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Is fructose consumption associated with diet quality?: A cross-sectional study

Eda Keskin[1], Havvanur Yoldas Ilktac[2]*

[1]*Department of Nutrition and Dietetics, Faculty of Health Sciences, Istanbul Medipol University, Istanbul, Türkiye;*
[2]*Department of Nutrition and Dietetics, Faculty of Health Sciences, Istanbul Medeniyet University, Istanbul, Türkiye*

***Corresponding Author:** Havvanur Yoldas Ilktac, Department of Nutrition and Dietetics, Faculty of Health Sciences, Istanbul Medeniyet University, Istanbul, Türkiye. Email: havvanuryoldas@gmail.com

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Abstract

The aim of this study was to evaluate the relationship between the consumption of fructose and the score of the diet quality in healthy adults. This cross-sectional study included 100 healthy adults. A 3-day dietary record and a 24-item fructose frequency questionnaire were used to evaluate the nutritional status and fructose consumption of individuals. Anthropometric parameters were measured. The Dietary Quality Index-International (DQI-I) scores were calculated for the evaluation of dietary quality. The mean total DQI-I scores were 58.6 ± 7.7, and a total of 82% of adults had a DQI-I score in the "needs improvement diet" category. Total DQI-I scores of the moderate fructose consumption group were significantly higher than the high fructose consumption group. High fructose consumption was also significantly and negatively associated with the total DQI-I score ($r = –0.369$, $p = 0.000$). It was determined that there is a correlation between fructose consumption and diet quality. As fructose consumption increases, diet quality scores tend to decrease. To enhance diet quality in adults, it would be beneficial to regularly assess dietary habits and provide nutritional education.

Keywords: adult; dietary intake; dietary quality index; food; fructose; nutrition

Introduction

Carbohydrates are one of the main nutrients found abundantly in foods, required for the vital activities of many organisms (Wheeler and Pi-Sunyer, 2008; Clemente-Suárez *et al*., 2022). It is one of the simplest form of sugars needed for human metabolism found naturally in honey, fruit, and some root vegetables (Akram and Hamid, 2013; Kopec and Beton-Mysur, 2024). In addition to natural foods, fructose is consumed through commercial products such as high fructose corn syrup (HFCS), which is industrially produced from sucrose and/or corn starch; these are mainly added to foods (Johnson and Murray, 2010). Fructose consumption, which has increased in proportion to HFCS consumption in recent years, has long attracted the attention of the public and the scientific world due to its negative effects on health. It is well known that high consumption of fructose, specifically metabolized by the liver, plays a role in many diseases (nonalcoholic fatty liver disease, obesity, dyslipidemia, hypertension, etc.) (Hosseini-Esfahani *et al*., 2011; Rippe and Angelopoulos, 2013; Kolderup and Svihus, 2015; Malik and Hu, 2015; Mock *et al*., 2017).

Due to differences in metabolic pathways, less insulin is secreted in the body after fructose consumption compared to glucose consumption (Hannou *et al*., 2018). It has also been reported that high fructose consumption reduces circulating leptin and insulin concentrations and postprandial ghrelin suppression, resulting in weight

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gain due to high-calorie intake (Edwards *et al.*, 2016). This effect of fructose on hormones explains some of the reported associations between increased fructose consumption and increased prevalence of obesity (Page and Melrose, 2016; Triantafyllou *et al.*, 2016; Yau *et al.*, 2017). For healthy adults, the consumption of fructose should not exceed 25% of the total daily energy intake. Consumption in excess of this level has been identified as a potential contributing factor in the etiology of obesity (Hernández-Díazcouder *et al.*, 2019; Stricker *et al.*, 2021). Additionally, it causes metabolic comorbidities such as increased visceral fat accumulation, impaired postprandial fat oxidation, and visceral adiposity (Dornas *et al.*, 2015; King *et al.*, 2018).

