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Analysis of the Relationship between Sleep Duration and Body Mass Index in a South Korean Adult Population: A Propensity Score Matching Approach

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Background: One-third of the present adults in South Korea are obese, and previous studies have demonstrated that sleep duration is considered a risk factor for obesity. Hence, I assessed the relationship between sleep duration and body mass index in a South Korean adult population.

Methods: This cross-sectional study consists of a representative sample of 4,218 South Korean adults (20-64 years) who participated in the sixth Korea National Health and Nutrition Examination Survey (2015). As statistical analysis methods, data were analyzed using chi-square test and multiple logistic regression. Propensity score matching (PSM) was applied to control selection bias, and obesity-related factors were used as covariates in PSM.

Results: According to the multiple logistic regression analysis, people who sleep for more than seven hours a day were less likely to be obese than those who sleep for less than seven hours a day in the pre-match (OR = 0.75, 95%CI = 0.65-0.88) and post-match (OR = 0.77, 95%CI = 0.65-0.90) samples.

Conclusions: This finding suggests that South Korean adults who reported sleeping more than 7 hours a day were linked to decreased body mass index. Hence, the proper amount of sleep is necessary to reduce the prevalence of obesity in this population.

Key Words: Sleep duration, Body mass index, Obesity, Propensity score matching, Adult population

INTRODUCTION

Obesity is a medical condition in which excess body fat accumulates to the extent that it can have a negative impact on human health. Obesity is a main risk factor for non-communicable diseases such as heart disease, type 2 diabetes, obstructive sleep apnea, cancer, and osteoarthritis [1]. Obesity is mainly caused by lifestyle and genetic factors. The major lifestyle risk factors for obesity are excessive food intake and lack of physical activity [2]. At present, we are facing a major obesity pandemic around the globe. In 2014, 600 million adults (13%) and 42 million young children under five were obese around the world [3]. With this trend, the American Medical Association (AMA) categorized obesity as a disease in 2013 [4,5]. In South Korea, the prevalence of obesity among adults (over the age of 19) has consistently increased from 1998 to 2013 (Fig. 1). According to Korea Health Statistics 2013, the prevalence of obesity was 32.5% for adults (over the age of 19) in

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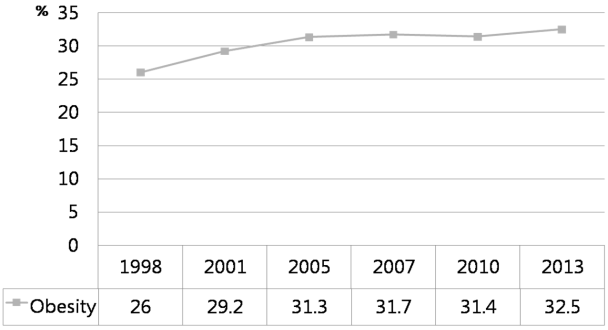

Fig. 1. Obesity (BMI) trend for South Korean adults (over 19). Source: Ministry of Health and Welfare, 2014, Korea Health Statistics 2013.

2013. In other words, one-third of the present adults in South Korea are obese. In addition, the average amount of sleep per night reported in South Korean adults was 6.7 hours in 2013 [6]. The American National Sleep Foundation recommended that the ideal sleep duration for adults (20-64) is 7 to 9 hours a day [7]. Numerous studies have shown that short sleep duration (less than 7 hours a day) was related to higher body mass index among adults. In longitudinal studies, Hasler et al. (2004) asserted that there was a strong association between short sleep duration (less than 6 hours a day) and obesity, with an adjusted odds ratio of 0.50 for sleep duration predicting obesity over a 13-year period [8]. According to 6-year prospective data from the Quebec Family Study, short sleepers (sleeping 5-6 hours a day) were more likely to be obese than normal sleepers (sleeping 7-8 hours a day) [9].

In cross-sectional studies, Ford et al. (2014) asserted that short sleepers (sleeping less than 6 hours a day) were as much as 1.7 kg/m^2 heavier than long sleepers (sleeping more than 7 hours a day) [10]. Grandner et al. (2015) claimed that short sleep duration was associated with higher BMI among adults (18-49 years) [11]. Nathaniel et al. (2010) maintained that short sleep (sleeping less than 7 hours a day) was associated with increased BMI after adjusting for genetics and shared environment [12]. Park et al. (2007) argued that there was a negative association between sleep duration and body mass index among Korean adults after controlling for the potential confounding variables [13]. However, all of these studies used conventional regression techniques that were not adjusted for the selection bias present in observational studies [14,15]. Hence, these studies have been limited in determining whether there is a causal effect of sleep duration on body mass index. To identify a more robust measure of the association between sleep duration and body mass index, propensity score matching is applied in the present study.

