Introduction

Sleep is one of the fundamental needs of life as evidenced by the association of sleep deprivation with multiple health issues. Short sleep alleviates awake neurochemical systems leading to an upregulation of orexigenic hormones, activation of reward centers, and decreased daytime physical activity. All these factors culminate in the development of obesity, and obesity leads to disturbed sleep due to complete or partial obstruction of upper airways because of fat deposition. Thus, a vicious cycle is established between obesity and poor sleep. Although the causal association of short sleep and obesity has been well established in various epidemiological and experimental studies, sleep assessment is still a neglected aspect of management in obese people.

Context: Short sleep and obesity have a causal association with each other. Obesity is also associated with metabolic imbalances. However, a subset of 20%-30% of obese population have only few metabolic complications, known as metabolically healthy obese (MHO) and rest with worsened metabolic profile are known as metabolically abnormal obese (MAO). Aims: To find the association between sleep quality and metabolic health of adult obese males. Setting and Design: The study was a cross-sectional study conducted at medicine out-patient department of the institute. Methods and Material: In this study, hundred adult obese males of age group 25–60 years, with Body mass index (BMI) ≥ 25 Kg/m², were divided into MHO and MAO, based on their metabolic health using Joint Interim criteria. Sleep quality was assessed using Pittsburgh sleep questionnaire index (PSQI). Statistical analysis used: The data obtained were analyzed using PAST statistical software. Results: The two groups MHO and MAO presented with significant differences in their mean age and BMI (P = 0.0001). The global score of PSQI was significantly high for MAO than MHO with mean values of 8.24 ± 3.60 and 6.65 ± 3.58, respectively (P = 0.016). Sleep disturbances score was significantly high in MAO (P = 0.0001). Significant associations were observed for global score with age, BMI, waist circumference, fasting blood sugar, and triglycerides. Conclusions: Poor sleep quality was significantly associated with detrimental metabolic profile and BMI. The metabolic health worsened with increasing age and obesity.

Keywords: Metabolic syndrome, obesity, sleep

Abstract

Context: Short sleep and obesity have a causal association with each other. Obesity is also associated with metabolic imbalances. However, a subset of 20%-30% of obese population have only few metabolic complications, known as metabolically healthy obese (MHO) and rest with worsened metabolic profile are known as metabolically abnormal obese (MAO). Aims: To find the association between sleep quality and metabolic health of adult obese males. Setting and Design: The study was a cross-sectional study conducted at medicine out-patient department of the institute. Methods and Material: In this study, hundred adult obese males of age group 25–60 years, with Body mass index (BMI) ≥ 25 Kg/m², were divided into MHO and MAO, based on their metabolic health using Joint Interim criteria. Sleep quality was assessed using Pittsburgh sleep questionnaire index (PSQI). Statistical analysis used: The data obtained were analyzed using PAST statistical software. Results: The two groups MHO and MAO presented with significant differences in their mean age and BMI (P = 0.0001). The global score of PSQI was significantly high for MAO than MHO with mean values of 8.24 ± 3.60 and 6.65 ± 3.58, respectively (P = 0.016). Sleep disturbances score was significantly high in MAO (P = 0.0001). Significant associations were observed for global score with age, BMI, waist circumference, fasting blood sugar, and triglycerides. Conclusions: Poor sleep quality was significantly associated with detrimental metabolic profile and BMI. The metabolic health worsened with increasing age and obesity.

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have increased mortality risk. A subset of 20%–30% obese individuals have been identified as a different phenotype who have a lower mortality risk as that of normal-weight people, and this phenotype is labeled as metabolically healthy obese (MHO).[6] The MHO have none or very few metabolic complications, normal or minimally deranged hormonal profile, and less physical disabilities as compared to metabolically abnormal obese (MAO).[7] Therefore, studying biochemical profile along with anthropometric and clinical parameters, obese can be grouped for evaluation of susceptibility toward other clinically important health issues. Because sleep deprivation and obesity have a close and causal association, sleep quality could be different in the two phenotypes. Therefore, we planned this study with the intent to assess and compare the sleep quality of individuals of MHO and MAO.

### Subjects and Methods

After obtaining approval from the institutional ethics committee, this cross-sectional study was commenced on obese adult males of age group 18–60 years, attending the medicine outpatient department of the institute. Exclusion criteria for this study were night shift workers, current smokers/alcoholics, using medications that affect sleep architecture, patients having acute respiratory disorders, COPD, psychiatric and other painful illnesses, respiratory failure, and history of drug abuse.