It is generally assumed that high-quality diets have more nutrient-rich foods and less added sugar, salt, and saturated fat. This can help in the development of public health recommendations to help make healthier food choices and reduce the risk of developing diet-related chronic diseases (Cara *et al.*, 2024). Today, diet quality indexes have become important tools to help individuals evaluate their daily diets and eating habits (Guerrero and Pérez-Rodríguez, 2017). One of these indexes, the Dietary Quality Index-International (DQI-I), is a measurement tool that reveals the general diet quality, developed within the scope of daily food and nutritional intake recommendations. The DQI-I provides information about many aspects of a diet, including nutritional overall variety, adequacy, moderation, and overall balance (Kim *et al.*, 2003). In addition to making comparisons in the daily diets of different population groups (such as adolescents, pregnant women, elderly), it is also used to compare diet quality between countries. This index is frequently preferred in the literature in determining diet quality (Tur *et al.*, 2005; Najibi *et al.*, 2023). Based on this information and considering the increasing fructose consumption in the world, it is important to examine the relationship between fructose consumption and diet quality. A review of the literature reveals no studies that have examined the relationship between diet quality and fructose consumption. The aim of this study was to evaluate the relationship between the consumption of fructose and the score of the DQI-I in healthy adults. We hypothesize that high fructose consumption among healthy adults negatively impacts diet quality.

Materials and Methods

Study design and population

A cross-sectional research was carried out at the Istanbul Medipol University Hospital in Istanbul, Türkiye. The following were selected as eligible: healthy adults (18–55 years) who were in good general health, communicative, and volunteered to participate in the research. Individuals who were pregnant or lactating, chronic diseases (including diabetes, hormonal, cardiovascular diseases, mental diseases), and regularly taking medication or supplements were excluded. Because of the high risk of developing chronic diseases in older ages, the study determined the cutoff age as 55 years (Diaz *et al.*, 2021). A total of 100 healthy individuals were included in this research.

This study was performed in line with the principles of the Declaration of Helsinki. Ethical approval was obtained from Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee (no. 28864 and dated August 23, 2017). Participants signed an informed consent form before the start of the research.

Sociodemographic data and dietary intake

Sociodemographic information and dietary habits were collected by the researcher using a structured questionnaire; the data included age, sex, education level, smoking (smoker/nonsmoker), and marital status.

Dietary records were performed on three days (two on weekdays and one on weekends) to determine the nutritional status of individuals. They were provided with verbal and written instructions on how to record their food and drink consumption. Food records were checked by the researcher and any missing information was clarified with the individuals. To analyze the nutrient analysis, the "Nutrition Information Systems Package Program" (BEBIS) (version 8.1, Istanbul, Türkiye) was used. As a result of the nutritional analysis, individuals' energy (kcal) and macronutrients (carbohydrate [energy %], protein [energy %], total fat [energy %], and dietary fiber [g]) intakes were obtained.

Assessment of fructose consumption

The fructose consumption of adults was assessed through a fructose consumption frequency form, which covers the consumption frequency and quantity of foods containing natural fructose and HFCS. In this study, people were asked which fruits and how many were used in fruit juice consumption, and the natural juice category was included in the fruit consumption group. The daily amount of fructose consumed was analyzed using the BEBIS.

Assessment of diet quality

Developed by Kim *et al.* (2003), the DQI-I was used to evaluate the diet quality of individuals. In the DQI-I calculation, four key items are considered: variety, adequacy, moderation, and overall balance. First, variety has two indicators: the overall variety of different food groups (meat and meat products, fish and shellfish, eggs, milk and milk products, legumes, grains, vegetables, and fruits) and the within-group variety of protein sources (meat and meat products, fish and shellfish, eggs, milk and milk products, legumes). The second component is adequacy that contains the vegetable, fruit, and grain groups, fiber, protein, iron, calcium, and vitamin C. Third, the amounts of total fat, saturated fat, cholesterol, sodium, and empty calorie foods are evaluated in the moderation component, where the amounts of nutrients obtained through food consumption records are compared to the Recommended Dietary Allowances (RDA) of the Institute of Medicine (IOM) of the National Academy of Sciences. In the last component, macronutrient and fatty acid ratios are considered in the calculation of the overall balance. The results obtained are calculated according to 0–20 points for variety, 0–40 points for adequacy, 0–30 points for moderation, and 0–10 points for general balance. Scores of each component in the four categories are summed to obtain the final DQI score. The total DQI-I score ranges from 0 to 100, with 0 being the poorest and 100 being the highest dietary quality (Kim & Bae, 2016; Cho *et al*., 2021). In our study, individuals' total DQI-I scores were classified into three groups: A score <50 indicates a "poor quality diet", from 50 to 80, a "needs improvement diet" quality, and a score >80, a "good diet" quality (Foroumandi *et al*., 2020).