MATERIALS AND METHODS

1. Study design and participants

This study used data from the sixth Korea National Health and Nutrition Examination Survey (2015). The KNHANES is an ongoing surveillance system in Korea that assesses the health and nutritional status of Koreans since 1998, performed by the Korea Centers for Disease Control and Prevention. The KNHANES aims to monitor trends in health risk factors and the prevalence of major chronic diseases and provides data for the development and assessment of health policies and programs in Korea. This nationally representative cross-sectional survey collects data on socio-demographic characteristics, health behaviors, quality of life, healthcare utilization, anthropometric measures, biochemical and clinical profiles for chronic diseases, and dietary intakes of about 10,000 Koreans individuals every year [16]. My study did not require approval from an institutional review board because the KNHANES data are secondary and do not include personal information. This cross-sectional study consists of a representative sample of 4,218 South Korean adults (20-64 years) who participated in the sixth KNHANES (2015). I analyzed secondary data that contained detailed responses relating to socio-demographic variables, health behavior, and health status including objective assessment of obesity, amount of time spent in sedentary behaviors, physical activity, and sleep duration.

2. Measures

1) Sleep duration

I treated sleep duration as a binary index variable (long sleepers: sleeping more than 7 hours a day; short sleepers: sleeping less than 7 hours a day) based on response to the following item: How many hours do you sleep a day?

2) Body mass index

Body mass index is calculated by dividing weight by

height squared and is closely connected with both percentage body fat and total body fat [17]. People with a BMI of 25 kg/m^2 to 29 kg/m^2 are considered overweight, and people with a BMI of 30 kg/m^2 or more are classified as obese [18]. However, the WHO Western Pacific Region (WPRO) has redefined BMI in consideration of Asian physical characteristics. In specific, Asian people with a BMI of 23 kg/m^2 to 25 kg/m^2 are considered overweight, and Asian people with a BMI of 25 kg/m^2 or more are classified as obese [19]. I treated BMI classification as a binary index variable (Normal: BMI $\leq$ 24.9; Obesity: $\geq$25.0).

3) Covariates: Obesity-related factors

Excessive body weight is related to various diseases such as cardiovascular diseases, type 2 diabetes, obstructive sleep apnea, cancer, osteoarthritis, and asthma. As a result, obesity has been known to decrease life expectancy [20]. Obesity is caused by various socio-demographic and health behavior factors. These socio-demographic factors include gender, education, and income. Among men, obesity prevalence is generally similar at all income and education levels, with a tendency to be slightly higher at higher income and education levels. Among women, in contrast, obesity prevalence increases as income and education decrease [16]. Second, health behavior factors including excessive food intake and physical activity level are known risk factors for obesity [21-24].

(1) Socio-demographic variables

Age was categorized into five groups (20-29, 30-39, 40-49, 50-59, 60-64 years), and income level was categorized into quartiles. Education level was categorized into four groups (graduation from university or more, graduation from high school, graduation from middle school, and graduation from elementary school), and job was categorized into seven groups (Manager or specialized job, Office clerk, Service worker, Farmer or fisher, Technician or Factory worker, Simple labor, Unemployed).

(2) Health behavior variables

Physical activity was categorized into two groups (Yes: at least 2 hrs, 30 min of high exercise and 1 hr, 15 min of moderate exercise per week; No) The average time spent in sedentary behaviors per day was categorized into four groups (more than 9 hours, 6-8 hours, 3-5 hours, 1-2 hours). The average daily calorie intake was categorized into four groups (less than 1,000 kcal, 1,001-2,000 kcal, 2,001-3,000 kcal, more than 3001 kcal).

