are food supplements that imitate the flavor of sugar with less calories and enhance the taste and/or texture of food. They also provide the body with calories, although NNSs provide fewer calories/gram because they are not totally absorbed by digestive system [6]. Expanding interest for such items has brought about a growth in the production of NNS [3].

Replacing sugar with NNS also supports diabetics to regulate their caloric intake and help them to plan their meals more flexibly. Sugar elimination is still something that is unlikely to happen in the near future. As NNS in food sources and drinks is being increasingly used around the world, there is rising awareness of the connection between obesity and diet [1].

NNS might be expected to reduce energy intake and body weight, however, many recent studies have shown that adding NNS to diet leads to increased appetite for sweet foods and promotes energy intake, thus affecting body weight and contributing to obesity, and health issues. Whether NNS is helpful or harmful for weight management is still a controversial topic [3,7].

In Lebanon, both artificial sweeteners and artificially sweetened products are common with 30% and 31% respectively of the population consuming them according to a recent survey in late 2020 [8]. The highest percentage of consumers (41%) made the shift to sweeteners from regular tabletop sugar which is substantially pure sucrose, about one year prior to this survey. So, there is evidence of increasing NNS consumption in Lebanon. Because adding NNS to diet can lead to increased appetite and affect body weight in other populations, we evaluate its impact on the daily food consumption, appetite and body weight among adults residing in Mount Lebanon-the largest district in Lebanon. Based on our literature search, our study is the first such type in Lebanon and is therefore a good stepping stone for similar future studies to be conducted at the national level.

Materials and methods

Study design

A cross-sectional study was conducted on 553 healthy participants in December 2020 where only the quantitative data collection tool was used. Mount Lebanon was chosen among the eight governorates of Lebanon because of diversity of its residents. According to the Central Administration of Statistics, Mount Lebanon has a population of 22,673 [9].

The recruitment of participants occurred through social media where the researcher (RS) used her private platforms (Facebook, Instagram, and Whatsapp) to announce the study and its objectives. Those interested in participating in the study were invited to get in touch with the researcher through a post on her platform or a comment on her related post. This was done as a first round, afterwards, the sampling continued using a snowballing effect where participants started to explain about the study to

other people and guide them to be in contact with the researcher if they were interested to participate in the study.

The study, its objective, the inclusion and exclusion criteria, expected duration for completing the questionnaire and the ethical considerations were announced through social media. A structured questionnaire was shared with people meeting the inclusion criteria. The inclusion criteria was as follows: Lebanese citizen, people aged 18 to 55, non-athletes, adults who do not drink alcohol heavily, do not take medications that can affect food intake, were of normal weight and neither pregnant nor lactating women.

Sampling and sample size

A snowballing sampling technique was used to recruit participants for this online study as the sample was completed by recruiting participants on the referral of primary study participants. They were all adults since the adult population is the highest consumer of NNS in Lebanon. The sample size of this study ($n = 553$) was calculated using the equation of Krejcie and Morgan [10] for a population size of $N = 6{,}765$ who were all adults aged between 18 and 55 years.

Data collection methods

A self-administered questionnaire was used to collect the data online from participants. It was developed on the basis of the Council On Nutrition Appetite Questionnaire (CNAQ) and Food Frequency Questionnaire [11–13]. It included 5 main sections as follows:

The first section entailed questions about the demographic characteristics (age, sex, level of education, employment status and salary range), the second section included anthropometric measurements of participants height and weight within ± 0.5 cm and ± 0.1 kg respectively, the third one focused on the method and frequency of consuming NNS products. Section four was about assessing the dietary pattern and appetite scale of participants. Section five included a validated food frequency questionnaire aiming at noting participants' frequency of consumption of the various food types. Weight loss was not assessed. Instead, Body Mass Index (BMI) was used for assessing body weight. Anthropometric measurements for height and weight were not obtained due to COVID-19 related lockdowns. So, they were self-reported. For adults, BMI was interpreted using standard weight status categories. These categories were similar for men and women of all body types. Appetite was measured using an ordinal scale: 'very poor or poor', 'average', 'good' and 'very good'.

Before launching data collection, the questionnaire was translated into Arabic and tested in both Arabic and English formats. The questionnaire was distributed randomly to people - colleagues, neighbours, and friends not living in Mount Lebanon to make sure that the questionnaire is culturally acceptable and that it captured all the required information. After finalizing the testing period, the questionnaire was finalized and issued in the final Arabic and English versions.

