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Nutrition in Health and Disease

Dietary Consumption of Lutein and Zeaxanthin in Panama: A Cross-Sectional Study

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Abstract

Background: The macular pigments of the eye increase with a diet rich in lutein and zeaxanthin, both of which are phytochemicals and important for visual health.

Objective: We aimed to determine the dietary consumption of lutein and zeaxanthin in adults working at the Universidad de Panamá (University of Panama), Panama City.

Method: This was a cross-sectional study with 164 subjects including both men and women >18 y of age and employed at the University of Panama, Panama City, Panama. The data collection was carried out between May and September 2017. A semiquantitative food frequency questionnaire was applied with 43 foods high in lutein and zeaxanthin, which included eggs as the only source of animal protein, 23 vegetables, 15 fruits, and 4 foods prepared with corn as an ingredient.

Results: The mean ± SD age was 45.7 ± 12.7 y (72% women). The mean ± SD and median (IQR) lutein consumption were 2.063 ± 2.334 mg/d and 1.512 (1.385) mg/d, respectively; and for zeaxanthin these were 0.858 ± 0.866 mg/d and 0.550 (0.819) mg/d, respectively. The food products that contributed the most dietary lutein and zeaxanthin were tomatoes, corn tortilla, and egg yolk.

Conclusion: The consumption of lutein and zeaxanthin is low among people working at the University of Panama, and this is not associated with sociodemographic variables.
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Introduction

Lutein and zeaxanthin are antioxidants that protect the retina and lens against ultraviolet and blue spectrum light. Deficiencies cause a decrease in the density of the macular pigment (1, 2). Progressive visual decline has consequences on people's quality of life. In addition, visual impairment can lead to uncomfortable situations such as incomplete and blurred vision or even permanent blindness (3), which has a negative impact on people close to those affected that includes additional expenses and special care. These diseases can be avoided, and their progression can be reduced or treated better with a healthy diet containing a naturally high content of lutein and zeaxanthin (4).

Although macular diseases usually appear among the elderly, some studies show that regular dietary consumption of lutein and zeaxanthin contributes to a lower incidence of age-related macular degeneration (AMD) (5). On the other hand, there are several factors that influence lutein and zeaxanthin consumption. They mostly derive from plants, so their contribution in the diet could be conditioned by seasonality, prices, and geographic location (5, 6).

In Panama, the population's consumption of these 2 carotenoid antioxidants is unknown. However, there is a high prevalence of visual impairment in the general population (7). A study conducted by López et al. (8) evaluated 4125 people in Panama and reported that the prevalence of blindness is at a medium level compared with what is found in other countries of the region.

Keywords: lutein, zeaxanthin, consumption, Panama, carotenoids

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However, it should be possible to reduce these numbers, because 76.2% of cases of blindness and 85.0% of cases of severe visual impairment are due to preventable causes. Untreated cataracts were the most frequent cause of bilateral blindness, AMD represented 5.1%, and diabetic retinopathy 1.5% (7). Because the optimal intake of these carotenoids (lutein and zeaxanthin) is not known, the objective of the present study was to define the dietary consumption levels of lutein and zeaxanthin in adults working at the University of Panama, Panama City, Panama.

Methods

Design

This is a cross-sectional study including 164 subjects. Data collection was carried out from May to September 2017 by researchers from the School of Nutrition and Dietetics at the School of Medicine, University of Panama.

Population and study subjects

The individuals in the study included participants of both sexes and were ≥18 y old, apparently healthy, working as administrative staff at the University of Panama, and representing a population of a low to middle socioeconomic level. Although the study participants are not representative of the Panamanian population at large, it is relevant to know the dietary consumption of both phytochemicals in the urban context and at the low and middle socioeconomic levels. Foreigners, disabled citizens with difficulties in answering the survey, and participants with non-Panamanian diets, for example Indian, Arabic, or Chinese ethnic groups, were excluded. Volunteers without physical or mental disabilities were included. Participants were asked about their consumption of prophylactic supplements with or without lutein and zeaxanthin.

