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ORIGINAL CONTRIBUTION

Inverse association between the frequency of nut consumption and obesity among Iranian population: Isfahan Healthy Heart Program

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Abstract
Purpose Recently, controversies have arisen concerning the association between nut intake and obesity. This study was performed to investigate the relationship between nut consumption and obesity among Iranian adults.
Methods In a cross-sectional survey, 9,660 randomly chosen adults aged ≥19 years were selected based on gender, age and their settlement distributions in three districts of central Iran in 2007. Nutritional behaviors including regular intake of walnuts, almonds, pistachios, hazelnuts and sunflower seed were assessed by validated 48-item-food-frequency questionnaire and a 24-h recall questionnaire. Using hierarchical logistic regression test, odds ratio (OR) 95 % CI of obesity based on nut consumption was determined in an unadjusted and four adjusted models.
Results The results showed a significant association between high nut consumption and lower prevalence of overweight or general obesity as well as abdominal obesity in women ($p = 0.01$ and $p = 0.047$, respectively), but not men. The frequency of nut consumption was associated with lower risk of overweight or general obesity [OR (95 % CI) 0.57 (0.38–0.86)] and abdominal obesity [OR (95 % CI) 0.51 (0.28−0.95)] only in women. After adjusting for gender, age and other potential confounders, the strength of the associations was blunted, but they were still significant.
Conclusions Frequent nuts and seeds consumption, particularly ≥1 time/day, had an inverse association with all classes of obesity among women.

Keywords Nut · Obesity · Overweight · Body mass index · Waist circumference · Iran · Adult

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Introduction

Obesity is placed to be a major risk factor for a wide range of diseases, affecting more than 400 million people worldwide [1, 2]. It is also becoming epidemic in developing nations, including Asian countries [3]. The World Health Organization has warned about the increasing burden of obesity in countries, which has adopted a Western lifestyle [4]. About 42.8 % men and 57 % women in Iran suffer from overweight or obesity, from which 11.1 % of men and 25.2 % of women are obese [5]. Obesity is not a single disorder, but a complex multifactorial disease with genetics, physical activity and diet playing a crucial role in its prevalence. Despite a large body of research, the nutritional etiology of obesity has yet remained controversial [6]. Previous studies have consistently shown that, by virtue of their unique composition, nuts and seeds are more likely to reduce risk of cardiovascular diseases, type 2 diabetes and hypertension [7, 8], and improve serum lipid and lipoprotein profiles [9, 10]. Nuts are nutrient-dense foods comprising complex matrices rich in unsaturated fatty acids as well as other bioactive compounds. Although fat is less notorious to cause weight gain than other sources of calories [11], there is sustained concern regarding high intakes of this energy-dense, high fat food, leading to excessive weight gain. This belief is widely accepted by the general public and health professionals alike. For that reason, individuals attempting to lose weight may avoid consuming nuts for their high-energy density [12]. Contrary to expectations, epidemiologic studies have suggested a negative or inverse relation between regular nut intake and body weight [3, 13, 14]. Mechanisms underlying the association between nut consumption and weight loss are not yet fully understood but might be explained by the altered resting energy expenditure, increased satiety or inefficient absorption of energy from nuts [15]. In addition to epidemiologic evidence, randomized controlled clinical trials have already concluded that nuts do not promote significant weight gain [16–18]. This cross-sectional study was a unique study in Iran and Middle East, conducted to assess the association of nuts and seeds consumption with prevalence of overweight or obesity among Iranian population.

Subjects and methods

Sampling

This cross-sectional study used the data from phase III of the Isfahan Healthy Heart Program (IHHP), which was conducted in the districts of Isfahan, Najafabad and Arak in 2007. This study was approved by the Research Council of Isfahan Cardiovascular Research Center (ICRC), affiliated with Isfahan University of Medical Sciences. The design of this community-based interventional program has been published elsewhere [19, 20]. Stratified cluster random sampling was performed for the selection of 9,660 individuals aged at least 19 years in both rural and urban areas [19, 20]. Several clusters were selected in each district to represent the pattern of population distribution.

