Paradigm Academic Press
Journal of Innovations in Medical Research
ISSN 2788-7022
JAN. 2023 VOL.2, NO.1

Relationship Between Sleep Deprivation and the Incidence of Overweight or Obesity in Chinese Adults: A Systematic Review and Meta-Analysis of Prospective Studies

Hao Xue[1], Siyu Zhao[1], Xiangxue Wang[1], Fan Li[1], Shang Wang[1], Zhaohong Xie[1], Wei Shang[1] & Chao Lai[1]

[1] School of the Second Hospital, Cheeloo College of Medicine, Shandong University, Jinan, 250033, China

Correspondence: Chao Lai, School of the Second Hospital, Cheeloo College of Medicine, Shandong University, Jinan, 250033, China.

doi:10.56397/JIMR/2023.01.04

Abstract

Overweight and obesity in adults have become a global public health problem. Epidemiological studies suggest that sleep duration may contribute to the incidence of overweight and obesity in all stages of life. China has an increasing prevalence of overweight and obesity, and sleep deprivation is common among Chinese adults. The aim of this systematic review and meta-analysis was to assess the prospective relationship between insufficient sleep and the incidence of overweight or obesity in Chinese adults and estimate the risk. A systematic search was performed on June 6, 2021, of Embase, PubMed, and Web of Science. The exposure was the sleep duration, and the outcome measure was the incidence of overweight or obesity. The odds ratios, relative risks, hazard ratios, and 95% confidence intervals (CI) were extracted. Heterogeneity and publication bias of the studies were checked with a sensitivity analysis. Four studies fulfilled the criteria for inclusion. A total of 34,877 and 184,796 participants (Chinese men and women, age > 18 years) were included for the analyses of general and central obesities, respectively. The pooled relative risks for a short sleep duration were 1.06 (95% CI: 0.90, 1.25; I^2 = 0.00) and 1.12 (95% CI: 1.07, 1.16, I^2 = 0.00) for the incidence of general and central obesities, respectively. Studies showed no significant heterogeneity. In conclusion, this study showed that a short sleep duration was associated with the development of central obesity but not with that of general obesity in Chinese adults.

Keywords: sleep duration, obesity, meta-analysis, Chinese, adult

1. Introduction

In recent decades, adult obesity has become a major global public health concern, leading to the growth of chronic illness and a decline in the quality of life of patients and a large socioeconomic burden (Blüher M., 2019; Wu Y., 2006). Global obesity could significantly impact the global prevalence of work impairment, cancer, type 2 diabetes, osteoarthritis, cardiovascular disease, and sleep apnea (Wu Y., 2006; Visscher, T. L., & Seidell, J. C., 2001). Over the past few decades, obesity has reached epidemic proportions and is now acknowledged as a significant contributor to the global disease burden (World Health Organization, 2000). From 1975 to 2014, the prevalence of adult male obesity (body mass index [BMI] ≥ 30 kg/m^2) increased from 3.2% to 10.8%, while that of adult female obesity (BMI ≥ 30 kg/m^2) increased from 6.4% to 14.9%. In 2014, the prevalence of morbid obesity (BMI ≥ 40 kg/m^2) was 0.64% in men and 1.6% in women (NCD Risk Factor Collaboration (NCD-RisC), 2016). Estimations indicate that 57.8% of the adult population worldwide (3.3 billion people) would have a BMI ≥ 25 kg/m^2 by 2030 (Finkelstein, E. A., Khavjou, O. A., Thompson, H., Trogdon, J. G., Pan, L., Sherry, B., & Dietz, W., 2012; Kelly, T., Yang, W., Chen, C. S., Reynolds, K., & He, J., 2008). Consequently, the disease burden associated with obesity is anticipated to increase in the near future. In many countries and regions, the proportion of adults with overweight or obesity is higher than that of adults with normal weight (NCD Risk

Factor Collaboration (NCD-RisC), (2016). The negative health implications of obesity pose a greater threat to public health than those of poverty or famine (Bhupathiraju, S. N., & Hu, F. B., 2016).

China is the world's largest developing economy and the most populous developing country. In the past several years, China's rapid socioeconomic development in the living conditions of inhabitants has contributed significantly to a rise in the incidence of obesity, particularly in metropolitan regions (Gu, D., Reynolds, K., Wu, X., Chen, J., Duan, X., Reynolds, R. F., Whelton, P. K., He, J., & InterASIA Collaborative Group, 2005). In 2010, the proportions of general and central obesities were 5.2% and 32.3%, respectively, among adults (Zhang, X., Zhang, M., Zhao, Z., Huang, Z., Deng, Q., Li, Y., Pan, A., Li, C., Chen, Z., Zhou, M., Yu, C., Stein, A., Jia, P., & Wang, L., 2020). Unhealthy eating habits and a sedentary lifestyle, such as an excessive intake of fast food and insufficient physical exercise, respectively, are the primary environmental variables contributing to the prevalence of obesity (Pan, X. F., Wang, L., & Pan, A. 2021). Sleep is a modifiable factor influencing adult body weight changes (Kohatsu, N. D., Tsai, R., Young, T., Vangilder, R., Burmeister, L. F., Stromquist, A. M., & Merchant, J. A., 2006). Sleep deprivation alters hormone levels. For example, leptin and ghrelin, which increase appetite, contribute to obesity in adults with sleep deprivation (Reutrakul, S., & Van Cauter, E., 2018). Sleep deprivation is widespread among Chinese adults (Lu, K., Chen, J., Wu, S., Chen, J., & Hu, D., 2015; Song, Q. F., Liu, X. X., Hu, W. N., Han, X. C., Zhou, W. H., Lu, A. D., Wang, X. Z., & Wu, S. L., 2017). In 2013, an epidemiological study involving Chinese adults (age > 18 years) from the northern Chinese city of Tangshan revealed that < 35% of respondents slept over 8 h every day on average (Lu, K., Chen, J., Wu, S., Chen, J., & Hu, D., 2015). Sleep and obesity have been linked in previous epidemiological studies from western countries; most cross-sectional studies have revealed that sleep duration has an inverse linear relationship with obesity (Cappuccio, F. P., Taggart, F. M., Kandala, N. B., Currie, A., Peile, E., Stranges, S., & Miller, M. A., 2008). A questionnaire survey of approximately 17,000 university students aged 17–30 years from 27 colleges not associated with health sciences from 24 nations revealed that sleep deprivation (< 7 h every night on average) was correlated with a high self-rated state of ill-health in both men and women (Steptoe, A., Peacey, V., & Wardle, J., 2006). East Asian countries have the shortest sleep duration and the highest rates of associated infirmity, the cause of which should be further investigated. A prospective longitudinal study showed that sleep deprivation preceded the development of obese or overweight (Guo, Y., Miller, M. A., & Cappuccio, F. P., 2021). Numerous cross-sectional studies from China have investigated the association of the sleep duration with the obesity risk. In a study involving Chinese undergraduates aged 18–24 years, individuals who slept < 6 h every day on average had a 2.3-fold increased obesity risk compared to those who slept ≥ 8 h every day on average (Yang, Y., Miao, Q., Zhu, X., Qin, L., Gong, W., Zhang, S., Zhang, Q., Lu, B., Ye, H., & Li, Y., 2020). Cross-sectional relationships could not establish causality because of the study design. Longitudinal prospective studies evaluating the chronology and causation between the sleep duration and obesity risk are unavailable in China.

The aim of the present study was to (1) systematically evaluate prospective longitudinal studies on the link between sleep deprivation and overweight or obesity in Chinese adults; (2) conduct a meta-analysis to determine if the data prove the existence of a prospective association between sleep deprivation and overweight or obesity in Chinese adults; and (3) quantify the negative effects of general and central obesities in Chinese adults with sleep deprivation.

2. Materials and Methods

2.1 Registration

This systematic review was registered with PROSPERO before completion of the initial search (registration no.: CRD42021260558).