Power and sample size

The participants were selected based on the objective of the study, which was to identify the dietary consumption pattern of lutein and zeaxanthin in a representative sample of adults working at the University of Panama. The sample size was calculated to give a reliable estimate of the mean zeaxanthin intake. In total, 164 subjects were evaluated. To estimate the power of the sample size, STATA 12.0 (StataCorp LP, College Station, TX) was used with the following parameters: Ho = mean 0.124 according to what was reported by Florian et al. (2002) (9); Ha = observed mean 0.858 ["Sampsi 0.124 0.858, SD (0.866) n (164) onesam"]. The estimated power for the comparison of the observed mean with the reference value of zeaxanthin intake allowed a power of 90% to be reached. The sampling method applied was "as per convenience," depending on the willingness of the subjects to participate.

Procedures

Semiquantitative FFQ. A semiquantitative FFQ was applied with a specific list of 43 foods containing lutein and zeaxanthin commonly consumed in the Panamanian population. The availability and affordability of food products at the time of the study were considered. The lutein and zeaxanthin amounts were estimated through the use of data from tables published by Murillo et al. (10). The survey model was taken from the validated FFQ of the University of Arizona of the United States (1994) (11). The options in the questionnaire were multiple-choice and included never (0), 1 time/wk (1), 2–3 times/wk (2), 4–6 times/wk (3), 1 time/d (4), >2 times/d (5), ≤1 time/mo (6), and >2 times/mo (7).

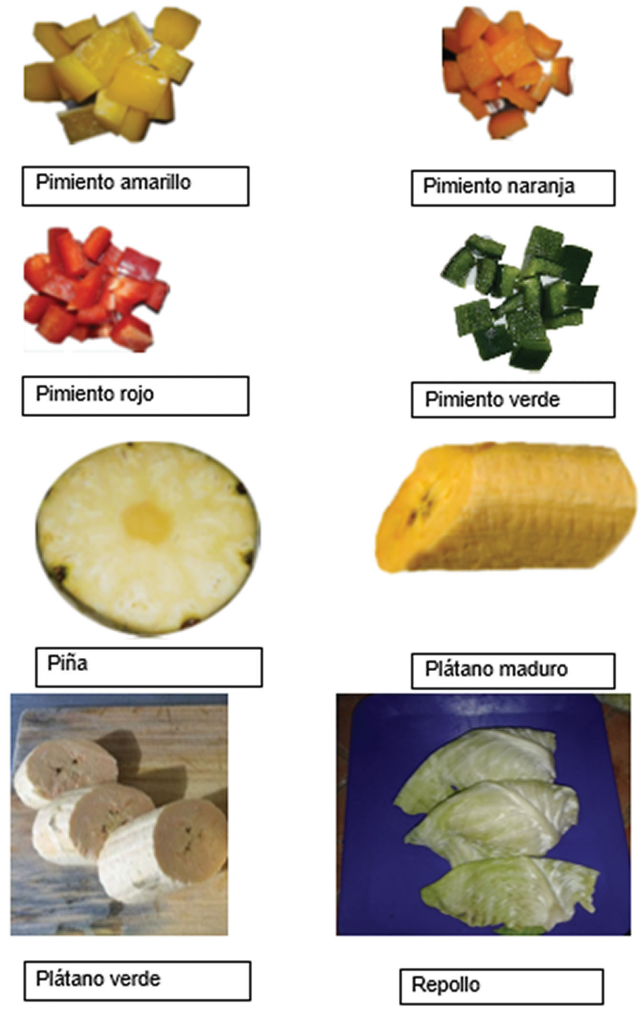

FIGURE 1 Example of food identification catalog.