Adults who had lived in one of the study districts for at least 6 years were randomly selected from the age groups of 19–24, 25–34, 35–44, 45–64 and ≥65 years. Pregnant women and subjects with mental impairment were excluded. The IHHP sampling method is published in detail elsewhere [19]. In the current study, based on age and gender distribution, a subsample of 2,000 participants was randomly selected, and an additional 24-h recall questionnaire was administered for each subject.

Data collection

IHHP-eligible individuals received a 30-min home interview by trained health professionals. The questionnaire covered socioeconomic and demographic characteristics as well as behavioral features such as dietary intake, smoking habits and physical activity [19]. Information on physical activity was obtained from interviews using the Baecke physical activity questionnaire. Daily leisure time, household, occupational, and transportation physical activity, and total physical activity were accordingly calculated [20]. Information on subjects' past medical and drug history, consisting of dyslipidemia, diabetes and hypertension (HTN), was obtained by trained physicians.

Through a standardized interview, trained medical personnel performed the anthropometric measurements as follows: Weight was measured on a scale to the nearest 0.5 kg, with minimum necessary clothing, and height was measured to the nearest 0.5 cm using a non-elastic meter while subjects were in a standing position with shoulders in a normal state and bare feet [21]. In the same standing position, waist circumference (WC) was measured at a level midway between the lower rib margin and iliac crest with the tape horizontal and around the body. Hip circumference was also measured at the point of maximum circumference over the buttocks using a non-elastic meter [21]. Overweight or obesity was defined as BMI ≥25 kg/m^2. Abdominal obesity was defined based on the International Diabetic Federation definition for European population (WC ≥80 cm in female and WC ≥94 cm in male), which is also considered the scale for Eastern Mediterranean and Middle East population [22].

Dietary assessment

The commonly consumed nuts and seeds in Iran (walnuts, almonds, pistachios, hazelnuts and sunflower seeds) were assessed by posing individualized questions through a validated 48-item-food-frequency questionnaire (FFQ) [23]. The FFQ contained questions on food consumption per week and was adapted from the Non-communicable Disease Intervention program questionnaire. The questions had an open-ended format with facial and content validation via five nutrition experts. The FFQ precision was pretested among 200 adults aged 19–69 who were not participants of the main study and completed the questionnaire twice with a 2-week interval to assess test–retest reliability ($r = 0.8$). Criterion validity was compared to three 24-h recall questionnaires. The validity and reproducibility were 0.47 and 0.63, respectively, for nuts and seeds consumption [24].

Total energy intake was assessed via a 24-h dietary recall with the use of the Iranian Food Consumption Program (IFCP) Nutrient Database, designed by ICRC [25], based on the Iranian Food Composition Table [26]. Trained dietitians assisted the participants in filling in, as well as reviewing and entering the data from the FFQs.

Statistical analysis

Frequencies of the categorical variables and mean and standard deviations of the continuous variables were used to summarize the data. Chi-squared statistics and Student's *t* tests were used to compare baseline characteristics between quartiles of nuts and seeds consumption. Using a residual model, the nuts and seeds intake were used as independent variables. Analysis of variance (ANOVA) was used to compare the mean of different variables in nuts and seeds quartiles.

Hierarchical logistic regression was used to determine effect sizes according to different categories of confounders. In this regard, simple logistic regression was primarily fitted to evaluate the crude relations between obesity and the quartiles of nuts and seeds intake. Subsequently, multiple logistic regressions were applied to find the adjusted associations. Participants who consumed nuts <1 time/week were used as the reference category. In the crude model, the associations of nuts and seeds intake and obesity occurrence were assessed without any adjustment. The initial adjusted model was defined comprising age (year) and energy intake (kcal) as covariates (model 1). We fitted model 2 to assess additional adjustment for smoking status (never/past/current), education level (illiteracy and elementary/guidance and high school/college and university), diabetes mellitus (yes/no), hypertension (yes/no), dyslipidemia (yes/no), total fat (% of energy), fiber intake (g/1,000 kcal), physical activity (METS min/day), fruits and vegetables, sweets, red meat and fast food (times/week).

