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Bachelor's thesis in Human Movement Science
Supervisor: Stine Trollebø
May 2022

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Abstrakt

Bakgrunn: Siden 1975 har antall tilfeller av fedme i verden tredoblet seg, og er idag en av de viktigste årsakene til tidlig død. Samtidig som forekomsten av fedme har økt, har søvnvarighet generelt i befolkningen gått ned. Fedme og søvn kan måles både objektivt og subjektivt. Er det egentlig en forskjell på subjektiv og objektiv målemetode når man ser på assosiasjonen mellom fedme og søvnvarighet? **Metode**: Studiene ble funnet gjennom databasene Scopus og PubMed. Kriterier for inkluderte studier var: fagfellevurdering, skrevet på engelsk, kliniske- og observasjonsstudier og nøkkelordene måtte være til stede i abstrakten. Utvalget måtte være voksne uten noen form for sykdom. **Resultat**: Åtte studier ble til slutt inkludert i litteraturstudien. To av de tre studiene som målte søvn objektivt fant ingen assosiasjon mellom kort søvn tid og fedme, mens alle de fem studiene som målte søvn subjektivt fant en assosiasjon med unntak av en. **Konklusjon:** Det er en forskjell mellom objektiv og subjektiv målemetode når det kommet til søvn tid og assosiasjonen med fedme, der subjektiv målemetode viser en assosiasjon mens objektiv ikke gjør det, med noen unntak. Det er likevel nødvendig med videre forskning på området for å gi en sikker evidensbasert konklusjon.

Abstract

Background: Since 1975 the incidence of obesity has tripled worldwide, and it is one of the most important factors related to premature death today. While the incidence of obesity has increased, sleep duration in the general population has decreased. Obesity and sleep can be measured both objectively and subjectively. Is there a difference in subjective and objective measurement methods when looking at the association between obesity and sleep duration? **Method:** The studies were found by using the databases Scopus and PubMed. The studies had to be peer-reviewed, written in English, clinical- and observational studies, and the keywords had to be present in the abstract. The sample had to be adults without any kind of disease. **Result**: Eight studies were eventually included in this literature review. Two of the three studies that measured sleep duration objectively found no association between short sleep duration and obesity, while almost all the five studies that measured sleep duration subjectively found an association, with one exception. **Conclusion:** It is a difference between objective and subjective measuring methods when assessing the association between sleep duration and obesity. Subjective measuring methods show an association, but objective do not, with a few exceptions. There is still a need for further research in the area to provide a safe, evidence-based conclusion.

Keywords: Adults - Obesity - Objective and subjective measurements - Sleep duration

1.Introduction

According to Worlds Health Organization (WHO) over 4 million people die as a result of obesity or overweight each year, and the prevalence worldwide has nearly tripled since 1975 (1). Obesity is one of the most important factors related to premature death, as obesity is a risk factor mainly for cardiovascular diseases which was the major cause of death in 2012 (1). Obesity is, according to WHO defined as abnormal or excessive fat accumulation that presents a health risk. Body Mass Index (BMI) is the most common method for measuring obesity and can be easily calculated by gathering height and weight from an individual (2). When measuring BMI, a standard cutoff point of 30 is considered obese, and over 25 is considered overweight (1). Another method for measuring obesity is Waist Circumference (WC), which is a simple way to measure "abdominal obesity" at the natural waist (2).

An increase in BMI is related to the risk of noncommunicable diseases such as diabetes and cardiovascular diseases (1). Obesity is largely preventable, on an individual level as well as on a community level (1). The fundamental cause of obesity is an imbalance in energy intake and expenditure, as well as reduced physical activity in our everyday life (1). Previous research has been done on obesity and its relation to reduced physical activity, however, there are still some aspects of obesity in our everyday life that are yet to be investigated (3).

Sleep, as well as physical activity, is important in our everyday life. On average, most adults need about 7-9 hours of sleep (4). Sleep is important because it keeps body and mind healthy, and it is important for overall health (4). Sleep can be measured in different ways, and the current gold standard is polysomnography (PSG). (5,6). PSG measures different parameters of sleep (brain dynamics, eye movements, muscle activity, respiratory function) by using surface electrodes. Typically, the participants spend a night in a sleep laboratory while being monitored by a sleep technician. Therefore, PSG can be expensive and is not commonly used in large population samples (5). On the other hand, there is an approach developed for use in larger population samples, which is the wrist-worn accelerometer actigraphy. The wrist actigraphy measures wrist movement, to assess sleep or waking state. Unlike the PSG, wrist actigraphy is inexpensive and does not disturb your sleep like the PSG might do (5).