The portion sizes of the foods were estimated with the use of a food recognition catalogue (see **Figure 1**) and a standardized portion weight corresponding to the catalog images, based on which participants selected the portion size or fraction of it. The data were transformed to consumption data by estimating weight in grams from the selected portion, and the consumption per week of the phytochemicals content in milligrams per day was established for each standard portion. To obtain the individual intake, the content of each phytochemical was estimated in the different portion weights of foods. Then the month, week, and daily intake were estimated through the use of the algorithms proposed by Pakseresht et al. (12) for a semiquantitative FFQ. The minimum recommendations of 2.4 mg/d for lutein and 1.3 mg/d for zeaxanthin were used to define the minimum daily requirements needed to prevent health or clinical implications (13, 14).

Application of the surveys. A previously validated digital survey was applied to a small sample of 10 subjects. The validation procedure was performed with the use of Toshiba portable tablet devices (Toshiba, Encore 2; Tokyo, Japan). The purpose of the validation was to ensure the clarity of the questions and the quality of the data collected. Likewise, it is worth noting that the surveys were reviewed by 2 nutritionists participating in the study to guarantee adequate data collection and quality assurance of the information.

Surveys. Before the data collection, in April 2016, all response options were given number codes and the 2 Toshiba tablets were programmed into an online cloud-based Excel Macros visual basic book. This digital survey was done according to the paper survey model.

Food recognition catalog. A food recognition catalog with images of foods used to identify the food products included in the surveys was created. To analyze the consumption data, the food products were weighed 3 times in their edible form. The mean of the 3 weights was calculated to obtain the value of the portion to be used in the food consumption frequency survey. These values were used in the analyses of the results.

Classification of food content of lutein and zeaxanthin. Forty-three food sources of lutein and zeaxanthin present in the Panamanian diet were identified. These foods were categorized as 23 vegetables, 15 fruits, 4 minimally processed prepared foods containing corn, and 1 food from an animal source (eggs). In terms of lutein content per 100 g, there are 5 foods with very high content of lutein, 3 with high content, and 35 with low content among the foods identified. Regarding zeaxanthin, 1 food with very high content was identified, 1 with high content, 32 with low content, and 9 with no reported content, as shown in **Table 1**. According to Britton and Khachik (15), a very high carotenoid content is considered as >2 mg/100 g, and a high carotenoid content from 0.5 to 2 mg/100 g (see Table 1).

Statistical analysis. All analyses were performed with the STATA 12.0 statistical package. Statistical significance was established when the P value of the statistical tests was $P < 0.05$. The continuous variables are presented as mean ± SD or median (IQR) in their respective units of measurement. The categoric variables were presented as frequencies and percentages and the proportion of participants with low consumption of lutein and zeaxanthin was compared with the use of the chi-square test. To determine the magnitude of the association between the dietary consumption of lutein or zeaxanthin and the sociodemographic variables, multivariate modeling through multivariate linear regression was applied. The selection of the regression model was obtained with the use of a stepwise procedure to determine those variables that were related to the dependent variable (lutein/zeaxanthin) with a probability of $P < 0.10$.

Ethical considerations

All participants received information on the purpose of the study, the procedures, and the potential risks and benefits. Subsequently, they were asked to sign an informed consent form. The participation was voluntary and there was no monetary or other kind of compensation provided for study participation. The study protocol was approved by the Ethics Committee of the University of Panama.

Results

Participants' sociodemographic characteristics

Consumption was studied for the 164 participants. Mean ± SD age was 45.7 ± 12.7 y, and 72% were women. Regarding the age categories, 34.7% were between 20 and 41 y, 36.0% between 42 and 63 y, and 29.3% between 54 and 77 y. Eighty percent reported having studied at university, 88% work 8 h/d, and 94% have a salary >$800.00/mo. The participants in the study reside mainly in Panama City (68%) and to the west of Panama (32%) (see **Table 2**).

