Biotech Health Sci. 2016 November; 3(4):e38652. doi: 10.17795/bhs-38652.

Published online 2016 August 16. **Research Article**

The Association Between Sleep Quality and Metabolic Factors and Anthropometric Measurements

Maryam Khorasani,[1] Asghar Mohammadpoorasl,[2,*] and Maryam Javadi[1,3]

[1]Department of Nutrition, Qazvin University of Medical Sciences, Qazvin, IR Iran
[2]Tabriz Health Services Management Research Center, Tabriz University of Medical Sciences, Tabriz, IR Iran
[3]Children Growth Research Center, Qazvin University of Medical Sciences, Qazvin, IR Iran

[*]*Corresponding author*: Asghar Mohammadpoorasl, Tabriz Health Services Management Research Center, Tabriz University of Medical Sciences, Tabriz, IR Iran, E-mail: ampoorasl@gmail.com

Received 2016 April 21; **Revised** 2016 July 13; **Accepted** 2016 July 18.

Abstract

Background: Several studies have shown that sleep disorders may lead to metabolic or endocrine changes including insulin resistance, diabetes, obesity, cardiovascular disease and stroke.

Objectives: The aim of this study was to investigate the association between sleep quality and metabolic factors and anthropometric measurements among personnel of a central petrochemical company in Tehran.

Methods: This cross-sectional study was conducted on 400 personnel of a central petrochemical company in Tehran, during year 2015. Demographic information including age, gender, educational status, employment duration, working hours per day, marital status, smoking, medical history for disease and drug use, were collected by a questionnaire. Systolic and diastolic blood pressure and also height and weight were measured by standard methods and body mass index (BMI) was calculated. Pittsburg sleep quality index (PSQI) was performed to assess participants' sleep quality. Serum concentrations of fasting glucose and lipid profiles were measured by the related biochemical kits. Logistic regression analysis was used for multivariate adjusting of factors associated with sleep quality.

Results: The mean score for participants' Pittsburgh sleep quality index (PSQI) was 4.77 ± 2.62. About 30% of participants had had bad sleep quality. A high body mass index (BMI) ($P < 0.001$) and high waist circumference ($P = 0.016$) were inversely associated with sleep quality. Serum concentration of very-low-density lipoprotein (VLDL) ($P = 0.004$) and triglyceride ($P = 0.001$) were statistically higher in participants with lower sleep quality than with those with higher sleep quality. The group with a good sleep quality had a higher serum high density lipoprotein-cholesterol (HDL-c) than those with a poor sleep quality ($P = 0.034$). Being female increased the risk of poor sleep quality by 2.5 folds, and with increasing BMI (OR = 1.17) and serum triglyceride (OR = 1.02) the risk of poor sleep quality was increased.

Conclusions: People with a poor sleep quality had a higher BMI, waist circumference and serum triglyceride levels and a lower HDL-c concentration. Furthermore, BMI and serum triglyceride concentration are independently associated with the score of sleep quality. Indeed, it is recommended for people to screen for sleep quality to start necessary interventions.

Keywords: Sleep Quality, Lipid Profile, Serum Glucose, Body Mass Index, Insulin Resistance, Petrochemical Company

1. Background

Sleep is a dynamic and highly organized biological process (1) and also one of the important elements in 24-hour life cycle, which is considered an important part of life and accompanied by the reconstruction of physical and mental power (2). Sleep disorders are among the biggest mental disorders (1) and insomnia is one of the most common sleep disorders (3). Sleep quality and quantity are important for the natural function of body's daily hormonal and metabolic processes as well as appetite balance (4).

Chronic lack of sleep is accompanied by metabolic and endocrine changes as well as long-term pathological outcomes. Additionally, different studies have demonstrated that sleep duration is related to diabetes (5), obesity (6) and cardiovascular diseases (7). Decreased sleep quality without change during sleep is related to resistance to insulin and diabetes (8). Short and long sleeps are both related to metabolic syndrome (9) and short sleep is a risk factor for heart attack (10). Life quality and people's activity during waking hours are influenced by people's sleep quality (11). Some studies have reported a relationship between sleep quality and being overweight and components of metabolic syndrome, but limited controversy, which cannot provide good evidence, may be because of insufficient adjustment of confounding factors such as gender and lifestyle habits.