2.2 Literature Search

On June 6, 2021, Embase, PubMed, and Web of Science electronic databases were searched in all fields, including study titles, using keywords. Keywords were as follows: "sleep" OR "sleep-disordered breathing" OR "bedtime" AND "BMI" OR "body mass index" OR "weight" AND "waist circumference" OR "waist" OR "WHR" OR "waist/hip ratio" AND "obese" OR "overweight" OR "adiposity" OR "adipose tissue" AND "anthropometry" OR "body composition" OR "body constitution" AND "adults" AND "China" OR "Chinese" AND "cohort." The search was conducted without language constraints. Original articles were screened for eligible studies, and review articles were searched for other eligible studies.

2.3 Inclusion and Exclusion Criteria

Inclusion criteria were: (1) examination of the association of the sleep duration and the development of overweight, obesity, or BMI alterations; (2) involvement of Chinese adults (age > 18 years at baseline); (3) longitudinal observational study design; and (4) a short sleep duration as the exposure and the development of overweight, obesity, or BMI alterations as the outcome.

Exclusion criteria were: (1) no record of the sleep duration; (2) no data of the Chinese population; (3) no associated indicators of overweight or obesity; and (4) cross-sectional, retrospective, case–control, case series, or meta-analysis study designs.

2.4 Data Extraction

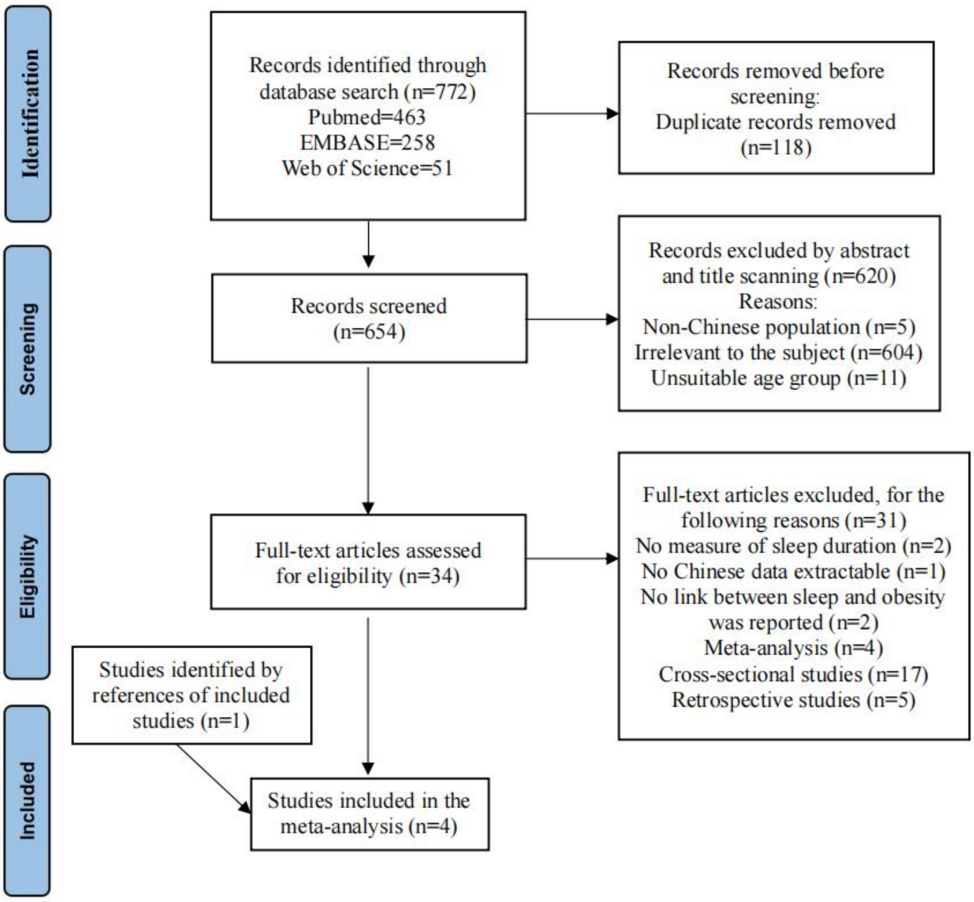


Figure 1. PRISMA flow chart. Studies contribute to the meta-analysis

Two researchers (H.X. & S.Y.Z.) collected data independently. Of the 772 articles initially screened, 654 were recognized as duplicates and excluded (Figure 1).

Table 1. Longitudinal studies selected from the search

Author (Year)	City Baseline Sample size Follow-up	Age Sleep exposure: Definition & assessment	Obesity outcome: definition & assessment
Zhou (2020)	Henan 2007-2008 N=17,265(of which 12,446 used in longitudinal analysis) (12,402 for general obesity) (7,867 for abdominal obesity) 6 years	≥18 yrs Sleep duration was divided into five groups: <6.5, 6.5-7.5, 7.5-8.5, 8.5-9.5, and≥9.5 h/d Self-reported	General obesity was defined as body mass index (BMI) ≥28 kg/m2 (47). Abdominal obesity was defined as waist circumference (WC) ≥90 cm for men and WC ≥ 80 cm for women according to the International Diabetes Federation Epidemiology Task Force Consensus Group (48) Weight, height and WC were measured by well-trained researchers

Ning (2020)	Qingdao, Harbin, Liuzhou, Suzhou, Haikou Sichuan, Zhejiang, Hunan, Gansu, Henan 2004-2008 N=24,996 (19,638 for general obesity) (14,808 for central obesity) 8.0 ± 0.8 years	30-79 yrs Sleep duration was divided into four groups: ≤6 hours (short sleep),7 hours, 8 hours, and ≥9 hours (long sleep) Self-reported	General obesity was defined as BMI ≥ 28.0 kg/m2(49). Central obesity was defined as WC ≥ 90 cm in males and WC ≥ 80 cm in females according to International Diabetes Federation cutoffs for South Asians, Chinese, and Japanese (48). Weight, height and WC were measured by well-trained researchers
Hong (2011)	Nanjing 2004 N=2 837 3 years	≥35 yrs Sleep duration was divided into five groups: ≤5 hours (short sleep), 6 hours (short sleep), 7 hours, 8 hours, and ≥9 hours (long sleep) Self-reported	Obesity was defined as BMI ≥ 28.0 kg/m2 (50). Weight and height were measured by well-trained researchers
Deng (2017)	Taiwan 1996-2014 N=162,121 Unknown	20-80 yrs Sleep duration was divided into three groups:<6 hours, 6-8 hours, and >8 hours Self-reported	Central obesity was defined as waist circumference over 80 cm in women and over 90 cm in men (51). Weight, height, and WC were measured by trained professionals

After screening the titles and Abstracts, 34 full-text articles were evaluated using the inclusion and exclusion criteria. Simultaneously, we assessed the references to the articles that were included. Finally, four articles were eligible for the meta-analysis (five involving general obesity and four involving central obesity; Table 1). Disagreements were resolved by consensus. For mediation, a third reviewer (F.L.) was involved. The collected information included the first author's surname; year of publication; demographic characteristics of the studied population; follow-up duration; study period and location; sample size; methods of measuring sleep duration; categories of sleep duration; methods of assessing exposure; definitions of outcomes; odds ratios (ORs), relative risks (RRs), and/or hazard ratios (HRs) for general or central obesity and correlating 95% confidence intervals (CIs); and adjusted variables. The meta-analysis was performed using data from the most adjusted model in each study.

2.5 Exposure and Outcome

Adults' sleep duration and reference categories vary throughout the lifespan (Ohayon, M. M., Carskadon, M. A., Guilleminault, C., & Vitiello, M. V., 2004); therefore, the categorization approach employed in the initial studies was applied to determine the definition of a short sleep duration. Table 1 summarizes the various definitions of a short sleep duration as exposure; RR of the short sleep duration in comparison with medium and long sleep durations; and definitions of overweight, general obesity, and central obesity as outcomes. Articles that utilized BMI as the outcome instead of overweight, general obesity, or central obesity have been cited to support the meta-analysis.

