

Research Article

Sleep Duration Related to its Effect on Blood Pressure, Blood Glucose and BMI- A Systematic Review and Meta-Analysis

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Abstract

Objective: Sleep quality and its relation with optimal health is still controversial. So, The aim was to examine and gain insight into sleep duration and its impact on blood pressure, body mass index and blood glucose in adults.

Methods: No RCTs were found between 1997 to 2019. A systematic review was then performed using cohort and cross-sectional studies including quantitative and qualitative data.

Results: A total of 186921 patients from 19 eligible studies were included. Significant findings were seen for patients who slept <8 hours in association with hypertension (OR 0.88; 95% CI 0.86-0.91) as well as, obesity (OR 0.78; 95% CI 0.73-0.84). No significant difference was noted regarding sleep duration and impaired blood glucose.

Conclusions: There is possibly a link between shorter hours of sleep (<8 hours a night) and the development of hypertension and obesity but not impaired glucose tolerance. Further research must be conducted with consistently reproducible methods and results in order to definitively conclude causation.

Keywords: Sleep duration; Blood pressure; Blood glucose; Adults; Obesity.

Introduction

Sleep and its contribution to optimal health and well being have been the focus of clinical research for many decades but still, there is a lack of consensus on sleep quality and its duration. There is, however, satisfactory evidence that highlights the relationship between poor sleep and its impact on humans identifying the significant risk for developing hypertension, increased blood glucose and obesity [1]. Sleep arrears affect carbohydrate metabolism and endocrine function negatively, similar to that seen in normal ageing but with an increase in severity [2]. Using the benchmark of 8 hours of daily sleep the objective of this review is to relate the results of less than 8 hours of sleep with an increase in hypertension, blood glucose, and body mass index [3]. We hope that the results would support the insight into the duration of sleep and its role in changing the morbidity and mortality associated with the global epidemic of hypertension, diabetes mellitus, and obesity.

Methods

Summary of Methods

A systematic review of the existing English literature was performed followed by meta-analysis to study the association between lack of adequate sleep in adults and the risk of having higher blood pressure, blood sugar and BMI. This was done in concordance with the methods outlined by the Cochrane Handbook for Systematic Reviews of Interventions [4].

Literature Search

A literature search was done for published articles in the English language in PubMed, Medline, Cochrane, EMBASE and Google Scholar databases. The literature search included the following keywords: "Sleep duration" or "Lack of sleep" or "Effect of sleep duration" in association with "HTN" or "high blood pressure" or "obesity" or "high BMI" or "high blood sugar"

or “Diabetes mellitus” or “sleep loss” or “adult sleep disorders”.

Selection of studies

All initially screened articles were entered in an excel sheet database. Six reviewers screened the title and abstract and full texts separately following inclusion and exclusion criteria. The studies that were included had to mention an effect or association of the duration of sleep in adults to two three variables mentioned above even if this was a secondary outcome in the study. The studies were randomly assigned to the reviewers and the studies were classified as “Include”, “Exclude” or “Unsure”. A third reviewer settled discrepancies.

Eligibility Criteria

Inclusion criteria

Study type: Randomized control trials, cohort and cross-sectional studies were included (no RCT was found). The studies were included if it mentioned sleep duration in hours and if it showed an effect or association with any of the three variables of interest (blood pressure, blood sugar, and BMI).

Population: Studies including adults (age 18 years or older). Some patients had sleep apnea. No further sleep disorder or psychiatric disorders were included.

Intervention and comparison related: Intervention and comparison were adults who slept less than 8 hours of sleep (this number was approximated depending on the study data) and adults who slept 8 hours or more.

Reported information (outcomes): Studies that included data on three outcome variables: high blood pressure (or HTN), high blood sugar (or DM) and high BMI (overweight or obesity) were included. Obesity was defined as a body mass index (BMI) ≥ 30 kg/m² for men as well as for women [5]. Overweight was a BMI > 25 kg/m² [5]. HTN was defined as a diagnosis of systolic blood pressure ≥ 140 mm Hg, or diastolic blood pressure ≥ 90 mm Hg [6]. Hyperglycaemia was defined as a diagnosis of DM (Diabetes mellitus), or capillary blood sugar ≥ 126 mg/dL if ≥ 8 h after the last meal; or capillary blood sugar ≥ 200 mg/dL if < 8 h after the last meal [7]. Impaired glucose tolerance was defined as capillary blood sugar ≥ 140 mg/dL, 2 hours post glucose challenge.

Exclusion criteria

Non-original studies, structured abstracts, studies with unobtainable full text, case reports, case series, and commentary were excluded. Studies that included population less than 18 years old and people with psychiatric illnesses were also excluded. In addition, excluded studies were those that didn't show a correlation of sleep duration to the three variables of interest or studies without

a specified number of hours. Studies that defined obesity by waist girth rather than BMI were also excluded.

Full-text screening

After reviewing the title and abstract by two reviewers independently, and a third reviewer to settle discrepancies if needed, the full text was reviewed further to ascertain eligibility and extract data.

Data extraction and management

Studies meeting the inclusion criteria were included for data extraction. A data extraction form was developed using Excel sheet and the following data were extracted from the full-text article: first author name, year of publication, journal name, hours of sleep reported, study population age and gender, number of people with the reported variables of interest (BMI, blood pressure and blood glucose), the total number of participants, the type of the study and the country in which the study was done.

Data Analysis (Quantitative and Narrative synthesis)

Each reviewer was assigned a specific number of journal articles to extract data. Both quantitative (means and odds ratios) and narrative data were extracted using two Excel sheets. The Excel sheets captured study findings in narrative form. The same variables were used: author's name, year of publication, journal name, hours of sleep reported, study population age, gender and the number of people with the reported variables of interest (BMI, blood pressure and blood glucose), the total number of participants and the type of the study conducted.