2. Objectives

According to the importance of prevention, control of chronic diseases such as cardiovascular diseases, type-2 diabetes, obesity and high blood fat, and studying the relationship between sleep quality and anthropometric and metabolic parameters is important for maintaining and promoting health as well as decreasing treatment costs. The present study was done to investigate the relationship between sleep quality and metabolic factors as well as anthropometric indices among the staff of Tehran central petrochemical company.

3. Methods

3.1. Study Participants

This cross-sectional study was done as an analytical and cross-sectional work on all of official staff of Tehran central petrochemical company in 2015 (n = 400). Participants who didn't provide informed consent and didn't complete the study questionnaire were excluded from the study. After explaining the objectives and details of the project, an informed consent letter was obtained from interested participants before entering the study.

Demographic characteristics including age, gender, education, employment duration, working hours, marital status, smoking history and medical and therapeutic history of the participants were gathered by a demographic information questionnaire and face-to-face interviews.

3.2. Evaluating Anthropometric Status

Height and weight were measured by standard methods and BMI was also calculated. Height was measured using a Seca height gauge with 0.1 accuracy while having no shoes on, in a standing position, looking straightforward, and placing shoulders and back of the feet in one direction. Weight was measured twice with 0.1 kg accuracy using a Seca scale while having no shoes on, wearing minimum clothing and after execration. In the case of difference between the two measurements by more than 0.1 kg, the average was calculated after the third measurement. Body Mass Index was calculated by dividing weight (in kg) by square of height (in m). Waist circumference was measured by positioning a tape-measure right above the iliac crest. Then, the three measurements were done with 0.1cm accuracy and the average calculation was reported.

3.3. Evaluating Blood Pressure

Systolic and diastolic blood pressure was measured three times by a trained nurse from the right arm in a sitting and silent condition, with five-minute rests between each measurement and using a mercury manometer and Korotkoff sound technique; the average of the three measurements was registered.

3.4. Evaluating Sleep Quality

To study the sleep quality of people in this study, the Pittsburgh sleep quality index (PSQI) was used. This questionnaire contains nine questions for evaluating seven components of sleep quality; time for sleeping, sleep duration, rate of effective sleep, sleep disorders, using hypnotic drugs, and daily activities due to sleepiness. Minimum and maximum scores considered for each component range from zero (no problem) to three (very serious problem). Finally, the scores are added and converted to a total score (0 - 10); a high score shows unsuitable sleep quality (12).

3.5. Laboratory and Biochemical Evaluation

At the beginning of the study, a 5 cc blood sample was taken from the brachial vein of the patients using a scalp vein in a sitting position on an armchair after a 12-hour fasting. To separate the serum, the samples were centrifuged at 3000 rpm for 10 minutes and at room temperature. The separated serum was incubated in a 1-mL micro tube for measuring the considered biochemical factor and was stored at -80°C until the test performance.

Fasting glucose concentration was measured using a glucose oxidase kit (Pars Azmoon, Tehran, Iran) by a photometric method with 5 mg/dL sensitivity using a spectrophotometer. Serum concentrations of triglyceride as well as very-low-density lipoprotein (VLDL) and high-density lipoprotein (HDL) cholesterol were measured using the kit and enzyme-colorimetric method (Pars Azmoon Company, Tehran, Iran), and TC concentration was measured using the kit and enzyme-photometric method (Pars Azmoon Company, Tehran, Iran) by a spectrophotometer. Sensitivity of the mentioned tests was respectively 1, 1 and 3, and 1 mg/dL cholesterol concentration was also calculated using the Friedewald formula (LDL = TC-HDL-TG.5.0) (13).