2.6 Confounders

Table 2. Covariates Used in Each Study

Study	Covariates
Zhou et al., 2020	age, gender, physical activity, smoking, drinking, education level, marital status, systolic blood pressure, diastolic blood pressure, fasting plasma glucose, and total cholesterol, triglycerides, and high-density lipoprotein cholesterol levels
Ning et al., 2020	age, sex, study region, education level, marital status, smoking, alcohol drinking,

	tea-drinking, diet frequency, physical exercise, snoring habit, depression, self-rated health, and history of diabetes
Hong et al., 2011	age, sex, waist circumference, hip circumference, moderate-intensity physical activity, living region, smoking, alcohol drinking, diet, profession, education level, and history of hypertension
Deng et al., 2017	Sex, age, education level, marital status, smoking, alcohol drinking, leisure-time physical activity, systolic blood pressure, diastolic blood pressure, fasting plasma glucose, total cholesterol to high-density lipoprotein cholesterol ratio, and triglycerides

Numerous confounding variables were adjusted for, including age, sex, physical activity, smoking, education level, and marital status (Table 2). For heterogeneity and sensitivity analyses, we collected RRs and/or HRs with respective 95% CIs.

2.7 Study Quality

Three researchers evaluated the methodological quality of the studies using the Newcastle–Ottawa Scale, which utilizes three components to assess the likelihood of bias in prospective studies: 1) participant selection (four items: exposed cohort's representativeness, equal derivation between the sources of exposed and unexposed cohorts' exposures, assessment, and demonstration that the outcome of interest was not present at the start of the study); 2) comparability (one item: comparability of cohorts based on the design or analysis); and 3) outcomes (three items: outcome assessment, sufficient follow-up duration, and sufficiency of follow-up). Each study is assigned a maximum of one point in the areas of participant selection and outcomes and a maximum of two points in the area of comparability. The Newcastle–Ottawa Scale has a maximum score of 9 (supreme quality), with scores of 0–3, 4–6, and 7–9 indicating low-, moderate-, and high-quality studies (Wu, W., Tong, Y., Zhao, Q., Yu, G., Wei, X., & Lu, Q., 2015). Disagreements were resolved by consensus.

2.8 Statistical Analysis

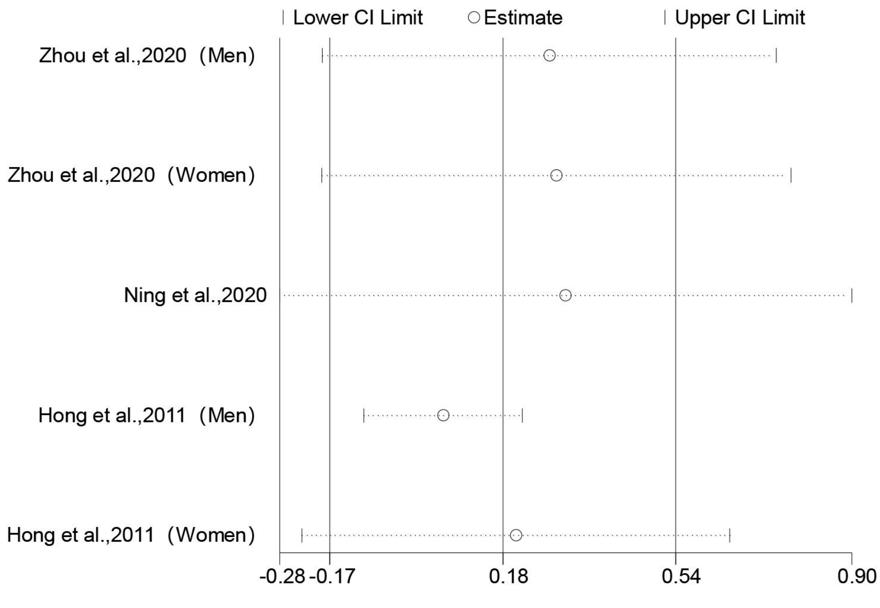


Figure 2. Sensitivity analysis of prospective observational studies on the effect of short sleep duration on the incidence of general obesity. Results are ln (relative risks) and 95% confidence intervals

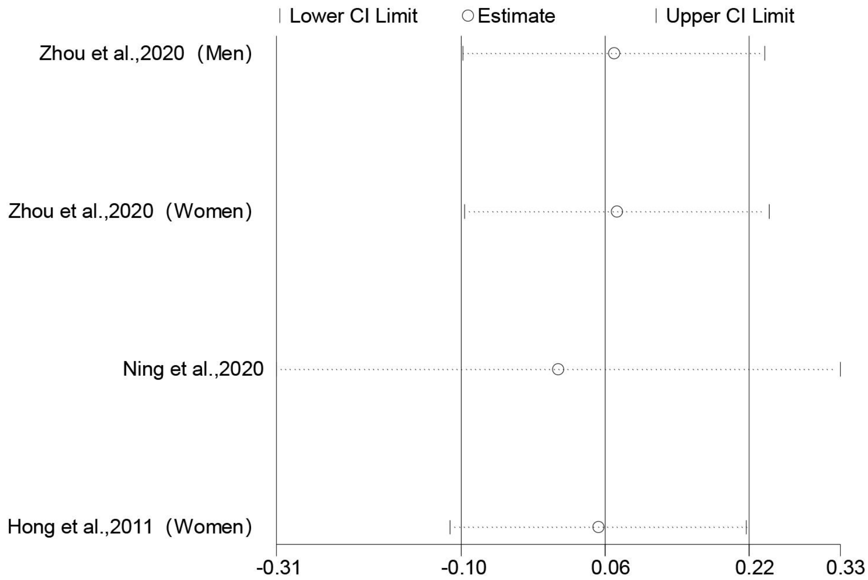


Figure 3. Sensitivity analysis of prospective observational studies on the effect of short sleep duration on the incidence of general obesity after removal of Hong et al. (Man). Results are ln (relative risks) and 95% confidence intervals

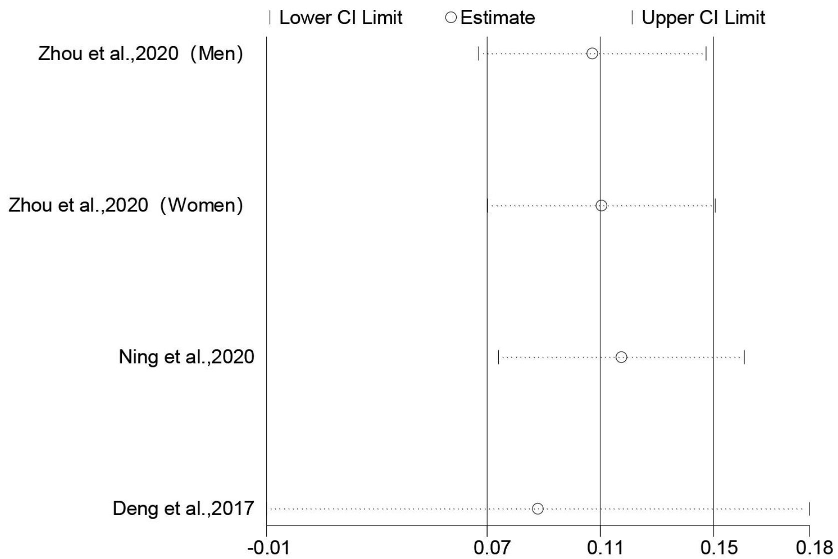


Figure 4. Sensitivity analysis of prospective observational studies on the effect of short sleep duration on the incidence of central obesity. Results are ln (relative risks) and 95% confidence intervals