All analyses were done based on gender. The Hosmer–Lemeshow (HL) test and pseudo-R^2 of the multiple logistic models were used to assess the goodness of fit (results not shown). Statistical analyses were performed using SPSS for Windows version 15 (SPSS Inc, Chicago, IL, USA). The significance level was set at $p < 0.05$.

Results

The study sample included 829 (51 %) men and 789 (49 %) women. The mean nuts and seeds intake was 3.75 ± 3.2 times/week for the whole population. In the unadjusted analysis, participants with higher nuts and seeds consumption had higher intakes of energy, total fat, MUFA and PUFA (% of energy), sweets, red meat, fast food as well as fruit and vegetables (times/week) (all p<0.01). They also had a higher socioeconomic status (p<0.001) and a higher prevalence of hypertension as well as diabetes mellitus ($p < 0.001$ and $p = 0.02$, respectively) (Table 1).

More frequent nuts and seeds consumption was not significantly associated with the mean BMI and WC in both genders (Table 2); however, the prevalence of overweight or general obesity as well as abdominal obesity in women was significantly related to less nuts and seeds intake ($p = 0.01$ and $p = 0.047$, respectively).

As shown in Table 3, odds ratios (ORs) (95 % CI) of the crude model in the highest quartile of nuts and seeds indicated a significant association with a lower risk of overweight or general obesity in women, but not in men [OR (95 % CI) 0.57 (0.38–0.86)]. The results were nearly the same in model 1, with adjustment for age and energy intake, and model 2, with additional adjustment for smoking status, education level, physical activity, diabetes mellitus, hypertension, dyslipidemia and total fat, fiber, fruits and vegetables, sweets, red meat and fast food intake. However, ORs attenuated marginally in fully adjusted model [0.61 (0.44−0.85)]. In women, ORs (95 % CI) of abdominal obesity followed a similar trend as those of overweight or general obesity. In the fully adjusted model, ORs of abdominal obesity were 0.63 (0.33−0.87), even though in male subjects, ORs (95 % CI) of general and abdominal obesity revealed no significant differences in neither crude nor multivariate models in all quartiles of nuts and seeds intake (Tables 3, 4).

Discussion

In this study, nut consumption had an inverse association with BMI and WC in females, but not in males. In addition, females in the higher quartile of nuts and seeds consumption were less likely to be overweight, generally obese, or abdominally obese. Recent systematic review and meta-analysis of the randomized nut-feeding trials demonstrated that diets enriched with nuts were not associated with higher body weight or waist circumference compared to control diets [27]. Because nuts contain a high fat content, the observed inverse relationship between the frequency of nut consumption and weight gain might seem counterintuitive, but identical results were obtained by large prospective cohorts with sufficiently long follow-up [14, 28, 29].

Short- and medium-term controlled-feeding trials were also in accordance with these results, showing that diets supplemented with nuts do not induce weight gain in spite of the higher energy intake [30, 31]. In two reviews of 15 human intervention trials, regarding the possible effects of nut consumption on body weight changes [32, 33], self-selected diets including nuts did not have a tendency to increase body weight in free-living populations. A similar trend concerning frequent nut consumers having a lower BMI than non-consumers was obtained by Bes-Rastrollo et al., who underlined a lower possible risk of weight gain and developing obesity in regular nut consumers. A large proportion of healthy middle-aged women showed a lower tendency for weight gain among frequent nut consumers during an 8-year follow-up period [29]. Moreover, the SUN Study (28-month prospective study) also reported a significant inverse association between nut consumption and weight gain [12]. We observed that in women, nut