3.6. Statistical Analysis

To statistically analyze the data, the SPSS software (ver. 22) was used. The quantitative variables were reported as mean, standard deviation, minimum and maximum. The qualitative and ranking variables were reported in the forms of numbers and percentages. To study the relationship between sleep quality and variables of gender, marital status, smoking, disease and drug consumption history and literacy, the chi-square test was used. Means of the quantitative variables in both groups with bad and good sleep were compared using independent t-test. Logistic regression model with backward-LR model was utilized for assessing sleep quality-related factors. In this model, the variables which were related to sleep quality at 0.2 level in univariate analyses were entered. Alpha level of less than 0.05 was considered significant.

4. Results

Frequency distribution of the participants based on the qualitative variables is shown in Table 1. As seen in this table, 34.1% and 65.9% of the participants were female and male, respectively; 86% were married; and 11.9% had cigarette smoking history.

Mean and standard deviation of the quantitative variables are shown in Table 2. As seen in this table, the mean age of participants was 48.27 ± 7.68 years old. Also they

Table 1. Frequency Distribution of the Participants Based on Qualitative Variables

Variable	Number	Percentage
Gender		
Female	132	34.1
Male	255	65.9
Marital status		
Single	54	14
Married	333	86
Cigarette smoking		
Yes	46	11.9
No	341	88.1
Having a defined disease, Drug consumption		
Yes	293	75.7
No	94	24.3
Educational level		
Diploma or less	46	11.9
Under graduate	208	53.9
Post graduate	132	34.1

had high body mass index (26.7) and total cholesterol level (191.7).

The mean of PSQI score for all the participants was equal to 4.77 + 2.62 (min: 0 and max: 17). Considering a score of higher than five as bad sleep quality, the results showed that 115 (29.7%) had bad sleep quality. No statistically significant relationship was observed between the qualitative variables of gender, marital status, educational level, cigarette smoking, having a defined disease and sleep quality of the participants ($P > 0.05$).

Comparison of the mean of quantitative variables in both groups with bad and good sleep quality showed that the mean body mass index ($P < 0.001$) and waist circumference ($P = 0.016$) were high in participants with bad sleep quality. Serum levels of VLDL ($P = 0.004$) and triglyceride ($P = 0.001$) were significantly higher in the participants with bad sleep quality than those with good sleep quality. Conversely, serum level of HDL cholesterol in the participants with good sleep quality was significantly higher than those with bad sleep quality ($P = 0.034$) (Table 3).

Table 4 shows the results of logistic regression model of the factors related to sleep quality. In this model, the variables related to sleep quality at 0.2 level in the univariate analysis were entered in the model (gender, marital status, BMI, serum triglyceride, employment period, waist circumference, VLDL and HDL). As shown in the results, being a female increased bad sleep quality by about 2.5 times. Also, with the increase of BMI (OR = 1.17) and serum triglyceride (OR = 1.02), the risk of bad sleep quality increased.

5. Discussion

Results of this study showed that 29.7% of participants had had bad sleep quality. In this research, there was no statistically significant relationship between the qualitative variables of marital status, education, as well as smoking background, disease/drug consumption history and the sleep quality of the participants. Nevertheless, most epidemiologic studies have shown the potential of women for insomnia (14). A meta-analytical study on 31 related articles has demonstrated a risk ratio of 1.41 (1.28 - 1.55: CI95%) in females compared with males. Of course, in a few studies, no relationship has been found between gender and sleep quality (15). Furthermore, investigations have shown that sleep disorder is higher in divorced and separated women than those who are married. Also, the effect of marital status was stronger in males than females. A part of the observed differences in gender and marital status can be due to lower socio-economic condition of women and divorced individuals (16). Regarding the relationship between smoking and sleep quality, large cohort studies have shown that smokers have lower sleep quality and more insomnia symptoms than non-smokers (17). Also, low level of education among females and not males with cardiovascular diseases, was accompanied by low sleep quality (18).