When measuring obesity and sleep, we can distinguish between objective and subjective measuring methods (6). Objective methods contain measurements by devices/instruments and are not influenced by anyone's perspective or opinion. Objective data is gathered in a controlled environment with the possibility to easily repeat the same measurements, which over time can create reliability and validity (6). On the other hand, subjective measurement is based on how the participant feels, and how they experience different matters. Subjective data is normally gathered by interviews or self-reported questionnaires (6).

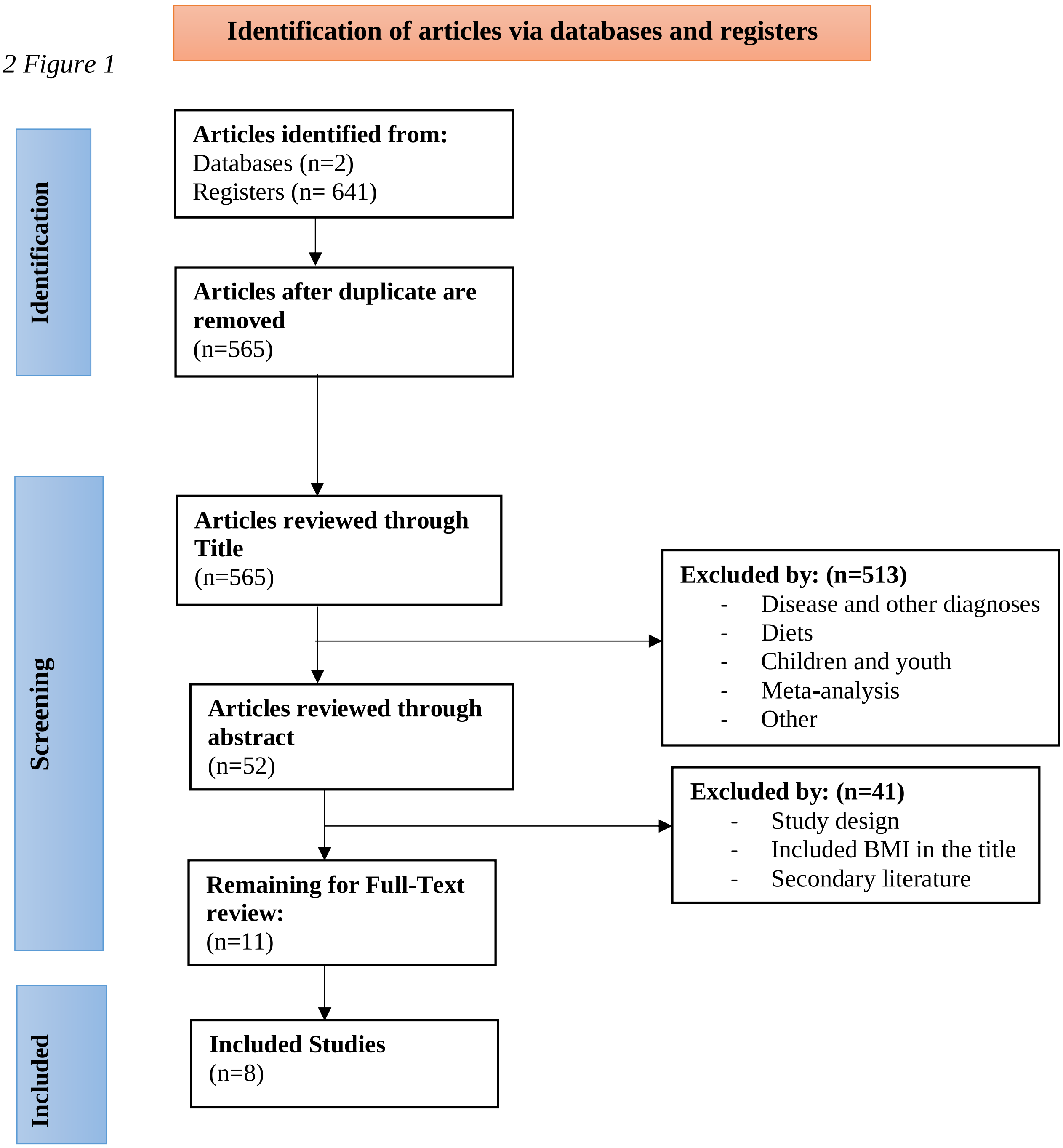
Over the last decade sleep duration has been of great interest in the general population, as there have been reports showing a reduced substantial sleep duration. Parallel to this, the prevalence of obesity has increased, and some studies have investigated a possible connection between the two (3). Several studies have examined the association between sleep duration and obesity (7–14), but research on the association between sleep duration and obesity still remain scarce in the literature. Therefore, this thesis is going to investigate whether there *is a difference between subjective and objective measuring methods when assessing the association between sleep duration and obesity among adults?*