Dietary consumption of lutein and zeaxanthin

The mean ± SD and median (IQR) of lutein consumption were 2.063 ± 2.334 mg/d and 1.512 (1.385) mg/d, respectively; and for zeaxanthin they were 0.858 ± 0.866 mg/d and 0.550 (0.819) mg/d, respectively. The food products that contributed the most content of dietary lutein and zeaxanthin were tomatoes, corn tortilla, and egg yolk (see **Table 3**). Despite the existence of supplements with lutein and/or zeaxanthin on the local market, only 1 person reported taking them prophylactically.

Association between lutein and zeaxanthin intake with sociodemographic variables

When correlating the sociodemographic variables studied with lutein and zeaxanthin consumption, the only associations found were between the consumption of lutein and sex (male compared with female): β (95% CI), −0.84 (−1.62, −0.06; $P = 0.035$); and between the consumption of lutein and age: 0.04 (0.01, 0.06; $P = 0.015$). No association was observed between the sociodemographic variables and the consumption of zeaxanthin (see **Table 4**). Furthermore, only a small proportion of study participants (23.8%) were taking ≥2.4 mg/d for lutein and less than onefifth (19.5%) were taking ≥1.3 mg/d for zeaxanthin (13, 14) (see **Figure 2**).

Discussion

These findings show low consumption of both lutein and zeaxanthin. In the case of lutein, these findings are consistent with a study conducted in the United States, in which an intake of 1.7 mg/d of lutein was reported (16). In spite of this, the consumption obtained was higher for both phytochemicals when compared with developing countries. In a study conducted in Brazil, it was observed that the mean intake of lutein from fruit and vegetables was 0.8 mg/d and for zeaxanthin, 0.06 mg/d (17). Likewise, it was higher than that reported in a study conducted in Cuba, in which the authors observed a mean lutein consumption of 0.79 mg/d and for zeaxanthin, 0.12 mg/d (9).

Most recently, Duran-Cabral et al. (18) reported a dietary consumption of lutein of 0.976 ± 0.229 mg/d, and of zeaxanthin of 0.684 ± 0.197 mg/d, in a small sample (n = 50) of citizens in the Dominican Republic. These findings are consistent with our results considering the geographic, social, and cultural similarities between Dominicans

TABLE 1 Mean weight and content of lutein and zeaxanthin in the portions of foods selected for the surveys[1]