In this study, body mass index and high waist circumference showed a significant relationship with low sleep quality. Also, serum levels of VLDL cholesterol and triglyceride in people with low sleep quality was significantly higher than participants with good sleep quality. Conversely, the serum level of HDL cholesterol in people with good sleep quality was significantly higher than those with bad sleep quality. Also, in logistic regression analysis, being a female increased the risk of bad sleep by about 2.5 times and, with increasing BMI and triglyceride, the risk of bad sleep quality increased by 1.17 and 1.02 times, respectively.

Several cross-sectional studies have represented a reverse relationship between BMI and sleep duration (19-21); however, a study on 1986 males, aged 55 to 69 years old, showed no significant relationship between the prevalence of insomnia and age, BMI, and smoking (22). Obesity risk is higher in those sleeping less than five hours per day; such obesity is for more related to waist circumference and stomach obesity and is independent of BMI (19). In one study, BMI, waist circumference and body fat percentage were related to sleep quality score (23).

In this regard, it has been suggested that sleep duration is a stronger factor than sleep quality for metabolic

Table 2. Mean and Standard Deviation of Quantitative Variables

Variable	Min	Max	Mean	Standard Deviation
Age, y	26	63	48.27	7.68
Employment period, y	1	38	21.59	8.08
Working hours per day,h	6	13.5	9.27	1.35
Body Mass Index	18.0	48.2	26.73	4.08
Waist circumference	44	124	92.53	11.06
Systolic BP, mm/Hg	75	190	117.06	13.45
Diastolic BP, mm/Hg	19	140	78.24	9.86
FBS, mg/dl	90	323	95.02	22.14
VLDL- C, mg/dL	60	100	27.63	13.77
HDL- C, mg/dL	19	149	46.76	13.47
LDL- C, mg/dL	25	249	118.32	34.34
TG, mg/dL	85	502	139.62	67.46
TC, mg/dL	131	458	191.7	44.74

Abbreviations: BP, blood pressure; FBS, fasting blood sugar; VLDL-C, very low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglyceride; TC, total cholesterol.

Table 3. Comparing Mean of Quantitative Variables in the two Groups with Good and Bad Sleep Quality

Variable	Sleep Quality		P Value
	Good	Bad	
	Mean (SD)	Mean (SD)	
Age	48.01 (7.92)	48.90 (7.07)	0.279
Employment period	21.21 (8.35)	22.51 (7.37)	0.127
Working hours per day	9.25 (1.34)	9.33 (1.40)	0.613
Body Mass Index	26.05 (3.50)	28.34 (4.86)	< 0.001
Waist circumference	91.58 (10.30)	94.79 (12.46)	0.016
Systolic BP, mm/Hg	117.17 (13.82)	116.80 (12.59)	0.807
Diastolic BP	78.64 (9.72)	77.30 (10.16)	0.221
FBS	95.3 (22.20)	94.35 (22.08)	0.699
VLDL- C	26.3 (13.50)	30.68 (13.97)	0.004
HDL- C	47.7 (14.10)	44.53 (11.60)	0.034
LDL- C	117.05 (34.79)	121.31 (33.22)	0.265
TG	132.21 (64.01)	157.13 (72.30)	0.001
TC	190.88 (46.08)	193.62 (41.53)	0.583

Abbreviations: BP, blood pressure; FBS, fasting blood sugar; VLDL-C, very low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglyceride; TC, total cholesterol.

syndrome and glucose intolerance, while sleep quality does not intermediate the relation between sleep duration and metabolic syndrome (24). In a cross-sectional study on the general population, global PSQI score and its components (especially, sleep latency and sleep disturbance) were associated with metabolic syndrome (25).