As this study was aimed at assessing the quantitative association of sleep deprivation and negative effects of general or central obesity prospectively, RRs as a measure of impact were computed using ORs and/or HRs with the corresponding 95% CIs from each study. When no standard error value was available, it was calculated algebraically using the 95% CI of the estimated RR. For $I^2 > 50\%$, we employed the inverse variance method and a random-effects analysis model (Deng, J., Zhou, F., Hou, W., Silver, Z., Wong, C. Y., Chang, O., Huang, E., & Zuo, Q. K., 2021). For $I^2 < 50\%$, we employed the inverse variance method and a fixed-effects analysis model (WHO Rapid Evidence Appraisal for COVID-19 Therapies (REACT) Working Group, Sterne, J., Murthy, S., Diaz, J. V., Slutsky, A. S., Villar, J., Angus, D. C., Annane, D., Azevedo, L., Berwanger, O., Cavalcanti, A. B., Dequin, P. F., Du, B., Emberson, J., Fisher, D., Giraudeau, B., Gordon, A. C., Granholm, A., Green, C., Haynes, R., … Marshall, J. C., 2020). A collective analysis was performed by estimating the collective RR of general or central obesity with the corresponding 95% CI. Asymmetry in the funnel plot was used to identify the publication bias. Considering the small number of data points (< 10) in each dataset, Egger's and Begg's tests were not used to determine the funnel plot symmetry (Begg, C. B., & Mazumdar, M., 1994; Egger, M., Davey Smith, G., Schneider, M., & Minder, C., 1997; Lau, J., Ioannidis, J. P., Terrin, N., Schmid, C. H., & Olkin, I., 2006). Sensitivity tests were used to determine the effect of each study on the meta-analysis as a whole, which removed studies one-by-one to determine the extent to which the findings' inferences depended on one or multiple studies (Figure 2–4). This systematic review and meta-analysis was performed in accordance with the PRISMA 2009 checklist and flow diagram for filtering the literature based on the relevant inclusion and exclusion criteria (Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group, 2009). Statistical analyses were performed using Stata version 14.0.

3. Results

3.1 Study Characteristics

The meta-analysis included four longitudinal studies, with five groups of general obesity and four groups of central obesity (Deng, H. B., et al, 2017; Ning, X., et al, 2020; Zhou, Q., et al, 2020; Hong, X., et al, 2011). Zhou et al. (Zhou, Q., et al, 2020) and Hong et al. (Hong, X., et al, 2011) performed a subgroup analysis by sex. Therefore, we performed a subgroup analysis by sex as well. The overall population comprised a total of 207,219 participants, including 34,877 with general obesity and 184,796 with central obesity, from 11 Chinese provinces. The sample size of the studies varied from 2,837 to 162,121 participants. Information was extracted from the peer-reviewed studies. Zhou et al., Hong et al., and Ning et al. (Ning, X., et al, 2020) provided RRs for general obesity, and Zhou et al., Deng et al. (Deng, H. B., et al, 2017), and Ning et al. provided RRs for central obesity. Meta-analyses were conducted using the incidence of general (five groups from three articles, n = 34,877) or central (four groups from three articles, n = 184,796) obesity as the outcome. Numerous sensitivity tests were provided in the articles to examine the probable discrepancies in estimates caused by using various criteria to determine the result. Table 1 summarizes the studies.

3.2 Study Quality

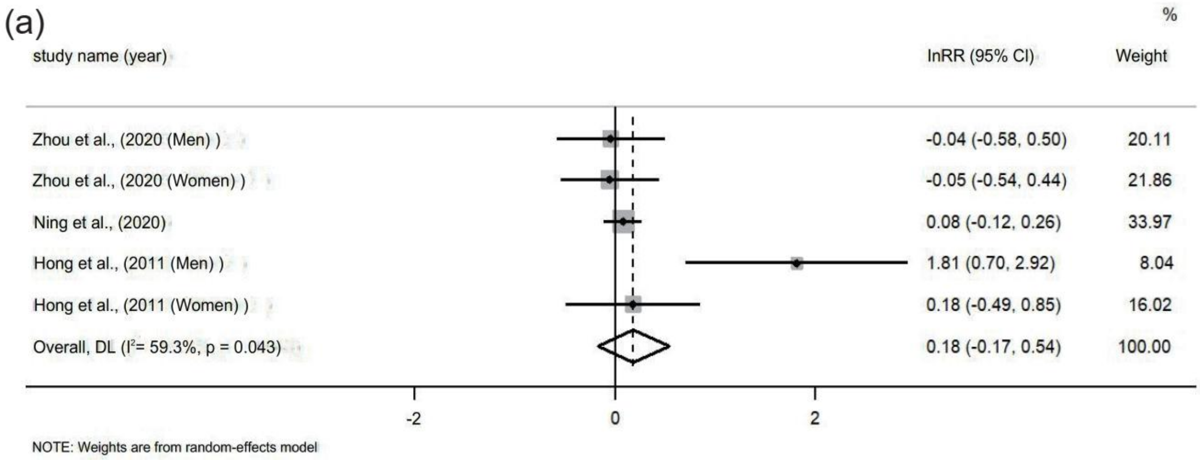
Table 3. Study Quality Assessment

Study/item	Rep.of the exposed cohort	Selection of the non exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	
Zhou et al., 2020	D (0)	A (+1*)	C (0)	A (+1*)	
Ning et al., 2020	A (+1*)	A (+1*)	C (0)	A (+1*)	
Hong et al., 2011	A (+1*)	A (+1*)	C (0)	A (+1*)	
Deng et al., 2017	D (0)	A (+1*)	C (0)	A (+1*)	
Study/item	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow up of cohorts	total
Zhou et al., 2020	A (+2**)	B (+1*)	A (+1*)	B (+1*)	7
Ning et al., 2020	A (+2**)	B (+1*)	A (+1*)	B (+1*)	8
Hong et al., 2011	A (+2**)	B (+1*)	B (0)	B (+1*)	7
Deng et al., 2017	A (+2**)	B (+1*)	B (0)	B (+1*)	6

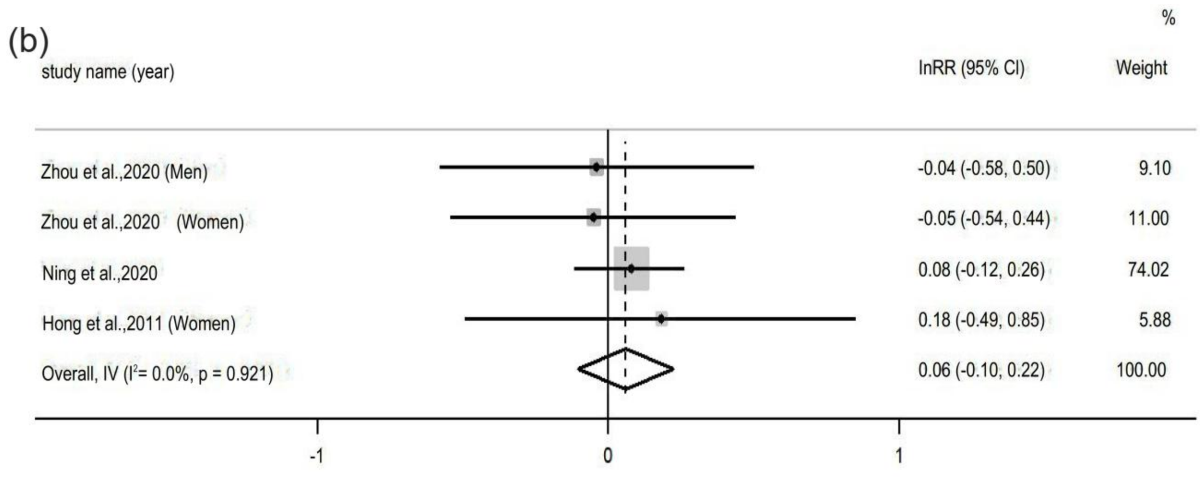
Key: The scoring of each item to the total of the study quality assessment is represented between each parenthesis. For the item “adequacy of follow up of cohorts”, the criteria for scoring “C” (0) was a lost to follow up of 30% of the participants of the cohort.