3. Statistical analysis

1) Propensity score matching

Propensity score matching was applied to control confounding factors such as selection bias. Propensity score matching was first proposed by Rosenbaum and Rubin in 1983 and is based on the counterfactual concept and can help reinforce causal arguments in observational studies by reducing selection bias [25,26]. The propensity score is a balancing score. In the present study, sleep duration (long sleepers: 0, short sleepers: 1) was used as the dependent variable, and obesity-related variables (age, gender, education, household income, job, sedentary behaviors, physical activity, and average daily calorie intake) were used as covariates in propensity score matching. Second, treatment cases (long sleepers) were matched with control cases (short sleepers) using 1:1 nearest neighborhood matching. Third, histogram analysis and covariate difference analysis were performed after propensity score matching to assess the effect of matching. Statistical analysis was conducted using SPSS (version 23.0, SPSS Inc., Chicago, IL).

2) Chi-square test

Chi-square test was performed to compare the distribution of covariates before and after propensity score matching. Statistical analysis was conducted using SPSS (version 23.0, SPSS Inc., Chicago, IL).

3) Multiple logistic regression

Multiple logistic regression was performed to analyze the association between sleep duration and body mass index among South Korean adults before and after propensity score matching. The independent variable was sleep duration, and the dependent variable was body mass index. Covariates were other obesity-related factors such as age, gender, education, household income, job, sedentary behaviors, physical activity, and average daily calorie intake. I divided the regression analysis into two parts. Using the full

sample (pre-matching sample) of South Korean adults, I first generated a logistic regression model. After propensity score matching, I performed logistic regression analysis using the reduced sample (post-matching sample) containing only matched cases. Statistical analysis was conducted using SPSS (version 23.0, SPSS Inc., Chicago, IL) (Fig. 2).

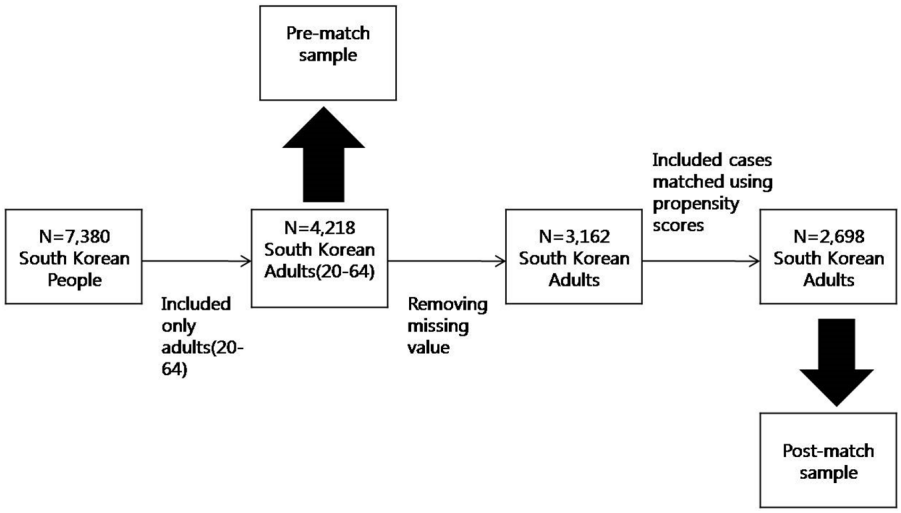

Fig. 2. Research frame: Korea National Health and Nutrition Examination Survey (2015).

