Original Article

Nighttime snacking is associated with risk of obesity and hyperglycemia in adults: a cross-sectional survey from Chinese adult teachers

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Abstract

Relationship between nighttime snack and human health conditions remains unclear. In this paper, we analyzed the association of frequency of nighttime snacking with obesity, hyperlipidemia and hyperglycemia using a Chinese teacher cohort. The Chinese teacher study contains 22,176 of the general adult population operated on in 2015. Information of nighttime snacking frequency was acquired by questionnaire. Overweight and obesity outcome were assessed by body mass index (BMI), and hypertension; hyperlipidemia and hyperglycemia were self-reported. Associations between nighttime snacking consumption and outcomes were performed with multivariat regression and further stratification analyses. We found a significant association (OR 2.11, 95% CI 1.24, 3.62; P for trend < 0.001) between most frequent nighttime snacking and hyperglycemia. A remarkable association was also observed between most frequent consumption of nighttime snack and obesity (OR 3.10, 95% CI 1.63, 5.89; P for trend < 0.001). The present results provide epidemiological evidence that consumption of nighttime snack was associated with obesity and hyperglycemia in Chinese adult teachers. However, the underlying mechanisms still need further investigation.

Keywords: nighttime snacking, obesity, hyperglycemia

Introduction

Obesity is highly prevalent and increasing worldwide. The global prevalence of obesity doubled from 1980 to 2010[1]. The worldwide prevalence of obesity in men increased from 4.8% to 9.8% and women from 7.9% to 13.8% from 1980 to 2010. The percentages of the overweight and obese are projected to increase in

almost all countries with 1.5 billion people overweight in 2015. Obesity is not only a chronic disease that can be a hazard to our health, but high-risk for many chronic non-communicable diseases, such as type II diabetes, cardiovascular disease, respiratory diseases, and so on. Globally, the overweight and obese are responsible for 44% of the diabetes burden, 23% of the ischemic heart disease burden and 7%–41% of certain cancer burdens[2]. In the USA, the economic cost of obesity amounted to as much as $117 billion in 2001. Just like an epidemic disease, obesity has spread and engulfed the entire world.

Even the prevalence of obesity is high in both developed and developing countries; the etiology of obesity is considered complicated. As far as we know, the high risk factors of obesity are complex including genetics, diet, life styles, and so on[3]; however, the mechanisms remain unclear. One of the latest studies, which is the largest Genome Wide Association Study (GWAS) meta-analysis for body mass index (BMI) so far, conducted by Locke AE *et al.*, provided evidence supporting the role of genetic factors in the obese and nearly doubles the number of BMI-associated loci[4–6]. Even previous studies indicated that about 40%–70% of inter-individual variability in BMI, which is commonly used to assess obesity, can be attributed to genetic factors[7], diet is still recognized as an important and most effective way to control body mass. More fruit and vegetable consumption, which is among the dietary behaviors, may help adults prevent weight gain. However, whether the effects are independent of reductions in energy, intake is still uncertain[8–9]. In addition, animal and human studies indicated that alteration of the gut microbial ecosystem may have an effect on obesity[10–13].

Among these risks of obesity, diet is recognized as an important and easy way to induce becoming overweight or obese. The traditional concept of nutrition focuses on the amount and types of nutrients in foods being consumed. However, new perspectives of nutrition emphasize the circadian timing of food intake[14]. O'Reardon *et al.* found that reducing the energy intake in the first half of the day and greatly increasing it during the second half of the day were associated with obesity[15]. A recent study conducted by Watanabe *et al.* investigated the relationship between the timing of meals and obesity from 766 residents of Toon City. The result showed that people who skipped breakfast had a higher BMI and waist circumference than those who did not[16]. Some persons stay up until one or two o'clock in the morning being the norm, making a nighttime snack become a necessity after a long work day. However, epidemiologic studies with the associations between nighttime snacking and obesity were limited. We explored the associations of having a nighttime snack with obesity in populations from the Chinese Teacher Cohort (CTC). Having a nighttime snack can also affect human metabolic status[17]; furthermore, we investigated the associations of having a nighttime snack with hypertension, hyperlipidemia, and hyperglycemia.

