Original Article

Sleep deprivation is related to obesity and low intake of energy and carbohydrates among working Iranian adults: a cross sectional study

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Sleep deficiency is becoming widespread in both adults and adolescents and is accompanied by certain behaviors that can lead to obesity. This study aims to investigate differences in sleep duration of overweight/obese and normal weight groups, and the association between sleep deprivation and obesity, dietary intake and physical activity. A cross-sectional study was conducted among 226 Iranian working adults (109 men and 117 women) aged 20 to 55 years old who live in Tehran. Body weight, height, waist and hip circumferences were measured, and BMI was calculated. Questionnaires, including the Sleep Habit Heart Questionnaire (SHHQ), International Physical Activity Questionnaire (IPAQ) and 24-hour dietary recall, were interview-administered. Subjects were categorized as normal weight (36.3%) or overweight/obese (63.7%) based on WHO standards (2000). Overweight/obese subjects slept significantly (p<0.001) later (00:32±00:62 AM) and had shorter sleep duration (5.37±1.1 hours) than normal weight subjects (23:30±00:47 PM and 6.54±1.06 hours, respectively). Sleep duration showed significant (p<0.05) direct correlations to energy (r = 0.174), carbohydrate (r = 0.154) and fat intake (r = 0.141). This study revealed that each hour later in bedtime (going to bed later) increased the odds of being overweight or obese by 2.59-fold (95% CI: 1.61-4.16). The findings in this study confirm that people with shorter sleep duration are more likely to be overweight or obese; hence, strategies for the management of obesity should incorporate a consideration of sleep patterns.

Key Words: body weight, dietary intake, obesity, physical activity, sleep deprivation

INTRODUCTION

Obesity is one of the main public health problems in industrialized countries and in some developing countries. In 2005, more than 300 million people were obese (BMI ≥30 kg/m^2), and one billion people were overweight (BMI ≥25 kg/m^2).[1] Being overweight and obese are increasing in all parts of the world, including Iran. The prevalence of overweight and obesity in Iranian females is 41.1% and 22.5%, respectively, and among Iranian males it is 39.2% and 10.5%, respectively.[2]

The increasing trend in obesity is due to multiple behavioral, environmental, social, and genetic factors.[3] Behavioral factors, such as dietary intake and physical activity, are usually considered to be major causes of obesity, which triggers inflammation followed by type 2 diabetes.[4] Balancing energy intake with energy expenditure is vital in preventing obesity,[5] and understanding the effects of insufficient sleep on caloric intake and physical activity levels could also help to prevent obesity. Indeed, dietary intake and activity level do not completely explain the fast growing rate of obesity,[6] hence, there is a need to find new approaches for preventing obesity.

Recent data indicate decreasing sleep duration and increasing obesity in North America, and this phenomenon has encouraged researchers to study the metabolic effects of sleep deprivation.[7] This deficiency is accompanied by certain behaviors including lower physical activity that can lead to weight gain and obesity.[8] Cumulative evi-

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dence indicates that short sleep duration is associated with a higher risk of obesity.[9,10]

To date, very few studies on the sleep duration of Iranian adults and its relation to obesity have been reported.[11] Haghighatdust *et al* studied young female students in Isfahan. The current study was conducted among working adults of Tehran and aims to determine the role of sleep in obesity. Besides that, we aimed to compare the mean difference in terms of sleep duration between normal weight and overweight/obese individuals, and to investigate their relationship with other obesity risk factors such as physical activity, sedentary lifestyle and food intake.

METHODS

Study design

A cross-sectional study was conducted in several organizations in the Tehran metropolitan area. Four offices were randomly selected from geographically different areas. The respondents included employees of the Etka hyper market in the north, Bina hospital in the east, Refah headquarters in the south and a municipality in the west of Teheran. Participants were aged 20-55 years old. The study protocol was approved by the Medical Research and Ethics Committee of the Universiti Kebangsaan Malaysia (UKM) in accordance with Declaration of Helsinki, prior to the data collection. Permission to conduct the study in each location was obtained from the administrators of each office.

Screening of participants

Screening of the participants included measuring weight, height, waist circumference (WC) and hip circumference (HC), and calculating BMI. We utilized systematic random sampling to enroll the subjects in each office. Subjects who were undergoing a weight loss program, were physically or mentally disabled, had acute or chronic diseases (eg, acute-flu; chronic-diabetes), were pregnant or lactating, or underweight (BMI <18.5) were excluded from this study. A total of 245 consent forms with detailed explanations of the study were distributed to participants who had been previously selected. Among them, 226 were completed and returned, and a total of 226 participants aged 20-55 years were enrolled in this study.

