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Original article

Sleep efficiency and duration assessed with metabolic holter: associate with body composition and dietary components

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Summary. *Objective:* This study was planned to determine the associations between sleep duration, efficiency, quality with dietary components in adults**.** *Methods:* This cross-sectional study was conducted with young adults aged between 19-30 years. Sleep duration and efficiency were assessed with Metabolic Holter. Sleep quality was assessed with Pittsburgh Sleep Quality Scale. Three consecutive days' dietary record was taken at the same time with metabolic holter. Body composition was analyzed with Bioelectric Impedance Analysis. *Results:* Body fat mass, body fat percent, waist circumference, and waist/hip ratio was found higher in females with poor sleep efficiency, and decreased sleep efficiency correlated with increased waist/hip ratio (r=-0.324; p=0.054). Being female gender and decreased fat mass were shown as major predictors for increased sleep efficiency according to regression analyses. Also, in females with poor sleep quality had higher percentage of body fat mass and body mass index than females with good sleep quality ($p<0.05$). The body mass index and waist/hip ratio were found higher in males with sleep duration <7 hours. Decreased sleep efficiency correlates with increased body fat mass and the body fat percent in males ($p<0.05$). Daily dietary protein, tryptophan, polyunsaturated fatty acids and cholesterol intake are significant higher in males who sleep ≥7 hours ($p<0.05$). *Conclusion:* Poor sleep efficiency and short sleep duration in males and poor sleep efficiency in females is associated with increased obesity indicators. These associations were found to be partially related by nutrient intakes, especially in males.

Keywords: Sleep duration, sleep efficiency, sleep quality, dietary intake

Introduction

Sleep problems such as insufficient sleep (short sleep duration and poor sleep quality) have been extensively reported in modern societies during recent years (1). Sleep can be assessed from the two aspects of quantity (such as short sleep duration: <7 hours, long sleep duration: >9 hours, changes in sleep duration) and quality (such as sleep latency, sleep fragmentation, sleep deprivation, sleep disturbances and sleep apnea). In addition, sleep efficiency commonly defined as the ratio of total sleep time in a night compared to the total amount of time spent in bed (2).

Changes in mean sleep duration, quality and efficiency are associated with many health problems (3). Short sleep duration is associated with weight gain and obesity, diabetes, cardiovascular disease, psychiatric illness, performance deficits and total mortality. Similarly, long sleep duration is associated with the poor physical and mental health (4-7). Furthermore, individuals with poor quality of sleep report significantly more problems with physical and psychological health than those experiencing a good quality of sleep (8).

Sleep deprivation (insufficient sleep duration) leads to changes in diet and appetite, and increases the risk of developing diseases by alterations in metabolic regulation (9). Theoretically, sleep duration influences the appropriate time to eat (10). After sleep restriction, leptin levels reduce and ghrelin levels increase (11, 12). In addition, many factors related to eating patterns, such as skipping breakfast, eating at late hours and a reduction in the number of meals, are associated with altered metabolic response, poor diet quality and obesity (13, 14). The frequency of breakfast skipping is higher in individuals with reduced sleep duration (15).

Sleep duration and diet connections have been demonstrated in previous studies. Increased unhealthy eating habits, such as a preference for fatty foods, skipping breakfast, an increase in snacking and frequency of eating out, are associated with short sleep duration (7, 16, 17). Both short and long sleep duration are associated with a higher body mass index (BMI) (4, 18-20). Individuals who sleep less than six hours per day tend to be more overweight or obese (21).

Dietary factors affecting sleep quality can be easily improved; however, changing the sleep quality independently is not possible. Although, sleep quality may be improved with some lifestyle modifications such as exercise, modifying nutritional habits are more practical than changing lifestyle behaviors (22). For this reason, it is important to evaluate the relationship between sleep quality and duration, and food intake (7, 23).

Sleep quality has been assessed using various methods, including subjective measurements and objective measurement. Subjective measurements mainly contribute to define the effects of sleep disturbance in individuals, in addition to objective measurements can distinguish the sleep and wake more correctly and they gave another sleep evaluation parameter is sleep efficiency (24, 25). As a metabolic holter, Sense Wear Armband-derived sleep duration, and sleep efficiency were validated by polysomnography. It was reported that Sense Wear Armband a reliable method for determining sleep when compared with the gold standard polysomnography (26).

Inadequate and unbalanced diet and low physical activity level are the main mediators leading obesity and alteration of the body fat composition. On the other hand, the duration and quality of sleep effect on food preference, meal frequency, and the total amount of food consumption (9, 13).

With this background, sleep duration, quality and efficiency should be considered together with energy and nutrient intake, as well as body composition and obesity. Therefore, this study was planned to determine the relationship between sleep duration, quality, and efficiency with nutritional status.

Material and Methods

Sample and Procedure

This study was conducted in Gazi University, Department of Nutrition and Dietetics. Eighty-three volunteers were included at baseline. However, twenty-three participants were excluded because of technical reasons (eleven participants did not wear the metabolic holter for three days consecutively, seven participants were disturbed to wear metabolic holter and five participants' data could not be transferred to the software). Finally, this cross-sectional study was completed with 60 healthy individuals (24 males, 36 females) aged 19-30 years. Subjects were selected considering not having any chronic diseases: diabetes mellitus, hypertension, cardiovascular diseases etc, and not receiving hormone treatment and medication and, for female subjects in pregnancy and lactation period were excluded.