The average Newcastle–Ottawa Scale score was 7.00 ± 0.5, signifying a moderate to high quality. The question with the lowest percentage in agreement was question no. #3 (Ascertainment of exposure). Table 3 shows the results of the quality assessment.

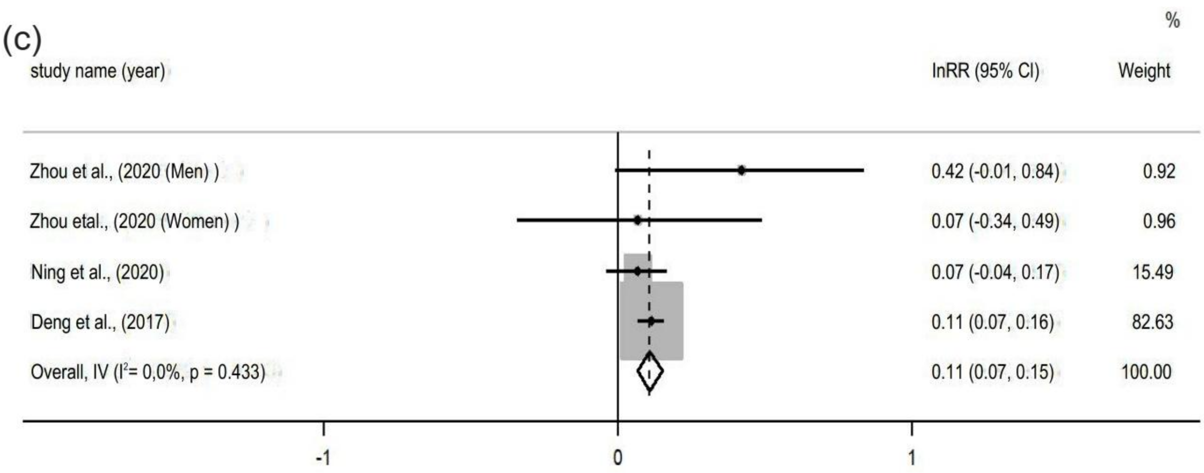
3.2.1 Association of Sleep Deprivation and the Development of Central or General Obesity in Chinese Adults



(a)



(b)



(c)

Figure 5. Forest plot of prospective observational studies on the effect of short sleep duration on the incidence of general obesity (a), general obesity after removal of Hong et al. (Man) (b), and central obesity (c) in Chinese adults. Results are ln (relative risks) and 95% confidence intervals

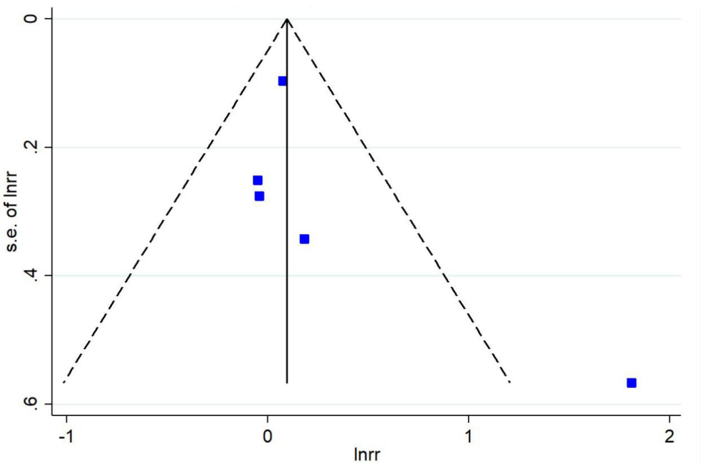


Figure 6. Funnel plot of prospective observational studies on the effect of short sleep duration on the incidence of general obesity

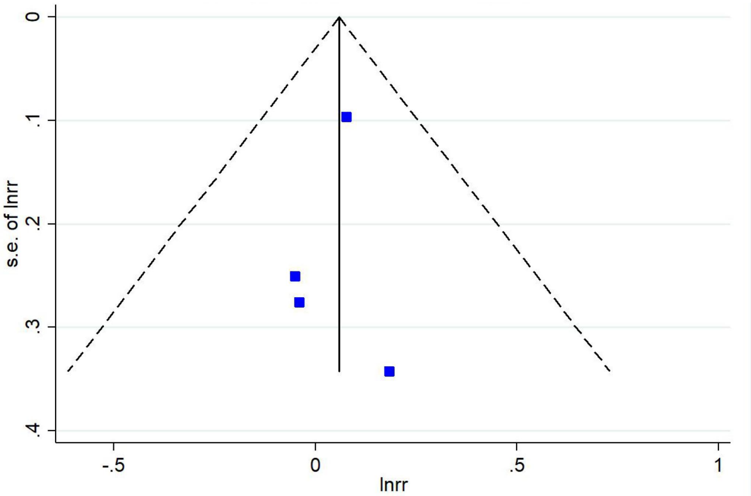


Figure 7. Funnel plot of prospective observational studies on the effect of short sleep duration on the incidence of general obesity after removal of Hong et al. (Man)

Table 4. Incidence of general obesity and Dropout Rates

	exposed	non-exposed	% dropout
Zhou et al., 2020	8.1% females / 6.5%	9.2% females / 8.4%	14.5
Ning et al., 2020	5.4%	5.0%	unclear
Hong et al., 2011	3.8% females / 4.4%	3.2% females / 0.7%	27.9

Figure 5a shows the forest plot of the prospective longitudinal correlations of sleep deprivation and general obesity. The collective analysis showed no significant direct association of sleep deprivation with the incidence of general obesity, with an RR of 1.20 (95% CI: 0.84, 1.71). No significant heterogeneity was observed (I^2 = 59.3%; p = 0.043) (Guo, Y., Miller, M. A., & Cappuccio, F. P., 2021). Table 4 shows the incidence rates. Figure 6 shows the funnel plot. However, the publication bias was not assessed because of the small number of studies (Li, L., Zhang, S., Huang, Y., & Chen, K., 2017). Sensitivity tests showed that variations in the calculated RR ranged from 1.06 to 1.36 and that the calculated heterogeneity ranged from 0% to 69.2%. The maximum value was found after eliminating Hong et al.'s study (women; Figure 2) (Hong, X., Li, J., Liang, Y., Wang, Z., & Li, F., 2011). After eliminating Hong et al.'s study (men), the cumulative RR was 1.06 (95% CI: 0.90, 1.25), and the groups showed significant heterogeneity (I^2 = 0.00%; p = 0.921; Figure 5b). Figure 7 shows the funnel plot. However, because of the small number of studies, the publication bias was not assessed (Li, L., Zhang, S., Huang, Y., & Chen, K., 2017). Sensitivity tests showed that variations in the calculated RR were small, ranging from 1.01 to 1.07, and that the calculated heterogeneity was 0% (Figure 3).

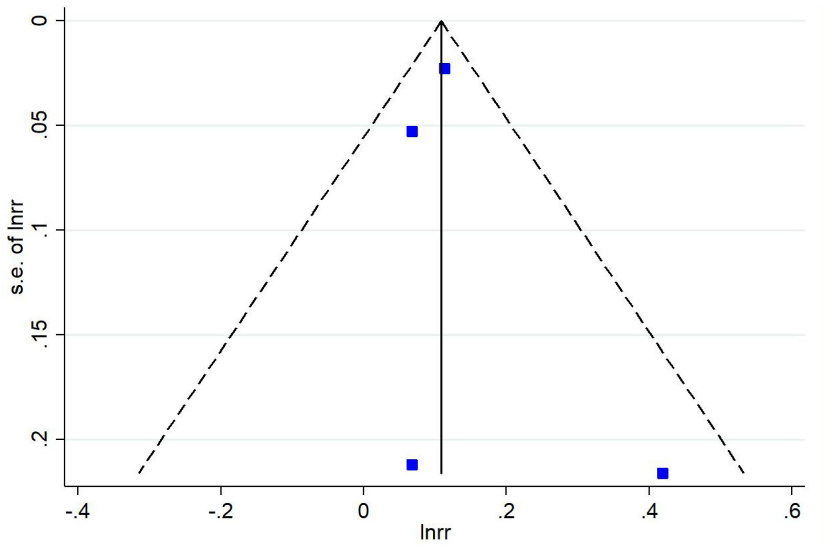


Figure 8. Funnel plot of prospective observational studies on the effect of short sleep duration on the incidence of central obesity