Sampling method

Sample size formula for comparing the mean difference of sleep duration between two groups $n = 2 (z_1\text{-}\alpha/2 + z_1\text{-}\beta)^2 / (d^*/\sigma)^2$,[12] was used. To achieve a power of 80% and a confidence level of 95% adjusting for a 10% drop out, we needed a minimum 104 subjects in each group by sex. Participants were then grouped in to normal weight (BMI 18.5-24.9) or overweight/obese (BMI ≥25) groups based on WHO BMI categories.[5]

Data collection

Data were collected for all respondents who had signed informed consent, based on inclusion criteria.

Assessment of anthropometry and body composition

Participants' anthropometric measurements, including weight, height, WC and HC were recorded. Weight was measured to the nearest 0.1 kg with the subject wearing light clothing, without shoes or socks. Weighing was performed in the morning before breakfast using a TANITA Digital Bathroom Scale HD 309 (Tanita, Japan). Height was measured to the nearest 0.1 cm using a SECA stadiometer (Seca 213, Germany). For the height measurement, the subject's head was kept in the Frankfurt horizontal plane, the heels were placed together, and the shoulders were in a normal position.[13] We calculated BMI as weight (kg) divided by height (m^2). A BMI value of 18.5-24.9 kg/m^2 was considered as normal weight and overweight/obese was defined as BMI ≥25 kg/m^2.[5] Waist and hip circumferences were measured to the nearest 0.5 cm with Lufkin tape (W606 PM Cooper Industries, USA). Waist circumference was measured at the midpoint of the lower border of the rib cage and the iliac crest at the end of normal expiration without pressing the skin. Hip circumference was measured at the level of the greatest posterior protuberance of the buttocks.[13] The Bioelectrical Impedance Analysis (BIA) method, (Omron hand-held model HBF 306, Omron, Japan) was used to obtain body fat percentage (BF%) of normal, overweight and obese subjects.

Assessment of dietary intake

Food intake was assessed using three-days of 24-hour dietary recall, for two week-days and one day during the weekend. Subjects were interviewed, and the portion size of food items was estimated based on household measurements. Data were converted to grams, and a software program (Nutrition 4), based on Iranian foods, was used to analyze the energy and other macronutrients. The results were reported as a mean of three days of recall.

Assessment of sleep duration

Sleep duration was assessed using SHHQ.[14] This questionnaire was validated by the Sleep Heart Health Study, which is a multi-center cohort study implemented by the National Heart Lung and Blood Institute. From the questionnaire, six questions related to the study, namely bed time, wake up time, sleep duration during weekend and during weekdays, were chosen and translated into Persian. To test the reliability, after adapting the questionnaire, we pretested the instrument on 10% of the study population. The Cronbach's α of the adapted questionnaire was 0.78, and the questionnaire is considered reliable.

The duration of sleep was determined with the following formula (5 × period of time sleeping during working days + 2 × period of time to sleep on weekends) divided by 7.[15,16]

Assessment of physical activity status

The International Physical Activity Questionnaire (IPAQ) short version was used in this study.[17] Physical activity of subjects was measured in four domains; vigorous intensity, moderate intensity, walking and sitting. The IPAQ data were converted to (MET-min/wk) by multiplying the number of minutes that was detected for each activity class by the number of days per week and the specific MET score for that activity, then data were reported as median value and interquartile range (IQR). Total physical activity (MET-min/wk) was assessed by adding up of walking, moderate and vigorous activity. Sitting time of

subjects was reported as (min/wk) by median value and interquartile range (IQR).[18] The validity of IPAQ was verified by Craig *et al*.[17] Translation to Persian was followed by back translation and reliability testing.[19,20]

Statistical analysis

All data were analyzed using the SPSS statistical program (version 19.0, Chicago IL). The normal distribution of variables was tested using the Kolmogrov-Smirnov test, histograms and p-p plots. All tests were two-tailed with a significance of $p<0.05$ or a 95% confidence interval (CI). Anthropometric measurements, sleep duration and dietary intake including (energy, carbohydrate, protein and fat) between overweight/obese and normal weight women were compared using independent samples t-tests, and that between overweight/obese and normal weight men were compared using Welch's t-test. The physical activity level of the subjects was reported as median and IQR, and Mann-Whitney U test was employed for comparison. Furthermore, for determining the relationship of sleep behavior and anthropometric indices, physical activity levels and dietary intake of subjects, correlation coefficients (partial for normal variables and Spearman for non-normal data) were computed. Stepwise logistic regression was performed to determine the odds ratio of risk factors including age, sleep duration, bed time, wake up time, physical activity, sedentary status, energy, carbohydrate, protein and fat intakes.