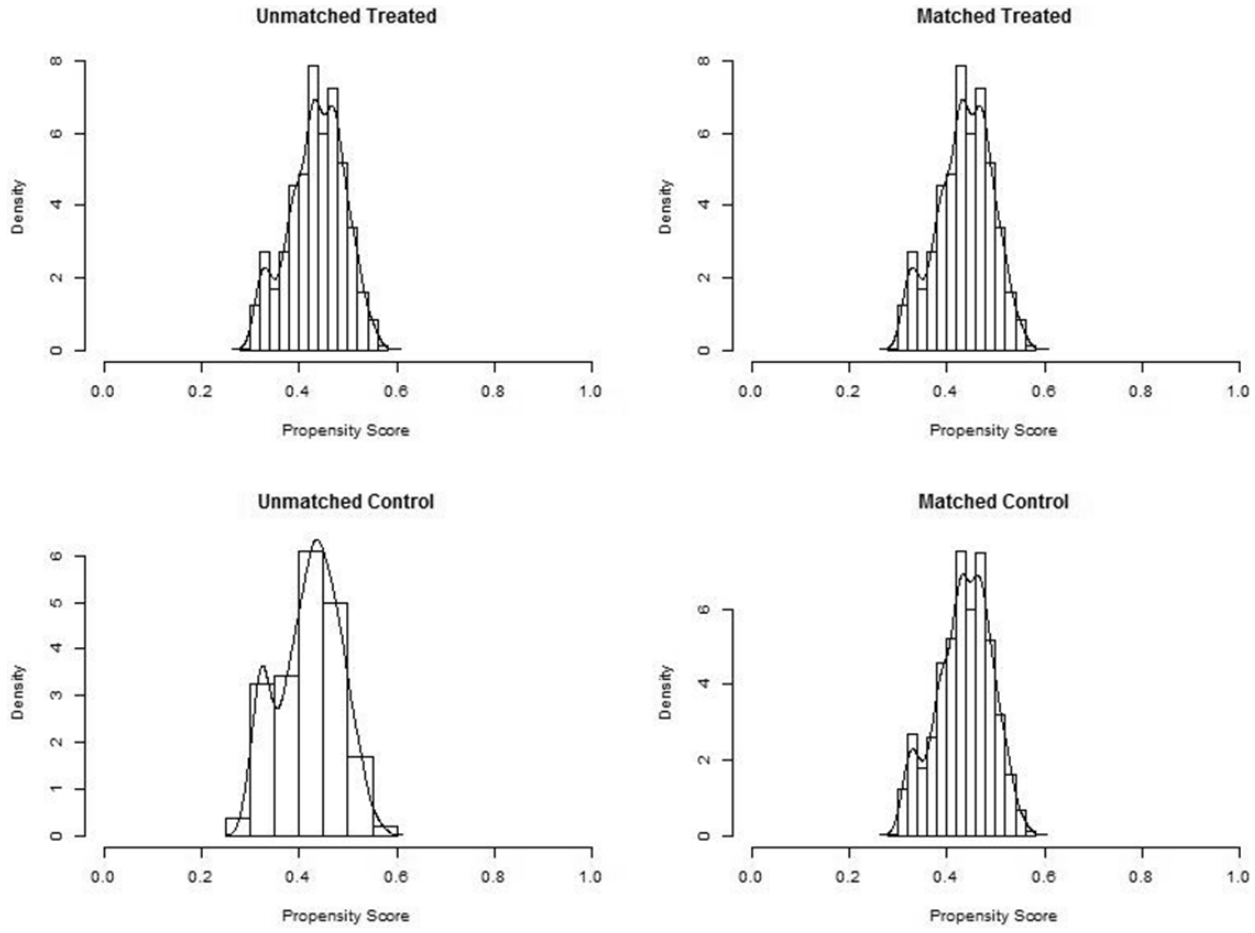

Fig. 3. Histograms of propensity score before and after matching.

RESULTS

Fig. 3 shows the histograms before and after propensity score matching. The histograms before matching show some differences. In contrast, the histograms after matching are very similar. Hence, Fig. 3 shows that matching worked very well.

Table 1 shows the association between sleep duration and body mass index among South Korean adults in the large (pre-matching) and small (post-matching) samples. The analysis using the pre-matching sample identified a negative relationship (OR = 0.75, $p < 0.001$) between sleep duration and body mass index among South Korean adults after adjusting for other obesity-related variables in the model. The pre-matching analysis also showed significant associations between body mass index and the following covariates: gender, age, income level, education level, energy intake, and sedentary hours per day.

Table 1 also displays the association between sleep duration and body mass index among South Korean adults in

Table 1. Multiple logistic regression models of the association between sleep duration and body mass index among South Korean adults