Subjects and methods

Study population

The characterizations of the CTC were collected using an online anonymous questionnaire in Jiangsu Province in 2015. A total of 22,956 teachers, between the age of 20-65 years, completed the questionnaire survey. After excluding subjects who were pregnant, those who were less than 20 years old and missing data, the analysis enrolled 22,179 participants, yielding a participation rate of 96.6%. All the participants were local school teachers in primary high schools or colleges in the area of Jiangsu province, which included 89 schools in total

Questionnaire survey

In the CTC, the standardized questionnaire contains frequency of nighttime snack intake (0 time/week, 1-3 times/week, 4-6 times/week, 7 times/week), age, gender (male, female), height, body weight, smoking status (never: smoking < 20 cigarettes in the past year, ever: smoking ≥ 20 cigarettes in the past year), drinking status (never: never drink in the past year; ever: at least once drink in the past year) and region of Jiangsu Province (south, center, and north). In our questionnaire instructions, nighttime snacking was defined as any food consumption after 09:00 pm. The nighttime snack consumption time period examined was at least a week before the subjects filled out the questionnaire.

Evaluation of obesity, hypertension, hyperlipidemia and hyperglycemia

The body mass index (BMI) was calculated as weight (kg) divided by height squared (m²). Overweight and obesity was defined by BMI index based on optimal cut-off points of BMI for the CTC data[18]. In short, participants were divide into underweight (BMI < 18.5), normal weight (BMI, 18.5-24.99), overweight (BMI, 25-28) and obese (BMI > 28), respectively. Hypertension, hyperlipidemia and hyperglycemia were all obtained from questionnaire. Hypertension, hyperlipidemia and hyperglycemia were defined according to participants who self-reported of a previous diagnosis by a physician or healthcare professional.

Table 1 **Demographic data of nighttime snack consumption**

Demographic variables	Nighttime snacking consumption				P vlaue
Frequency (times per week)	0	1-3	4-6	7	
Total	142	1,952	4,365	15,720	
Gender					0.179
Male (47.7)	80 (56.3)	937 (48.0)	2,099 (48.1)	7,463 (47.5)	
Female (52.3)	62 (43.7)	1,015 (52.0)	2,266 (51.9)	8,257 (52.5)	
Age (Years)					<0.001
<30 (18.8)	39 (27.5)	626 (32.1)	1,080 (24.7)	2,421 (15.4)	
30-50 (74.6)	97 (68.3)	1,284 (65.8)	3,133 (71.8)	12,035 (76.6)	
>50 (6.6)	6 (4.2)	42 (2.2)	152 (3.5)	1,264 (8.0)	
BMI (kg/m^2)					<0.001
<18.5 (52.5)	61 (43.0)	880 (45.1)	2,173 (49.8)	8,523 (54.2)	
18.5-24.99 (30.5)	49 (34.5)	685 (35.1)	1,395 (32.0)	4,627 (29.4)	
25-28 (14.3)	20 (14.1)	310 (15.9)	676 (15.5)	2,165 (13.8)	
>28 (2.7)	12 (8.5)	77 (3.9)	121 (2.8)	405 (2.6)	
Smoking status					<0.001
Never (86.2)	103 (72.5)	1,582 (81.0)	3,688 (84.5)	13,735 (87.4)	
Ever (13.8)	39 (27.5)	370 (19.0)	677 (15.5)	1,985 (12.6)	
Drinking status					<0.001
Never (69.6)	88 (62.0)	1,271 (65.1)	2,883 (66.0)	11,196 (71.2)	
Ever (30.4)	54 (38.0)	681 (34.9)	1,482 (34.0)	4,524 (28.8)	
Region					0.399
South Jiangsu (25.4)	28 (19.7)	475 (24.3)	1,096 (25.1)	4,024 (25.6)	
Central Jiangsu (34.2)	45 (31.7)	672 (34.4)	1,494 (34.2)	5,373 (34.2)	
North Jiangsu (40.4)	69 (48.6)	805 (41.2)	1,775 (40.7)	6,323 (40.2)	

N (%) Never smoking: smoking <20 cigarettes in the past year; Ever smoking: smoking ≥20 cigarettes in the past year; Never drinking: never drink in the past year; Ever drinking: at least once drink in the past year.

Covariates

Age was a continuous variable. Gender, smoking and drinking status were binary variables and living region was a categorical variable. Blood pressure, blood lipid and blood glucose were classified as two outcomes "normal" and "abnormal" by a physician or healthcare professional.

Statistical analysis

Chi-square tests were used to analyze the general characteristic variables under different nighttime snack consumption conditions. Multinomial logistic regression models were performed to explore the association of overweight, obesity, hypertension, hyperlipidemia and hyperglycemia status with nighttime snack intake frequencies as age- and gender- adjusted and multivariate adjusted. Because we used the multinomial logistic model, the outcome variables of this study were defined as "normal" and "abnormal", such as overweight and not overweight, obese and non-obese, hyperglycemia and non-hyperglycemia. Multivariate logistic regression models were used, adjusted for age, gender, smoking condition, drinking condition, and living region. The "0 time/a week" was regarded as the reference value. We used 0.05 as the cut off P value for statistical significance. We analyzed all data calculations with the Statistical Analysis Systems software package version 9.2 (SAS Institute, Inc., Cary, NC, USA).