In our study, there was a relationship between sleep quality and some metabolic syndrome components. Regarding sleep disorder and metabolic syndrome along with their components, two studies have demonstrated

Table 4. Logistic Regression Model of Factors Related to Sleep Quality[a]

Variable	OR	CI95%	P Value
Gender			
Male	1	-	
Female	2.49	1.46 - 4.27	00001
Marital status			
Single	1	-	
Married	2.29	1.06 - 4.96	0.035
BMI	1.17	1.09 - 1.24	< 0.001
TG	1.02	1.01 - 1.03	0.001

Abbreviations: BMI, body mass index; TG, triglyceride.
[a] In this model, the variables of employment period, waist circumference, as well as VLDL and HDL cholesterol were controlled.

that sleep disorder is a factor contributing to the risk of obesity (26). Higher scores of sleep disorder have been related to upper percentiles of waist circumference, high TC, and high non-HDL cholesterol. The present study showed that people with higher sleep disorder had bigger waist circumference, which was in line with the results of studies by Narang et al. (27).

Subjects with metabolic syndrome have higher global PSQI scores and a higher risk of being poor sleepers. Of the five components of metabolic syndrome, hyperglycemia and low HDL-C are independently associated with the global PSQI scores, while low HDL-C is an independent predictor of being a poor sleeper. In an investigation, low HDL cholesterol, not triglycerides, has been introduced as the independent index of low sleep quality (28); however, in another study, no relationship was seen between HDL cholesterol or triglyceride and sleep quality score (23). In our study, a relationship was observed between serum triglyceride and unsuitable sleep quality. In another work, increased triglyceride values were significantly related to sleep duration (20). In another study, the participants with higher levels of TC and triglyceride as well as lower HDL-C had shorter sleep than those with a normal level of such factors (29).

Over a ten-year follow-up, longer objective sleep duration was longitudinally and significantly associated with a poorer lipid profile (30). In the present study, no relationship was found between blood pressure and sleep quality score, which was parallel to the results of Jennings et al. (23). Blood pressure of the participants in the present study was normal and less than the above-mentioned studies, which can lead to insignificance of statistical analyses. In some researches, total score of sleep quality and its components were related to high blood pressure and hypertension (31). Poor sleep quality was significantly associated with resistance to treatment in hypertensive females, independent of cardiovascular and psychiatric confounders (32). In another study, difficulty falling asleep was associated with metabolic syndrome, in particular, with high blood pressure (33). However, no relationship was seen between sleep quality and arterial blood pressure amongst the elderly (34). The reason for such a difference could be attributed to the studied population and race, recognition criteria, or the applied statistical methods.

The mechanism accounting for the relationship between sleep quality and metabolic syndrome components has not yet been identified. Activity of the hypothalamus-pituitary-adrenal axis has an important role in the pathogenesis of metabolic syndrome (35) and can lead to insomnia (36). Also, many short-term studies have shown that sleep limitation leads to insulin resistance, which has an important role in the pathophysiology of metabolic syndrome (37). Sleep limitation may increase inflammatory mediators of cardiovascular risk such as C-reactive protein (CRP) (38). Insufficient sleep can increase food intake and maintain energy in the body via organizing some neuroendocrine, metabolic and behavioral compatibility (39). Increased weight and appetite changes might be related to changes in leptin and ghrelin concentrations induced by sleep limitation and changes in work shifts (40). Police officers, who had sleep hours of less than five showed higher levels of leptin than those with five to seven hours of sleep (41). Additionally, wake-sleep cycle is disturbed among police officers as a result of shifting the working plan. It seems that this working plan cycle can increase the risk of sleep disorders and metabolic syndrome (42).

Despite reports on the relationship between unsuitable sleep and obesity in epidemiologic studies, it should be taken in to account that all of these studies (whether among adults or children) have been based on personal reports. Furthermore, most of these investigations have been cross-sectional, which means that their results could not imply any cause-and-effect relation. Short sleep can increase weight; yet, being overweight and obese can lead to sleep disorders. Therefore, more studies should be performed in this field as prospective and interventional researches using objective tools of sleep and obesity. Another weakness of the present study was the lack of measuring plasma concentration of the intervening hormones in the relationship between sleep quality and measured factors.

In conclusion, the present study showed that the individuals with low sleep quality had higher BMI, waist circumference, and serum triglyceride as well as lower HDL cholesterol level. Also, BMI and serum triglyceride were independently related to sleep quality score; therefore, it is recommended for such people to be screened for their sleep quality and undergo necessary measures.