Variables		Pre-matching sample (N = 3,162)		Post-matching sample (N = 2,698)	
		Adj. odds ratio	95% C.I.	Adj. odds ratio	95% C.I.
Sleep duration	<7 hours	Reference		Reference	
	≥7 hours	0.754***	[0.646, 0.880]	0.765**	[0.649, 0.902]
Gender	Female	Reference		Reference	
	Male	1.796***	[1.498, 2.153]	1.704***	[1.402, 2.071]
Age (years)	60-64	Reference		Reference	
	50-59	1.087	[0.843, 1.401]	1.118	[0.858, 1.457]
	40-49	1.027	[0.773, 1.364]	1.037	[0.771, 1.395]
	30-39	0.879	[0.645, 1.198]	0.868	[0.624, 1.207]
	20-29	0.578**	[0.417, 0.803]	0.578**	[0.403, 0.829]
Income level	1st quartile (highest)	Reference		Reference	
	2nd quartile	1.160	[0.955, 1.409]	1.165	[0.946, 1.436]
	3rd quartile	1.309*	[1.056, 1.622]	1.427**	[1.133, 1.796]
	4th quartile (lowest)	1.201	[0.897, 1.610]	1.258	[0.924, 1.712]
Occupation	Unemployed	Reference		Reference	
	Manager, specialized job	1.150	[0.886, 1.491]	1.124	[0.846, 1.492]
	Office clerk	1.162	[0.878, 1.538]	1.090	[0.805, 1.477]
	Service worker	1.170	[0.910, 1.488]	1.033	[0.793, 1.347]
	Farmer or fisher	1.242	[0.818, 1.895]	1.239	[0.798, 1.925]
	Technician, factory worker	0.895	[0.669, 1.200]	0.931	[0.681, 1.274]
	Simple labor	1.289	[0.978, 1.765]	1.243	[0.904, 1.707]
Education level	University or more	Reference		Reference	
	High school	1.109	[0.908, 1.354]	1.179	[0.949, 1.465]
	Middle school	1.329	[0.974, 1.814]	1.291	[0.930, 1.792]
	Elementary school	2.216***	[1.606, 3.058]	2.289***	[1.634, 3.207]
Energy intake (calories)	>3,000 kcal	Reference		Reference	
	2,001-3,000 kcal	0.716**	[0.565, 0.909]	0.670**	[0.519, 0.864]
	1,001-2,000 kcal	0.814	[0.641, 1.032]	0.788	[0.611, 1.017]
	≤1,000 kcal	0.974	[0.681, 1.393]	1.007	[0.689, 1.472]
Sedentary hours per day	≥9 hours	Reference		Reference	
	6-8 hours	0.735**	[0.603, 0.896]	0.748**	[0.604, 0.926]
	3-5 hours	0.869	[0.711, 1.062]	0.889	[0.718, 1.102]
	1-2 hours	1.189	[0.818, 1.727]	1.144	[0.772, 1.695]
Physical activity	Yes	Reference		Reference	
	No	0.963	[0.823, 1.127]	0.912	[0.771, 1.079]

*p < 0.05, **p < 0.01, ***p < 0.001.

post-matching samples after propensity score matching using 1:1 nearest neighborhood matching. After adjusting for all covariates in the model, sleep duration remained a significant predictor (OR = 0.77, $p < 0.01$) of body mass index among South Korean adults. The post-matching analysis also showed significant associations between body mass index and the following covariates: gender, age, income level, education level, energy intake, and sedentary hours per day.

Table 2 shows the general characteristics of participants and the summary of results before and after propensity score matching. The total number of participants in the pre-matching sample was 3,162 (long sleepers: 1813, short sleepers: 1349). In contrast, the total number of participants in the post-matching sample was 2,698 (long sleepers: 1349, short sleepers: 1349). Chi-square analysis showed significant differences between samples of long sleepers and short sleepers for each of the covariates in the pre-match sample. Comparatively, differences among covariates between long sleepers and short sleepers were decreased, as shown by the smaller number of variables and larger p-value for the Chi-square test in the post-matching sample.

DISCUSSION

The purpose of this study was to analyze the relationship between sleep duration and body mass index among South

Table 2. Covariate imbalance before and after matching based on the propensity score