Anthropometric data

Details of the anthropometric measures have been described elsewhere (Keskin and Yoldas Ilktac, 2022). Briefly, the body mass index (BMI), waist circumference (WC), and waist-hip ratio (WHR) of the individuals were assessed. The BMI was calculated using the following formula: body weight (kg) to height (m) square. An unstretched tape measure (accuracy 0.5 cm) was used to measure waist and hip circumference. WHR was derived from the equation WC (cm)/hip circumference (cm). The World Health Organization (WHO) classification was used to evaluate WC (risk: > 94 cm for men, > 80 cm for women) (WHO, 2008).

Statistical analysis

The data analysis was conducted using SPSS Statistics software, version 22.0 (SPSS Inc, Chicago, IL, USA). Results were shown in mean and standard deviation (SD) or number (n) and percentage (%). The Chi-square test was used to evaluate categorical variables between the fructose consumption groups. The normality of quantitative variables was assessed using the Kolmogorov-Smirnov test. In the quantitative comparison of the two groups, variables with and without normal distribution were evaluated using Student's *t*-test and Mann-Whitney U-test, respectively. The correlation between fructose consumption and total DQI-I scores was evaluated using Spearman's correlation test. Statistical significance was defined as $p < 0.05$.

Results

Table 1 shows the baseline characteristics of the individuals. The mean age of the individuals was 32.8 ± 11.0, and almost half (49%) of the individuals had university and postgraduate education. According to the data obtained from the measurement of body composition, the BMI values of men and women were determined as 27.3 ± 4.8 kg/m^2 and 24.9 ± 4.8 kg/m^2, respectively. Waist circumference measurements in men were found to be risky, according to WHO. It was found that the daily fructose consumption of men was significantly higher than that of women ($p = 0.002$), as 32% of the men consumed > 50 g fructose daily and 18% of the women consumed > 50 g/day.

The daily total energy and fiber intakes of the high fructose consumption group were statistically higher than the moderate fructose consumption group, while their daily protein intakes were lower ($p < 0.05$) (Table 2).

The total DQI-I score was 58.6 ± 7.7 and the variety, adequacy, moderation, and overall balance scores were 16.9 ± 2.9, 33.0 ± 3.4, 8.1 ± 4.1, and 3.4 ± 1.7, respectively. Total DQI-I score of the high fructose consumption group (51.8 ± 6.2) was found to be significantly lower than the moderate fructose consumption group (60.8 ± 6.9), and 52% of individuals in the high fructose consumption group had poor diet quality ($p < 0.05$). The differences in total DQI-I and some DQI-I category scores (variety and moderation) between fructose consumption groups were different ($p < 0.05$). For both the fructose consumption patterns, adequacy scores were highest, followed by variety and moderation scores which were higher in the high fructose consumption group than in the moderate fructose consumption group ($p < 0.01$) (Table 3).

As shown in Figure 1, there was a negative weak correlation between fructose consumption and total DQI-I scores ($r = -0.369$, $p < 0.01$).

Discussion

Today, high levels of sugar consumption cause concern due to its association with noncommunicable diseases

Table 1. Baseline characteristics of the individuals.