Review Manager Software (RevMan 5.3) [8] was used to conduct the analyses. For this review, the effect estimates were calculated odds ratio (OR) for dichotomous outcomes. Findings from studies that reported no data or OR were reported narratively. The I² statistic was reported as a measure of inconsistency. Heterogeneity was assessed by visual inspection of a forest plot along with consideration of the chi-squared test and the I² statistic. We interpreted the I² estimate as “might not be important” (0% to 40%), “moderate” (30% to 60%), “substantial” (50% to 90%) or “considerable” (75% to 100%) as recommended in the Cochrane Handbook for Systematic Reviews of Interventions [4].

Assessment of methodological quality of included studies

For observational studies (non-RCTs), the ROBINS-I (Risk Of Bias In Non-randomized Studies - of Interventions) criteria were used to assess the risk of bias in six fields: 1) Confounding factors, 2) Sampling, 3) Classification of intervention, 4) Bias due to missing data, 5) Bias in the measurement of outcomes, and 6) Bias in the selection of the reported results [9] as seen in Figures 1 and 2 below.

Study	Risk of bias domains							Overall
	D1	D2	D3	D4	D5	D6	D7	
Aziz et al (2017)	-	-	+	+	+	+	+	-
Brocato et al (2015)	+	-	-	+	-	+	-	-
Fang et al (2012)	-	+	+	-	+	-	-	-
Gangwisch et al (2005)	-	X	X	+	!	+	-	!
Gottlieb et al (2005)	-	-	+	+	X	-	X	X
Gottlieb, Redline, Neito et al (2006)	+	+	+	+	-	+	+	-
Guo et al (2016)	-	+	+	+	+	-	+	-
Hart et al (USA 2013)	X	+	X	X	+	X	+	!
Hasler et al (2004)	-	+	+	+	-	+	-	-
Hwang et al (2015)	!	!	-	X	!	-	X	!
Kawabe et al (2008)	-	X	-	+	-	-	X	X
Ko et al (2007)	+	+	-	+	+	+	-	-
Lauderdale et al (2009)	+	+	+	+	-	-	-	-
Li et al (2019)	-	+	+	+	+	+	-	-
Lin et al (2016)	+	+	+	+	+	+	-	-
Najafian et al (2018)	+	+	+	+	+	+	-	-
Sepahvand et al (2014)	+	+	+	+	+	+	+	+
Shulman et al (2018)	-	-	-	-	-	X	!	!
Song MY et al (2016)	-	-	+	+	X	+	X	X

Domains:
D1: Bias due to confounding.
D2: Bias due to selection of participants.
D3: Bias in classification of interventions.
D4: Bias due to deviations from intended interventions.
D5: Bias due to missing data.
D6: Bias in measurement of outcomes.
D7: Bias in selection of the reported result.

Judgement
! Critical
X Serious
+ Moderate
- Low

Figure 1: Risk of bias visualization tool traffic light plot [10].

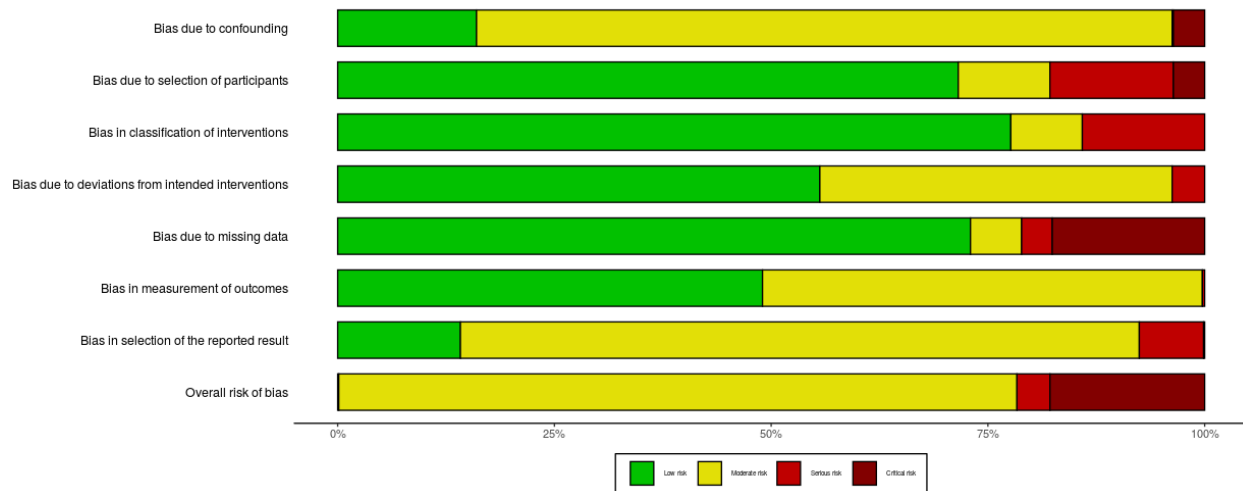


Figure 2: Risk of bias visualization tool weighted bar plot [10].

Results

The search yielded 84 results and 65 were excluded after title/abstract and full text screening (Figure 3). 19 studies were eligible for data abstraction. No RCT, 5 cohort studies and 13 cross sectional surveys were included.