Table 5. Incidence of central obesity and Dropout Rates

	exposed	non-exposed	% dropout
Zhou et al., 2020	37.4% females / 19.2%	36.9% females / 17.4%	14.5
Ning et al., 2020	34.5%	32.5%	unclear
Deng et al., 2017	3.4%	2.5%	unclear

Figure 5c depicts a forest plot of the prospective longitudinal correlations of sleep deprivation and central obesity. The collective RR was 1.12 (95% CI: 1.07, 1.16). No significant heterogeneity was observed (I^2 = 0.00%; p = 0.433). Table 5 shows the incidence rates. Figure 8 shows the funnel plot. However, because of the small number of studies, the publication bias was not assessed (Lau, J., Ioannidis, J. P., Terrin, N., Schmid, C. H., & Olkin, I., 2006). Additional sensitivity tests revealed that the estimated RR ranged from 1.09 to 1.12 and that the estimated heterogeneity was 0% (Figure 4).

4. Discussion

This study was a systematic review and meta-analysis of the longitudinal relationship between sleep deprivation and the prevalence of general or central obesity among Chinese adults. The results showed that sleeping less than the age-appropriate duration increases the chance of developing central obesity in Chinese adults. However, sleeping less than the age-appropriate amount did not affect the likelihood of developing general obesity in Chinese adults.

This study has several strengths. First, this was the first systematic review and meta-analysis involving a prospective cohort of Chinese adults of the prospective relationship between sleep deprivation and the development of general or central obesity. The aggregated data indicated that a short sleep duration was prospectively associated with a 25.3%–26.0% higher likelihood of developing central obesity in men and women in China (Pan, X. F., Wang, L., & Pan, A., 2021). The findings of central obesity in this study are similar to those in previous meta-analyses of cross-sectional cohorts involving western populations but not the Chinese population (Sperry, S. D., Scully, I. D., Gramzow, R. H., & Jorgensen, R. S., 2015). Second, the estimated magnitude of the effect was sufficient to have a significant public health impact if sleep deprivation prevention measures were applied to Chinese citizens. Finally, the analyses revealed no evidence of considerable inter-study heterogeneity.

The overall results indicated that sleep deprivation was not prospectively associated with a higher likelihood of developing general obesity in Chinese adults. Our findings contradict those of previous meta-analyses of prospective cohort studies involving only Western populations and not the Chinese population (Cappuccio, F. P., Taggart, F. M., Kandala, N. B., Currie, A., Peile, E., Stranges, S., & Miller, M. A., 2008; Wu, Y., Zhai, L., & Zhang, D., 2014). However, our results on general obesity are consistent with Chen et al.'s conclusion that sleeping < 6 h every day on average is not associated with general obesity in Chinese postmenopausal women (Chen, J. L., Guo, J., Mao, P., Yang, J., Jiang, S., He, W., Lin, C. X., & Lien, K., 2021). This disparity might be explained by the ethnic composition of the study populations. Further studies are required to identify the mechanisms underlying the phenomenon.

This study has some limitations. First, considering the small number of studies included in the meta-analysis, additional research including more studies is required to corroborate the findings. Second, the quality of data in this study could not be higher than that in the included studies. Third, the generalizability of the results is poor. Fourth, the extent to which confounders were controlled varied among studies, with most studies including sex and age as regulated variables. Nevertheless, we could not adjust confounding variables in the included studies. Fifth, the method of assessing the sleep duration through self-report questionnaires is subject to uncertainty in accuracy and recollection bias. Sixth, we excluded other potent sleep characteristics, such as sleep habits and patterns. They may raise adults' likelihood of developing overweight or obesity (Madrid-Valero, J. J., Martínez-Selva, J. M., & Ordoñana, J. R., 2017) or interact with the quantity in assessing the negative effects. Finally, because of the small number of studies, the possibility of publication bias could not be estimated. While several constraints are unavoidable, findings of this study support the continued development of population fitness policies aimed at protecting sleeping patterns in Chinese people.

Because this meta-analysis included prospective longitudinal studies, causation between sleep deprivation and the development of central obesity in Chinese adults could be established. Nevertheless, we could not elucidate the potential mechanisms underlying this association.

Sleep deprivation affects the body's hormonal reactions and energy equilibrium, resulting in an increase in the orexigenic factor ghrelin, a decrease in the anorexigenic hormone leptin, an increase in appetite, and finally obesity (Spiegel, K., Tasali, E., Penev, P., & Van Cauter, E., 2004; St-Onge M. P., 2013; Buxton, O. M., Pavlova, M., Reid, E. W., Wang, W., Simonson, D. C., & Adler, G. K., 2010). Additionally, sleep deprivation is associated with reduced glucose tolerance (Buxton, O. M., Pavlova, M., Reid, E. W., Wang, W., Simonson, D. C., & Adler, G. K., 2010). Furthermore, sleep deprivation activates inflammatory pathways that might be associated with the development of obesity (Miller, M. A., & Cappuccio, F. P., 2007).

A short sleep duration has been linked to obesity-related behaviors, such as snacking between meals (Ohida, T., Kamal, A. M., Uchiyama, M., Kim, K., Takemura, S., Sone, T., & Ishii, T., 2001). Sleep deprivation improves the processing of hedonic stimuli inside the cerebral cortex, resulting in increased food intake. Additionally, people who lack adequate sleep consume more calories than normal to meet their physiological requirement for wakefulness (St-Onge M. P., 2013; Benedict, C., Brooks, S. J., O'Daly, O. G., Almèn, M. S., Morell, A., Åberg, K., Gingnell, M., Schultes, B., Hallschmid, M., Broman, J. E., Larsson, E. M., & Schiöth, H. B., 2012; Chaput J. P., 2014). Each element outlined above would eventually affect adults' eating habits or calorie consumption, leading to an elevated BMI or increased weight.

Additional factors, such as fatigue and exhaustion, from sleep deprivation may contribute to the prolongation of inactive time and lower energy consumption (Chaput J. P., 2014). Adults who use digital devices excessively develop sleep disruptions and restriction of melatonin secretion (Chang, A. M., Aeschbach, D., Duffy, J. F., & Czeisler, C. A., 2015). Additionally, comorbidities, such as psychological health disorders and long-term conditions, reduce the sleep duration and frequency of physical activities, resulting in decreased energy expenditure and increased weight (Cappuccio, F. P., Taggart, F. M., Kandala, N. B., Currie, A., Peile, E., Stranges, S., & Miller, M. A., 2008; Chaput J. P., 2016).

Studies have established a correlation between sleep deprivation and the development of central obesity throughout an individual's lifespan, along with possible health consequences. The sleep duration should be quantified more accurately and objectively, accounting for sleep quality and additional elements that influence sleep. Simultaneously, studies should examine the impact of psychiatric disorders (Clarke, L., Chisholm, K., Cappuccio, F. P., Tang, N., Miller, M. A., Elahi, F., & Thompson, A. D., 2021) on the sleep duration and the development of obesity, determining if these elements are mediating factors.

5. Conclusions

This systematic review and meta-analysis established an association between sleep deprivation and the development of central obesity in Chinese adults. However, sleep deprivation did not correlate with the development of general obesity in Chinese adults. In the future, intervention studies should focus on establishing techniques to prevent adults from decreasing their normative sleep demand and on boosting sleep duration to lower the risk of developing central obesity. Public health agencies of China should impart health education to adults and encourage them to adopt a healthy lifestyle to decrease obesity rates.

Fund Project

This work was supported by the Shandong University Multidisciplinary Research and Innovation Team of Young Scholars (2020QNQT019). The manuscript was drafted and revised by the authors in accordance with ICJME standards for authorship. The corresponding author had full access to all the data and final responsibility for the decision to submit for publication.