Characteristic	Total (n = 100)	Women (n = 50)	Men (n = 50)
Age (years)	32.8 ± 11.0	29.1 ± 8.2	36.6 ± 12.2
Marital status, n (%)			
Single	47 (47.0)	32 (64.0)	15 (30.0)
Married	53 (53.0)	18 (36.0)	35 (70.0)
Education level, n (%)			
Primary school	7 (7.0)	3 (6.0)	4 (8.0)
Secondary school	12 (12.0)	-	12 (24.0)
High school	32 (32.0)	16 (32.0)	16 (32.0)
University and postgraduate	49 (49.0)	31 (62.0)	18 (36.0)
Smoking, n (%)			
Current smoker	29 (29.0)	8 (16.0)	21 (42.0)
Never smoker	71 (71.0)	42 (84.0)	29 (58.0)
Daily smoking use	11.34 ± 6.48	9.37 ± 6.61	12.09 ± 6.44
Alcohol, n (%)			
Current drinker	6 (6.0)	2 (4.0)	4 (8.0)
Never drinker	94 (94.0)	48 (96.0)	46 (92.0)
BMI (kg/m^2)*	26.1 ± 4.9	24.9 ± 4.8	27.3 ± 4.8
Waist circumference (cm)*	87.9 ± 14.7	78.6 ± 10.2	97.2 ± 12.5
Waist-to-hip ratio*	0.82 ± 0.09	0.75 ± 0.06	0.89 ± 0.06
Fructose consumption,[a] n (%)			
≤ 50 g/day	75 (75.0)	41 (82.0)	34 (68.0)
> 50 g/day	25 (25.0)	9 (18.0)	16 (32.0)
Fructose consumption (g/day)*	35.4 ± 16.4	30.4 ± 16.0	40.4 ± 15.4
Sucrose consumption (g/day)*	66.1 ± 31.4	57.5 ±30.0	74.7 ± 30.6

Values are presented as mean ± standard deviation or number (%).
BMI: body mass index.
[a]Fructose consumption was categorized into moderate consumption (≤ 50 g/day) and high consumption (> 50 g/day).
*BMI (p = 0.014), waist circumference (p = 0.000), waist-hip ratio (p = 0.000), daily fructose consumption (p = 0.002), and daily sucrose consumption (p = 0.006) in men were found to be significantly higher than women.

Table 2. Daily macronutrient intakes according to fructose consumption.

	Total (n = 100)	Fructose consumption change groups		p-value
		MFCG (≤ 50 g/day) (n = 75)	HFCG (> 50 g/day) (n = 25)	
Total energy (kcal)[a]	2096.1 ± 558.7	1931.5 ± 490.5	2590.1 ± 454.7	<0.001**
Carbohydrate (E%)[a]	49.5 ± 7.9	48.6 ± 7.6	51.9 ± 8.3	0.073
Dietary fiber (g)[b]	25.1 ± 7.7	23.0 ± 6.3	31.5 ± 8.2	<0.001**
Protein (E%)[b]	14.3 ± 4.9	14.9 ± 5.5	12.7 ± 2.1	0.013*
Total fat (E%)[b]	35.9 ± 7.2	36.4 ± 7.3	34.5 ± 6.9	0.105

Values are presented as mean ± standard deviation.
E%, energy percentage; HFCG, high fructose consumption group; MFCG, moderate fructose consumption group.
Bold indicates statistically significant difference; *p < 0.05, **p < 0.01.
[a,b]Based on Student's *t*-test and Mann-Whitney U test, respectively.

Table 3. DQI-I scores according to fructose consumption.

	Total (n = 100)	Fructose consumption change groups		p-value
		MFCG (≤ 50 g/day) (n = 75)	HFCG (> 50 g/day) (n = 25)	
DQI-I groups				**< 0.001*,a**
Poor quality diet	18 (18.0)	5 (6.7)	13 (52.0)	
Needs improvement diet	82 (82.0)	70 (93.3)	12 (48.0)	
Good diet	-	-	-	
Total DQI-I scores	58.6 ± 7.7	60.8 ± 6.9	51.8 ± 6.2	**< 0.001*,b**
DQI-I category scores				
Variety	16.9 ± 2.9	17.9 ± 2.5	14.1 ± 1.9	**< 0.001*,b**
Adequacy	33.0 ± 3.4	33.3 ± 3.4	32.3 ± 3.3	0.164
Moderation	8.1 ± 4.1	8.7 ± 3.8	6.0 ± 4.6	**0.002*,b**
Overall balance	3.4 ± 1.7	3.3 ± 1.5	5.3 ± 2.3	0.080

Values are presented as number (%) or mean ± standard deviation.
MFCG, moderate fructose consumption group; HFCG, high fructose consumption group.
[a,b]Based on Chi-Square test and Mann-Whitney U, respectively.
Bold indicates statistically significant difference; *p < 0.01.