RESULTS

There were 109 men (48.2%) and 117 women (51.8%) in this study. Based on the entire sample, 82 (36.2%) of the study participants were normal weight, of which 28% were men and 72% were women. There were 144 (63.8%) overweight/obese subjects of which 59.7% were men and 40.3% were women. Table 1 shows general characteristics and anthropometry variables of both normal-weight and over-weight/obese men and women. Overweight/obese men and women were older ($p<0.05$) and had statistically higher anthropometric variables [weight, WC, HC, BMI ($p<0.01$) and BF% ($p<0.001$)] in comparison to normal weight subjects; however, normal weight subjects of both sexes were taller.

Table 2 shows, the sleep behavior, dietary intake and physical activity of the participants. There was a significant mean difference in bedtime ($p<0.001$) and sleep duration ($p<0.001$, $p<0.01$) between normal weight and overweight/obese women and men, respectively. The greatest sleep duration in this study was 9.12 hour/day. Median physical activity levels of normal weight and

Table 1. Physical characteristic of participants

	Men (n=109)				Women (n=117)			
	Normal weight (n=23)		Overweight/obese (n=86)		Normal weight (n=59)		Overweight/obese (n=58)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (year)	35.3*	9.2	39.2	7.2	31.9**	6.9	35.7	8.1
Weight (kg)	71.5***	5.4	86.2	13.3	58.1***	5.6	72.6	7.5
Height (cm)	174***	4.0	172	7.8	160	5.7	159	6.2
WC (cm)	87.6***	6.1	101	8.1	76.0***	6.5	88.4	8.9
HC (cm)	99.3***	3.6	107	6.5	98.0***	5.5	106	4.6
BMI (kg/m^2)	23.5***	1.2	29.1	2.8	22.6***	1.6	28.6	2.8
BF%	22.9***	3.9	28.6	3.5	32.1***	3.4	37.4	3.8

SD: standard deviation; WC: waist circumference; HC: hip circumference; BMI: body mass index; BF%: body fat percentage.
Significant difference between weight groups within the same sex: * $p<0.05$, ** $p<0.01$ and *** $p<0.001$

Table 2. Sleep pattern, dietary intake, and physical activity of participants

	Men (n=109)		Women (n=117)	
	Normal weight (n=23)	Overweight/obese (n=86)	Normal weight (n=59)	Overweight/obese (n=58)
Sleep behavior, Mean (SD)				
Bedtime	23:51 (00:48)***	00:42 (00:50)	23:20 (00:46)***	00:17 (00:64)
Wake up time	06:53 (00:52)	06:57 (00:49)	07:00 (00:46)	06:50 (00:46)
Sleep duration (hour/day)	6.30 (1.09)**	5.37 (1.10)	6.37 (1.04)***	5.38 (1.08)
Intake, Mean (SD)				
Energy (kcal)	2402 (562)	2191 (499)	1780 (489)	1704 (575)
Carbohydrate (g)	363 (90.7)	323 (91.7)	249 (84.3)	239 (112)
Protein (g)	89.9 (16.7)	89.3 (21.3)	67.7 (21.5)	65.3 (18.5)
Fat (g)	69.7 (23.1)	63.7 (19.4)	59.2 (20.0)	53.7 (19.1)
Physical activity, Median (IQR)				
Walking (MET-min/wk)	693 (1155)	693 (1139)	693 (1139)	445 (495)
Moderate Intensity (MET-min/wk)	80 (780)	0 (240)	0 (240)	80 (480)
Vigorous activity (MET-min/wk)	640 (1200)*	0 (720)	0 (720)	0 (450)
Total activity (MET-min/wk)	2046 (2739)*	1430 (2691)	1430 (2691)	918 (1590)
Sitting (min/wk)	2940 (1960)	2940 (1365)	2940 (840)	2940 (840)

Bedtime: the time that subjects go to bed during weekend and weekdays Wake up time: the time that subjects wake up in the morning during weekend and weekdays
Significant difference between weight groups within the same sex: * $p<0.05$, ** $p<0.01$ and *** $p<0.001$
IQR: Interquartile range

Table 3. Partial correlation coefficients between sleep pattern and anthropometric indices, dietary intake, and physical activity status