2. Methods

2.1 Search strategy

Article search was conducted through the databases Pubmed and Scopus. The search consisted of combinations of the term’s “sleep”, “obesity”, “adults”, “sleep duration” and “associations”. These terms were combined with “AND” or “OR” to provide relevant articles for the study. This resulted in a total of 52 articles of interest after title review. To be included in this review the trials had to meet the following criteria: 1) written in a peer-reviewed journal 2) written in English 3) clinical trials and observational studies, and 4) published after year 2000. Trials were excluded if they 1) Included participants with various diseases 2) was conducted on children, and 3) was RCT studies and reviews. In the end, eight original articles were selected, as seen in Figure 1.

2.2 Figure 1



3.Results

The eight studies included in this review investigated the association between sleep duration and obesity among adults, by using subjective and objective measurements. All the studies included questionnaires and/or interviews to report the sleep duration, while three of the studies used actigraphy or PSG to measure sleep duration over a longer period. *Table 1* provides an overview of the articles included in this review. Additionally, the main findings from each study will be described individually.

Table 1- descriptive overview of original articles

Article	Study design	*n*	Sex	Measured sleep duration	Measuring device	Main result
Gildner et al. (2014)	Cohort	5273	Men and women	2 nights	**Subjective:** BMI, WC and face-to-face interviews	Short sleep duration in both men and women were significantly associated with higher BMI and WC measures (P<0.05)*
Patel et al. (2008)	Prospective cohort study	6329	Men and women	5.2 nights men, 4.1 nights women	**Subjective:** Sleep diary and questionnaire **Objective:** BMI and wrist actigraphy	A sleep duration of less than 5 h was associated with greater BMI in both men and women (OR:3.7 among men, OR:2.3 among women).
Vgontzas et al. (2013)	Longitudinal	815	Men and women	1 night	**Subjective:** Questionnaire and BMI **Objective:** PSG	Subjective short sleep duration was significantly associated with incident obesity (P<0.05)*.Objective short sleep duration was not significantly associated with incident obesity (P=0.609 in men, P=0.451 in women).
Chaput et al., (2008)	Prospective cohort study	276	Men and women	-	**Subjective:** Questionary and WC **Objective** BMI	Short- and long-duration sleepers were 35% and 25% more likely to have a 5-kg weight gain, as compared with normal-duration sleepers (P<0.05) *.
Watanabe et al. (2010)	Prospective design	34 852	Men and women	-	**Subjective:** Questionnaire **Objective:** BMI	Short sleep duration associated with weight gain and development of obesity (OR: 1.91 and 1.50) for men who slept <5 and 5-6 h. No significant association between sleep duration and weight gain or obesity among women.
Hasler et al. (2004)	Prospective cohort study	496	Men and women	-	**Subjective:** Interview and BMI	Associations between short sleep duration and obesity (OR: 7.4)*, negative association between sleep duration and BMI in young adults. Associations between obesity and sleep duration diminished after age 34.
Magee et al. (2012)	Cohort	40 034	Men and Women	-	**Subjective:** Self-report questionnaire **Objective:** BMI	Short sleep (<6h: OR:1.42, 6h: OR:1.35)* were associated with increased odds of obesity in women. In males short sleep (<6h: OR:1.72, 6h: OR:1.51)* were significantly associated with an increased likelihood of obesity.
Van Den Berg et al., (2008)	Cross-sectional study	983	Men and women	5-7 nights	**Subjective:** Home interviews **Objective:** Wrist actigraphy and BMI	Short sleepers (<5 h: OR: 2.76) and long sleepers (>8 h: OR: 2.93) were more likely to be obese, compared to those who slept 7-8 h. After adjustment for sleep fragmentation, the association between short sleep and obesity was no longer significant.