The study protocol was approved by the Ethical Committee of the Gazi University of Ankara/Turkey (77082166-604.01.02) and written informed consent was obtained from all participants.

Data Collection

Data were collected using a questionnaire prepared by researchers. General information and food records (3 days) of individuals were taken. Pittsburgh sleep quality scale (PSQI) was applied. Anthropometric measurements were measured following standardized procedures and body composition was analyzed by bioelectrical impedance analysis (BIA). Metabolic holter (BodyMedia Sense Wear™ Armband) was worn for three days in order to evaluate sleep efficiency and daily energy expenditure.

Objective Measurement of Sleep Duration and Efficiency (Metabolic Holter)

Multisensory body monitor (BodyMedia Sence Wear™ Armband) has been validated for use in estimating activity levels, energy expenditure. Furthermore, the sensors in the armband measure skin temperature, galvanic skin response, heat flux from the body, and movement to validate the detection of sleep and wake (27, 28).

All participants were instructed to wear multisensory body monitor for three consecutive days (one of the days is a weekend) on the triceps muscle of their right arm, at the midpoint between the acromion and olecranon processes. Sleep duration and efficiency (%) were assessed with Metabolic Holter for a total of 180 days. Sleep duration, efficiency and also daily energy expenditure data were obtained by movement, skin temperature, and stress sensors of the device and displayed with BodyMedia Sense Wear™ 7.0 professional software program.

Sleep efficiency (%) commonly defined as the ratio of total sleep time to time in bed ((total sleep time /time in bed)*100) (28). The cut off points of the percentage of sleep efficiency was determined 50th percentile (79.1%) and classified as high (≥79.1%) or low (<79.1%). Daily sleep duration data from armband was evaluated according to National Sleep Foundation recommendations and minimum sleep duration was taken as 7 hours in adult age group (29).

Subjective Measurement of Sleep Quality (Pittsburgh sleep quality scale)

Pittsburgh sleep quality scale (PSQI) was gold standard of subjective sleep quality that could reliably categorize individuals' sleep quality as either "good" or "poor" (24). The scale was developed by Buysse et al. in 1989 and it was shown adequate internal consistency, the test-retest reliability and validity (30). Reliability and validity of scale were conducted in our country in 1996 by Ağargün et. al., Cronbach's alpha internal consistency coefficient was found to be 0.804 (31). The PSQI has nineteen questions combined into seven clinically derived component scores from 0 to 3. These components are subjective (1) sleep quality, (2) sleep latency, (3) sleep duration, (4) normal sleep efficiency, (5) sleep disturbances, (6) the application of sleep medicine, and (7) daytime dysfunction. The sum of scores for these seven components yields PSQI total score ranging from 0 to 21. The PSQI scores >5 are indicative of poor sleep quality less than ≤5 is indicate of good sleep quality. The PSQI is quick and easy to administer, making it an attractive tool for sleep quality assessments (30).

Dietary Record

A consecutive three-day dietary record (one of the days is at weekend) was completed by all participants at the same time with metabolic holter. Food consumptions were taken by using Food and Nutrition Photo Catalog (32). Dietary data from the food records were entered into a food analysis software: Nutrition Information Systems (BEBIS) to calculate the total daily intake of energy and nutrients (33).

Anthropometric Measurements and Evaluation of Body Composition

Anthropometric measurements, including height (cm), waist and hip circumference (cm) were measured by well-trained investigators, using standard measurement protocols. Waist/hip was calculated, and used for correlation analyses. The individuals were weighed using a body composition analyzer (Tanita BC-418, Body Composition Analyzer) to the nearest 0.1 kg and also body fat mass (kg), lean body mass (kg), body water mass (kg) and body fat percentage (%) were obtained by this analyzer. All participants underwent body composition analysis following at least 4 hours fasting, not consume any fluid (water, tea, coffee etc.), not do heavy physical activity and not contain metal objects in any contact with skin. Waist circumference was measured at the mid-point, above the iliac crest and below the lowest rib margin at minimum respiration, using a flexible tape to the nearest 0.1 cm. The hip circumference measurement is taken from the widest part of the hip at side of the individual.

Statistical Analyses

Mean and standard deviation values of quantitative data obtained from individuals were given in tables according to their gender. Data were analyzed using visual (histogram and probability plots) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk test) to determine whether they are normally distributed. Significance was assessed using t-test or chi-square test for parametric data and Mann-Whitney U test for non-parametric data. Correlation between sleep efficiency and sleep quality with certain anthropometric measurements were calculated using Spearman/Pearson test. Correlation coefficients were determined and shown with Simple Scatter graph. Finally, a multiple linear regression model was used to identify independent predictors of sleep efficiency. The model fit was assessed using appropriate residual and goodness of fit statistics. The SPSS Version 15.0 statistical software package (34) was used for all analyses in the 95% confidence interval.