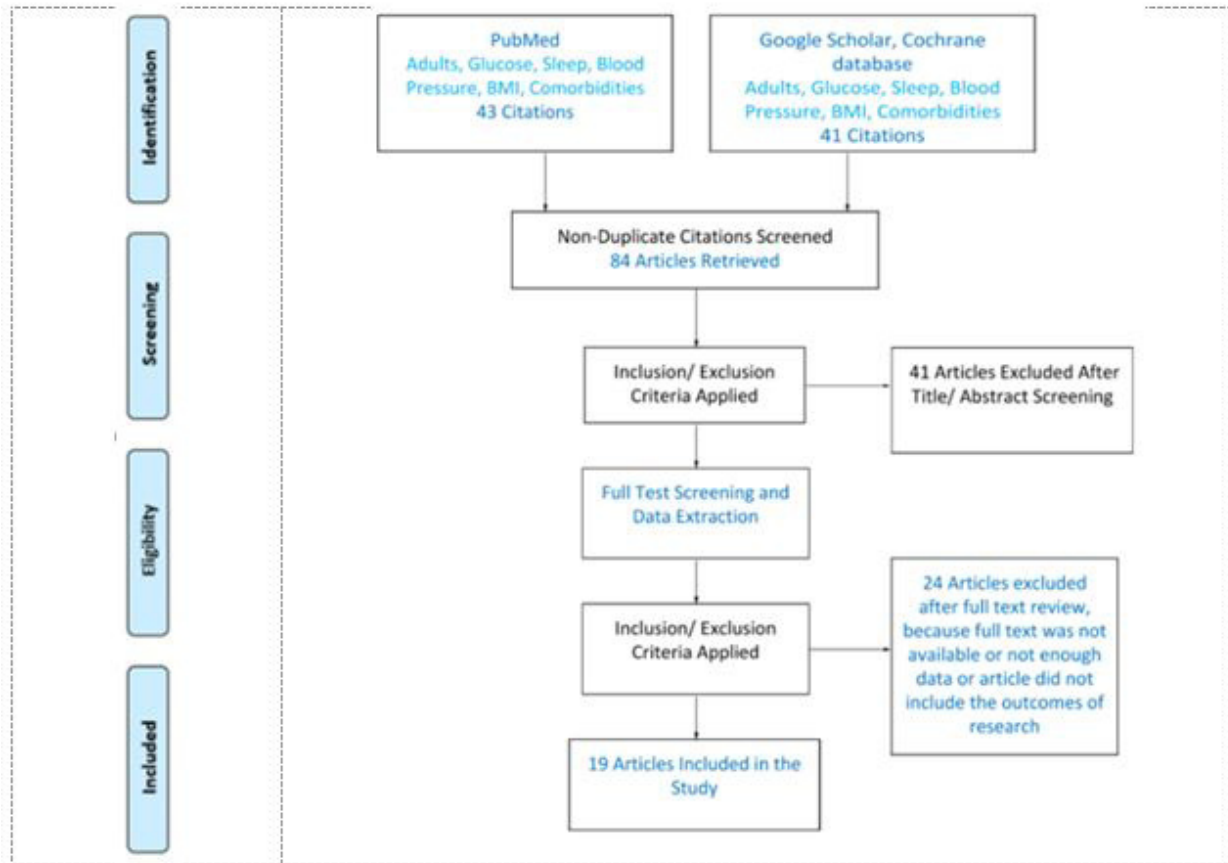


Figure 3: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram.

Quantitative data were extracted from studies (n=6) that outlined the number of participants who developed hypertension, diabetes/ glucose intolerance and changes in body mass index as a percentage of the total study population. Table 1 Shows the relation to sleep duration, three studies examined cases of hypertension (HTN), two studies gave data on diabetes/glucose intolerance and three studies submitted numbers for participants who fell into the obese category (BMI >30 kg/m²). The total number of participants were 115720, aged between 18 to 83 years old. Included studies were from the USA, China, Korea and Saudi Arabia. Figures 4-6 show the forest plots that represent data comparing <8 hours sleep to ≥8 hours sleep.

Reference	Type of Study	# of participants (n)	Age in yrs	Hrs of sleep	HTN	DM / glucose intolerance/ hyperglycemia	Obesity >30 kg/m ² BMI	Overweight >25 kg/m ² BMI
[13]	Cross sectional	9086	45-60 >65	< 8	2648 (29.14%)			
				≥8	1137 (12.51%)			

[9]	Cross sectional	71455	18-44, 45-64, >65	<8	10796 (15.11%)			
				≥8	8233 (11.52%)			
[17]	Cross sectional	6365	>18	<8			1127 (17.71%)	
				≥8			437 (6.87%)	
[11]	Cross sectional	1486	53-93	<8		225 (15%)		
				≥8		504 (33.92%)		
[5]	Cohort	2686	24-45 ≤24, ≥45	<8	165 (6.14%)	148 (5.51%)	239 (8.89%)	
				≥8	619 (23.05%)	495 (18.43%)	725 (26.99%)	
[10]	Cross sectional and Longitudinal analyses	9,588 for the cross-sectional analyses 8,073 for the 1987, 6,981 for the 1992 longitudinal analyses	34-83	<8			1109 (11.57%)	2053 (21.4%)
				≥8			1392 (14.51%)	764 (7.96%)

Obesity was a (BMI) ≥30 kg/m² for men as well as for women. Overweight was a BMI >25 kg/m². HTN (hypertension) was defined as a diagnosis of systolic blood pressure ≥140 mm Hg, or diastolic blood pressure ≥90 mm Hg. Hyperglycaemia was defined as a capillary blood sugar ≥126 mg/dL if ≥8 h after the last meal, or capillary blood sugar ≥140 mg/dL if <8 h after the last meal. Impaired glucose tolerance was defined as capillary blood sugar ≥140 mg/dL, 2 hours post glucose challenge. % expressed as a fraction of total population.

Table 1: Sleep Duration and its relation to impaired glucose tolerance, hypertension and elevated BMI.