Table 1 Characteristics of study population based on quartiles of nut intake

	Q_1 <1 time/week	Q_2 1–3 time/week	Q_3 4–6 time/week	Q_4 ≥1 time/day	*p* value[a]
Age (years)	38.3 (14.9)[b]	36.5 (13.9)	36.3 (14.5)	37.9 (14.8)	0.1
Physical activity (METS min/day)	781.5 (532)	846.8 (593.2)	858.1 (607.1)	834.7 (549)	0.4
Energy (kcal)	1,945.4 (953.1)	1,965.7 (842.9)	1,971.8 (736.2)	1,987.6 (830.2)	0.002
Carbohydrate (% of energy)	66.1 (12.7)	66.6 (12)	65.7 (12.7)	64.6 (12.1)	0.1
Total fat (% of energy)	22.2 (10.4)	21.6 (9.9)	22.6 (10.4)	24.1 (10.6)	0.004
Protein (% of energy)	15.3 (4.8)	15.2 (4.7)	15.1 (4.8)	14.4 (4.1)	0.1
Saturated fatty acid (% of energy)	7.9 (4.9)	7.4 (4.1)	8 (4.8)	8.2 (4.2)	0.1
Monounsaturated fatty acid (% of energy)	6.4 (4.2)	6 (3.6)	6.5 (4.0)	7.1 (4.1)	0.002
Polyunsaturated fatty acid (% of energy)	4.1 (3.4)	4.4 (3.9)	4.3 (3.8)	5.3 (4.8)	<0.001
Fiber (g/1,000 kcal)	9.4 (3.9)	9.8 (3.9)	9.9 (3.8)	9.9 (4)	0.2
Nuts and seed (time/week)	0.4 (0.39)	1.6 (0.42)	3.6 (0.9)	9.4 (4.7)	<0.001
Fruits and vegetables	14 (6.6)	16 (7.1)	17.4 (8)	20.4 (9)	<0.001
Sweets	1.5 (2.9)	2.1 (2.8)	3.5 (4)	4.2 (4.7)	<0.001
Red meat	2.8 (1.9)	3.2 (2)	3.4 (3)	3 (2.4)	<0.001
Fast food	0.6 (1.7)	0.6 (0.9)	0.7 (1.1)	0.9 (1.2)	0.005
Hydrogenated vegetable oil	5.7 (5.2)	5.9 (4.6)	6.1 (4.9)	6.3 (4.9)	0.5
Non-hydrogenated vegetable oil	5.7 (5.2)	5.9 (4.6)	6.1 (4.9)	6.3 (4.8)	0.5
Being male [*n* (%)]	203 (50.2)	213 (52.7)	203 (50.2)	210 (52)	0.6
Illiteracy and elementary [*n* (%)]	196 (48.5)	178 (44.1)	120 (29.7)	96 (23.9)	<0.001
Current smoker [*n* (%)]	58 (14.4)	49 (12.1)	70 (17.3)	60 (14.9)	0.8
Hypertension [*n* (%)]	75 (19.2)	73 (18.5)	39 (9.9)	40 (10.1)	<0.001
Diabetes mellitus [*n* (%)]	30 (7.4)	34 (8.4)	22 (1.4)	15 (3.7)	0.02
Dyslipidemia [*n* (%)]	267 (66)	56 (63.4)	250 (61.7)	250 (61.9)	0.5

[a] *p* value based on ANOVA test for comparing mean and Chi-squared test for comparing frequency

[b] *SD* standard deviation

Table 2 Mean and prevalence of obesity indicators based on quartiles of nut intake and gender