Results

According to body mass index 66.7% of male and 80.6% of female were in normal weight (18.5-24,9 kg/m^2), 20.8% of male and 8.3% of female were overweight (25.0-29,9 kg/m^2) and only 8.3% of male were obese (>30 kg/m^2) (Data not shown). General characteristics of subjects were shown in Table 1. The mean age of the male and female subjects were 25.7±2.89; 26.4±2.57 years respectively (p>0.05). PSQI scores and sleep duration were statistically similar in both genders. But sleep efficiency of females (80.6±9.80) was significantly higher than males (76.2±7.20).

Anthropometric measurements and body composition of the individuals according to gender, sleep duration, efficiency and quality classification were given in Table 2. Mean BMI values and waist-hip ratio was lower in males whose sleep duration ≥7 hours (respectively; 22.3±2.49 and 0.81±0.04) than whose sleep duration was 7 hours (25.5±3.06 and 0.87±0.05 respectively) (p<0.05). The mean percentage of body fat was higher in males with having sleep duration <7 hours than ≥7 hours but the difference was not statistically significant (p>0.05). There was no statistically significant difference between the mean sleep duration with anthropometric measurements and body composition in females (p>0.05).

Mean body fat mass, percentage of body fat, waist circumference and waist hip ratio values are significantly lower in females high sleep efficiency (p<0.05). Similar to females, mean body fat mass, percentage of body fat, waist circumference, waist hip ratio and BMI are lower in males with high sleep efficiency but not statistically significant (p>0.05). Also mean height is higher in males with high sleep efficiency (p=0.032). Anthropometric measurements and body composition of the males were not statistically different according to PSQI classification. However, females with poor sleep quality had significantly higher percentage of body fat and BMI than females with good sleep quality (p<0.05) (Table 2).

Table 1. General characteristics related to sleep of individuals by gender

General characteristics	Male (n:24)	Female (n:36)	p
	±SD	±SD	
Age (years)	25.7±2.89	26.4±2.57	0.533
Sleep quality (PSQI score)	4.7±2.40	5.5±2.60	0.266
Sleep efficiency (%)	76.2±7.20	80.6±9.80	**0.019***
Sleep duration (hour)	6.1±1.70	6.3±1.76	0.673
***p<0.05**			

Table 3 identifies the results of the multiple linear regression model, where six determinants significantly associated with sleep efficiency. Three of determinants percentage of body fat (%), body mass index (kg/m^2) and waist-hip ratio had negative predictors of sleep efficiency. Female gender and percentage of body fat (%) were most powerful determinants of sleep efficiency (p<0.05).

Dietary energy and nutrient intakes of the individuals were given in Table 4. Daily dietary protein, tryptophan, polyunsaturated fatty acids and cholesterol intake are higher in males with sleep duration ≥7 hours (respectively; 84.4±14.83 g, 932.4±152.20 mg, 30.5±5.05 g and 365.3±96.89 mg) than <7 hours (respectively; 72.0±21.28 g, 814.6±250.96 mg, 24.9±10.37 g and 248.0±85.73 mg) (p<0.05) (Table 4).

Correlation between sleep quality and sleep efficiency of individuals was shown in Figure 1A. Negative weak correlations between PSQI score and sleep efficiency was found (p=0.036). Increased sleep efficiency correlates decreased body fat mass and percentage of body fat in males (p<0.05) (Figure 1B and 1C). Liminal correlation between sleep efficiency and waist/hip ratio in females was indicated in Figure 1D (p=0.054).

Discussion

Sleep, like eating is an essential need. Nutrition and sleep are interrelated, each influence and is affected by the other. In the present study, we aimed to determine the possible relationships between sleep duration, quality, efficiency, dietary food & nutrient intake

Table 2. Anthropometric measurements and body composition of the individuals according to gender, sleep duration, efficiency and quality classification

Variables	Sleep duration				Sleep efficiency				Sleep quality			
	Male (n:24)		Female (n:36)		Male (n:24)		Female (n:36)		Male (n:24)		Female (n:36)	
	<7h (n:15)	≥7h (n:9)	<7h (n:21)	≥7h (n:15)	High (n:8)	Low (n:16)	High (n:22)	Low (n:14)	Poor (n:6)	Good (n:18)	Poor (n:18)	Good (n:18)
	±SD	±SD	±SD	±SD	±SD	±SD	±SD	±SD	±SD	±SD	±SD	±SD
Height (cm)	175.0±8.25	179.0±5.85	162.0±4.76	164.3±5.47	**180.8±4.73***	**174.3±7.88***	163.2±5.02	162.7±5.44	174.1±6.11	177.2±7.99	161.3±4.86	164.6±4.94
Weight (kg)	78.3±11.10	71.5±8.46	56.8±5.96	59.1±6.64	76.1±14.50	75.6±8.49	56.2±5.34	60.2±7.01	72.5±9.08	76.8±11.01	58.6±5.96	56.8±6.60
Body fat mass (kg)	15.0±5.94	11.3±4.70	15.0±4.11	16.6±5.00	12.1±6.61	14.4±5.25	**14.3±3.92***	**18.0±4.54***	11.1±6.97	14.4±5.17	16.8±3.89	14.6±4.89
Body lean mass (kg)	63.2±8.05	60.2±4.64	41.7±2.85	41.8±3.68	63.9±8.52	61.2±6.24	41.5±3.38	42.1±2.89	61.4±4.07	62.3±7.84	41.7±2.82	41.7±3.57
Percentage of body fat (%)	18.9±6.43	15.3±5.21	26.1±5.05	27.5±5.66	15.1±5.67	18.8±6.15	**24.9±5.12***	**29.5±4.35***	14.6±7.99	18.5±5.29	**28.5±4.32***	**25.0±5.68***
Waist circumference (cm)	89.8±8.04	82.5±9.70	74.7±6.70	77.2±8.32	86.0±9.42	87.7±9.39	**73.5±6.44***	**79.3±7.65***	85.0±9.69	87.8±9.24	77.7±6.63	73.8±7.83
Body mass index (kg/m²)	**25.5±3.06****	**22.3±2.49****	21.6±2.29	21.8±2.08	23.1±3.87	24.9±2.80	21.1±2.06	22.7±2.07	24.1±4.19	24.4±2.98	**22.5±1.94***	**20.9±2.16***
Waist-hip ratio	**0.87±0.05***	**0.81±0.04***	0.78±0.04	0.78±0.04	0.83±0.04	0.85±0.06	**0.77±0.04***	**0.79±0.03***	0.85±0.44	0.84±0.06	0.79±0.04	0.77±0.04