BMI: Body Mass Index WC: Waist Circumference PSG: Polysomnography OR: Odds Ratio *Significant association

3.1 Objective measurements

The studies performed by Patel et al. (8), Vgontzas et al. (9) and Van Den Berg et al. (14) conducted their studies using mainly objective measurements, and supplied with subjective measurements as well. Patel et al. (8) and Van Den Berg et al. (14) used wrist actigraphy to do the objective measurements, and supplied with a sleep diaries, questionnaires, and home interviews. Vgontzas et al. (9) performed a PSG measurement for one night, which is objective, and supplied with a sleep diary and questionnaire.

Patel et al. (8) found that short sleep (<5 h) was associated with greater BMI (average: +2.5 kg in men, +1.8 kg in women), when measured with wrist actigraphy and supplied with sleep diary. On the other hand, Van Den Berg et al. (14) found that both short sleepers (<5 h) and long sleepers (>8 h) were more likely to be obese, compared to those who slept 7 to <8 h. However, after adjusting for sleep fragmentation, the association between short sleep and obesity was no longer significant. This study used a combination of home interview, which is a subjective measurement, and wrist actigraphy, which is an objective measurement. The study from Vgnotzas et al. (9) combined objective- and subjective measurement methods, through the use of PSG and a questionnaire. The results showed that subjective measured short sleep duration was significantly associated with incident obesity ($P<0.05$). On the other hand, objective measured short sleep duration through PSG, was not significantly associated with incident obesity ($p=0.609$ in men and $p=0.451$ in women, respectively).

3.2 Subjective measurements

The five other studies included in this literature review (7,10–13) used subjective measurement methods to determine sleep duration, and three of them (8,9,14) used objective measurements when measuring BMI. The study from Gildner et al. (7) did only use subjective measurements when measuring BMI and WC, and conducted face-to-face interviews to report sleep. From these measurements the study found a significant association between short sleep duration (<6h) and higher BMI and WC measures in both men and women ($P<0.05$). Hasler et al. (11) as well, did only use subjective measurements like questionnaires and interviews to measure BMI and sleep duration for the study. The results showed a significant association between short sleep (<6h) and obesity at 27, 29 and 34 years, however there was no association between sleep and obesity from the age 34. By objectively measuring BMI and WC, and conducting questionnaires, the study from Chaput et al.(13) found that short- and long-duration sleepers were 35% and 25% more likely to have a 5-kg weight gain, as compared with normal-duration sleepers (P<0.05).

Another study using objective measurement of BMI in addition to a questionnaire was a study conducted by Watanabe et al. (10). They found that short sleep duration (<5 and 5-6 h), as well as long sleep duration (>9 h) were associated with an increased risk of gaining weight among men. No significant association between sleep duration and weight gain or obesity among women was found. The last study conducted by Magee et al. (12) gathered data by subjectively self-reporting sleep duration and questionnaires. The study found that short sleep duration (<6 h) was associated with an increased risk of obesity in women and men. Furthermore, long sleep duration (>9) was associated with obesity in males, but no association was detected among females.

In summary, two of the studies with mainly objective measurements found no association between short sleep duration and obesity when measuring with PSG and wrist actigraphy (9,14). The third study using wrist actigraphy and supplied with a questionnaire, found that short sleep duration was associated with greater BMI (8). All the five studies measuring sleep duration subjectively found an association between obesity and sleep duration, except Hasler et al. (11) which found no association after the age of 34, and Magee et al.(12) who did not find any association between long sleepers and obesity.

4.Discussion

This thesis investigated if there is a difference between measuring objectively or subjectively when assessing the association between sleep duration and obesity among adults. Based on the results from the included studies, most of the studies used subjective methods to measure sleep duration found an association between short sleep and obesity. The exception was Watanabe et al. (10) who only found this association among men. The three studies (8,9,14) that mainly used objective measurements, had different outcomes. Two of the studies (9,14) found no significant association when measuring objectively with wrist actigraphy and PSG. The third one (8) found that short sleep duration was associated with greater BMI when measuring with wrist actigraphy. In total, most of the included studies found an association between sleep duration and obesity, but this varied between subjective and objective measurement methods, sex and age.