Acknowledgments

We would like to thank all the participants of this study.

Footnote

Authors' Contribution: Study design, Maryam Khorasani, Maryam Javadi and Asghar Mohammadpoorasl; data collection, Maryam Khorasani; data analysis, Maryam Khorasani and Asghar Mohammadpoorasl; academic writing, Maryam Khorasani; critical revision of the manuscript, Maryam Javadi and Asghar Mohammadpoorasl.

References

1. Hays RD, Martin SA, Sesti AM, Spritzer KL. Psychometric properties of the Medical Outcomes Study Sleep measure. *Sleep Med.* 2005;**6**(1):41–4. doi: 10.1016/j.sleep.2004.07.006. [PubMed: 15680294].
2. Sadock B, Kaplan SV. Sadocks Synopsis of Psychiatry. 9 ed. Philadelphia: Williams and Wilkins; 2003.
3. Fiorentino L, Ancoli-Israel S. Insomnia and its treatment in women with breast cancer. *Sleep Med Rev.* 2006;**10**(6):419–29. doi: 10.1016/j.smrv.2006.03.005. [PubMed: 16963293].
4. Van Cauter E, Spiegel K, Tasali E, Leproult R. Metabolic consequences of sleep and sleep loss. *Sleep Med.* 2008;**9 Suppl 1**:23–8. doi: 10.1016/S1389-9457(08)70013-3. [PubMed: 18929315].
5. Chao CY, Wu JS, Yang YC, Shih CC, Wang RH, Lu FH, et al. Sleep duration is a potential risk factor for newly diagnosed type 2 diabetes mellitus. *Metabolism.* 2011;**60**(6):799–804. doi: 10.1016/j.metabol.2010.07.031. [PubMed: 20846701].
6. Cappuccio FP, Stranges S, Kandala NB, Miller MA, Taggart FM, Kumari M, et al. Gender-specific associations of short sleep duration with prevalent and incident hypertension: the Whitehall II Study. *Hypertension.* 2007;**50**(4):693–700. doi: 10.1161/HYPERTENSIONAHA.107.095471. [PubMed: 17785629].
7. 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. [PubMed: 20469800].
8. Rod NH, Vahtera J, Westerlund H, Kivimaki M, Zins M, Goldberg M, et al. Sleep disturbances and cause-specific mortality: Results from the GAZEL cohort study. *Am J Epidemiol.* 2011;**173**(3):300–9. doi: 10.1093/aje/kwq371. [PubMed: 21193534].
9. Wu MC, Yang YC, Wu JS, Wang RH, Lu FH, Chang CJ. Short sleep duration associated with a higher prevalence of metabolic syndrome in an apparently healthy population. *Prev Med.* 2012;**55**(4):305–9. doi: 10.1016/j.ypmed.2012.07.013. [PubMed: 22846501].
10. Payne JK, Held J, Thorpe J, Shaw H. Effect of exercise on biomarkers, fatigue, sleep disturbances, and depressive symptoms in older women with breast cancer receiving hormonal therapy. Oncology nursing forum; 2008.
11. Gooneratne NS, Weaver TE, Cater JR, Pack FM, Arner HM, Greenberg AS, et al. Functional outcomes of excessive daytime sleepiness in older adults. *J Am Geriatr Soc.* 2003;**51**(5):642–9. [PubMed: 12752839].
12. Buysse DJ, Reynolds CF, 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. [PubMed: 2748771].
13. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem.* 1972;**18**(6):499–502. [PubMed: 4337382].