***p<0.05, **p<0.01**

Table 3. Effects of some properties on sleep efficiency

	B	β	SE	t	p
MODEL 1					
Constant	122.217		21.746	5.620	<0.001
Gender	6.170	.336	5.174	1.192	0.238
Percentage of body fat (%)	-.588	-.466	.658	-.895	0.375
Waist circumference (cm)	.110	.120	.404	.273	0.786
Body mass index (kg/m2)	-.633	-.204	.816	-.777	0.441
Waist-hip ratio	-39.750	-.264	44.745	-.888	0.378
MODEL 2					
Constant	116.650		18.901	6.172	<0.001
Gender	4.726	.257	4.412	1.071	0.289
Percentage of body fat (%)	-.353	-.280	.275	-1.283	0.205
Body mass index (kg/m2)	-.366	-.118	.630	-.581	0.563
Waist-hip ratio	-29.752	-.198	23.959	-1.242	0.220
MODEL 3					
Constant	114.087		18.270	6.244	<0.001
Gender	6.332	.344	3.419	1.852	0.069
Percentage of body fat (%)	-.462	-.366	.200	-2.305	0.025
Waist-hip ratio	-34.979	-.232	22.076	-1.584	0.119
MODEL 4					
Constant	85.772		3.855	22.252	<0.001
Gender	9.390	.511	2.859	3.285	0.002
Percentage of body fat (%)	-.542	-.430	.196	-2.763	0.008

Multiple linear regression analysis **Model 1 R^2:0.46, Model 2 R^2:0.45, Model 3 R^2:0.45, Model 4 R^2:0.41, ($p < 0.05$) β:** Coefficient of regression**, SE:** Standard error of mean

and anthropometric parameters of body composition. Although, there are studies indicating sleep duration and quality were related with obesity indicators; sleep efficiency along with dietary energy and nutrient intake have not been studied. There is a lack of information about this issue (35, 36).

Low sleep quality and efficiency could be an indicator of obesity (37-40). Individuals with low sleep quality have more body fat mass and an increased obesity risk (39). Low sleep efficiency correlates with increased body fat mass (38). In the present study body fat mass, body fat percent, waist circumference and

Table 4. Energy and certain nutrients of the individuals according to gender and sleep duration classification

Energy and nutrients	**Male (n:24)**			**Female (n:36)**		
	< 7 hours (n:15)	**≥ 7 hours (n:9)**		**< 7 hours (n:21)**	**≥ 7 hours (n:15)**	
	±SD	±SD	p	±SD	±SD	p
Energy (kcal)	2116.8±829.52	2366.5±451.44	0.114	1756.7±508.37	1718.1±441.60	0.860
Protein (g)	72.0±21.28	84.4±14.83	**0.034***	59.9±13.56	58.8±14.58	0.885
Protein (%)	14.6±2.79	14.7±2.04	0.739	14.3±2.49	14.2±2.36	0.745
Fat (g)	91.8±24.74	109.8±25.08	0.060	79.0±22.52	73.9±24.32	0.574
Fat (%)	40.4±6.54	41.4±7.60	0.858	40.3±4.00	37.6±4.88	0.122
Carbohydrate (g)	241.0±134.35	255.3±76.07	0.325	194.5±67.28	200.3±47.52	0.619
Carbohydrate (%)	45.0±8.60	44.0±7.87	0.905	44.9±4.09	48.2±4.73	0.055
Dietary fiber (g)	20.4±13.17	24.7±5.55	0.053	19.4±5.66	20.7±4.52	0.619
Tryptophan (mg)	814.6±250.96	932.4±152.20	**0.043***	676.2±157.29	662.1±177.13	0.736
Saturated fatty acids (g)	29.4±7.61	31.9±9.38	0.493	26.2±8.30	24.8±9.37	0.736
Monounsaturated fatty acids (g)	31.3±7.95	39.4±12.20	0.053	27.8±7.56	25.0±10.03	0.173
Polyunsaturated fatty acids (g)	24.9±10.37	30.5±5.05	**0.043***	19.7±7.64	19.0±7.88	0.748
Cholesterol (mg)	248.0±85.73	365.3±96.89	**0.011***	220.1±109.14	227.9±127.52	0.987
Omega-3 fatty acids (g)	1.5±0.84	1.7±0.71	0.531	1.3±0.48	1.4±0.77	0.873
Omega-6 fatty acids (g)	23.3±9.77	28.6±5.06	0.064	18.2±7.23	17.2±7.50	0.619
Caffeine (mg)	0.9±2.11	4.1±10.94	0.238	1.8±3.45	1.1±3.42	0.102