	Bed time		Wake up time		Sleep duration	
	r	*p*-value	r	*p*-value	r	*p*-value
Age	0.06	0.385	-0.38	<0.001	-0.25	<0.001
Weight	0.30	<0.001	0.03	0.642	-0.24	<0.001
Height	-0.03	0.640	0.07	0.286	-0.04	0.482
WC	0.30	<0.001	-0.06	0.352	-0.30	<0.001
HC	0.25	<0.001	0.01	0.824	-0.24	<0.001
BMI	0.37	<0.001	0.01	0.853	-0.29	<0.001
BF%	0.27	<0.001	-0.10	0.115	-0.25	<0.001
Energy	-0.086	0.212	0.133	0.053	0.174	<0.05
Carbohydrate	-0.128	0.063	0.039	0.574	0.154	<0.05
Protein	0.011	0.876	0.134	0.051	0.122	0.075
Fat	-0.074	0.280	0.179	<0.01	0.141	<0.05
IPAQ-score	0.00	0.946	-0.09	0.203	-0.10	0.155
Sedentary	0.00	0.991	0.12	0.070	0.06	0.357

Partial correlation between sleep pattern and anthropometric indices, dietary intake, and physical activity status

Table 4. Determining odds ratio (OR) of being overweight and obese **(**adjusted for physical activity, sedentary status, and dietary intake including energy, carbohydrate, protein and fat)

Risk Factors	β	S. E	OR (95% confidence interval)	*p*
Age	0.098	0.029	1.09 (1.03-1.15)	<0.01
Sleep Duration	-0.749	0.233	0.47 (0.30-0.71)	<0.01
Bed Time	0.990	0.260	2.59 (1.61-4.16)	<0.001

overweight/obese subjects were calculated, and we found a significant difference only between vigorous and total intensity ($p<0.05$) between normal weight and overweight/obese males.

Table 3 illustrates the correlations between sleep behavior and age, anthropometric indices, dietary intake and the physical activity of subjects. The results revealed that all anthropometric characteristics (weight, WC, HC, BMI and BF%) of subjects, except for height, were positively related to having a later bedtime ($p<0.001$). Furthermore, sleep duration showed significant inverse relationship with age and anthropometric measurements ($p<0.001$) except for height. There is significant negative relationship between waking time and the age of subjects (r = -0.380, $p<0.001$). Sleep duration showed significant direct correlations with energy, carbohydrate and fat intake, (r = 0.174, r = 0.154 and r = 0.141, respectively, $p<0.05$). Our data on physical activity showed that there was no significant correlation between sleep behavior and the physical activity level of subjects.

Table 4 shows the odds ratio (OR) and 95% CI of the predictors for obesity, showing that subjects with longer sleep duration had a lower risk for being overweight and obese (OR: 0.47, 95% CI: 0.30-0.71). Each hour of increase in bedtime increases the odds of being overweight/obese by 2.59-fold (95% CI: 1.61-4.16). Older subjects had a probability of becoming overweight/obese that was 1.09-fold (95% CI: 1.03-1.15) higher compared to younger age subjects.

DISCUSSION

In this cross-sectional study, we found that short-sleepers had higher BMI, waist circumference, hip circumference, and percentage of body fat and were significantly older, but had less energy, carbohydrate and fat intakes compared to longer-sleepers, without any significant differences in physical activity levels**.**

In addition to sleep deprivation, our findings suggest that older age is one of the risk factors for obesity, and this result is supported by other studies,[21] that have found that mean BMI increases with age *(*$p<0.001$*)*. Another study[22] with a similar age range as our study (18-60 years) reported that the overweight group was significantly older than the normal weight group ($p<0.05$).

Because obesity may be related to higher weight, BMI and waist circumference,[23] in the present study, higher anthropometric indices of overweight/obese group may be explained by less sleep duration compared to the normal weight group. One study also suggested that the relative risk of being obese was significantly higher in subjects with sleep duration of less than 5 hours compared to participants with sleep duration of 5-7 hours.[24]

Our findings on sleep duration were consistent with previous cross-sectional studies,[25] suggesting significant inverse relationship between sleep duration and BMI *(*$p<0.01$*)*. Our study also found a negative relationship of sleep duration and positive relationship of bedtime with BMI, respectively (r = -0.298 and r = 0.372). In another recent longitudinal study,[26] negative association between sleep duration and obesity was reported.