Covariates: N (%)		Pre-matching sample (N = 3,162)			Post-matching sample (N = 2,698)		
		≥7 hours	<7 hours	p-value	≥7 hours	<7 hours	p-value
Total		1,813 (57.3%)	1,349 (42.7%)		1,349 (50.0%)	1,349 (50.0%)	
Gender	Female	1,106 (61.0%)	783 (58.0%)	0.050	786 (58.3%)	783 (58.0%)	0.469
	Male	707 (39.0%)	566 (42.0%)		563 (41.7%)	566 (42.0%)	
Age	60-64	211 (11.6%)	193 (14.3%)	<0.001	181 (13.4%)	193 (14.3%)	0.903
	50-59	498 (27.5%)	412 (30.5%)		428 (31.7%)	412 (30.5%)	
	40-49	418 (23.1%)	340 (25.2%)		327 (24.2%)	340 (25.2%)	
	30-39	372 (20.5%)	236 (17.5%)		241 (17.9%)	236 (17.5%)	
	20-29	314 (17.3%)	168 (12.5%)		172 (12.8%)	168 (12.5%)	
Icome Level	1st quartile (highest)	637 (35.1%)	506 (37.5%)	0.065	487 (36.1%)	506 (37.5%)	0.443
	2nd quartile	581 (32.0%)	392 (29.1%)		426 (31.6%)	392 (29.1%)	
	3rd quartile	431 (23.8%)	302 (22.4%)		303 (22.5%)	302 (22.4%)	
	4th quartile (lowest)	164 (9.0%)	149 (11.0%)		133 (9.9%)	149 (11.0%)	
Occupation	Unemployed	635 (35.0%)	373 (27.7%)	<0.001	370 (27.4%)	373 (27.7%)	0.544
	Manager, specialized job	287 (15.8%)	253 (18.8%)		249 (18.5%)	253 (18.8%)	
	Office clerk	202 (11.1%)	188 (13.9%)		169 (12.5%)	188 (13.9%)	
	Service worker	276 (15.2%)	208 (15.4%)		233 (17.3%)	208 (15.4%)	
	Farmer or fisher	64 (3.5%)	52 (3.9%)		55 (4.1%)	52 (3.9%)	
	Technician, factory worker	204 (11.3%)	146 (10.8%)		163 (12.1%)	146 (10.8%)	
	Simple labor	145 (8.0%)	129 (9.6%)		110 (8.2%)	129 (9.6%)	
Education Level	University or more	770 (42.5%)	543 (40.3%)	0.054	538 (39.9%)	543 (40.3%)	0.308
	High school	694 (38.3%)	512 (38.0%)		508 (37.7%)	512 (38.0%)	
	Middle school	185 (10.2%)	132 (9.8%)		159 (11.8%)	132 (9.8%)	
	Elementary school	164 (9.0%)	162 (12.0%)		144 (10.7%)	162 (12.0%)	
Energy Intake (Calories)	>3,000 kcal	257 (14.2%)	211 (15.6%)	0.193	193 (14.3%)	211 (15.6%)	0.309
	2,001-3,000 kcal	600 (33.1%)	422 (31.3%)		433 (32.1%)	422 (31.3%)	
	1,001-2,000 kcal	840 (46.3%)	609 (45.1%)		636 (47.1%)	609 (45.1%)	
	≤1,000 kcal	116 (6.4%)	107 (7.9%)		87 (6.4%)	107 (7.9%)	
Sedentary hours per day	≥9 hours	713 (39.3%)	554 (41.1%)	0.066	546 (40.5%)	554 (41.1%)	0.524
	6-8 hours	527 (29.1%)	347 (25.7%)		369 (27.4%)	347 (25.7%)	
	3-5 hours	502 (27.7%)	376 (27.9%)		376 (27.9%)	376 (27.9%)	
	1-2 hours	71 (3.9%)	72 (5.3%)		58 (4.3%)	72 (5.3%)	
Physical Activity	Yes	933 (51.5%)	684 (50.7%)	0.350	673 (49.9%)	684 (50.7%)	0.350
	No	880 (48.5%)	665 (49.3%)		676 (50.1%)	665 (49.3%)	

Korean adults. The results of this study are as follows.