***p<0.05**

waist/hip ratio were found significantly higher in female with low sleep efficiency than females with high sleep efficiency (Table 2). Similarly, percentage of body fat and BMI were higher in females with poor sleep quality (Table 2). Also, we found that sleep efficiency negatively correlates with body fat mass and body fat percent in males (Figure 1B and 1C). In accordance with these findings, previous studies report that greater BMI and body fat percent were associated with low sleep efficiency (41).

Decrease in sleep quality and efficiency may change an individual's behaviors regarding sleep patterns. In the present study, females with low sleep efficiency woke more often during the night than those with high sleep efficiency (x^2=7.819, p=0.05, data not shown). Similarly, a longitudinal follow-up study indicated that interruptions in females' sleep is a major risk factor for obesity (40). Interruptions to night sleep may cause night eating which reduces REM sleep and may cause fluctuations in insulin and GLP-1 concentration (37). We found that mean daily energy intake in females with poor sleep efficiency was higher than females with good sleep efficiency (respectively 1781.3±385.85 kcal, 1741.7±531.78 kcal, p>0.05). These results can explain; increasing percent of body fat and obesity tendency in female with poor sleep quality and efficiency. Sleep quality was also found to be low in males with low sleep quality. Males who sleep <7 hours have poor sleep quality score (PSQI score=5.1±2.65) and males who sleep more than seven hours have good sleep quality (PSQI score=4.3±2.23) (data not shown in Table). Furthermore, multiple linear regression analysis showed that being female gender and decreased fat mass were two major predictors to increase sleep efficiency in total (Table 3).

Short sleep duration which is another important risk factor, is associated with body weight gain and obesity (4, 9, 11, 12, 20). These relations are consistent with the present study results. The BMI values and waist/hip ratio were higher in males with a sleep duration of <7 hours (Table 2). It was found that a reduction in sleep duration affects general and abdominal obesity in males but not in women. The reason for this is that average sleep efficiency and sleep duration of men were lower than women in this study (Table 1). These findings indicate that insufficient sleep leads to increased obesity risk and gender differences should be considered when assessing sleep problems. Previous studies have reported that sex hormones may affect sleep patterns (42-44).