Contributors

H.X. was involved in the design, data collection, analysis, and writing of the manuscript. H.X., S.Y.Z., and F.L. were involved in data collection. H.X., X.X.W., and S.W. were involved in analysis. H.X., Z.H.X., W.S., and C.L. were involved in manuscript revision.

Declaration of Competing Interests

H.X., S.Y.Z., X.X.W., F.L., S.W., Z.H.X., W.S., and C.L. have no relevant conflicts of interest to declare. All authors approved the final version of this manuscript.

Data Availability Statement

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

PROSPERO Registration Number

CRD42021260558

References

Blüher M. (2019). Obesity: global epidemiology and pathogenesis. Nature reviews. *Endocrinology, 15*(5), 288–298. https://doi.org/10.1038/s41574-019-0176-8

Wu Y. (2006). Overweight and obesity in China. *BMJ (Clinical research ed.), 333*(7564), 362–363. https://doi.org/10.1136/bmj.333.7564.362

Visscher, T. L., & Seidell, J. C. (2001). The public health impact of obesity. *Annual Review of Public Health, 22*, 355–375. https://doi.org/10.1146/annurev.publhealth.22.1.355.

World Health Organization, (2000). Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organization technical report series, 894, i–253.

NCD Risk Factor Collaboration (NCD-RisC), (2016). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *Lancet (London, England), 387*(10026), 1377–1396. https://doi.org/10.1016/S0140-6736(16)30054-X.

Finkelstein, E. A., Khavjou, O. A., Thompson, H., Trogdon, J. G., Pan, L., Sherry, B., & Dietz, W. (2012). Obesity and severe obesity forecasts through 2030. *American Journal of Preventive Medicine, 42*(6), 563–570. https://doi.org/10.1016/j.amepre.2011.10.026.

Kelly, T., Yang, W., Chen, C. S., Reynolds, K., & He, J. (2008). Global burden of obesity in 2005 and projections to 2030. *International Journal of Obesity, 32*(9), 1431–1437. https://doi.org/10.1038/ijo.2008.102.

Bhupathiraju, S. N., & Hu, F. B. (2016). Epidemiology of Obesity and Diabetes and Their Cardiovascular Complications. *Circulation Research, 118*(11), 1723–1735. https://doi.org/10.1161/CIRCRESAHA.115.306825.

Gu, D., Reynolds, K., Wu, X., Chen, J., Duan, X., Reynolds, R. F., Whelton, P. K., He, J., & InterASIA Collaborative Group, (2005). Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet (London, England), 365*(9468), 1398–1405. https://doi.org/10.1016/S0140-6736(05)66375-1.

Zhang, X., Zhang, M., Zhao, Z., Huang, Z., Deng, Q., Li, Y., Pan, A., Li, C., Chen, Z., Zhou, M., Yu, C., Stein, A., Jia, P., & Wang, L. (2020). Geographic Variation in Prevalence of Adult Obesity in China: Results From the 2013-2014 National Chronic Disease and Risk Factor Surveillance. *Annals of Internal Medicine, 172*(4), 291–293. https://doi.org/10.7326/M19-0477.

Pan, X. F., Wang, L., & Pan, A. (2021). Epidemiology and determinants of obesity in China. The lancet. *Diabetes & Endocrinology, 9*(6), 373–392. https://doi.org/10.1016/S2213-8587(21)00045-0.

Kohatsu, N. D., Tsai, R., Young, T., Vangilder, R., Burmeister, L. F., Stromquist, A. M., & Merchant, J. A. (2006). Sleep duration and body mass index in a rural population. *Archives of Internal Medicine, 166*(16), 1701–1705. https://doi.org/10.1001/archinte.166.16.1701.

Reutrakul, S., & Van Cauter, E. (2018). Sleep influences on obesity, insulin resistance, and risk of type 2 diabetes. *Metabolism: Clinical and Experimental, 84*, 56–66. https://doi.org/10.1016/j.metabol.2018.02.010

Lu, K., Chen, J., Wu, S., Chen, J., & Hu, D. (2015). Interaction of Sleep Duration and Sleep Quality on Hypertension Prevalence in Adult Chinese Males. *Journal of Epidemiology, 25*(6), 415–422. https://doi.org/10.2188/jea.JE20140139.

Song, Q. F., Liu, X. X., Hu, W. N., Han, X. C., Zhou, W. H., Lu, A. D., Wang, X. Z., & Wu, S. L. (2017). Night Sleep Duration and Risk of Cognitive Impairment in a Chinese Population: A Cross-sectional Study. *Biomedical and Environmental Sciences: BES, 30*(10), 749–757. https://doi.org/10.3967/bes2017.100.

Cappuccio, F. P., Taggart, F. M., Kandala, N. B., Currie, A., Peile, E., Stranges, S., & Miller, M. A. (2008). Meta-analysis of short sleep duration and obesity in children and adults. *Sleep, 31*(5), 619–626. https://doi.org/10.1093/sleep/31.5.619.

Steptoe, A., Peacey, V., & Wardle, J. (2006). Sleep duration and health in young adults. *Archives of Internal Medicine, 166*(16), 1689–1692. https://doi.org/10.1001/archinte.166.16.1689.

Guo, Y., Miller, M. A., & Cappuccio, F. P. (2021). Short duration of sleep and incidence of overweight or obesity in Chinese children and adolescents: A systematic review and meta-analysis of prospective studies. *Nutrition, Metabolism, and Cardiovascular Diseases: NMCD, 31*(2), 363–371. https://doi.org/10.1016/j.numecd.2020.11.001.

Yang, Y., Miao, Q., Zhu, X., Qin, L., Gong, W., Zhang, S., Zhang, Q., Lu, B., Ye, H., & Li, Y. (2020). Sleeping Time, BMI, and Body Fat in Chinese Freshmen and Their Interrelation. *Obesity Facts, 13*(2), 179–190. https://doi.org/10.1159/000506078.

Ohayon, M. M., Carskadon, M. A., Guilleminault, C., & Vitiello, M. V. (2004). Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: developing normative sleep values across the human lifespan. *Sleep, 27*(7), 1255–1273. https://doi.org/10.1093/sleep/27.7.1255.

Wu, W., Tong, Y., Zhao, Q., Yu, G., Wei, X., & Lu, Q. (2015). Coffee consumption and bladder cancer: a meta-analysis of observational studies. *Scientific Reports, 5*, 9051. https://doi.org/10.1038/srep09051.

Deng, J., Zhou, F., Hou, W., Silver, Z., Wong, C. Y., Chang, O., Huang, E., & Zuo, Q. K. (2021). The prevalence of depression, anxiety, and sleep disturbances in COVID-19 patients: a meta-analysis. *Annals of the New York Academy of Sciences, 1486*(1), 90–111. https://doi.org/10.1111/nyas.14506.

WHO Rapid Evidence Appraisal for COVID-19 Therapies (REACT) Working Group, Sterne, J., Murthy, S., Diaz, J. V., Slutsky, A. S., Villar, J., Angus, D. C., Annane, D., Azevedo, L., Berwanger, O., Cavalcanti, A. B., Dequin, P. F., Du, B., Emberson, J., Fisher, D., Giraudeau, B., Gordon, A. C., Granholm, A., Green, C., Haynes, R., … Marshall, J. C. (2020). Association Between Administration of Systemic Corticosteroids and Mortality Among Critically Ill Patients With COVID-19: A Meta-analysis. *JAMA, 324*(13), 1330–1341. https://doi.org/10.1001/jama.2020.17023.

Begg, C. B., & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. *Biometrics, 50*(4), 1088–1101.

Egger, M., Davey Smith, G., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ (Clinical research ed.), 315*(7109), 629–634. https://doi.org/10.1136/bmj.315.7109.629.