	Q_1 <1 time/week	Q_2 1–3 time/week	Q_3 4–6 time/week	Q_4 ≥1 time/day	*p* value[a]
Body mass index (kg/m^2)					
Male	26.10 (4.4)[b]	25.86 (4.8)	25.84 (4.5)	25.32 (4.3)	0.4
Female	25.80 (4.1)	25.22 (4.3)	25.13 (4.2)	24.62 (4.2)	0.06
Waist circumference (cm)					
Male	91.30 (13.2)	91.76 (12.9)	91 (13.5)	90.18 (12)	0.8
Female	91.59 (11.7)	88.27 (12.9)	89.30 (11.7)	88.50 (11.7)	0.1
Overweight obesity [*n* (%)]					
Male	109 (55)	118 (56)	110 (56)	102 (51)	0.6
Female	111 (57)	86 (48)	93 (49)	81 (43)	0.047
Abdominal obesity [*n* (%)]					
Male	64 (44)	73 (47)	61 (42)	56 (39)	0.5
Female	113 (85)	89 (68)	133 (77)	99 (74)	0.01

[a] *p* value based on ANOVA test for comparing mean and Chi-squared test for comparing frequency

[b] *SD* standard deviation

consumption was associated with a lower prevalence of overweight or general obesity as well as abdominal obesity. Moreover, the highest quartile of nuts and seeds intake in the crude and multivariate adjusted models was significantly related to a lower risk of overweight or general obesity as well as abdominal obesity in women. Our results concur with a recent cross-sectional study of 7,210 men and women in which, compared to non-consumers, women with regular nut consumption showed lower ORs of overweight or general obesity by 28 and 7 %, respectively [34].

The Nurses' Health Study also reported a slightly lower risk of obesity among those who consumed nuts regularly

Table 3 Odds ratio of overweight or obesity based on quartiles of nut intake and gender

	Q_1 <1/week OR (95 % CI)	Q_2 1–3 time/week OR (95 % CI)	Q_3 4–6 time/week OR (95 % CI)	Q_4 ≥1 time/day OR (95 % CI)
Female				
Crude[a]	1	0.69 (0.46–1.04)	0.72 (0.48–1.07)	0.57 (0.38–0.86)
Model 1[b]	1	0.64 (0.43–0.98)	0.70 (0.46–1.04)	0.56 (0.37–0.84)
Model 2[c]	1	0.68 (0.45–1.05)	0.71 (0.56–1.06)	0.61 (0.44–0.85)
Male				
Crude	1	1.02 (0.69–1.52)	1.02 (0.69–1.52)	0.82 (0.55–1.22)
Model 1	1	1 (0.67–1.48)	1 (0.67–1.49)	0.81 (0.55–1.21)
Model 2	1	1.02 (0.69–1.50)	1.05 (0.81–1.65)	0.98 (0.67–1.21)

[a] Unadjusted

[b] Adjustment for age and energy (kcal)

[c] Additionally adjustment for smoking status (never/past/current), education level (illiteracy and elementary/guidance and high school/college and university), diabetes mellitus (yes/no), hypertension (yes/no), dyslipidemia (yes/no), total fat (% of energy), fiber intake (g/1,000 kcal) and physical activity (METS min/day), fruits and vegetables, sweets, red meat and fast food (time/week)

Table 4 Odds ratio of abdominal obesity based on quartiles of nut intake and gender

	Q_1 <1/week OR (95 % CI)	Q_2 1–3 time/week OR (95 % CI)	Q_3 4–6 time/week OR (95 % CI)	Q_4 ≥1 time/day OR (95 % CI)
Female				
Crude[a]	1	0.38 (0.21–0.70)	0.59 (0.32–1.08)	0.51 (0.28–0.95)
Model 1[b]	1	0.35 (0.19–0.64)	0.56 (0.30–1.04)	0.48 (0.26–0.90)
Model 2[c]	1	0.40 (0.21–0.76)	0.71 (0.37–1.37)	0.63 (0.33–0.87)
Male				
Crude	1	1.1 (0.7–1.73)	0.90 (0.56–1.43)	0.80 (0.50–1.9)
Model 1	1	1.06 (0.67–1.68)	0.87 (0.54–1.39)	0.79 (0.49–1.27)
Model 2	1	1.07 (0.67–1.73)	1.07 (0.65–1.76)	0.97 (0.59–1.59)