The research Ethics Committee of the Holy Spirit University of Kaslik approved the study and oral consent was provided to all participants. Each participant provided written consent to participate in the study [14].

Statistical analysis

All data were analyzed using SAS version 9.4 [15]. The characteristics of the participants (i.e., sociodemographic, weight, height and BMI) were analyzed and presented as frequencies and percentages or mean±standard error. Chi-squared test was used to evaluate the association between two categorical variables, two independent sample t test was used to find the statistical difference in mean between two groups. Tetrachoric correlation was used to find the association between a binary variable (e.g., NNS consumption) and an ordinal variable (e.g., participants' appetite rating). T test was used to assess whether the correlation differed statistically from zero. Partial proportional odds logistic model was used to find the effect of a binary variable (e.g., NNS consumption), on an ordinal dependent variable (e.g., participants' appetite rating), after controlling for potential confounders (e.g., age, sex and education), as the proportional odds assumption was violated for some but not all covariates.

Polychotomous logistic model was used to find the effect of a binary variable (e.g., NNS consumption), on a nominal dependent variable (e.g., grains, bread, artificially sweetened non-alcoholic beverages, fruits and non-sweetened juices, snacks), after controlling for potential confounders (e.g., age, sex and education). Multiple linear regression model was used to find the effect of a binary variable (e.g., NNS consumption), on a continuous dependent variable (e.g., BMI), after controlling for potential confounders (e.g., age, sex and education). For all analyses, p-value$\leq$0.05 was used to detect any statistically significant effect.

Results

Descriptive analysis

A total of 553 participants completed the survey. Of the participants, majority were females constituting 53% while 47% were males (Figure 1). The vast majority reported holding a high school diploma or at least one university degree (data not shown).

Most of participants (35.4%) were aged 18–24 years, followed by 18.4% aged 25–29 years. Of the 150 people who reported consuming NNS, most (n = 70, 46.9%) reported taking it as tablets. The next most common response was from those who consumed liquid forms of NNS (n = 49, 32.9%). As for the reasons of NNS consumption, r 95.0% (n = 143) reported consuming NNS to enjoy the sweet taste without any added calories and for managing their weight. In addition, out of 148 NNS consumers who reported their duration, 96 or 64.9% consumed it for more than one year.

The mean BMI of participants was 24.12 kg/m^2 (SE=0.17) which fell within the healthy range of 18.5–24.9 kg/m^2. There was no significant difference in mean BMI between men and women (Table 1).

Effects of NNS consumption

The difference in bread consumption between those consuming and not consuming NNS as shown in Table 2 was statistically significant (p<0.0001) with smaller percentages for frequencies 2–3, 4–5 and 6 or more times per day in the NNS group compared to the other. Also, smaller percentages of NNS consumers ate grains for these frequencies than those who were not NNS consumers; the difference was significant (p=0.002).

Compared to those who did not consume NNS, those consuming NNS drank significantly (p=0.007) different artificially sweetened beverages with lower percentages for frequencies 4–5 and 6 or more times per day (Table 2). Between those who consumed and did not consume NNS but ate and drank the same total quantity of fruits and non-sweetened juices per day, the difference in percentages was not statistically significant (p=0.150).

Tables 3 and 4 show that when compared to NNS non-consumers, those consuming NNS ate less snacks and meals respectively for frequencies 3–4, 5–6 and 7 or more times per day. The overall association was significant (p<0.0001) for snacks but non-significant (p=0.4198) for meals.

There was negatively significant association (tetrachoric correlation=-0.4467, p<0.0001) between consuming NNS and self-rating of appetite by respondents (Table 5).

However, based on multivariate analysis (partial proportional odds regression), after controlling for age, sex and education, those who consumed NNS had non-significantly lower odds of appetite rating than those who did not (Table 6a). Furthermore, the odds increased non-linearly with rating, the highest being for 'good' vs 'very poor/poor' appetite rating which was still not significant.

After controlling for the three factors, BMI was non-significantly higher for those consuming NNS than those who did not (Table 6b).