Lau, J., Ioannidis, J. P., Terrin, N., Schmid, C. H., & Olkin, I. (2006). The case of the misleading funnel plot. *BMJ (Clinical research ed.), 333*(7568), 597–600. https://doi.org/10.1136/bmj.333.7568.597.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group, (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Medicine, 6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097.

Deng, H. B., Tam, T., Zee, B. C., Chung, R. Y., Su, X., Jin, L., Chan, T. C., Chang, L. Y., Yeoh, E. K., & Lao, X. Q. (2017). Short Sleep Duration Increases Metabolic Impact in Healthy Adults: A Population-Based Cohort Study. *Sleep, 40*(10), 10.1093/sleep/zsx130. https://doi.org/10.1093/sleep/zsx130.

Ning, X., Lv, J., Guo, Y., Bian, Z., Tan, Y., Pei, P., Chen, J., Yan, S., Li, H., Fu, Z., Chen, Y., Du, H., Chen, Z., Yu, C., Li, L., & China Kadoorie Biobank (CKB) Collaborative Group, (2020). Association of Sleep Duration with Weight Gain and General and Central Obesity Risk in Chinese Adults: A Prospective Study. *Obesity (Silver Spring, Md.), 28*(2), 468–474. https://doi.org/10.1002/oby.22713.

Zhou, Q., Wu, X., Zhang, D., Liu, L., Wang, J., Cheng, R., Lin, J., Liu, Y., Sun, X., Yin, Z., Li, H., Zhao, Y., Ren, Y., Liu, D., Chen, X., Liu, F., Cheng, C., Guo, C., Li, Q., Tian, G., … Hu, F. (2020). Age and sex differences in the association between sleep duration and general and abdominal obesity at 6-year follow-up: the rural Chinese cohort study. *Sleep Medicine, 69*, 71–77. https://doi.org/10.1016/j.sleep.2019.12.025.

Hong, X., Li, J., Liang, Y., Wang, Z., & Li, F. (2011). The Relationship between Sleeping Duration and Obesity: A Three-Year Follow-up Study in Nanjing. *Chin J Prev Contr Chron Dis*, (03), 226–230. doi:10.16386/j.cjpccd.issn.1004-6194.2011.03.027.

Li, L., Zhang, S., Huang, Y., & Chen, K. (2017). Sleep duration and obesity in children: A systematic review and meta-analysis of prospective cohort studies. *Journal of Paediatrics and Child Health, 53*(4), 378–385. https://doi.org/10.1111/jpc.13434.

Sperry, S. D., Scully, I. D., Gramzow, R. H., & Jorgensen, R. S. (2015). Sleep Duration and Waist Circumference in Adults: A Meta-Analysis. *Sleep, 38*(8), 1269–1276. https://doi.org/10.5665/sleep.4906.

Wu, Y., Zhai, L., & Zhang, D. (2014). Sleep duration and obesity among adults: a meta-analysis of prospective studies. *Sleep Medicine, 15*(12), 1456–1462. https://doi.org/10.1016/j.sleep.2014.07.018.

Chen, J. L., Guo, J., Mao, P., Yang, J., Jiang, S., He, W., Lin, C. X., & Lien, K. (2021). Are the factors associated with overweight/general obesity and abdominal obesity different depending on menopausal status? *PloS One, 16*(2), e0245150. https://doi.org/10.1371/journal.pone.0245150.

Madrid-Valero, J. J., Martínez-Selva, J. M., & Ordoñana, J. R. (2017). Sleep quality and body mass index: a co-twin study. *Journal of Sleep Research, 26*(4), 461–467. https://doi.org/10.1111/jsr.12493.

Spiegel, K., Tasali, E., Penev, P., & Van Cauter, E. (2004). Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Annals of Internal Medicine, 141*(11), 846–850. https://doi.org/10.7326/0003-4819-141-11-200412070-00008.

St-Onge M. P. (2013). The role of sleep duration in the regulation of energy balance: effects on energy intakes and expenditure. *Journal of Clinical Sleep Medicine: JCSM: official publication of the American Academy of Sleep Medicine, 9*(1), 73–80. https://doi.org/10.5664/jcsm.2348.

Buxton, O. M., Pavlova, M., Reid, E. W., Wang, W., Simonson, D. C., & Adler, G. K. (2010). Sleep restriction for 1 week reduces insulin sensitivity in healthy men. *Diabetes, 59*(9), 2126–2133. https://doi.org/10.2337/db09-0699.

Miller, M. A., & Cappuccio, F. P. (2007). Inflammation, sleep, obesity and cardiovascular disease. *Current Vascular Pharmacology, 5*(2), 93–102. https://doi.org/10.2174/157016107780368280.

Ohida, T., Kamal, A. M., Uchiyama, M., Kim, K., Takemura, S., Sone, T., & Ishii, T. (2001). The influence of lifestyle and health status factors on sleep loss among the Japanese general population. *Sleep, 24*(3), 333–338. https://doi.org/10.1093/sleep/24.3.333.

Benedict, C., Brooks, S. J., O'Daly, O. G., Almèn, M. S., Morell, A., Åberg, K., Gingnell, M., Schultes, B., Hallschmid, M., Broman, J. E., Larsson, E. M., & Schiöth, H. B. (2012). Acute sleep deprivation enhances the brain's response to hedonic food stimuli: an fMRI study. *The Journal of Clinical Endocrinology and Metabolism, 97*(3), E443–E447. https://doi.org/10.1210/jc.2011-2759.

Chaput J. P. (2014). Sleep patterns, diet quality and energy balance. *Physiology & Behavior, 134*, 86–91. https://doi.org/10.1016/j.physbeh.2013.09.006.

Chang, A. M., Aeschbach, D., Duffy, J. F., & Czeisler, C. A. (2015). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proceedings of the National Academy of Sciences of the United States of America, 112*(4), 1232–1237. https://doi.org/10.1073/pnas.1418490112.

Chaput J. P. (2016). Is sleep deprivation a contributor to obesity in children? *Eating and Weight Disorders: EWD, 21*(1), 5–11. https://doi.org/10.1007/s40519-015-0233-9

Clarke, L., Chisholm, K., Cappuccio, F. P., Tang, N., Miller, M. A., Elahi, F., & Thompson, A. D. (2021). Sleep disturbances and the at Risk Mental State: A systematic review and meta-analysis. *Schizophrenia Research, 227*, 81–91. https://doi.org/10.1016/j.schres.2020.06.027.

Zhou, B. F., & Cooperative Meta-Analysis Group of the Working Group on Obesity in China, (2002). Predictive values of body mass index and waist circumference for risk factors of certain related diseases in Chinese adults--study on optimal cut-off points of body mass index and waist circumference in Chinese adults. *Biomedical and Environmental Sciences: BES, 15*(1), 83–96.

Alberti, K. G., Zimmet, P., Shaw, J., & IDF Epidemiology Task Force Consensus Group, (2005). The metabolic syndrome--a new worldwide definition. *Lancet (London, England), 366*(9491), 1059–1062. https://doi.org/10.1016/S0140-6736(05)67402-8.

Chen, C., Lu, F. C., & Department of Disease Control Ministry of Health, PR China, (2004). The guidelines for prevention and control of overweight and obesity in Chinese adults. *Biomedical and Environmental Sciences: BES, 17* Suppl, 1–36.

Zhou, B., & Coorperative Meta-Analysis Group of China Obesity Task Force, (2002). *Chinese Journal of Epidemiology, 23*(1), 5–10.

Alberti, K. G., Eckel, R. H., Grundy, S. M., Zimmet, P. Z., Cleeman, J. I., Donato, K. A., Fruchart, J. C., James, W. P., Loria, C. M., Smith, S. C., Jr, International Diabetes Federation Task Force on Epidemiology and Prevention, Hational Heart, Lung, and Blood Institute, American Heart Association, World Heart Federation, International Atherosclerosis Society, & International Association for the Study of Obesity, (2009). Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation, 120*(16), 1640–1645. https://doi.org/10.1161/CIRCULATIONAHA.109.192644.