4.1 Objective measurements- strengths and weaknesses

Three of the included studies (8,9,14) used primarily objective measurements to investigate the association between sleep duration and obesity. Van Den Berg et al. (14) and Patel et al. (8) conducted sleep duration measurements over 4-7 nights, while Vgontzas et al.(9) measured only one night. The studies Van Den Berg et al. (14) and Patel et al. (8) both used wrist actigraphy to investigate the sleep duration among the participants and executed home interviews (14) and sleep diary/questionnaire (8) in addition. After adjusting for fragmentation in sleep duration, there was no association between short sleep duration (<5h) and obesity in the Van Den Berg et al. (14) study. However, long sleep duration (>8h) was still associated with a higher risk of obesity. On the other hand, Patel et al. found that short sleep duration (<5h) was associated with greater BMI. Vgontzas et al. (9) used PSG and self-report questionnaire to measure sleep duration in their study. The result indicated that subjective short sleep duration was significantly associated with incident obesity, but objectively short sleep duration was not significantly associated with incident obesity.

PSG and actigraphy is the most common devices when measuring sleep objectively (6), although PSG is considered the current gold standard (5). As mentioned earlier PSG measurements is normally conducted in a sleep laboratory over one night, and require continually supervision of a sleep technician (5). On the other hand, actigraphy can be worn and used for several weeks, which can provide more reliable data (6), and can explain why there was no association between the objective measured sleep and obesity in the Vgontzas et al. (9) study. In addition, actigraphy is mostly used in larger population samples rather than PSG, because it is less invasive and expensive (6). Actigraphy also allows the participants to conduct their day as normal, and remain in their natural sleep environment (6,8,14). It is recommended to keep a sleep diary in addition to the actigraphy, as an actigraphy are not able to tell the difference between time a sleep from time awake in bed (5,6,15). This can result in an over/under-estimation of sleep duration, which furthermore can provide inaccurate data for the studies. Moreover, this can explain why there was no association between short sleep duration and obesity in the study from Van Den Berg et al. (14).

4.2 Subjective measurements- strength and weakness

Five of the included studies used subjective measurements to investigate sleep duration, in form of questionnaires and interviews. The study from Gildner et al. (7) measured sleep duration over two nights, but the rest of the studies had a follow-up time over several years. The subjective measurement method used in the study from Gildner et al. (7) was face-to-face interviews. The study found that shorter sleep duration in men and women was associated with higher BMI (7). Whether this is a valid result can be difficult to say, as the study only was conducted over two nights. In addition, since self-reporting is used, it is often difficult for individuals to separate time in bed and asleep, and therefore over/under-estimate sleep duration (6).

Another study that also used interviews were Hasler et al. (11). The results showed that there was a strong association between short sleep duration and obesity, but only at the ages 27, 29 and 34 years. Compared to the study from Gildner et al. (7), Hasler et al.(11) had a follow-up period for 13 years, which can make the results more valid even when using subjective measurements. The study from Chaput et al. (13) used a questionnaire to gather data on sleep duration, which showed that short and long sleep duration had an association with weight gain and higher BMI. Both Watanabe et al. (10) and Magee et al. (12) collected their data during a health check and used self-report forms to report sleep. Both studies showed that there was an association between short sleep duration and the development of obesity, however Watanabe et al. (10) did only find this association in men. A strength in both studies was that they had a large population sample, which can give a more valid result.

The advantage of using subjective measurements is that they are affordable and easy to administer (6). Most of the included studies used some form of subjective measurement, which makes it easier to compare across other studies. In addition, previous studies have also shown a good agreement when comparing subjective measurements with actigraphy (13). However, subjective measurements on sleep duration have its limitations. It is difficult for the participants to accurately report the hours of sleep. They may have irregular sleeping habits, and it is hard to establish how many hours they slept. For example, they may report sleep duration from the time they go to bed rather when they actually fall asleep. This can result in an overestimation or underestimation of sleep duration (6).