Table 6c shows the effect of NNS consumption on grains, bread, fruits and non-sweetened juices, artificially sweetened non-alcoholic beverages after controlling for the effects of age, sex and education. The odds of grains consumption were significantly lower for those consuming NNS 'once a day' and '2–3 times a day' respectively than those not consuming NNS. The result was similar for bread consumption except that the significant reduction in odds were found for bread consumed '2–3 times a

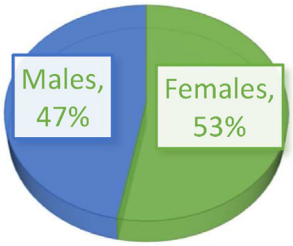

Figure 1. Sex Distribution of Study Participants.

day' and '4–5 times a day' respectively. The odds of consuming fruits and non-sweetened juices at different intensities which were associated with NNS consumption were lower compared to NNS non-consumption, without reaching statistical significance. However, for artificially sweetened non-alcoholic beverages, the odds was significantly lower only when they were consumed '4–5 times a day'. For snacks, the odds were significantly lower when they were consumed '3–4 times a day' and '5 or more times a day'.

Discussion

The objectives of this study were to assess the impacts of the consumption of NNS on the daily food consumption, appetite and weight control among residents of Mount Lebanon which is the largest district of Lebanon. Among the 553 participants, a high percentage (71.9%) reported not consuming NNS. In addition, a high percentage (64.9%) of NNS consumers reported a duration of more than 1 year. Several studies have found that NNS consumption increases energy intake [[16–18]] while another found that it decreases [19].

Those who consumed NNS did not report significantly lower appetite rating than those who did not, after controlling for confounding by age, sex and education. This finding was in line with another study [20] which showed that NNS consumption was not linked to augmented appetite. This contradicted with another study [21] which indicated that NNS in drinks exerted an increasing impact on appetite in general, and on appetite for sweet-tasting products such as sugary snacks. To explain this difference further research is required.

A very high percentage (95%) of the respondents who consumed NNS reported that they enjoyed the sweet taste without the added calories but did not consume it for managing their weight. This is not in line with the literature where it was noted that although NNS is produced to provide people with sugar like taste it helps in weight management including reduction by controlling related energy intake [22–24]. Further research is required to explain this difference.

The frequency distribution of meals for those who consumed NNS and those who did not was not significantly different. The percentages consuming high frequency of meals such as 3 to 4 meals per day or 5 or more meals per day were slightly lower for those consuming NNS. In contrast, the pattern was in the opposite direction for those consuming no meal or 1 to 2 meals per day. These findings supported both Cong *et al.* [25] and Sylvetsky and Rother [7] in terms of the direction of the relationship, however statistical significance was found only for the latter.

Table 1
Mean BMI by NNS consumption.

Weight Indicator	NNS (artificial sweeteners) consumption		p-value
	Yes (N=150) Mean ± SE	No (N=376) Mean ± SE	
BMI	24.28 ± 0.31	24.05 ± 0.21	0.215

Table 2
NNS consumption and daily food consumption.

Variable	NNS (artificial sweeteners) consumption				p-value
	Yes (N=150)		No (N=376)		
	Number	Percentage	Number	Percentage	
Bread					
None	28	19.18%	7	1.86%	<0.0001^
Once a day	73	50.00%	15	3.99%	
2-3 times per day	39	26.71%	104	27.66%	
4 or more times per day	6	4.10%	250	46.49%	
Total	146	100%	376	100%	
Grains (rice, burghul, quinoa)					
None	53	37.06%	72	20.63%	0.0025^
Once a day	68	47.55%	203	58.17%	
2-3 times per day	19	13.29%	65	18.62%	
4 or more times per day	3	2.10%	9	2.58%	
Total	143	100%	349	100%	
Fruits and non-sweetened juices					
None	34	23.94%	63	18.53%	0.151^
Once a day	39	27.46%	109	32.06%	
2-3 times per day	40	28.17%	116	34.12%	
4-5 times per day	21	14.79%	44	12.94%	
6+ times per day	8	5.63%	8	2.35%	
Total	142	100%	340	100%	
Artificially sweetened non-alcoholic beverages (coffee, tea)					
None	36	25.17%	80	23.05%	0.0065^
Once a day	49	34.27%	117	33.72%	
2-3 times per day	51	35.66%	93	26.80%	
4-5 times per day	6	4.20%	46	13.26%	
6+ times per day	1	0.70%	11	3.17%	
Total	143	100%	347	100%	

Note: ^P-values reported in red are significant at 0.05 level of significance.