[a] Unadjusted

[b] Adjustment for age and energy (kcal)

[c] Additionally adjustment for smoking status (never/past/current), education level (illiteracy and elementary/guidance and high school/college and university), diabetes mellitus (yes/no), hypertension (yes/no), dyslipidemia (yes/no), total fat (% of energy), fiber intake (g/1,000 kcal) and physical activity (METS min/day), fruits and vegetables, sweets, red meat and fast food (time/week)

during a 16-year follow-up period [8]. Mozaffarian et al., indicated that nut consumption was associated with less adiposity in observational studies, as well as in RCTs. Interestingly, it was found that weight loss diets enriched with nuts resulted in comparable or even greater overall weight loss [35].

Recently, promising roles of nuts in body weight regulation have been presented. The efficacy of a Mediterranean-style diet, with nuts as a main constituent, in reducing weight was reported by McManus et al. [36]. Compared to the standard low-fat diet, the moderate-fat and rich in nuts diet showed a decrease in body weight and waist circumference after 18 months, and with greater long-term participation and adherence, improvements in weight loss. A possible explanation could be the weight stabilizing effect of nuts due to their satiating ability, which makes nuts a replacement for other food components in the diet [37, 38]. More striking is that in many surveys, additional contribution of nuts into the diet was not associated with an increase in body weight even when total energy intake is substantially higher [39, 40].

Our results also did not support any substantial association between quartiles of nuts and seed consumption and prevalence of overweight or general obesity in men. The results were similar in relation to risks for overweight or general and abdominal obesity in men. To our knowledge, there is no published report on gender-specific weight differences, as result of nuts or seeds consumption;

however, we may suggest that varying dietary patterns and lifestyle adoption between men and women may explain the inconsistent results.

Proposed explanations for mechanistic and biological properties of nuts in lowering or maintaining body weight include reverse causation, enhanced energy expenditure through physical activity or augmented resting metabolic rate, increased satiety and consequently decreased intake of other foods and incomplete absorption [41]. The combination of high protein and unsaturated fat content in nuts might be responsible for the boost in resting energy expenditure, diet-induced thermogenesis, and correspondingly lower fat deposition [42]. In addition, obese individuals, compared to lean people, may tend to avoid nuts due to their high fat and energy content. Besides, adult nut eaters may tend to engage in higher levels of physical activity than non-nut consumers [43]. In a study by Wien et al. [44], the authors highlighted that the substitution of nuts for carbohydrates in the diet could improve insulin sensitivity and result in weight loss. The structure of lipid-storing granules in nuts, accompanied with various fiber components and incomplete mastication, may explain low-fat absorption leading to loss of available energy [33, 41].

Strengths and limitations

This study covered three different counties with a variety of socioeconomic statuses, which make it a unique and important dataset in Iran and the Middle East. However, its cross-sectional design may, hypothetically, hold deficit evidence to support the roles of naturally occurring components in nuts, which might be responsible for their property in weight control. The FFQ had no data on portion sizes; therefore, it was impossible to assess the amount of nut consumption, in servings or grams. However, some investigators believe that data on portion sizes do not add much to the dietary data. In addition, we could not compute total energy, which was an important confounder in this study.

Conclusion

Results from this study supported an inverse relationship between frequent nut consumption and all classes of obesity among female subjects. The prevalence of obesity in women, but not in men, was also inversely associated with higher nut consumption. More studies are needed to illustrate the efficacy of nuts in weight-related changes among the male population. The longer duration of follow-up in cohort studies might provide statistics to establish optimum levels of nut consumption, type and the preparation methods responsible for higher influential effects on BMI and WC and the degree of protection against obesity.

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Conflict of interest We declare there is no conflict of interest.

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