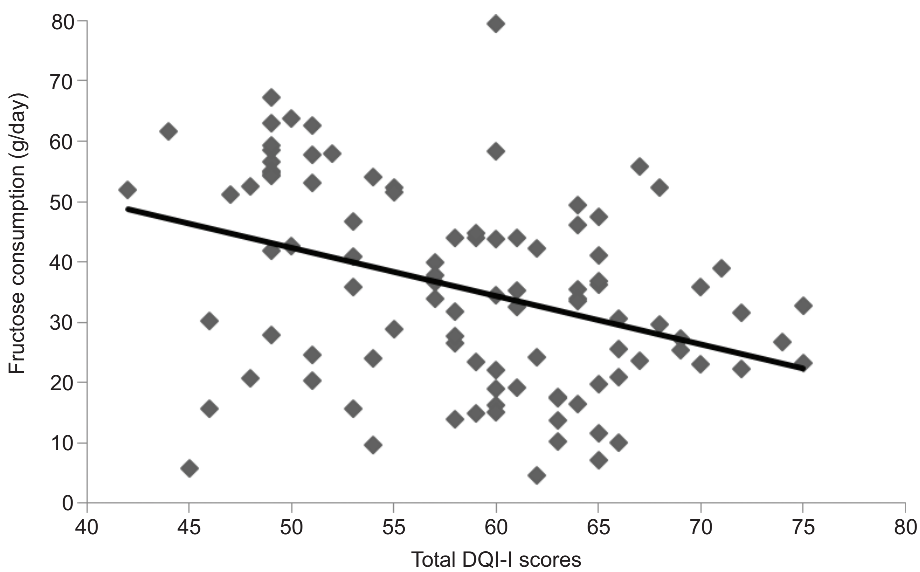

Figure 1. Correlation between the fructose consumption and total DQI-I score.

and obesity risk (Slining and Popkin, 2013). According to the guidelines published by the WHO in 2015, daily sugar consumption (such as HFCS, sucrose, and sugars naturally found in foods) should be less than 10% of total energy (WHO, 2015). The American Heart Association (AHA) recommends that the consumption of added sugar be less than 100 kcal/day (< 25 g) for women and 150 kcal/day (< 36 g) for men (Johnson *et al*., 2009). In research, examining the long-term effects of added sugars from beverages and foods in the USA, it was determined that total fructose (from 45.7 g/day to 53.7 g/day per person) and HFCS (from 0.5 g/day to 52.4 g/day per person) consumption had increased over the last 50 years (Duffey and Popkin, 2008). In another study, examining the fructose consumption of American children and adults, it was found that a total of 21,483 individuals consumed an average of 54.7 g/day fructose. Additionally, fructose and carbohydrate consumption constituted 10.2% and

19.7% of the total energy intake, respectively (Vos *et al.*, 2008). In the study conducted by Sluik *et al.* (2015), the average fructose consumption of 3817 individuals aged 7–69 was determined as 49 g/day and constituted 9% of daily energy intake (Sluik *et al.*, 2015). When the 24-hour dietary records of 28 Australian individuals aged between 18 and 60 were examined, the mean fructose consumption was determined as 28.9 g/day (men: 29.5 g/day, women: 28.4 g/day) and sucrose consumption was 32.7 g/day (men: 35.5 g/day, women: 29.9 g/day) (Jameel *et al.*, 2014). The mean daily consumption of fructose and sucrose in our study population was 35.3 ± 16.4 g and 66.1 ± 31.4 g, respectively. The percentage of the total daily energy intake (men: 6.7%, women: 6.7%) and carbohydrate (men: 13.8%, women: 13.4%) provided by fructose was found to be lower than that reported in previous studies. Consistent with the literature, men were found to consume significantly more sucrose and fructose than women (Table 1). It was thought that men's higher fructose and sucrose consumption may be due to their higher daily consumption of foods such as fruit, sugar, honey, soft drinks, and desserts compared to women.