Most NNS consumers reported eating bread 4 to 5 times per day while most not consuming it reported eating bread once a day. The difference between consuming or not consuming NNS and frequency of consuming bread, grain, sugary snacks and non-alcoholic artificially sweetened beverages was each statistically significant. This contradicts Sylvetsky and Rother [7] which indicated that including NNS in the diet was supportive for weight loss in a randomized controlled trial.

The finding that those who consume NNS eat fewer snacks per day than non-consumers might be related to the fact that NNS consumption in various cases was linked to a prudent diet particularly if the main goal for consuming these products was to manage or decrease weight [19].

The study has both strengths and limitations. First, the study is the first of its kind to be conducted in Lebanon. It presents various insights into NNS consumption and related effects on daily food intake, weight control and appetite which are still topics for further research.

Table 3
NNS consumption and number of snacks consumed per day.

Variable	NNS (artificial sweeteners) consumption				p-value
	Yes (N=150)		No (N=376)		
	Number	Percent	Number	Percent	
Number of Snacks Per Day					
Less than one snack	23	15.33%	44	11.70%	<0.0001
1-2 snacks a day	100	66.67%	189	50.27%	
3 or more snacks a day	27	18.00%	143	38.04%	
Total	150	100%	376	100%	

Table 4
NNS consumption and dietary patterns.

Variable	NNS (artificial sweeteners) consumption				p-value
	Yes (N=150)		No (N=376)		
	Number	Percent	Number	Percent	
Number of Meals per Day					
Less than one meal a day	4	2.67%	8	2.13%	0.4198
1-2 meals a day	57	38.00%	117	31.12%	
3-4 meals a day	84	56.00%	227	60.37%	
5 or more meals a day	5	3.33%	24	6.38%	
Total	150	100%	376	100%	

The results of this study cannot be generalized to the whole population of Lebanon as this is a study conducted only in the district of Mount Lebanon. Another study limitation is related to the fact that in view of COVID-19 pandemic and its related preventive measures particularly lockdowns, the data collection was conducted through an online survey which hindered the researchers' ability to ask the respondents to specify their exact quantitative daily intake of NNS and sugar. This limitation restricted the age groups targeted by the study to those between 18 to 29 years. Because of COVID-19 related lockdowns it wasn't possible to obtain anthropometric measures of respondents' height and weight. So, BMI was calculated using self-reported weight and height which is a study limitation. Also, noting that this is a cross-sectional study, the answers by respondents may be influenced by recall bias as they may not have been well prepared to recall their daily intake of NNS containing products. To ease the recall of NNS containing products the respondents were shown their samples and given examples of such food products.

Table 5
NNS consumption and participants' appetite rating.

Variable	NNS (artificial sweeteners) consumption				Tetrachoric correlation (p-value)
	Yes (N=150)		No (N=376)		
	Number	Percent	Number	Percent	
Participants' Appetite Rating					
Very poor/Poor	3	2.00%	22	5.85%	-0.4467 (<0.0001)
Average	51	34.00%	104	27.66%	
Good	41	27.33%	132	35.11%	
Very Good	55	36.67%	118	31.38%	
Total	150	100.00%	376	100%	

Table 6a
Partial proportional odds logistic regression of appetite rating on NNS after controlling for the effects of age, sex and education.

Covariate	Dependent variable			
NNS	Appetite rating			
Contrast	Odds ratio	SE	p-value	95% CI
Average vs very poor/poor appetite	0.522	0.345	0.346	0.135, 2.020
Good vs very poor/poor appetite	0.994	0.108	0.976	0.650, 1.519
Very good vs very poor/poor appetite	0.725	0.106	0.131	0.478, 1.101

Note: The effects of control variables age, sex and education are not shown. The effect of only sex satisfied the proportional odds assumption.

Table 6b
Multiple linear regression of BMI on NNS after controlling for the effects of age, sex and education.

Covariate	Dependent variable			
	BMI			
	Coefficient	SE	p-value	95% CI
NNS	0.559	0.365	0.126	-0.158, 1.277

Note: The effects of control variables age, sex and education are not shown.

Table 6c
Polychotomous logistic regressions of consumption of grains, bread, fruits and non-sweetened juices, artificially sweetened non-alcoholic beverages and snacks on NNS after controlling for the effects of age, sex and education.