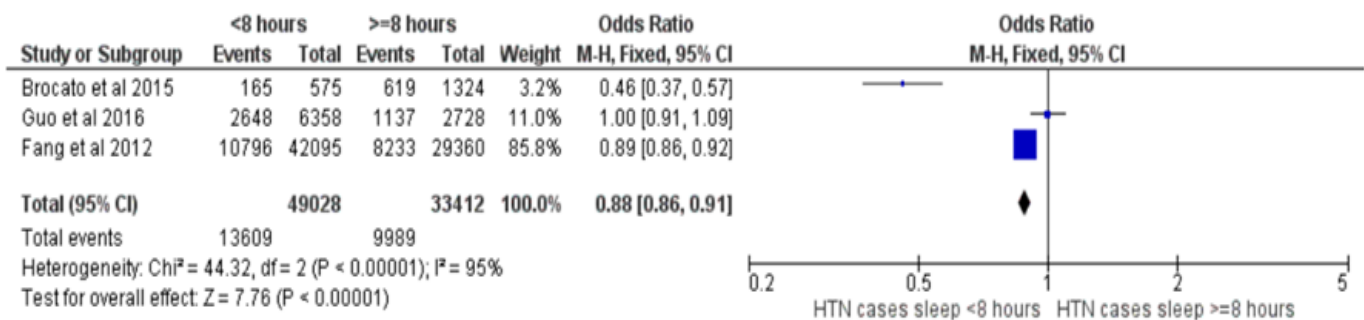


Figure 4: Forest plot showing patients who were diagnosed with hypertension and the relation to their duration of sleep.

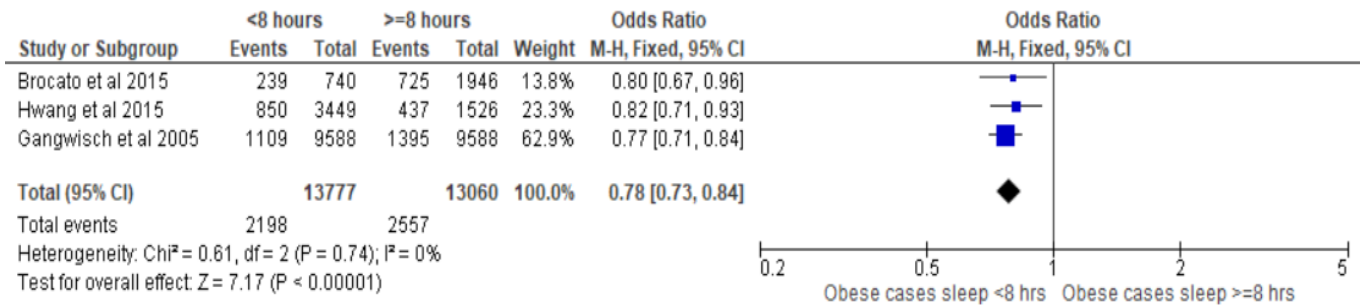


Figure 5: Forest plot showing patients who fell into the category of obese in relation to their sleep duration.

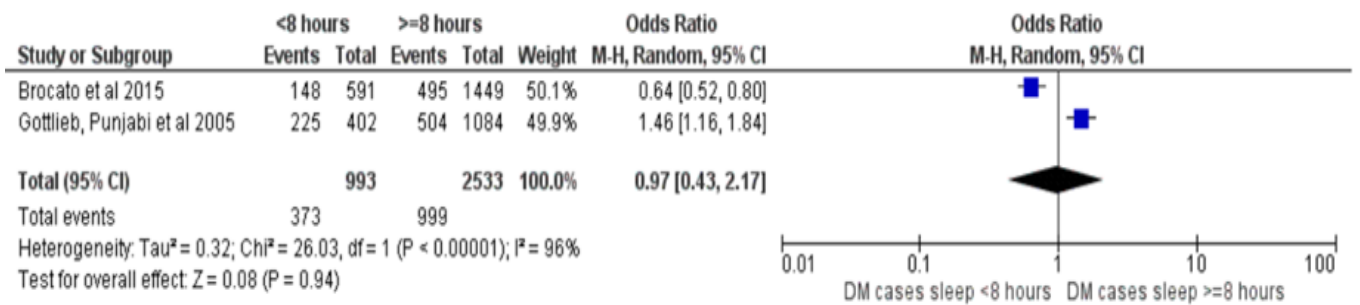


Figure 6: Forest plot showing patients who fell into the category of DM/glucose intolerance in relation to their sleep duration.

The rest of the studies (n=16) was recorded in a narrative summary table (Table 2). Seven studies had hypertension as an outcome, five reported BMI, two on diabetes, one examined both HTN and BMI and one on all 3 outcomes. The total number of participants for these studies was 71201 but it must be taken into consideration that information from two of those articles [11,12] are present in both tables. Brocato, et al. was the only study that addressed 3 outcomes [11]. Regarding Hwang, et al. Table 1 reflects the obese cases those authors reported and Table 2 shows their conclusions on hypertension [12].