As a result of the multiple logistic regression analysis of the association between sleep duration and body mass index, people who sleep for more than seven hours a day were less likely to be obese than those who sleep for less than seven hours a day in both the pre-matching (OR = 0.75, $p < 0.001$) and post-matching (OR = 0.77, $p < 0.01$) samples. Hence, my finding is consistent with previous studies that have reported that short sleep duration was related to elevated body mass index. In cross-sectional studies, short sleep duration (less than 7 hours a day) was related to higher body mass index among adults [10-13]. However, longitudinal studies on the association between sleep duration and obesity are controversial. Hasler et al. (2004) and Chaput et al. (2008) argued that short sleepers (sleeping less than 6 hours a day) were associated with obesity and weight gain [8,9] According to the Whitehall II Study with 5 years of follow-up, in contrast, short sleep duration (sleeping less than 5 hours a day) was not significantly related to significant changes in BMI [27]. Gangwisch et al. (2005) insisted that there was a nonsignificant relationship between sleep duration and body mass index over 10 years in a sample of about 2,500 men and 1,100 women [28]. I think the reason why longitudinal studies produced different research results is that each research study used different selection criteria for participants and different statistical methods. The mechanism through which short sleep increases body mass index has not been clearly defined. Some possible mechanisms have been suggested such as insulin and glucose dysregulation, [29] an orexigenic pattern due to decreased leptin and increased ghrelin, [30] increased caloric consumption or other dietary changes, [31] increased systemic inflammation, [32] and reduced physical activity caused by increased daytime sleepiness [33]. The significance of the present research study is as follow. This study is observational using secondary data. Unlike experimental studies, observational studies are susceptible to potential confounding factors such as selection bias [14,15]. In order to control selection bias, propensity score matching is applied in the study. This study is significant in the sense that it was a first attempt to apply propensity score matching to analyze the relationship between sleep duration and body mass index for improving the accuracy of study in South Korea.

My results should be considered in light of several limitations. First, the study design is cross-sectional. Hence, I was not able to confirm the temporal causal relationship between sleep duration and body mass index. Second, I analyzed a relatively small sample size because the health interview and nutrition survey were conducted by self-reported survey, which might yield a lot of missing information. Third, I only focused on the relationship between short sleep duration (sleeping less than 7 hours a day) and obesity. Hence, follow-up study needs to be conducted about the obesity risk of long sleep duration (sleeping more than 9 hours a day).

In conclusion, there was a negative relationship between sleep duration and body mass index among South Korean adults. This finding suggests that South Korean adults who reported sleeping more than 7 hours a day were linked to decreased body mass index. Hence, the proper amount of sleep is necessary to reduce the prevalence of obesity in this population.

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REFERENCES

1. Haslam DW, James WP. Obesity. *Lancet* 2005;366: 1197-209.
2. Yazdi FT, Clee SM, Meyre, D. Obesity genetics in mouse and human: back and forth, and back again. *PeerJ* 2015;3:e856. https://doi.org/10.7717/peerj.856.
3. WHO: Obesity and overweight [Internet]. Geneva: World Health Organization; c2017 [cited 2017 Apr 07]. Available from: http://www.who.int/mediacentre/factsheets/fs311/en/
4. Pollack A, editor. A.M.A. recognizes obesity as a disease [Internet]. New York Times; [updated 2013 Jun 18; cited 2017 Apr 07]. Available from: http://www.nytimes.com/2013/06/19/business/ama-recognizes-obesity-as-a-disease.html.
5. Weinstock M, editor. The facts about obesity [Internet]. Hospitals & Health Networks; [updated 2013 Jun 21; cited 2017 Apr 07]. Available from : http://www.hhnmag.com/articles/6385-the-facts-about-obesity.