Food products	Latin name	Mean weight per edible portion, g/d	Carotenoids per usual portion, mg		Carotenoids per 100 g, mg	
			Lutein	Zeaxanthin	Lutein	Zeaxanthin
Apricot	*Prunus armeniaca*	120.12	0.036	0.024	0.03	0.02
Banana	*Musa paradisiaca*	130	0.044	0	0.034	0
Broccoli	*Brassica oleracea (italica)*	120	0.127	0	0.106	0
Cabbage	*Brassica oleracea (viridis)*	60	0.15	0.006	0.25	0.01
Carrot	*Daucus carota*	67	0.241	0	0.36	0
Chicheme, 10% corn drink	*Zea mays* (drink)	320	0.056	0.074	0.018	0.023
Ciruela traqueadora (jocote)	*Spondias purpurea*	80	0.504[2]	0.064	0.630[2]	0.08
Corn	*Zea mays*	125	0.098	0.13	0.078	0.104
Corn tortilla, 90% corn	*Zea mays*	65	0.133	0.185	0.205	0.285
Corn flour	*Zea mays*	120	0.126	0.564	0.105	0.47
Egg yolk		19	0.143[2]	0.094	0.753[2]	0.495
Green pepper	*Capsicum annuum*	40	0.101	0	0.253	0
Green plantain	*Musa paradisiaca (AAB)*	95	0.021	0	0.022	0
Indian mustard	*Brassica juncea*	51.5	2.771[3]	0.041	5.381[3]	0.08
Kidney beans	*Phaseolus vulgaris*	40	0.172	0.001	0.43	0.003
Kiwi	*Actinidia deliciosa*	73.96	0.052	0	0.07	0
Lettuce	*Lactuca sativa*	41	0.082	0.004	0.2	0.01
Mango	*Mangifera indica*	195.5	0.117	0.098	0.06	0.05
Naranjilla (wild apple)	*Solanum quitoense*	157	0.298	0	0.19	0
Orange	*Citrus sinensis*	125.56	0.027	0.027	0.022	0.022
Orange melon	*Cucumis melo*	203	0.038	0.013	0.019	0.006
Orange pepper	*Capsicum annuum*	30	0.213[2]	1.674[3]	0.710[2]	5.580[3]
Passion fruit	*Pasiflora edulis*	72	0.012	0.014	0.017	0.019
Peach	*Prunus persica*	85	0.066	0.033	0.078	0.039
Pineapple	*Ananas camosus*	195	0.013	0.013	0.007	0.007
Plum	*Prunus domestica*	80	0.046	0.005	0.058	0.006
Potato	*Solanum tuberosum*	170	0.088	0.963[2]	0.052	0.566
Pumpkin	*Curcubita maxima*	110	5.861[3]	0.137	5.328[3]	0.125
Red grapefruit	*Citrus grandis*	130.56	0.026	0.026	0.02	0.02
Red papaya	*Carica papaya*	140	0.028	0.084	0.02	0.06
Red pepper	*Capsicum annuum*	35	0.059	0.118	0.169	0.337
Ripe plantain	*Musa paradisiaca (AAB)*	100	0.066	0	0.066	0
Romaine lettuce	*Lactuca sativa (longifolia)*	50	1.055[3]	0	2.110[3]	0
Spinach	*Spinacea juncea*	8	0.35[3]	0.006	4.375[3]	0.075
Sweet corn bun, 95% corn	*Zea mays*	157	0.418	0.058	0.266	0.037
Sweet potato	*Ipomoea batatas*	124.85	0.112	0.037	0.09	0.03
Tangerine	*Citrus reticulata*	95.04	0.19	0.2	0.2	0.21
Tomato	*Solanum lycopersicum*	126	0.258	0.099	0.205	0.079
Watercress	*Nasturitum officinale*	9	0.385[3]	0.004	4.278[3]	0.044
Yellow pepper	*Capsicum annuum*	25	0.073	0.145[2]	0.292	0.580[2]
Yellow potato	*Solanum tuberosum*	157	0.096	0.069	0.061	0.044
Yellow pumpkin/zucchini	*Sicona odorífera*	203	0.02	0.081	0.01	0.04

[1]The weight of the food is given in its edible portion, lutein, and zeaxanthin content (15).
[2]High content of carotenoids (0.005–0.02 mg/g) (10, 15).
[3]Very high content of carotenoids (>0.02 mg/g).

and Panamanians. However, to complement these descriptive analyses, there is still a need for a large-sample population study to define nutritional requirements for both lutein and zeaxanthin.

It is worth mentioning that the food product that contributes most to the consumption of lutein and zeaxanthin in the Panamanian study population is the green plantain. The "Standard of Living Survey 2008" showed that green plantain was used in 80% of the households surveyed (19). However, in Panama, the green plantain is almost always consumed in the form of *patacón*, a popular food that involves deep frying the plantain in vegetable oil, and very rarely in other ways. Despite this, green plantain can be considered a source of lutein and zeaxanthin and therefore a key food in preventing AMD in Panama, as well as other conditions related to carotenoid deficiency.