Reference	# of pts	Mean age (yrs)	Study design	Outcome studied	Statistical analysis	Conclusion
[25]	12492	38.89 +/- 14.93	Cross sectional	HTN	Multiple logistic regression	<ol style="list-style-type: none"> Sleep < 5 hrs/day was linked to a higher risk for HTN (OR = 2.52, 95% CI: 2.17-2.93) Sleep duration of ≥9 hrs was linked to a decrease in risk for HTN (OR = 0.71, 95% CI: 0.56-0.89) Sleep <5 hrs (OR = 1.67, 95% CI: 1.29-2.16) or 6-8 hrs (OR = 1.28, 95% CI: 1.02-1.59) was linked to higher odds for HTN among women < 60 years old
[22]	19407	47.07 +/-13.40	Cross sectional	HTN	χ ² tests Univariate and multivariate logistic regressions	<ol style="list-style-type: none"> Sleep < 7 hrs/day was linked to an increased risk of HTN adults (18-44 years old) (OR = 1.24, 95% CI: 1.05-1.46) Sleep duration and HTN in adults (4579 years old) showed no significant association
[33]	4748	35.5	Cross sectional	HTN	T-tests, ANOVA or χ ² test Multiple logistic regression analysis	<ol style="list-style-type: none"> Sleep < 6 hr/day (after controlling confounders) was linked to an increased odds for HTN (OR = 1.79; 95% CI 1.05-3.03) in comparison to patients who slept for 6-8 hrs/day.

[17]	6365	44.0 +/- 0.3	Cross sectional	HTN	Pearson's chi-square test Linear regression analysis Logistic regression analysis	<ol style="list-style-type: none"> 1. Sleep ≤ 5 hrs/day was linked to a higher systolic and diastolic pressure. 2. Sleep ≤ 5 hrs/day had a higher rate of HTN according to JNC 7 guidelines (OR = 1.864, 95% CI = 1.446-2.403). 3. Sleep ≤ 5 hrs/day had a higher rate of HTN according to JNC 8 guidelines (OR = 1.908, 95% CI = 1.483-2.456).
[18]	478	39.0	Cohort	HTN	Paired t-test, χ^2 test	<ol style="list-style-type: none"> 1. Sleep < 7 hours showed higher morning systolic blood pressure and heart rate compared with days with sleep between 7 and 8 hours, but no difference was found in diastolic blood pressure. (p<0.01).
[12]	5910	63.1 +/- 10.7	Cross sectional	HTN	χ^2 test, ANOVA, logistic regression	<ol style="list-style-type: none"> 2. Sleep <6hrs/night linked with an increased risk of HTN (OR = 1.66, (95% CI 1.35-2.04). 3. Sleep 8-9 hrs/night and >9 hrs/night linked with an increased risk of HTN, (OR = 1.19, 95% CI 1.04-1.37) and (OR = 1.30, 95% CI 1.04-1.62), respectively.
[32]	219	PISA: 52 +/- 7 (for \leq and ≥ 7 hrs sleep) LIMBS: 50 +/- 13 (≤ 7 hrs) 49 +/- 11 (≥ 7 hrs)	Cohort	HTN	t-test, χ^2 test, linear regression	<ol style="list-style-type: none"> 1. Sleep <7 hrs/day linked to a higher 24 mean SBP for both the PISA and LIMBS studies
[3]	9505	42.80 +/- 12.1	Cross sectional	BMI	Regression analyses	<ol style="list-style-type: none"> 1. Sleep < 6 hr/day had nearly twice the odds of morbid obesity (BMI ≥ 35 kg/m²) compared to those who slept 6–7.9 hrs (OR = 1.8; 95% CI 1.5–2.2).
[14]	250	21.9 +/- 2.2	Cross sectional	BMI	Pearson correlation, ANOVA, linear regression	<ol style="list-style-type: none"> 1. Sleep ≤ 6 hrs/day on work/school days is linked to a higher BMIs in young adults (18-25 years old).
[15]	496	32.5	Cohort	BMI	χ^2 and t tests, simple linear regression, random regression	<ol style="list-style-type: none"> 1. Sleep <6 hrs/day was linked to obesity in 27, 29, 34 year olds with an OR 8.2 (CI 1.9-36.3), OR 4.6 (CI 1.3-16.5) and OR 3.5 (CI 1.0-12.2) respectively. 2. Association not shown in 40 year olds.
[20]	4793	42.4 +/- 8.9	Cross sectional	BMI	t-test, χ^2 test, ANOVA, ANCOVA (ANOVA with covariates), multiple linear regression	<ol style="list-style-type: none"> 1. Sleep <6 hrs/day and working hours >9 hrs/day were associated with an increased BMI

[21]	612	45.2 +/- 3.6	Cohort	BMI	Linear regression	2. Shorter sleep duration (<6.1 hrs/day on average) and higher BMI were linked. However, this finding is not consistent over the course of 5 years.
[31]	221	61.27	Cross sectional	HTN BMI	Fisher's exact test	1. Sleep <5 hrs/night or >9 hrs/night were more likely to have hypertension compared to patients that slept 7-8 hours.
[5]	2686	not stated	Cohort	HTN BMI DM	χ^2 tests Linear regression	3. Sleep >8 hrs/day were found to be associated with all three outcomes: obesity, hypertension and hyperglycemia (controlling for nutrition or physical activity) OR for obesity, hypertension and hyperglycaemia was 1.54 (95% CI 1.20 to 1.98), 1.89 (95% CI 1.45 to 2.48) and 1.59 (95% CI 1.19 to 2.13) respectively. 4. Sleep <7hrs/day slight increase in risk for obesity (OR 1.09; 95% CI 0.77 to 1.53) and a decrease in risk for HTN (OR 0.77; 95% CI 0.53 to 1.14) and hyperglycaemia (OR 0.89; 95% CI 0.59 to 1.35). This was not statistically significant.
[23]	1533	not stated	Cross sectional	DM	ANOVA, Scheffe's test, χ^2 test, logistic regression model	1. Sleep \leq 5 hrs/day associated with a 5.24-fold risk of diabetes and this correlation was particularly strong in young adults (19-44 years old) (95%CI 1.17-23.47).
[11]	1,486	70.2 +/- 8.5	Cross sectional	DM	ANOVA or contingency table analysis	1. Sleep \leq 5 hrs/night was shown to be linked to an increase in odds of DM and IGT (OR 2.51, 95% CI 1.57-4.02). 2. Sleep =6 hrs/night was shown to have an OR for DM/IGT of 1.66 (95% CI, 1.15-2.39).