Results

General characteristics

The demographic characteristics and nighttime snack statuses of the CTC are presented in *Table 1*. Briefly, the CTC survey contained 22,179 participants including 47.7% males and 52.3% females. The age of most participants (74.6%) in CTC was in the range of 30-50 years. Of these 22,179 people, only 13.8% had ever smoked and 30.4% had ever consumed alcohol.

Association of nighttime snacking intake with obesity

We found a significant association between the highest frequency nighttime snacking consumption (7 times/ week) and increased risk of obesity either adjusted for age and gender (OR = 3.69, 95% CI 1.96, 6.96; *P* for trend < 0.001) or in the multivariate logistic regression (OR = 3.10, 95% CI 1.63, 5.89; *P* for trend < 0.001) analysis (*Table 2*). A similar but weak association was observed in the 4-6 times/week group either adjusted for age and gender (OR = 1.76, 95% CI 1.36, 2.28; *P* for trend < 0.001) or in the multivariate logistic regression (OR = 1.61, 95% CI 1.24, 2.09; *P* for trend < 0.001) analysis. Then, we performed analysis stratified by age, gender, smoking and drinking status and found that nighttime snacking 7 times a week was a positive association with being obese in females, persons aged 30-50 years and those who ever have had a drink or smoked, whereas among males, < 30 years old and those who never have had a drink or smoked, there was no associations between nighttime snacking and being obese (*Fig. 1A*).

Association of nighttime snacking intake with hyperglycemia

A significantly positive association was observed between the highest frequency nighttime snacking consumption (7 times/ week) and increased risk of hyperglycemia either adjusted for age and gender (OR = 2.21 95% CI 1.29, 3.78; *P* for trend < 0.001) or in the multivariate logistic regression (OR = 2.11, 95% CI 1.24, 3.62; *P* for trend < 0.001) analysis (*Table 2*). When the analysis was stratified by age, gender smoking and drinking status, nighttime snacking 7 times a week exhibited a positive association with being hyperglycemic in people aged 30-50 years and those who ever have had a drink or smoked, whereas among < 30 years old people and those who never had a drink or smoked, there was no associations between nighttime snacking and being hyperglycemic (*Fig. 1B*). However, no differences were observed between males and females. No significant associations were observed between nighttime snacking consumption and risk of hyperlipidemia.

Discussion

Our study first showed that the frequent consumption of nighttime snack was associated with increasing the risk of obesity and hyperglycemic statuses in Chinese adult teachers. When the results were stratified by age, gender, smoking and drinking status, the data showed that teachers aged 30-50 years and those who have ever drunk or smoked are yet to be correlated with obesity and hyperglycemia, compared to the same frequency of nighttime snack. Females were significantly associated

Table 2	**Nighttime snack consumption in predicting obesity and hyperglycemia**					
	Nighttime snacking	Overweight	Obesity	Hypertension	Hyperlipidemia	Hyperglycemia
Unadjusted	0 time/week	Reference	Reference	Reference	Reference	Reference
	1-3 times/week	1.23 (1.11, 1.35)	1.17 (0.95, 1.44)	0.92 (0.81, 1.05)	1.10 (1.01, 1.19)	1.24 (1.09, 1.41)
	4-6 times/week	1.39 (1.21, 1.59)	1.84 (1.43, 2.37)	0.88 (0.72, 1.07)	1.15 (1.03, 1.29)	1.05 (0.86, 1.28)
	7 times/week	1.29 (0.78, 2.14)	4.14 (2.21, 7.75)	1.12 (0.61, 2.09)	1.36 (0.91, 2.04)	2.02 (1.19, 3.40)
	P for trend	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Age- and gender-adjusted	0 times/week	Reference	Reference	Reference	Reference	Reference
	1-3 times/week	1.27 (1.15, 1.40)	1.13 (0.91, 1.39)	1.10 (0.95, 1.26)	1.23 (1.12, 1.34)	1.45 (1.26, 1.66)
	4-6 times/week	1.46 (1.37, 1.68)	1.76 (1.36, 2.28)	1.13 (0.92, 1.38)	1.38 (1.22, 1.57)	1.31 (1.07, 1.60)
	7 times/week	1.24 (0.74, 2.08)	3.69 (1.96, 6.96)	1.17 (0.62, 2.21)	1.34 (0.87, 2.06)	2.21 (1.29, 3.78)
	P for trend	< 0.001	< 0.001	0.110	< 0.001	< 0.001
Multivariate adjusted	0 times/week	Reference	Reference	Reference	Reference	Reference
	1-3 times/week	**1.23 (1.11, 1.36)**	1.06 (0.86, 1.32)	1.06 (0.92, 1.22)	**1.19 (1.08, 1.30)**	**1.42 (1.24, 1.63)**
	4-6 times/week	**1.40 (1.22, 1.62)**	**1.61 (1.24, 2.09)**	1.07 (0.87, 1.31)	**1.32 (1.16, 1.50)**	**1.27 (1.04, 1.55)**
	7 times/week	1.14 (0.68, 1.92)	**3.10 (1.63, 5.89)**	1.12 (0.59, 2.12)	1.27 (0.82, 1.96)	**2.11 (1.24, 3.62)**
	P for trend	< 0.001	< 0.001	0.343	< 0.001	< 0.001