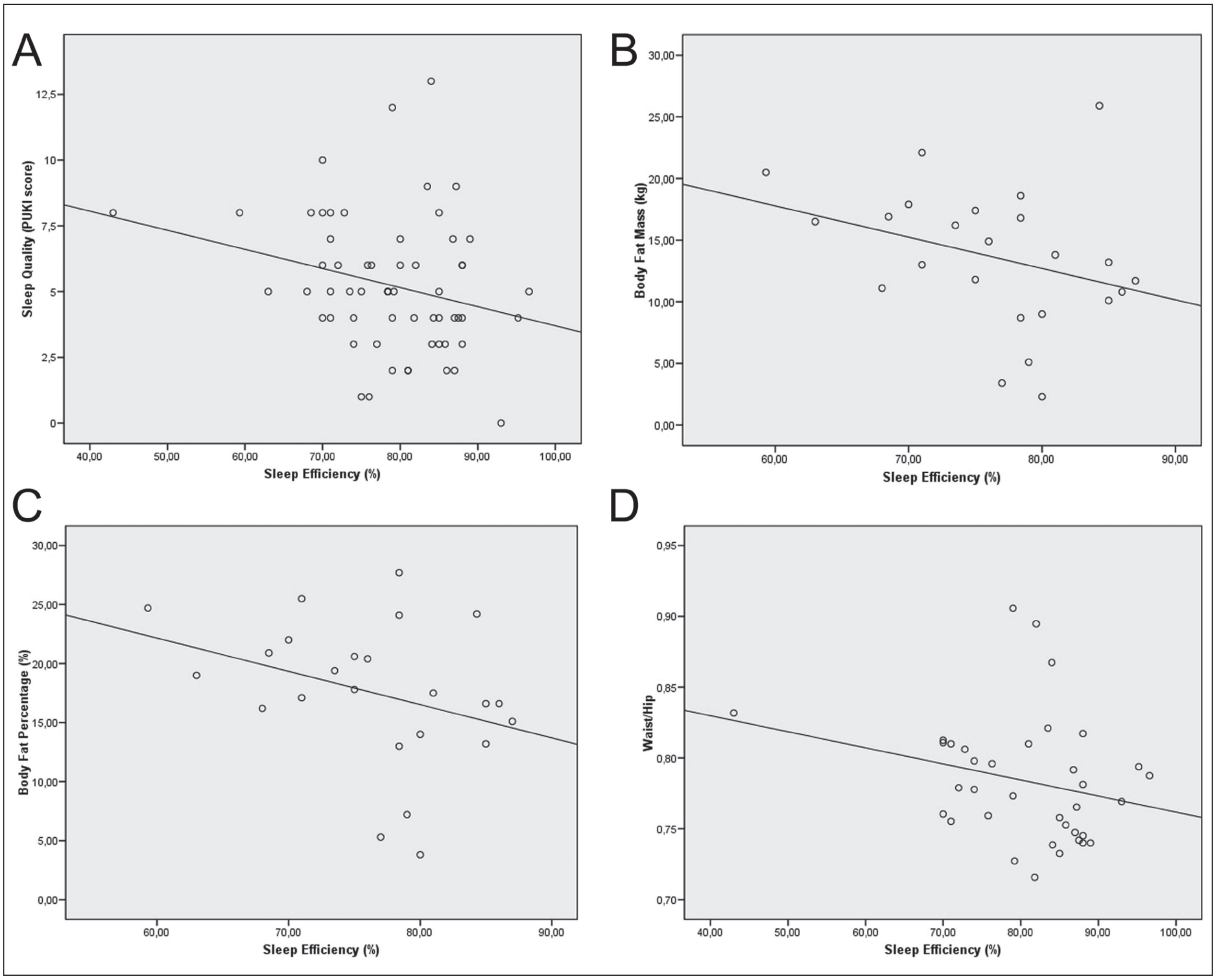

Figure 1. Relationship between sleep efficiency with total PSQI score and sleep efficiency with body composition of individuals according to gender **a.** Correlation between sleep quality and sleep efficiency of individuals (r=-0.272; p=0.036) **b.** Correlation between sleep efficiency and body fat mass in males (r=-0.412; p=0.045) **c.** Correlation between sleep efficiency and percentage of body fat in males (r=-0.431; p=0.036) **d.** Correlation between sleep efficiency and waist hip ratio in females (r=-0.324; p=0.054)

Insufficient sleep duration was indicated as one of the potential risk factors for increased food intake (4). When sleep duration is restricted, food intake may increase during awake time and, in particular, increased fat intake and decreased carbohydrate consumption leads to obesity by affecting total energy balance (45, 46). Spiegel et. al. showed that fat and carbohydrate intake increased after sleep restriction in healthy adolescents (12). Another study was stated that nocturnal sleep duration was negatively associated with fat and energy intake in females (47). In the present study, it was found that energy and nutrients intake of females were not statistically significant different according to sleep duration (Table 4). A large sample nationally representative study in the US showed that sleep duration who had less than 6 hours, mean carbohydrate, protein and cholesterol intake was lower (4). Similar to these results dietary energy, protein, fat, carbohydrate and cholesterol intake were found lower in males with sleep <7 hours, and the differences were statistically significant for only dietary protein and cholesterol intakes in this study (p<0.05) (Table 4).

It was reported that interaction between macronutrient composition of the diet with sleep parameters such as sleep quality, efficiency, and duration was weak. Studies emphasized that tryptophan is the most promising candidate as a sleep-promoting micronutrient because of it is a precursor to the sleep-regulating hormone serotonin (1, 48). Tryptophan is often mentioned as important in the proposed relationships between diet and sleep (7). Results of this study support this opinion, especially males whose sleep duration is ≥7 hours have higher levels of tryptophan intake ($p<0.05$) (Table 4).

Sleep quality was evaluated by the PSQI, sleep duration and efficiency were assessed by a Metabolic Holter Armband in the current study. The PSQI is a validated instrument and records the statements of the individual; its use together with objective methods increases the reliability of the sleep data obtained. The Metabolic Holter Armband was shown to be as reliable as polysomnography, which is the gold standard for assessing sleep efficiency (49, 50). In this study, however, there was a weak negative correlation between sleep efficiency values obtained by the armband and sleep quality scores obtained from the PSQI (Figure 1A). Thus, this study has been strengthened by using an objective method, instead of a subjective method alone.

In conclusion, decreases in both sleep efficiency and sleep duration in both genders are associated with obesity indicators. Problems with sleep duration, efficiency and quality can vary with gender. It is emphasized that sleep is an important modulator of the neuroendocrine system. Therefore inadequate sleep duration and quality strong risk factor for obesity and also associated with diseases such as atherosclerosis (51) hypertension (52), type 2 diabetes (53) and metabolic syndrome (54). However, the individual's sleep state is not routinely questioned and it is often overlooked. The sleep quality and duration of individuals should be taken into account for weight loss program and also the practice of medical nutrition therapy of chronic diseases. In this regard, it would be also useful to query the individual's sleeping habits when taking a dietary history. On the other hand, there is a need for further intervention studies in order to clarify the underlying hormonal mechanisms, the association between sleep quality and food/nutrients intake and obesity.

Limitations

Cross-sectional nature of the study does not give causality, and generalization is not possible for the whole population.

Conflict of Interest

No potential conflict of interest relevant to this article was reported by the authors.