In addition to green plantain, the most consumed lutein and zeaxanthin food sources in the study population were tomatoes, egg yolks, green peppers, ripe plantains, fried corn tortillas, red peppers,

TABLE 2 Characteristics of participants[1]

Variable	Unit/categories	Mean ± SD/*n* (%)
Age	Years old	45.7 ± 12.7
Sex	Male	46 (28)
	Female	118 (72)
Education	High school	32 (19.5)
	University	132 (80.4)
Marriage status	Married	100 (60.9)
	Single	64 (39.0)
Income	≥$800.00/mo	88 (53.6)
	<$800.00/mo	76 (46.3)
Area of residence	Panama City	111 (68)
	West of Panama	53 (32)

[1]Data presented as mean ± SD or frequency and percentage.

beans, banana, and yellow potato. However, it is important to consider the bioavailability of the phytochemicals in these foods because they are mostly vegetable sources. It has been described that despite their high content, the absorption of carotenoids in these foods is affected by the presence of fat and the cooking method used (5). Egg yolks were the only animal-origin food source of lutein and zeaxanthin reported in this study. It should be noted that egg yolks have been described by other authors as a good source of carotenoid content (20).

When comparing the dietary consumption of lutein and zeaxanthin in our study participants with that reported in a study conducted in the United States by Abdel-Aal et al. (21), 42% of the surveyed Panamanians have >1.17 mg of lutein consumption/d and 29.3% have a zeaxanthin consumption above a range of 1–3 mg/d. This comparison suggests that a small portion of the study population reaches the values found by Abdel-Aal et al. However, these numbers do not reach 50%. The foods most frequently consumed, reported above, could be used as examples in a nutritional counseling session to promote necessary diet change to achieve greater dietary consumption.

In the present study, no significant association was found between the consumption of lutein or zeaxanthin and the sociodemographic variables except for sex and age. More than 70% of participants were classified as low consumers of both lutein and zeaxanthin, with women consuming significantly less zeaxanthin than men (see Figure 2). Few studies have analyzed the relation between dietary consumption of these phytochemicals and sociodemographic variables. However, Johnson et al. (22) reported the relation of dietary consumption of lutein and zeaxanthin with age, sex, and ethnicity in a large-sample epidemiologic study in the United States. In the present work, it was assumed that at the low- and middle-income range of participants, marital status would have some relation with consumption. This was hypothesized to be due to the degree of purchasing power, and to the fact that in a nuclear family, a better eating pattern might be observed. However, these hypotheses would have to be proven with additional large-scale epidemiologic studies, as well as with qualitative designs that have significant cultural and social aspects included in relation to eating patterns of the population.

To reach the suggested minimum daily consumption values of 2.4 mg lutein/d (13) and 1.3 mg zeaxanthin/d (14), a daily intake of ≥3 servings of fruits and 5–10 servings of vegetables (known to be food sources of lutein and zeaxanthin) will be needed. Recipes with lutein- and zeaxanthin-rich ingredients (for example tortilla made with corn flour) are important because they could contain high levels of these phytochemicals. Although it is true that consumption of unprocessed natural foods is generally recommended, in some cases it may be beneficial to use minimally processed foods with lutein- and zeaxanthin-rich ingredients appreciated by consumers.

An added value to the present study is the increased awareness among participants. Most of them were unaware of the benefits of lutein and zeaxanthin to their health, and the study motivated them to improve their diets. This shows the need for improving information, education, and communication interventions in food and nutrition for targeted populations. Furthermore, in the social context in which the study was carried out, the food items studied are part of a healthy diet and are available and accessible at local markets. Another strength of the study was the methodological design applied, utilizing modern technology in the collecting of information. The use of a computer connected to the Internet was very useful for streamlining the work and allowing uniformity when analyzing the data collected. This also guaranteed the reliability and quality of the information collected.