Multivariate logistic regression models were used, adjusted for age, gender, smoking condition, drinking condition, and living region. Bold type represents random effects estimates.
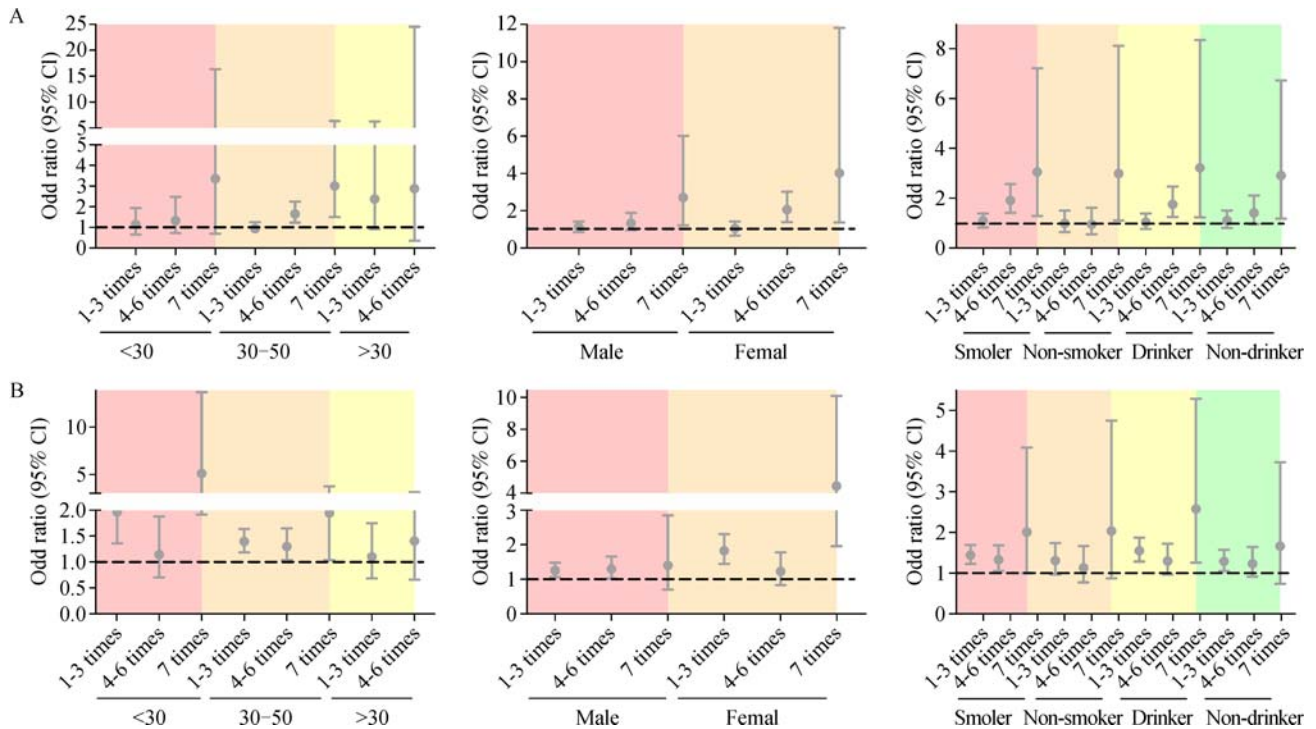
Fig. 1 **Stratified analysis of association between nighttime snacking and the risk of obesity or hyperglycemia.** The analysis is stratified by age, gender, smoking and drinking status. A: The outcome is obesity. B: The outcome is hyperglycemia. Data are expressed as odds ratio (OR) and 95% confidence interval (95%CI).

with obesity, while males were not, even in the same frequency of nighttime snacking whereas, when it comes to hyperglycemia, there is no difference between males and females.