A Western diet is defined as a diet characterized by a high consumption of simple carbohydrates and fat, low fiber, and vitamin/mineral content. When the daily diet patterns of individuals with this dietary pattern were examined, it was determined that simple carbohydrate consumption is provided, especially by high amounts of soft drinks, and therefore their consumption of sugar, artificial fructose (such as HFCS), and sweeteners is high (García-Montero *et al.*, 2021; Inci *et al.*, 2023). In a study aiming to determine the amount and sources of fructose in the diet of adults and children, the major sources of fructose consumption were determined to be sugar-sweetened beverages (30%) and fruit or fruit juice (19%) (Vos *et al.*, 2008). Similar results were shown in another research conducted in the Netherlands. In this study, it was found that fructose consumption was highly related to the consumption of soft drinks, fruits, and packaged foods (cake, cookies, etc.) (Sluik *et al.*, 2015). Although these foods are rich in fructose, their frequent consumption and inclusion in daily nutrition may cause individuals' daily energy consumption to increase. In our study, the daily energy consumption of those who consumed high fructose was found to be higher ($p < 0.05$). A comparison of macronutrient intake revealed that the group consuming high fructose had a lower daily protein consumption than the other group ($p < 0.05$) (Table 2). This finding suggested that the individuals consuming high fructose in our study may have a Western diet because they have higher total daily energy and lower protein consumption.

Diet quality indexes are used to examine the general nutritional status of individuals and to determine to what extent their eating behaviors are healthy. DQI-I is one such index (Gil *et al.*, 2015). Studies have demonstrated that the DQI-I is a beneficial tool for assessing diet quality (Kant, 1996; Kim *et al.*, 2003). In a study conducted in Korea on 166 pregnant women diagnosed with gestational diabetes, the total DQI-I score was determined as 61.7 ± 7.1. Dietary models of pregnant women were classified and only the DQI-I variety scores were determined to be significantly higher in the Western diet model compared to the carbohydrate-vegetable model (Shin *et al.*, 2015). In the study, which aimed to evaluate whether DQI-I was suitable to be used as an index of diet quality in Mexican university students (n = 400), it was found that the students' general diet was of poor quality (mean total DQI-I score 53.8 ± 11.4). When the DQI-I subgroups were examined, the highest score was adequacy, followed by moderation, variety, and overall balance (Espino-Rosales *et al.*, 2023). In another study of 320 Korean adults, the total DQI-I score was calculated as 64.9 ± 10.0 (men: 65.5 ± 9.6, women: 64.9 ± 10.2), and the subgroup scores, from high to low, were adequacy, moderation, variety, and overall balance (Lee *et al.*, 2016). Although there are different results in the literature, in our study the total DQI-I score was determined as 58.6 ± 7.7 and the order of DQI-I subgroups (adequacy > variety > moderation > overall balance) was found to be different from the results of the studies mentioned above. In addition, our study found a weak negative relationship between diet quality and fructose consumption ($p < 0.05$). Diet quality was significantly lower in the high fructose consumption group than in the moderate fructose consumption group. This result suggests that high fructose intake is provided by artificial sources of fructose, and the fact that adequacy, variety, and moderation scores in the high fructose consumption group are lower than the other consumption group supports our view.

Our research had several plus points. First, to our knowledge, the relationship between diet quality and daily fructose consumption was examined for the first time. Second, to measure dietary quality, we used the DQI-I, which has been validated in different populations and assesses not only nutrients but also individuals' dietary habits under four main aspects such as variety, adequacy, moderation, and overall balance. Our study also had several limitations. Because it was a cross-sectional research, the mechanism of the association between fructose consumption and diet quality could not be determined. In this study, mean fructose consumption amounts were determined. Another limitation was that fructose intake sources were not specifically examined in the analysis section. Different fructose consumption amounts were associated with the diet quality index. Comprehensive prospective studies in larger and different populations are needed to determine the causal relationship and improve our current results.

Conclusions

As a result, it was found that individuals with high fructose consumption had lower daily protein consumption, higher daily total energy and fiber consumption, and lower DQI variety and moderation scores compared to individuals with moderate fructose consumption. According to the results of this study, it was determined that there was a negative relationship between fructose consumption and dietary quality scores. It is thought that it is important for individuals to limit their daily fructose consumption and more importantly, to get their fructose from natural fructose-containing sources in order to improve the quality of their diet. In this regard, it would be useful to raise awareness of individuals about artificial fructose and natural fructose sources and to provide nutritional education to increase their awareness. In future studies, it is recommended to evaluate the effects of specific foods on diet quality rather than evaluating general diet quality.

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Author Contributions

All authors contributed equally to this article. This article was produced from the first author's master's thesis.

Conflicts of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

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