In the present work, only the food sources of lutein and zeaxanthin studied by Murillo et al. (10) of the University of Panama in 2010 were used, as well as the egg values reported by Goodrow et al. (20) in the United States in 2006. However, it is known that some preparations with foods containing lutein and zeaxanthin, but not included in the

TABLE 3 The top 10 food products consumed and their contribution of lutein and zeaxanthin[1]

		Σ lutein + zeaxanthin, mg/d		Lutein, mg/d		Zeaxanthin, mg/d	
Food name	Latin name	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
Green plantain	*Musa paradisiaca (AAB)*	0.029 ± 0.042	0.016 (0.021)	0.029 ± 0.042	0.016 (0.021)	0.000 ± 0.000	0.000 (0.000)
Tomato	*Solanum lycopersicum*	0.411 ± 0.444	0.210 (0.501)	0.297 ± 0.321	0.152 (0.363)	0.114 ± 0.123	0.058 (0.139)
Egg yolk		0.153 ± 0.138	0.084 (0.102)	0.092 ± 0.083	0.051 (0.061)	0.061 ± 0.055	0.033 (0.040)
Green pepper	*Capsicum annuum*	0.076 ± 0.112	0.038 (0.131)	0.076 ± 0.112	0.038 (0.131)	0.000 ± 0.000	0.000 (0.000)
Ripe plantain	*Musa paradisiaca (AAB)*	0.088 ± 0.120	0.043 (0.093)	0.088 ± 0.120	0.043 (0.093)	0.000 ± 0.000	0.000 (0.000)
Corn tortilla	*Zea mays*	0.175 ± 0.219	0.108 (0.244)	0.075 ± 0.094	0.046 (0.105)	0.100 ± 0.125	0.061 (0.139)
Red pepper	*Capsicum annuum*	0.076 ± 0.129	0.021 (0.082)	0.025 ± 0.043	0.007 (0.027)	0.051 ± 0.086	0.014 (0.055)
Kidney beans	*Phaseolus vulgaris*	0.085 ± 0.095	0.049 (0.098)	0.085 ± 0.094	0.049 (0.098)	0.000 ± 0.001	0.000 (0.001)
Banana	*Musa paradisiaca*	0.025 ± 0.025	0.018 (0.030)	0.025 ± 0.025	0.018 (0.030)	0.000 ± 0.000	0.000 (0.000)
Yellow potato	*Solanum tuberosum*	0.069 ± 0.088	0.031 (0.094)	0.040 ± 0.051	0.018 (0.055)	0.029 ± 0.037	0.013 (0.039)

[1]Values are means ± SDs or medians (IQRs). Σ, summation.

TABLE 4 Association between lutein or zeaxanthin consumption and sex or age[1]

		For lutein		For zeaxanthin	
Variables	Unit	β (95% CI)	P	β (95% CI)	P
Sex	Female vs. male	–0.84 (–1.62, –0.06)	0.035	–0.24 (–0.54, 0.06)	0.112
Age	Δ1 y	0.04 (0.01, 0.06)	0.015	0.003 (–0.01, 0.01)	0.541

[1]Modeled through multivariate linear regression analysis.

study, could be considered when evaluating the total intake of these phytochemicals in the population.

Another limitation to this study is the seasonality and availability of 2 important foods in the Panamanian context: *zapote* and *pixbae* (peach palm fruit). *Zapote* has only 1 mo of harvest and is sold in only certain markets of the country and in small quantities. *Pixbae* appeared at the end of the study only, so its inclusion in the FFQ was difficult. Similarly, other limitations include sample size, the consumption record method used for the FFQ, and the study design. It is noteworthy that this work is one of the first to evaluate the dietary intake of these carotenoids in Panama and can establish links to preventing visual diseases in the country. Finally, the lack of a Panamanian food composition table with the contents of lutein and zeaxanthin as well as the lack of cutoffs to establish an adequate intake were also limiting factors.

In conclusion, the consumption of lutein and zeaxanthin is low among people working at the University of Panama, and this is not associated with sociodemographic variables. Dietary consumption of lutein and zeaxanthin is a concern because cases of visual diseases have been reported in the young adult population of Panama.