Generally, more BF% represents more obesity. Two studies on sleep quality and weight gain reported that individual weight gain is due to less sleep duration or less sleep quality.[27] In another cross-sectional analysis,[28] it was suggested that sleep fragmentation is linked with BMI. However, the opposite is also possible, namely, that obesity reduces quality of sleep or sleep duration. Thus, our finding of a significant positive correlation of later bedtime and significant negative correlation of longer sleep duration with BF% has been confirmed (r = 0.270; r

= -0.257 $p<0.001$). Physiological studies emphasize probable hormonal mechanisms that lead to decrease in leptin and increase in ghrelin levels, and on their role in short sleep duration and increase in weight. Ghrelin and leptin levels are directly associated with hunger and satiety, respectively.[15]

There are confounding aspects to our data on energy and carbohydrate intake after sleep restriction. In reference to the correlation of sleep behavior and dietary intake, subjects who had shorter sleep duration had significantly lower energy, carbohydrate and fat intake. It means that participants who reported less sleep, also reported less dietary intake. This result contrasts those of previous studies. Previous findings reported that sleep deprivation led to increased dietary intake and those with less sleep duration showed more energy and carbohydrate intakes.[11,29-31] Another study also suggested that persons who had less sleep may gain weight because of increased hunger or late-night eating.[32] Because the current study found contrary results in dietary intake, it may be concluded that sleep duration is one of the important key factors for being overweight or obese.

One explanation for the differing results may be the under-reporting of energy intake of overweight and obese subjects. In the current study, 60.4% of overweight and obese groups under-reported their energy intake, and the most under-reporting of energy was associated with overweight/obese groups, especially overweight/obese women (76%). Several previous studies have reported that overweight and obese participants tended to under-report energy intake.[33,34] In Western countries, the percentage of under-reporting range from 10% to 83%.[32] Thus, based on the tendency of the overweight/obese subjects to under-report their dietary intake, the possibility of controversial results on dietary intake for this study is not impossible.

Physical inactivity may lead to weight gain in short-sleepers,[35] but our findings relating to physical activity and sleep duration contradict this hypothesis.[36] Our findings on physical activity support some earlier studies that did not find any significant differences in physical activity levels between short- and long-sleepers.[37,38] Hence, it may be concluded that other mechanisms may contribute to obesity in sleep deprived individuals.

This study is not without its own strengths and weaknesses. The inclusion of only four offices is a limitation of our study, mainly due to lack of funding and resources. However, as we had included offices in four different areas of Tehran, namely north, south, east and west, and hence this should provide some representativeness to our sample. Sleep habit, dietary intake and physical activity were assessed using questionnaire and self-reported information is known to depend on participants' memory and could be over- or under-reported. In our study, we were also not able to ascertain whether sleep deprivation led to obesity or vice versa. Besides, this study is the first that studied sleep pattern in relation to obesity among Tehranian adults, and was able to present other contributing factors related to overweight and obesity apart from sleep duration.

Conclusions

In conclusion, data from the current study suggest that later bedtime and shorter duration of sleep increases the risk of being overweight and obese among Iranian adults, and age may be linked to obesity. Finally, subjects with longer sleep duration (up to 9 hours/day) have lower risk of being overweight or obese. They also have lower BMI, body weight, waist and hip circumference, and BF%, as well as an overall healthier weight status. Hence, the findings from this study indicate that sleep patterns should be considered as an integral part of obesity management.

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AUTHOR DISCLOSURES

There is no competing interest regarding the publication of this article.

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Original Article

Sleep deprivation is related to obesity and low intake of energy and carbohydrates among working Iranian adults: a cross sectional study

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伊朗在職成人睡眠不足與肥胖、低熱量及碳水化合物攝取量之相關：橫斷性研究

睡眠不足在成年人及青少年已成為普遍的現象，這伴隨著某些行為可能導致肥胖。此研究目的為研究體重過重/肥胖及正常體位者的睡眠時間差異，以及睡眠不足與肥胖、飲食攝取及體能活動的相關性。本橫斷性研究的研究對象來自於居住在德黑蘭的 226 名伊朗在職成人(109 名男性及 117 名女性)，年齡介於 20 至 55 歲。測量受訪者的體重、身高、腰臀圍，並計算其 BMI。在面訪時使用包含睡眠習慣心臟問卷(SHHQ)、國際體能活動問卷(IPAQ)及 24 小時飲食回憶問卷。研究對象依據 WHO 標準(2000)被分類為正常體重(36.3%)或是體重過重/肥胖(63.7%)。體重過重/肥胖者(凌晨 00:32±00:62 就寢)比起正常體重者(夜晚 23:30±00:47 就寢及 6.54±1.06 小時睡眠)顯著較晚睡覺，且有較短的睡眠時間(5.37±1.1 小時)。睡眠時間則與熱量(r=0.174)、碳水化合物(r=0.154)及脂肪(r=0.141)攝取量有顯著的直接相關性。這個研究亦發現，就寢時間每延後一小時，體重過重或肥胖的機率則增加 2.59 倍(95% CI=1.61-4.16)。此研究結果證實，睡眠時間較短者較可能為體重過重或是肥胖；因此，肥胖的管理策略應同時考量睡眠模式。

關鍵字：體重、飲食攝取、肥胖、體能活動、睡眠不足