Another source of error that can occur when using subjective measurements is self-reporting of BMI. Participants can misreport their height and weight, which can lead to big differences in the BMI results. On the other hand, objectively measuring BMI is more expensive, and requires that every participant is measured the same way and with the same instruments. Although subjective methods of reporting BMI are inexpensive and can involve a larger sample size, it can provide imprecise results which can affect the outcome.

4.3 Short- and long sleep duration and obesity

As seen in this review, it is investigated whether there are any association between sleep duration and obesity. Almost all the included studies found an association between short sleep duration and obesity, but four of the studies also found this association with long sleep duration. Chaput et al. (13), Van Den Berg et al. (14) and Watanabe et al. (10) all found an association between long sleep duration (>9 h) and obesity. Although these studies had short sleep duration and obesity association as their main findings, they could still indicate an association with long sleep duration. Gildner et al. (7), Patel et al. (8),Vgontzas et al. (9) and Hasler et al. (11) only found this association between short sleep duration (<6h) and obesity. One factor that can affect the association between long sleep duration and obesity is the reduced energy consumption with increased bedtime (10). In one of the studies (13), the long sleepers had a greater BMI than the average at baseline, which may explain that they were more likely to gain weight over a 6-year period than those with lower BMI at baseline (13)

Several of the included studies mention changes in hormone levels when looking into the relationship between short sleep duration and obesity (6–8,10,13). Short sleep duration causes a hormonal change, that regulates your appetite. Reduced levels of leptin and increased levels of ghrelin can happen when the sleep duration is short, and that hormonal change can increase the participants appetite (7). This can provide a possible explanation for the increased incidence of obesity that occurs with short sleep duration in some studies (7,10,13).

4.4 Methodological assessments

A strength of the included studies is the relatively large sample size, from around 276 to 40, 000 participants. With such a large sample size, it will be possible to obtain a larger measurement, which can provide a more accurate and concrete result in contrast to studies with smaller samples. In the study by Patel et al. (8) it was found a significant association between sleep duration and obesity. This study had on average an older age group (65+) than the other studies, which may impact the results. As you get older, your general health decreases, and you may develop sleeping disorders more easily and other disorders as well (8). This fact may influence and strengthen the association between sleep duration and obesity. Van Den Berg et al. (14) also conducted the study on a population with a high average age (68y). Therefore, a misconception of sleep duration can occur because of the poor sleep quality due to old age, which leads to an underestimation of sleep duration (14). In addition, an older population can self-report insufficient sleep duration, due to cognitive decline.

Another factor that can influence the results of the different studies is the definition of obesity. Most studies had defined obesity with a BMI measure of >30, which the WHO also defines as obesity. However, the studies from Gildner et al. (7) Watanabe et al. (10) and Chaput et al. (13) had different definitions. Gildner et al. (7) had a population from different countries, and for most of them a BMI >30 was considered obese, except for China and India where a BMI >27.5 was considered obese. In Japan they also have different cutoff values for BMI, where a BMI >25 is considered obese (10). Chaput et al. (13) conducted the study in The United States, where obesity was defined as a BMI >32. These different measures of obesity can make it difficult to compare the studies to each other, as several participants may be overweight due to different cutoff values on BMI definition. Another factor that can affect the result is the definition on short sleep duration in the different studies. Some studies define short sleep as <5h, 5-6h and <6h, which can result in stronger or weaker association between sleep duration and obesity.

All the included studies had different follow-up time on sleep duration. The studies that used objective measurements had a follow-up time from one to seven nights on sleep duration. The studies that used subjective measurements had a follow-up time over several years, except Gildner et al. (7) who measured sleep duration over two nights. By different follow-up times, it can be difficult to compare the different studies to each other. With a follow-up time over several years, like the studies from Chaput et al. (13), Hasler et al. (11) and Watanabe et al. (10) more data will be collected, which can give more thorough results. In addition, a long follow-up time will give a better overview of the participants sleeping patterns, rather than measurements over one night.

A potential source of error in this thesis is an uneven distribution of studies including objective and subjective measuring methods. All the five included studies that used subjective measurement methods found an association between sleep duration and obesity, but only one of the objective studies found this association. This can be a factor that can affect the result in this thesis, which can lead to a greater association between sleep duration and obesity by using subjective measurements methods.