Table 2: Narrative synthesis table showing the relation of sleep duration to the outcomes: HTN, BMI and glucose intolerance.

Discussion

Sleep quality is invariably tied into multiple aspects of one's health. From memory retention to mood stabilization, insulin resistance to blood pressure regulation, a good night's sleep is recommended to maintain homeostasis within the human body. But what exactly is a "good" night's sleep? It is not clearly defined by any known guideline. There are many theories and expert opinions about the topic, but the fact is that with age, our body's requirements for sleep vary. The National Institute of Neurological Disorders and Stroke suggest that most adults need 7 to 9 hours at night until the age of 60 where sleep duration may be reduced [30]. This systematic review aims to take a few aspects of health (blood pressure, blood glucose and body mass index) and examine their relationship with sleep duration in adults over 18 years old.

Due to the nature of the subject being studied, much of the evidence is taken from cohort and cross-sectional studies.

Since sleep deprivation is detrimental to the human body, it would be unethical to subject a participant to poor quality sleep intentionally. Most of the data in this systematic review, therefore, stemmed from self-reported surveys. Fang, et al., Najafian, Nouri & Mohammadifard and Li, et al. were among the largest cross-sectional reports that were included, with over 10000 participants in each study [14,17,18]. All 3 papers investigated sleep duration and hypertension. We found that while most studies in our search collected data on hypertension, Body Mass Index (BMI) and diabetes, the figures were just a part of the population characteristics table and not necessarily the primary aim of the study to examine the relationship to sleep duration for all 3 outcomes.

The intrinsic flaw is that all the studies mentioned were not designed in the same way. Nor did they uniformly report their findings. This makes it difficult to compare and contrast their discoveries. Therefore, we constructed two tables to help display in an organized fashion the varying results.

The quantitative table (Table 1) summarizes the results of 6 selected studies. Although the systematic review was determined to find the association of sleep duration with all 3 entities of obesity, hypertension and diabetes mellitus there was considerable heterogeneity across the selected studies regarding age of the population, data analysis, comparators and thus study conclusions. This is shown in the forest plots where I^2 was greater than 50%. One out of six studies delivered all three associations with sleep hours [11]. Five studies reported just one association [hypertension: Fang, et al. [14] and Guo, et al. [13]; obesity/overweight: Gangwisch, et al. [16], and Hwang, et al. [12]; diabetes mellitus: Gottlieb, et al. [15].

The commonest association of less than 8-hour sleep duration was found to be with obesity (BMI >30 kg/m²) occurring in 3 out of 6 studies with the highest percentage of 17.71% found in Hwang et al total population of 6365 [12]. Conversely Brocato, et al. [11] showed that more than 8 hours of sleep had a higher percentage of obese patients (26.99%) out of 2686 participants in comparison to 8.89% in the less than 8 hours sleep category. Figure 5 shows obese cases related to sleep duration. The combined result is statistically significant favouring <8 hours sleep increasing the odds of a BMI >30 kg/m².

The strongest association of hypertension with less than 8 hours of sleep was found in 3 out of 6 studies with the highest percentage of 29.14% in 9086 participants in Guo, et al. [13] Similar to the trend with BMI, in the category of more than eight hours sleep 23.05% out of 2646 population in Brocato, et al. [11] developed hypertension. In the largest study with 71,455 participants in Fang, et al. [14] the percentage of hypertensive cases associated with the greater than 8 hours of sleep group were comparable at 15.11% and 11.52% respectively. Due to the proportion of new events, in a weighted forest plot (Figure 4), there seemed to be a statistical significance that favours a longer sleep duration (>8 hours) as a possible protective factor for hypertension.

Finally, diabetic/hyperglycaemic association with less than 8 hours of sleep was found in 2 out of 6 studies. Interestingly, both Gottlieb, et al. [15] and Brocato, et al. [11] had a higher percentage of their population developing diabetes with greater than 8 hours of sleep (33.92% and 18.43% respectively) compared to the group that slept less than 8 hours. The forest plot in Figure 6 demonstrates though, a lack of statistical significance for this finding.

In Table 2 we extracted the odds ratios as a way of reporting the most relevant findings. 7 studies addressed sleep and hypertension. The general trend is that sleep that lasts less than 5 to 7 hours a day leads to an increased odds of developing hypertension. Li, et al. [18] showed an Odds Ratio (OR) of 1.24 (95% CI: 1.05-1.46) only for patients aged 18 to 44 years old with less than 7 hours of sleep a day. Najafian, Nouri & Mohammadifard [17] quoted an OR of 2.52 (95% CI: 2.17-2.93) for less than 5 hours of sleep a day. This finding

was especially seen in women less than 60 years old [(OR=1.67, 95% CI: 1.29-2.16) for less than 5 hours sleep; (OR=1.28, 95% CI: 1.02-1.59) for 6-8 hours sleep]. Song, et al. [19] concluded that there was an increase in the odds of hypertension with less than 6 hours of sleep a day (OR=1.79; 95% CI: 1.05-3.03) after controlling for confounding factors (education, income, smoking, alcohol intake and physical activity). This study, however, targeted only pre-menopausal women in Korea who were not considered obese.