Previous epidemiological studies have investigated the association between nighttime eating and weight change. Some studies indicated that people who have a higher proportion of calories later in the day, compared with earlier in the day, are more likely to gain weight[19–23]. However, there are some studies that disagree with this view[24–27]. A recent study of Korean female nursing students reported that students involved in nighttime snacking behaviors had a higher BMI than those who were not[28]. However, in their study, nighttime snacking behaviors are defined as having nighttime snacking at least once during a 3-day recording period and subjects were only classified into dichotomies which might bring some bias. Moreover, all of participants in their study were females. To avoid these weaknesses, we used a time frame of one week to assess the frequency of nighttime snacking. Furthermore, we used a larger sample size and multinomial logistic regression models and adjusted with more covariates. The nighttime snacking state was then divided into four levels in our study. Thus, our results are more reliable.

We found a strong positive association between nighttime snack intakes with obesity in the Chinese. The

risk factors of obesity are multifaceted including genetics, environment, diet, physical inactivity, and so on[3]. Aside from genetic factors, diet is the most important factor for becoming overweight or obese[29]. With changes in lifestyle, more and more people like to eat nighttime snacks after a long work day. However, whether nighttime snack intakes are associated with obesity has been rarely reported. Night eating syndrome (NES) is characterized by a large percentage of total daily calories being consumed after dinner[30]. It has been reported that NES is associated with obesity[31–32]. Recent studies reported that NES is positively associated with a higher BMI[30]. It has been confirmed that nighttime eaters intake more calories every day, and this is the reason that they gained more weight[22]. However, Hibi et al.[33] suggested that dietary consumption time is more responsible for an overweight status than the contents of dietary intakes. Recent animal studies also demonstrated the same result. The enzymes linked with lipid metabolism (ACOTs) and the Krebs cycle (citrate synthase, CS) are decontrolled in Clock-deficient (Clock$^{-/-}$) mice in contrast with the wild-type[34]. Zurlo et al. demonstrated that reduction of fat oxidation, which led to a positive fat balance, could contribute to the development of obesity[35]. According to the study of Gluck et al.[36], nighttime eating behavior can increase respiratory quotient and decrease fat oxidation, which can cause fat accumulation. Collectively, these

findings provide explanations why more frequent nighttime snacking consumptions could increase the risk of obesity.

Another important finding in our study is that the consumption of nighttime snacking may increase the risk of hyperglycemia. Few studies have examined the association between nighttime snacking and glucose metabolism. A previous study found that blood glucose levels were lower during nocturnal fast than during nocturnal eating[37]. However, the concrete mechanism is unclear. Compared to the morning, oral glucose tolerance is impaired in the afternoon and evening in humans[38–40]. This may be one of the reasons why nighttime snacking can increase the risk of hyperglycemia.

There are several limitations in our study. First, hypertension, hyperlipidemia and hyperglycemia were defined according to participants who self-reported a previous diagnosis by a physician or healthcare professional. This may affect the accuracy of our results. Secondly, we did not obtain information about their physical activity level and genetic susceptibility, which are also important factors related with obesity and hyperglycemia. Thirdly, the CTC survey in the present design was a cross-section study; therefore, we were unable to ensure whether more frequent nighttime snacking affected obesity and hyperglycemia or vice versa. Fourthly, it has been reported that insufficient sleep is associated with adverse health outcomes. However, referring to the limitation of our study design, we cannot exclude the impact of insufficient sleep. Lastly, all study populations were made up of teachers, which may not accurately reflect the real association between nighttime snacking and risk of obesity or hyperglycemia in the general population of adults.

In conclusion, the rates of obesity and hyperglycemia are projected to increase in almost all countries. Both of them are high risk for many chronic non-communicable diseases , such as type II diabetes, cardiovascular disease, and respiratory diseases and so on. Dietary intervention is one of the efficient options for therapeutic regimen for patients with obesity and hyperglycemia prior to drug therapy. Despite these limitations, our results show that nighttime snacking may increase the risk of obesity and hyperglycemia and reduce the frequency of nighttime snacking. This may help us to prevent obesity and hyperglycemia.

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