Based on this thesis, future research should consider measuring sleep duration objectively by wrist actigraphy, and supply with subjective measurement methods, for example a sleep diary. Wrist actigraphy is known to overestimate sleep duration, and sleep diary and questionnaire known to underestimate (6). Therefore, a combination of subjective and objective measuring methods might give the most valid result. In addition, longitudinal research over a longer period is needed, to measure the participants natural sleep patterns. Moreover, future research should differentiate between young adults, adults, and elderly because sleep duration and sleep quality could change in these age groups.

6.Conclusion

Based on the findings in this review we can conclude there is a difference between subjective and objective measurements methods when assessing the association between sleep duration and obesity among adults. Several of the studies indicated an association between sleep duration and obesity, but this association was mostly shown in the studies with subjective measurements on sleep duration. Therefore, more studies should investigate the difference between the two measurement methods and conduct more studies with a combination of subjective and objective measurement methods. In addition, to get more precise and valid results, it is recommended to have a long follow-up time and a large sample size.

6.References

1. Obesity and overweight [Internet]. [cited 2022 Mar 8]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

2. Boston 677 Huntington Avenue, Ma 02115 +1495-1000. Measuring Obesity [Internet]. Obesity Prevention Source. 2012 [cited 2022 Mar 10]. Available from: https://www.hsph.harvard.edu/obesity-prevention-source/obesity-definition/how-to-measure-body-fatness/

3. Theorell-Haglöw J, Lindberg E. Sleep Duration and Obesity in Adults: What Are the Connections? Curr Obes Rep. 2016 Sep 1;5(3):333–43.

4. How Much Sleep Do We Really Need? [Internet]. Sleep Foundation. 2021 [cited 2022 Mar 8]. Available from: https://www.sleepfoundation.org/how-sleep-works/how-much-sleep-do-we-really-need

5. Marino M, Li Y, Rueschman MN, Winkelman JW, Ellenbogen JM, Solet JM, et al. Measuring Sleep: Accuracy, Sensitivity, and Specificity of Wrist Actigraphy Compared to Polysomnography. Sleep. 2013 Nov 1;36(11):1747–55.

6. Garfield V. The Association Between Body Mass Index (BMI) and Sleep Duration: Where Are We after nearly Two Decades of Epidemiological Research? IJERPH. 2019 Nov 6;16(22):4327.

7. Gildner TE, Liebert MA, Kowal P, Chatterji S, Josh Snodgrass J. Sleep duration, sleep quality, and obesity risk among older adults from six middle-income countries: findings from the study on global AGEing and adult health (SAGE). Am J Hum Biol. 2014 Dec;26(6):803–12.

8. Patel SR, Blackwell T, Redline S, Ancoli-Israel S, Cauley JA, Hillier TA, et al. The association between sleep duration and obesity in older adults. Int J Obes. 2008 Dec;32(12):1825–34.

9. Vgontzas AN, Fernandez-Mendoza J, Miksiewicz T, Kritikou I, Shaffer ML, Liao D, et al. Unveiling the longitudinal association between short sleep duration and the incidence of obesity: the Penn State Cohort. Int J Obes (Lond). 2014 Jun;38(6):825–32.

10. Watanabe M, Kikuchi H, Tanaka K, Takahashi M. Association of Short Sleep Duration with Weight Gain and Obesity at 1-Year Follow-Up: A Large-Scale Prospective Study. Sleep. 2010 Feb 1;33(2):161–7.

11. Hasler G, Buysse DJ, Klaghofer R, Gamma A, Ajdacic V, Eich D, et al. The association between short sleep duration and obesity in young adults: a 13-year prospective study. Sleep. 2004 Jun 15;27(4):661–6.

12. Magee CA, Iverson DC, Caputi P. Sleep Duration and Obesity in Middle-aged Australian Adults. Obesity. 2010;18(2):420–1.

13. Chaput JP, Després 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 Apr;31(4):517–23.

14. van den Berg JF, Knvistingh Neven A, Tulen JHM, Hofman A, Witteman JCM, Miedema HME, et al. Actigraphic sleep duration and fragmentation are related to obesity in the elderly: the Rotterdam Study. Int J Obes. 2008 Jul;32(7):1083–90.

15. How Is Actigraphy Used to Evaluate Sleep? [Internet]. Sleep Foundation. 2021 [cited 2022 Apr 22]. Available from: https://www.sleepfoundation.org/sleep-studies/actigraphy

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