Notably, Gottlieb, et al. [21] found an increased odds for hypertension with less than 7 hours of sleep (OR=1.19, 95% CI: 1.02-1.39) as well as, 8-9 hours a night (OR=1.19, 95% CI: 1.04-1.37) and greater than 9 hours a night (OR=1.30, 95% CI: 1.04-1.62). These participants were initially part of a cohort study on cardiovascular outcomes of obstructive sleep apnea/hypopnea. This underlying comorbidity predisposes a person to disrupted or poor quality sleep so the authors adjusted for the apnea/hypopnea index as well as gender, ethnicity, age and BMI. This adjustment resulted in a decreased odds ratio across the board for all sleep duration categories in this study (<6, 6-7, 8-9 and >9 hours of sleep a day) in comparison with the unadjusted model.

Five studies in the narrative synthesis table dealt with BMI. Three of which were based in the United States of America (USA) [23,24,27]. The Centers for Disease Control and Prevention (CDC) state that the prevalence of obesity in the USA in 2016 was 39.8%, especially affecting the ethnic group, Hispanics [31]. Aziz, et al. [23] investigated the sleep duration of participants in relation to morbid obesity (BMI >35 kg/m²). 55% of the subjects were Hispanic. The authors found that for <6 hours of sleep the odds of morbid obesity were 1.8 (95% CI 1.5-2.2) but this result might have been skewed due to the ethnicity of the population that was investigated. Similarly, Hart, et al. [24] and Lauderdale, et al. [27] linked <6 hours sleep with an elevated BMI. In the former study [24], which was done as an online survey, 74% of the subjects were non-Hispanic. The disadvantage of the survey was that 13% of subjects had missing data. In the latter study [27] participants were taken from an existing ongoing cohort for the Coronary Artery Risk Development in Young Adults (CARDIA) study. These authors utilized a non-invasive wrist activity monitor in addition to the person's sleep log and predetermined activity score in order to denote sleep duration. This method however was dependent on the participant accurately starting and ending their sleep time.

Statistics from Iran have shown that the prevalence of obesity is on the rise. In 2015, it was estimated to be 21.7% for people above 18 years old [32]. Sepahvand, et al. [28] looked at both hypertension and BMI in Iranian subjects linking it with sleep duration. They detected that participants in both extremes (<5 hours and >9 hours of sleep) were more likely to develop hypertension.

They stated that there was a significant link to BMI but it was not well elaborated upon in their discussion.

Two cross sectional studies looked at the association of sleep with diabetes. The Taiwanese study Lin, et al. [29] detected a 5.24-fold risk of diabetes for people 19-44 years old who slept <5 hours a day. In addition, Gottlieb, et al. [15] recorded an odds of 2.51 (95% CI: 1.57-4.02) for participants who slept \leq 5 hours a night.

The comment must be made that all 3 outcomes (hypertension, glucose intolerance and BMI) are not only affected by sleep duration but in turn, they impact one another. Truncal obesity for instance, is tied to insulin resistance [33]. Diabetes accelerates vascular inflammatory processes and the resulting endothelial dysfunction manifests as hypertension [34]. Not to mention, ethnicity and nutrition further complicate the relationship. In isolation, it may be difficult to conclude that sleep deprivation leads to one outcome over the other. Though the sleep hours have definitive health value as evidently reported, the insight into these indicators is pending since sleep itself is a very complex and dynamic phenomenon [35,36].

We conclude that there is at least a possible link between shorter hours of sleep and the development of hypertension and obesity. There was no statistically significant association between sleep duration and impaired glucose tolerance thus far. If further research is done to explore the association of sleep duration and quality with hypertension, glucose intolerance and BMI, the study design must include an objective way to judge sleep duration, rather than self-reporting [37,38]. In addition, the results must somehow be adjusted to account for age, gender, ethnicity and diet.

Limitations

This systematic review has several limitations. Firstly, the studies used were ones that were published only in the English language. It is possible that some relevant literature was missed by not looking for articles that could have been translated. Secondly, the literature search included studies published from 1997-2019. Some full texts references data from the 1970s to 1980s but data prior to that were not included. Thirdly, some of the parameters were largely self-recorded, this relies on the participant accurately logging their sleep duration which could have varied based on the subject involved. The review was also done within a time constraint because of the availability of the team of authors to work on this project. In addition, the review team did not contain an experienced statistician or methodologist. The relative inexperience could have affected the accuracy of the interpretation of data.