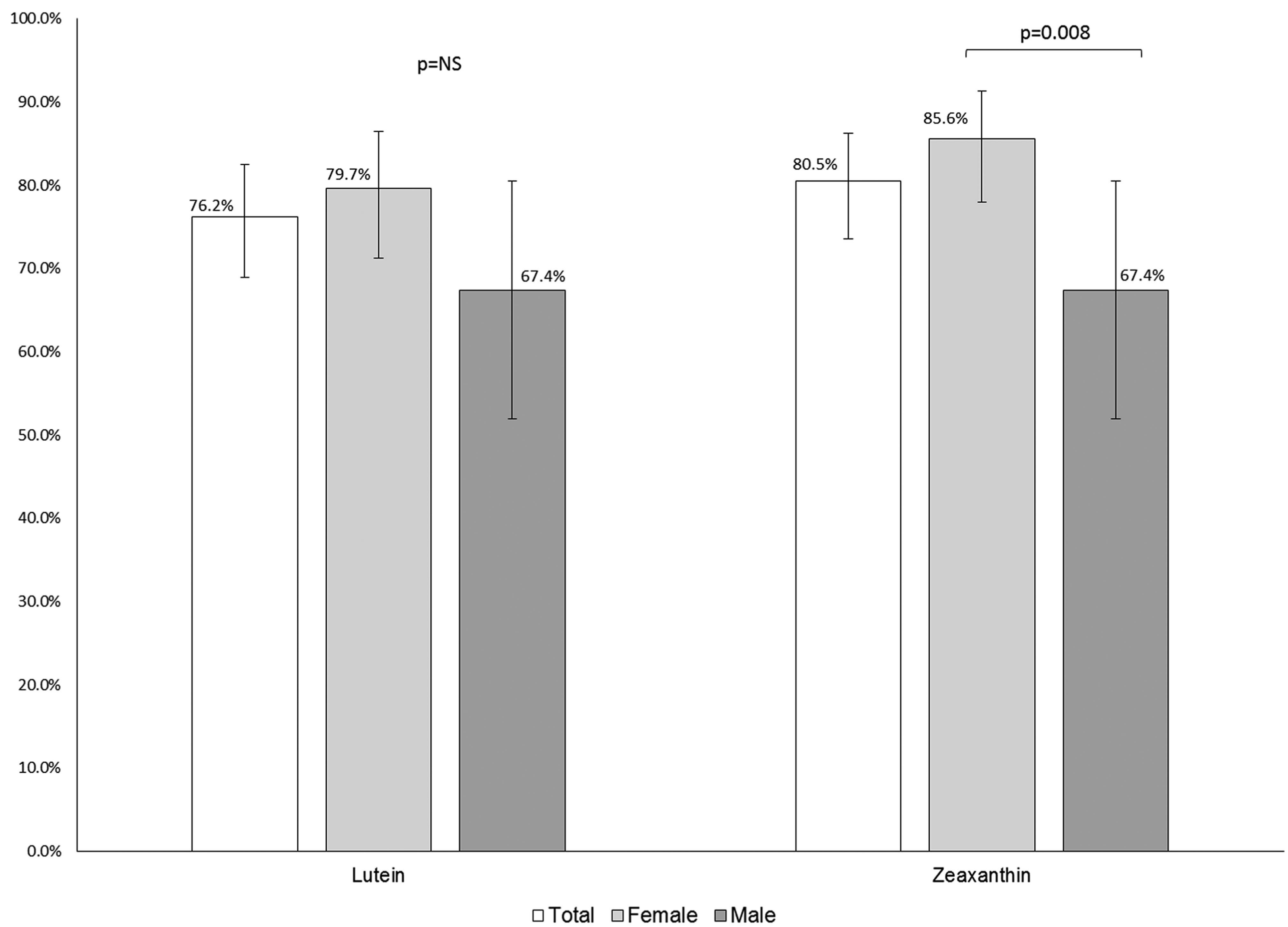

FIGURE 2 Proportions of participants with low consumption of lutein (<2.4 mg/d) and zeaxanthin (<1.3 mg/d). Data presented as proportions, lines correspond to the 95% CIs. *$P < 0.05$ after chi-square test.

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