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References

1. Chaput JP.Sleep patterns, diet quality and energy balance. Physiol Behav 2014;134:86-91.
2. Reed DL, Sacco WP. Measuring Sleep Efficiency: What Should the Denominator Be? J Clin Sleep Med 2016;12(2):263-6.
3. Ohayon MM. Epidemiology of insomnia: what we know and what we still need to learn. Sleep Med Rev 2002;6(2):97-111.
4. Grandner MA, Jackson N, Gerstner JR, Knutson KL. Dietary nutrients associated with short and long sleep duration. Data from a nationally representative sample. Appetite 2013;64:71-80.
5. Watanabe M, Kikuchi H, Tanaka K, Takahashi M. Association of short sleep duration with weight gain and obesity at 1-year follow-up: a large-scale prospective study. Sleep 2010;33(2):161-7.
6. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies. Sleep 2010;33(5):585-92.
7. Frank S, Gonzalez K, Lee-Ang L, Young MC, Tamez M, Mattei J.Diet and Sleep Physiology: Public Health and Clinical Implications. Front Neurol 2017; 8:393.
8. Lund HG, Reider BD, Whiting AB, Prichard JR.Sleep patterns and predictors of disturbed sleep in a large population of college students. J Adolesc Health 2010;46(2):124-132.
9. Patel SR, Hu FB. Short sleep duration and weight gain: a systematic review. Obesity 2008;16(3):643-653.
10. Laposky AD, Bass J, Kohsaka A, Turek FW. Sleep and circadian rhythms: key components in the regulation of energy metabolism. FEBS letters 2008;582(1):142-151.

11. Spiegel K, Leproult R, L'hermite-Balériaux M, Copinschi G, Penev PD, Van Cauter E. Leptin levels are dependent on sleep duration: relationships with sympathovagal balance, carbohydrate regulation, cortisol, and thyrotropin. J Clin Endocrinol Metab 2004; 89(11):5762-5771.
12. Spiegel K, Tasali E, Penev P, Van Cauter E. Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. Ann Intern Med 2004;141(11):846-850.
13. Bertéus Forslund H, Lindroos AK, Sjöström L, Lissner L.Meal patterns and obesity in Swedish women-a simple instrument describing usual meal types, frequency and temporal distribution. Eur J Clin Nutr 2002;56(8):740-747.
14. Turek FW, Joshu C, Kohsaka A, Lin E, Ivanova G, McDearmon E, Laposky A, Losee-Olson S, Easton A, Jensen DR, Eckel RH, Takahashi JS, Bass J. Obesity and metabolic syndrome in circadian Clock mutant mice. Science 2005;308(5724):1043-1045.
15. Qin LQ, Li J, Wang Y, Wang J, Xu JY, Kaneko T. The effects of nocturnal life on endocrine circadian patterns in healthy adults. Life Sci 2003;73(19): 2467-2475.
16. Imaki M, Hatanaka Y, Ogawa Y, Yoshida Y, Tanada S. An epidemiological study on relationship between the hours of sleep and life style factors in Japanese factory workers. J Physiol Anthropol Appl Human Sci 2002; 21(2):15-120.
17. Nishiura C, Hashimoto H. A 4-year study of the association between short sleep duration and change in body mass index in Japanese male workers. J Epidemiol 2010;20(5):385-390.
18. Grandner MA, Drummond SP. Who are the long sleepers? Towards an understanding of the mortality relationship. Sleep Med Rev 2007;11(5):341-360.
19. Grandner MA, Patel NP, Gehrman PR, Perlis ML, Pack AI. Problems associated with short sleep: bridging the gap between laboratory and epidemiological studies. Sleep Med Rev 2010;14(4):239-247.
20. Knutson KL. Sleep duration and cardiometabolic risk: a review of the epidemiologic evidence. Best Pract Res Clin Endocrinol Meta 2010;24(5):731-743.
21. Haghighatdoost F, Karimi G, Esmaillzadeh A, Azadbakht L. Sleep deprivation is associated with lower diet quality indices and higher rate of general and central obesity among young female students in Iran. Nutrition 2012;28(11):1146-1150.
22. Tworoger SS, Yasui Y, Vitiello MV, Schwartz RS, Ulrich CM, Aiello EJ, Irwin ML, Bowen D, Potter JD, McTiernan A. Effects of a year long moderate-intensity exercise and a stretching intervention on sleep quality in postmenopausal women. Sleep 2003;26(7):830-836.
23. King AC, Castro CM, Buman MP, Hekler EB, Urizar GG Jr, Ahn DK.Behavioral impacts of sequentially versus simultaneously delivered dietary plus physical activity interventions: the CALM trial. Ann Behav Med 2013;46(2):157-168.
24. Landry GJ, Best JR, Liu-Ambrose T. Measuring sleep quality in older adults: a comparison using subjective and objective methods. Front Aging Neurosci 2015;7:166.
25. Chen D, Yin Z, Fang B. Measurements and status of sleep quality in patients with cancers. Support Care Cancer 2018;26(2):405-414.
26. Sharif MM, BaHammam AS. Sleep estimation using BodyMedia's SenseWear™ armband in patients with obstructive sleep apnea. Ann Thorac Med 2013;8(1):53-57.
27. Roane BM et al. Estimating sleep from multisensory armband measurements: validity and reliability in teens. J Sleep Res, 2015;24(6):714-21.
28. Sharif MM, Bahammam AS. Sleep estimation using BodyMedia's SenseWear armband in patients with obstructive sleep apnea. Ann Thorac Med 2013;8(1):53-7.
29. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, Hazen N, Herman J, Katz ES, Kheirandish-Gozal L, Neubauer DN, O'Donnell AE, Ohayon M, Peever J, Rawding R, Sachdeva RC, Setters B, Vitiello MV, Ware JC, Adams Hillard PJ. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. Sleep Health 2015; 1(1): 40-43.
30. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28(2):193-213.
31. Ağargün M, Kara H, Anlar O. Pittsburgh uyku kalitesi indeksinin geçerliği ve güvenirliği. Türk Psikiyatri Dergisi 1996;7(2): 107-115.
32. Rakıcıoğlu N, Acar Tek N, Ayaz A, Pekcan G.Yemek ve Besin Fotoğraf Kataloğu Ölçü ve Miktarlar. 2 ed. Ankara: Ata Ofset Matbaacılık; 2009.
33. BeBiS, Nutrition Data Base Software Data Base Version 7. The German Food Code and Nutrient Data Base (BLS II.3, 1999) with additions from UDSA-sr and other sources; 2004.
34. SPSS, Statistical Package for the Social Sciences. Chicago, IL; USA; 2011.
35. Magee CA, Iverson DC, Huang XF, Caputi P. A link between chronic sleep restriction and obesity: methodological considerations. Public health 2008; 122(12):1373-1381.
36. Nagai M, Tomata Y, Watanabe T, Kakizaki M, Tsuji I. Association between sleep duration, weight gain, and obesity for long period. Sleep Med 2013;14(2):206-210.
37. Gonnissen HK, Adam TC, Hursel R, Rutters F, Verhoef SP, Westerterp-Plantenga MS. Sleep duration, sleep quality and body weight: Parallel developments. Physiol Behav 2013;121:112-116.
38. Kahlhöfer J, Karschin J, Breusing N, Bosy-Westphal A. Relationship between actigraphy-assessed sleep quality and fat mass in college students. Obesity 2016;24(2): 335-341.
39. Rahe C, Czira ME, Teismann H, Berger K. Associations between poor sleep quality and different measures of obesity. Sleep Med 2015;16(10):1225-1228.
40. Lyytikäinen P, Lallukka T, Lahelma E, Rahkonen O. Sleep problems and major weight gain: a follow-up study. Int J Obes 2011;35(1):109-114.
41. Wirth MD, Hébert JR, Hand GA, Youngstedt SD, Hurley