Covariate	Dependent variable			
NNS	Grains			
Contrasts	Odds ratio	SE	p-value	95% CI
Once a day vs none	0.439	0.122	0.008*	0.271, 0.710
2-3 times a day vs none	0.354	0.172	0.002*	0.180, 0.695
4 or more times a day vs none	0.580	0.363	0.452	0.140, 2.405
Covariate	Dependent variable			
NNS	Bread			
Contrasts	Odds Ratio	SE	p-value	95% CI
Once a day vs none	0.936	0.148	0.824	0.524, 1.673
2-3 times a day vs none	0.395	0.159	0.003*	0.211, 0.739
4 or more times a day vs none	0.217	0.265	0.004*	0.077, 0.615
Covariate	Dependent variable			
NNS	Fruits and non-sweetened juices			
Contrasts	Odds Ratio	SE	p-value	95% CI
Once a day vs none	0.596	0.151	0.088	0.329, 1.081
2-3 times a day vs none	0.636	0.147	0.124	0.357, 1.133
4 or more times a day vs none	0.877	0.166	0.693	0.456, 1.686
Covariate	Dependent variable			
NNS	Artificially sweetened non-alcoholic beverages			
Contrasts	Odds Ratio	SE	p-value	95% CI
Once a day vs none	0.825	0.140	0.494	0.475, 1.433
2-3 times a day vs none	1.027	0.142	0.926	0.587, 1.794
4 or more times a day vs none	0.247	0.236	0.003*	0.098, 0.625
Covariate	Dependent variable			
NNS	Snacks			
Contrasts	Odds Ratio	SE	p-value	95% CI
1-2 times a day vs none	1.125	0.157	0.708	0.608, 2.081
3-4 times a day vs none	0.427	0.185	0.043*	0.228, 0.978
5 or more times a day vs none	0.111	0.536	0.040*	0.014, 0.910

Note: *P-values reported in red are significant at 0.05 level of significance. The effects of control variables age, sex and education are not shown.

Conclusion

Food beverages containing high levels of sugar are among the main food items responsible for increasing obesity rates around the world. This study was conducted to address this issue in context of consumption of NNS with food products and its effect on weight control, caloric intake and appetite. It

was conducted in Mount Lebanon which is one of the largest districts in Lebanon. The majority of the people who reported consuming NNS were doing so for at least one year, for weight control and to enjoy the sweet taste while avoiding the added calories. A non-significant difference was found between the mean BMI of NNS consumers and that of those who did not consume NNS.

The results of this study in what relates to the difference in frequency of daily meals between NNS consumers and non-consumers was not significant. However, when those consuming and not consuming NNS consumed a specific diet like bread or grains or non-alcoholic beverages or sugary snacks, the daily frequency of each of these items was significantly smaller for NNS consumers. This finding supported previous studies which indicated that consumption of NNS with drinks and foods in the diet, could help to lose weight and reduce total caloric intake.

NNS consumers had non-significantly lower appetite than the non-consumers unless it was consumed with a specific diet like bread or grains or sugary snacks. NNS consumption is sometimes related to a certain dietary follow-up and steps to reduce food intake in a holistic way to start a "healthier" lifestyle. So, a longitudinal study will help to confirm the findings of this study. Given that long term NNS consumption is high in the Lebanese population studied, it is also important to determine any potential long-term impact of NNS consumption on the health, weight, and caloric intake of people. A larger or national level study using a face-to-face administered survey should also be conducted in Lebanon. However, this study is still of added value to the literature and a good stepping stone for future studies as discussed above.

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The study received no funding.

Author's contribution

HM contributed to study design, data analysis, manuscript preparation, critical review of manuscript; RS contributed to data analysis, manuscript preparation; RA contributed to data analysis, manuscript preparation; SY contributed to study design, manuscript preparation, critical review of manuscript. All authors read and approved the paper.

Conflict of interest statement

The authors declare no conflict of interest.

Ethical considerations

The research Ethics Committee of the Holy Spirit University of Kaslik approved the study and oral consent was provided to all participants. Each participant provided written consent to participate in the study. The participants were anonymous, and had the right to withdraw at any time. The gathered data was only used for the purpose of the study. Also, the study did not entail any questions that might harm the participants additional to the harm they might face during their daily activities.

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