14. Li RH, Wing YK, Ho SC, Fong SY. Gender differences in insomnia–a study in the Hong Kong Chinese population. *J Psychosom Res.* 2002;**53**(1):601–9. [PubMed: 12127178].
15. Ayas NT, White DP, Manson JE, Stampfer MJ, Speizer FE, Malhotra A, et al. A prospective study of sleep duration and coronary heart disease in women. *Arch Intern Med.* 2003;**163**(2):205–9. [PubMed: 12546611].
16. Arber S. Gender, marital status and sleep problems in Britain. *Przegl Lek.* 2012;**69**(2):54–60. [PubMed: 22768414].
17. Riedel BW, Durrence HH, Lichstein KL, Taylor DJ, Bush AJ. The relation between smoking and sleep: the influence of smoking level, health, and psychological variables. *Behav Sleep Med.* 2004;**2**(1):63–78. doi: 10.1207/s15402010bsm0201_6. [PubMed: 15600225].
18. Assari S, Moghani Lankarani M, Kazemi Saleh D, Ahmadi K. Gender modifies the effects of education and income on sleep quality of the patients with coronary artery disease. *Int Cardiovasc Res J.* 2013;**7**(4):141–6. [PubMed: 24757639].
19. Theorell-Haglow J, Berne C, Janson C, Sahlin C, Lindberg E. Associations between short sleep duration and central obesity in women. *Sleep.* 2010;**33**(5):593–8. [PubMed: 20469801].
20. Lee J, Choi YS, Jeong YJ, Lee J, Kim JH, Kim SH, et al. Poor-quality sleep is associated with metabolic syndrome in Korean adults. *Tohoku J Exp Med.* 2013;**231**(4):281–91. [PubMed: 24305464].
21. Valrie CR, Bond K, Lutes LD, Carraway M, Collier DN. Relationship of sleep quality, baseline weight status, and weight-loss responsiveness in obese adolescents in an immersion treatment program. *Sleep Med.* 2015;**16**(3):432–4. doi: 10.1016/j.sleep.2014.11.007. [PubMed: 25701536].
22. Elwood P, Hack M, Pickering J, Hughes J, Gallacher J. Sleep disturbance, stroke, and heart disease events: evidence from the Caerphilly cohort. *J Epidemiol Community Health.* 2006;**60**(1):69–73. doi: 10.1136/jech.2005.039057. [PubMed: 16361457].
23. Jennings JR, Muldoon MF, Hall M, Buysse DJ, Manuck SB. Self-reported sleep quality is associated with the metabolic syndrome. *Sleep.* 2007;**30**(2):219–23. [PubMed: 17326548].
24. Yoo H, Franke WD. Sleep habits, mental health, and the metabolic syndrome in law enforcement officers. *J Occup Environ Med.* 2013;**55**(1):99–103. doi: 10.1097/JOM.0b013e31826e294c. [PubMed: 23207742].
25. Okubo N, Matsuzaka M, Takahashi I, Sawada K, Sato S, Akimoto N, et al. Relationship between self-reported sleep quality and metabolic syndrome in general population. *BMC Public Health.* 2014;**14**:562. doi: 10.1186/1471-2458-14-562. [PubMed: 24903537].
26. Patel SR, Hu FB. Short sleep duration and weight gain: a systematic review. *Obesity (Silver Spring).* 2008;**16**(3):643–53. doi: 10.1038/oby.2007.118. [PubMed: 18239586].