References

1. Kim CE, Shin S, Lee HW, Lim J, Lee JK, et al. (2018) Association between sleep duration and metabolic syndrome: a cross-sectional study. *BMC Public Health* 18: 720.
2. Spiegel K, Leproult R, Van Cauter E (1999) Impact of sleep debt on metabolic and endocrine function. *Lancet* 354: 1435-1439.
3. Chaput JP, Dutil C, Sampasa-Kanyinga H (2018) Sleeping hours: what is the ideal number and how does age impact this? *Nat Sci Sleep* 10: 421-430.
4. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, et al (editors) (2019) *Cochrane Handbook for Systematic Reviews of Interventions* version 6.0 (updated July 2019). Cochrane, 2019.
5. Centers for Disease Control and Prevention (2017) *Defining Adult Overweight and Obesity*. *Overweight & Obesity*.
6. Williams B, Mancia G, Spiering W, Agabiti Rosei E, Azizi M, et al. (2018) 2018 ESC/ESH Guidelines for the management of arterial hypertension. *Eur Heart J* 39: 3021-3104.
7. American Diabetes Association (2019) 2. Classification and diagnosis of diabetes: standards of medical care in diabetes-2019. *Diabetes Care* 42: S13-S28.
8. Review Manager (RevMan) (2014) Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration.
9. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, et al. (2016) ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* 355: i4919.
10. McGuinness LA (2019) robvis: An R package and web application for visualising risk-of-bias assessments.
11. Brocato J, Wu F, Chen Y, Shamy M, Alghamdi MA, et al. (2015) Association between sleeping hours and cardiometabolic risk factors for metabolic syndrome in a Saudi Arabian population. *BMJ Open* 5: e008590.
12. Hwang HR, Lee JG, Lee S, Cha KS, Choi JH, et al. (2015) The relationship between hypertension and sleep duration: an analysis of the fifth Korea National Health and Nutrition Examination Survey (KNHANES V-3). *Clin Hypertens* 21: 8.
13. Guo J, Fei Y, Li J, Zhang L, Luo Q, et al. (2016) Gender- and age-specific associations between sleep duration and prevalent hypertension in middle-aged and elderly Chinese: a cross-sectional study from CHARLS 2011-2012. *BMJ Open* 6: e011770.
14. Fang J, Wheaton AG, Keenan NL, Greenlund KJ, Perry GS, et al. (2012) Association of sleep duration and hypertension among US adults varies by age and sex. *Am J Hypertens* 25: 335-341.
15. Gottlieb DJ, Punjabi NM, Newman AB, Resnick HE, Redline S, et al. (2005) Association of sleep time with diabetes mellitus and impaired glucose tolerance. *Arch Intern Med* 165: 863-867.
16. Gangwisch JE, Malaspina D, Boden-Albala B, Heymsfield SB (2005) Inadequate sleep as a risk factor for obesity: analyses of the NHANES I. *Sleep* 28: 1289-1296.
17. Najafian J, Nouri F, Mohammadifard N (2019) Association between sleep duration and hypertension: Isfahan Healthy Heart Program, Iran. *ARYA Atheroscler* 15: 22-26.
18. Li M, Yan S, Jiang S, Ma X, Gao T, et al. (2019) Relationship between sleep duration and hypertension in northeast China: a cross-sectional study. *BMJ Open* 9: e023916.

19. Song MY, Sung E, Jung SP, Lee KM, Keum SH, et al. (2016) The association between sleep duration and hypertension in non-obese premenopausal women in Korea. *Korean J Fam Med* 37: 130-134.
20. Kawabe H, Saito I (2008) Does short sleep duration in daily life affect morning home blood pressure? Evaluation in Japanese people. *Clin Exp Hypertens* 30: 183-190.
21. Gottlieb DJ, Redline S, Nieto FJ, Baldwin CM, Newman AB, et al. (2006) Association of usual sleep duration with hypertension: the Sleep Heart Health Study. *Sleep* 29: 1009-1014.
22. Shulman R, Cohen DL, Grandner MA, Gislason T, Pack AI, et al. (2018) Sleep duration and 24-hour ambulatory blood pressure in adults not on antihypertensive medications. *J Clin Hypertens (Greenwich)* 20: 1712-1720.
23. Aziz M, Osondu CU, Younus A, Malik R, Rouseff M, et al. (2017) The Association of Sleep Duration and Morbid Obesity in a Working Population: The Baptist Health South Florida Employee Study. *Metab Syndr Relat Disord* 15: 59-62.
24. Hart CN, Larose JG, Fava JL, James BL, Wing RR (2013) The association between time in bed and obesity risk in young adults. *Behav Sleep Med* 11: 321-327.
25. Hasler G, Buysse DJ, Klaghofer R, Gamma A, Ajdacic V, et al. (2004) The association between short sleep duration and obesity in young adults: a 13-year prospective study. *Sleep* 27: 661-666.
26. Ko GT, Chan JC, Chan AW, Wong PT, Hui SS, et al. (2007) Association between sleeping hours, working hours and obesity in Hong Kong Chinese: the 'better health for better Hong Kong' health promotion campaign. *Int J Obes (Lond)* 31: 254-260.
27. Lauderdale DS, Knutson KL, Rathouz PJ, Yan LL, Hulley SB, et al. (2009) Cross-sectional and longitudinal associations between objectively measured sleep duration and body mass index: the CARDIA Sleep Study. *Am J Epidemiol* 170: 805-813.
28. Sepahvand E, Jalali R, Mirzaei M, Kargar Jahromi M (2015) Association between short sleep and body mass index, hypertension among acute coronary syndrome patients in coronary care unit. *Glob J Health Sci* 7: 134-139.
29. Lin CL, Tsai YH, Yeh MC (2016) Associations between sleep duration and type 2 diabetes in Taiwanese adults: A population-based study. *J Formos Med Assoc* 115: 779-785.
30. (2019) *Brain Basics: Understanding Sleep*. National Institute of Neurological Disorders and Stroke.
31. Centers for Disease Control and Prevention (2018) *Adult Obesity Facts*.
32. Rahmani A, Sayehmiri K, Asadollahi K, Sarokhani D, Islami F, et al. (2015) Investigation of the prevalence of obesity in Iran: a systematic review and meta-analysis study. *Acta Medica Iranica* 53: 596-607.
33. Patel P, Abate N (2013) Body fat distribution and insulin resistance. *Nutrients* 5: 2019-2027.
34. Petrie JR, Guzik TJ, Touyz RM (2018) Diabetes, hypertension, and cardiovascular disease: clinical insights and vascular mechanisms. *Can J Cardiol* 34: 575-584.
35. Downes MJ, Brennan ML, Williams HC, Dean RS (2016) Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). *BMJ Open* 6: e011458.
36. (2019) Risk of bias tools - robvis (visualization tool).
37. Szymański FM, Filipiak KJ, Płatek AE, Karpiński G, Majstrak F, et al. (2014) Sleep duration in the first months after ST elevation myocardial infarction: an independent predictor of all-cause mortality. *Kardiol Pol* 72: 504-510.
38. Wong JN, McAuley E, Trinh L (2018) Physical activity programming and counseling preferences among cancer survivors: a systematic review. *Int J Behav Nutr Phys Act* 15: 48.