6. Ministry of Health and Welfare. Korea Health Statistics 2013: The 6th Korea national health and nutrition examination survey 2013, Ministry of Health and Welfare; Sejong, Korea. 2014.
7. National Sleep Foundation: National sleep foundation recommends new sleep times [Internet]. Washington DC: National sleep foundation; [updated 2015 Feb 2; cited 2017 Apr 07]. Available from: https://sleepfoundation.org/press-release/national-sleep-foundation-recommends-new-sleep-times.
8. Hasler G, Buysse DJ, Klaghofer R, Gamma A, Ajdacic V, Eich D, Rossler W, Angst J. The association between short sleep duration and obesity in young adults: a 13-year prospective study. *Sleep* 2004;27:661-6.
9. Chaput JP, Despres JP, Bouchard C, Tremblay A. The association between sleep duration and weight gain in adults: a 6-year prospective study from the Quebec Family Study. *Sleep* 2008;31:517-23.
10. Ford ES, Li C, Wheaton AG, Chapman DP, Perry GS, Croft J. Sleep duration and body mass index and waist circumference among U.S adults. *Obesity (Silver Spring)* 2014;22:598-607.
11. Grandner MA, Schopfer EA, Sands-Lincoln M, Jackson N, Malhotra, A. Relationship between sleep duration and body mass index depends on age. *Obesity (Silver Spring)* 2015;23:2491-8.
12. Nathaniel FW, Dedra B, Michael VV, Carolyn N, Jack GA. Twin study of sleep duration and body mass index. *J Clin Sleep Med* 2010;6:11-7.
13. Park YJ, Yim HW, Park YM, Lee WC. The association between sleep and obesity in Korean Adults. *J Prev Med Public Health* 2007;40:454-60.
14. Jang EJ, Ahn J, Jung SY, Hwang JS, Lee JY. Shim JI. Methods for the control of measured confounders in outcomes research. National Evidence-based Healthcare Collaborating Agency; Seoul, Korea. 2013.
15. Hammer GP, du Prel JB, Blettner M. Avoiding bias in observational studies. *Dtsch Arztebl Int* 2009;106:664-8.
16. Korea Centers for Disease Control and Prevention: Korea national health and nutrition examination survey (KNHANES) [Internet]. Osong, Korea: Korea Centers for Disease Control and Prevention; [cited 2017 Jan 15]. Available from: https://knhanes.cdc.go.kr/knhanes/index.do.
17. Gray DS, Fujioka K. Use of relative weight and body mass index for the determination of adiposity. *J Clin Epidemiol* 1991;44:545-50.
18. WHO: BMI classification [Internet]. World Health Organization; 2014 [cited 2017 Apr 07]. Available from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.
19. WPRO: The Asia-Pacific perspective: Redefining obesity and its treatment [Internet]. World Health Organization, Western Pacific Region; 2000 [cited 2017 Apr 07]. Available from: http://www.wpro.who.int/nutrition/documents/docs/Redefiningobesity.pdf.
20. Poulain M, Doucet M, Major GC, Drapeau V, Sériès F, Boulet L-P, Tremblay A, Maltais F. The effect of obesity on chronic respiratory disease: pathophysiology and therapeutic strategies. *CMAJ* 2006;174:1293-9.
21. Bojanowska E, Ciosek J. Can we selectively reduce appetite for energy-dense foods? An overview of pharmacological strategies for modification of food preference behavior. *Curr Neuropharmacol* 2016;14:118-42.
22. Katzmarzyk PT, Mason C. The physical activity transition. *J Phys Act Health* 2009;6:269-80.
23. Patel AV, Rodriguez C, Pavluck AL, Thun MJ, Calle EE. Recreational physical activity and sedentary behavior in relation to ovarian cancer risk in a large cohort of US women. *AM J Epidemiol* 2006;163:709-16.
24. Thorp AA et al. Deleterious associations of sitting time and television viewing time with cardiometabolic risk biomarkers: Australian diabetes, obesity and lifestyle (AusDiab) study 2004-2005. *Diabetes Care* 2010;33:327-34.
25. Randolph JJ, Falbe K, Manuel AK, Balloun JL. Practical assessment, research & evaluation. *Pract Assess Res Eval* 2014;19:1-6.
26. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. *Biometrike* 1983;70:41-55.
27. Stranges S, Cappuccio FP, Kandala NB, Miller MA, Taggart FM, Kumari M, Ferrie JE, Shipley MJ, Brunner EJ, Marmot MG. Cross-sectional versus prospective associations of sleep duration with changes in relative weight and body fat distribution: the Whitehall II Study. *Am J Epidemiol* 2008;167:321-9.
28. Gangwisch JE, Malaspina D, Boden-Albala B, Heymsfield SB. Inadequate sleep as a risk factor for obesity: analyses of the NHANES I. *Sleep* 2005;28:1289-96.
29. Knutson KL, Van Cauter E. Associations between sleep loss and increased risk of obesity and diabetes. *Ann N Y Acad Sci* 2008;1129:287-304.
30. 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;141:846-50.
31. St-Onge MP, Roberts AL, Chen J, Kelleman M, O'Keeffe M, RoyChoudhury A, Jones PJ. Short sleep duration increases energy intakes but does not change energy expenditure in normal-weight individuals. *Am J Clin Nutr* 2011;94:410-6.
32. Grandner MA, Sands-Lincoln MR, Pak VM, Garland SN. Sleep duration, cardiovascular disease, and proinflammatory biomarkers. *Nat Sci Sleep* 2013;5:93-107.
33. Grandner MA, Kripke DF. Self-reported sleep complaints with long and short sleep: a nationally representative sample. *Psychosom Med* 2004;66:239-41.