27. Narang I, Manlhiot C, Davies-Shaw J, Gibson D, Chahal N, Stearne K, et al. Sleep disturbance and cardiovascular risk in adolescents. *CMAJ.* 2012;**184**(17):913–20. doi: 10.1503/cmaj.111589. [PubMed: 23027917].
28. Hung HC, Yang YC, Ou HY, Wu JS, Lu FH, Chang CJ. The association between self-reported sleep quality and metabolic syndrome. *PLoS One.* 2013;**8**(1):54304. doi: 10.1371/journal.pone.0054304. [PubMed: 23342127].
29. Bjorvatn B, Sagen IM, Oyane N, Waage S, Fetveit A, Pallesen S, et al. The association between sleep duration, body mass index and metabolic measures in the Hordaland Health Study. *J Sleep Res.* 2007;**16**(1):66–76. doi: 10.1111/j.1365-2869.2007.00569.x. [PubMed: 17309765].
30. Petrov ME, Kim Y, Lauderdale D, Lewis CE, Reis JP, Carnethon MR, et al. Longitudinal associations between objective sleep and lipids: the CARDIA study. *Sleep.* 2013;**36**(11):1587–95. doi: 10.5665/sleep.3104. [PubMed: 24179290].
31. Liu RQ, Qian Z, Trevathan E, Chang JJ, Zelicoff A, Hao YT, et al. Poor sleep quality associated with high risk of hypertension and elevated blood pressure in China: results from a large population-based study. *Hypertens Res.* 2016;**39**(1):54–9. doi: 10.1038/hr.2015.98. [PubMed: 26333359].
32. Bruno RM, Palagini L, Gemignani A, Virdis A, Di Giulio A, Ghiadoni L, et al. Poor sleep quality and resistant hypertension. *Sleep Med.* 2013;**14**(11):1157–63. doi: 10.1016/j.sleep.2013.04.020. [PubMed: 23993872].
33. Mesas AE, Guallar-Castillon P, Lopez-Garcia E, Leon-Munoz LM, Graciani A, Banegas JR, et al. Sleep quality and the metabolic syndrome: the role of sleep duration and lifestyle. *Diabetes Metab Res Rev.* 2014;**30**(3):222–31. doi: 10.1002/dmrr.2480. [PubMed: 24123692].
34. Ji-Rong Y, Hui W, Chang-Quan H, Bi-Rong D. Association between sleep quality and arterial blood pressure among Chinese nonagenarians/centenarians. *Med Sci Monit.* 2012;**18**(3):36–42. [PubMed: 22367137].
35. Cagampang FR, Poore KR, Hanson MA. Developmental origins of the metabolic syndrome: body clocks and stress responses. *Brain Behav Immun.* 2011;**25**(2):214–20. doi: 10.1016/j.bbi.2010.09.005. [PubMed: 20851177].
36. Vgontzas AN, Chrousos GP. Sleep, the hypothalamic-pituitary-adrenal axis, and cytokines: multiple interactions and disturbances in sleep disorders. *Endocrinol Metabolism Clin North Am.* 2002;**31**(1):15–36.
37. Cornier MA, Dabelea D, Hernandez TL, Lindstrom RC, Steig AJ, Stob NR, et al. The metabolic syndrome. *Endocr Rev.* 2008;**29**(7):777–822. doi: 10.1210/er.2008-0024. [PubMed: 18971485].
38. Meier-Ewert HK, Ridker PM, Rifai N, Regan MM, Price NJ, Dinges DF, et al. Effect of sleep loss on C-reactive protein, an inflammatory marker of cardiovascular risk. *J Am Coll Cardiol.* 2004;**43**(4):678–83. doi: 10.1016/j.jacc.2003.07.050. [PubMed: 14975482].
39. Penev PD. Update on energy homeostasis and insufficient sleep. *J Clin Endocrinol Metab.* 2012;**97**(6):1792–801. doi: 10.1210/jc.2012-1067. [PubMed: 22442266].
40. Mullington JM, Haack M, Toth M, Serrador JM, Meier-Ewert HK. Cardiovascular, inflammatory, and metabolic consequences of sleep deprivation. *Prog Cardiovasc Dis.* 2009;**51**(4):294–302. doi: 10.1016/j.pcad.2008.10.003. [PubMed: 19110131].
41. Charles LE, Gu JK, Andrew ME, Violanti JM, Fekedulegn D, Burchfiel CM. Sleep duration and biomarkers of metabolic function among police officers. *J Occup Environ Med.* 2011;**53**(8):831–7. doi: 10.1097/JOM.0b013e31821f5ece. [PubMed: 21785371].
42. Violanti JM, Burchfiel CM, Hartley TA, Mnatsakanova A, Fekedulegn D, Andrew ME, et al. Atypical work hours and metabolic syndrome among police officers. *Arch Environ Occup Health.* 2009;**64**(3):194–201. doi: 10.1080/19338240903241259. [PubMed: 19864222].