TG, Shook RP, Paluch AE, Sui X, James SL, Blair SN. Association between actigraphic sleep metrics and body composition. Ann Epidemiol 2015;25(10):773-778.
42. Kische H, Ewert R, Fietze I, Gross S, Wallaschofski H, Völzke H, Dörr M, Nauck M, Obst A, Stubbe B, Penzel T, Haring R. Sex hormones and sleep in men and women from the general population: a cross-sectional observational study. J Clin Endocrinol Metab 2016; 101(11):3968-3977.
43. Lord C, Sekerovic Z, Carrier J. Sleep regulation and sex hormones exposure in men and women across adulthood. Pathol Biol 2014;62(5):302-310.
44. Mong JA, Cusmano DM. Sex differences in sleep: impact of biological sex and sex steroids. Philos Trans R Soc Lond B Biol 2016;371(1688):20150110.
45. Chaput JP, Sjödin AM, Astrup A, Després JP, Bouchard C, Tremblay A.Risk factors for adult overweight and obesity: the importance of looking beyond the 'big two'. Obes Facts 2010; 3(5):320-327.
46. Weiss A, Xu F, Storfer-Isser A, Thomas A, Ievers-Landis CE, Redline S. The association of sleep duration with adolescents' fat and carbohydrate consumption. Sleep 2010;33(9):1201-1209.
47. Grandner MA, Kripke DF, Naidoo N, Langer RD. Relationships among dietary nutrients and subjective sleep, objective sleep, and napping in women. Sleep Med 2010;11(2):180-184.
48. Peuhkuri K, Sihvola N, Korpela R. Diet promotes sleep duration and quality. Nutr Res 2012; 32(5):309-19.
49. Roane BM, Van Reen E, Hart CN, Wing R, Carskadon MA. Estimating sleep from multisensory armband measurements: validity and reliability in teens. J Sleep Res 2015; 24(6):714-721.
50. Alsaadi SM, McAuley JH, Hush JM, Bartlett DJ, McKeough ZM, Grunstein RR, Dungan GC, Maher CG. Assessing sleep disturbance in low back pain: the validity of portable instruments. PloS one 2014;9(4):95824.
51. Osonoi Y, Mita T, Osonoi T, Saito M, Tamasawa A, Nakayama S, Someya Y, Ishida H, Kanazawa A, Gosho M, Fujitani Y, Watada H. Poor sleep quality is associated with increased arterial stiffness in Japanese patients with type 2 diabetes mellitus. BMC Endocr Disord 2015;(18):15-29.
52. Javaheri S, Storfer-Isser A, Rosen CL, Redline S. Sleep quality and elevated blood pressure in adolescents. Circulation 2008;118(10): 1034-1040.
53. Yaggi HK, Araujo AB, McKinlay JB. Sleep duration as a risk factor for the development of type 2 diabetes. Diabetes care 2006; 29(3): 657-661.
54. Okubo N, Matsuzaka M, Takahashi I, Sawada K, Sato S, Akimoto N, Umeda T, Nakaji S.Relationship between self-reported sleep quality and metabolic syndrome in general population. BMC Public Health 2014;14(1):1.

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