### Study groups

The WHO based obesity classification for the Asia-pacific population, with the criteria of BMI ≥ 25 kg/m² was used for sample selection.[8] The joint interim criteria for the classification of MHO and MAO were used to divide the study sample into the study groups MHO and MAO. The classification is based on anthropometry, blood pressure, and metabolic profile with cut-off values of Waist circumference ≥ 102 cm, SBP ≥ 130 mmHg, DBP ≥ 85 mmHg, triglycerides ≥ 150 mg/dL, HDL ≤ 40 mg/dL, and fasting sugar ≥ 100 mg/dL. Obese individuals with ≤ 2 of these components were classified as MHO and the rest were MAO with ≥ 3 components.[9]

The study included 100 obese males. After taking their anthropometric measurements of height, weight, and waist circumference, their blood pressure was recorded. The venous blood sample was processed in Clinical Biochemistry laboratory of the institute, using Beckman Coulter Auto-analyzer AU680, based on enzymatic color/UV method, to assess fasting glucose, triglycerides, and HDL-cholesterol levels. Taking their anthropometric parameters and blood tests into consideration, the subjects were grouped into MHO or MAO as stated above.

### Sleep quality

The Pittsburgh sleep quality index (PSQI) which is one of the most widely used methods to assess sleep quality was used in the study.[10] Permission to use the same was taken through the proper channel. The PSQI is a self-reported well-validated sleep questionnaire that evaluates sleep for the past one month. It consists of 19 questions that are categorized into 7 components pertaining to different aspects of sleep culminating to give overall subjective sleep quality. Each component is scored on a 4-point scale from 0 (no problem)–3 (very severe problem). Each component represents different sleep properties like sleep duration, sleep latency, sleep efficiency, sleep quality, sleep disturbances, use of sleeping medication, and daytime dysfunction. The individual component scores are added to give a global score of 0–21 with a score of ≤5 meaning good sleepers and rest are poor sleepers, needing medical assistance. In the present study, the subjects of both groups were asked to fill up the questionnaire; the individual and global scores of which then were statistically analyzed to compare the subjective sleep quality of both groups.

### Statistical analysis

The scores obtained were statistically analyzed using PAST software.[11] The results were tested for normality by Shapiro–Wilk test, and Kruskal–Wallis test was used for the variance. Nonparametric test Mann–Whitney U test and Spearman correlation tests were used for analysis. Data were expressed in mean ± SD, median, percentages, and proportions.

### Results

As per the inclusion criteria, all the subjects were recruited with BMI above 25; however, a statistically significant difference in BMI was noted between the study groups with MAO having higher values. Interestingly, the same MAO group was having individuals with higher age groups. The study groups were made based on JIC having three or more positive out of six components; it is likely that the MAO group show higher values in those components in comparison to MHO group. However, the differences were statistically significant for waist circumference, systolic blood pressure, fasting blood sugar, triglyceride cholesterol, while not so for diastolic blood pressure and HDL cholesterol [Table 1].

The mean global scores of PSQI in MHO and MAO were 6.65 ± 3.58 and 8.24 ± 3.60, respectively, with a statistically

### Table 1: Anthropometric, clinical, and biochemical parameters of study subjects

| Parameters                  | MHO       | MAO       |
|-----------------------------|-----------|-----------|
| Number of subjects (n)      | 47        | 53        |
| Age (years)                 | 39.51±9.65| 50.47±8.69*|
| Height (cm)                 | 169.14±7.75| 164.14±8.91*|
| Weight (Kg)                 | 87.87±6.79 | 87.06±15.78 |
| BMI (Kg/m²)                 | 27.4±2.25  | 32.50±5.82*|
| Waist circumference (cm)    | 91.26±7.74 | 105.14±12.05*|
| Fasting sugar (mg/dL)       | 93.04±7.71 | 124.47±19.77*|
| SBP (mm/Hg)                 | 124.29±3.99| 130.83±5.71*|
| DBP (mm/Hg)                 | 81.06±2.59  | 82.03±3.99 |
| HDL (mg/dL)                 | 40.42±8.73  | 41.03±9.87 |
| TGL (mg/dL)                 | 129.27±54.34| 216.39±74.73*|

Data are presented as mean±standard deviation. MHO=Metabolically healthy obese; MAO=Metabolically abnormally obese; *indicates P<0.05, n=100
significant difference \((P = 0.016)\) indicating MAO group presented with poorer sleep quality than MHO. The individual component scores were not significantly different except for sleep disturbances \((P = 0.0001)\), which indicates that the MAO group presented with much severe sleep disturbances than MHO. However, MAO presented with a trend of higher scores for each component as compared to MHO pointing to the fact that the MAO have poor sleep quality as compared to their counterpart. The global score of the two groups was also significantly different with MHO having a better score than MAO. In addition, it was noted that even the MHO group was showing the average global score >5 suggesting that their sleep quality is also poor, probably because of their obesity, while the score worsened with increasing metabolic derangements associated with the group MAO.

When subjects were grouped based on their number of positive JIC parameters and global PSQI scores were compared among the groups, no significant difference between the groups was observed [Figure 1]. Even though the individuals having all the six components of JIC positive showed relatively higher global scores of PSQI, the inference was limited by the very few numbers of study subjects [Figure 1]. Nevertheless, there was a nearly bell-shaped distribution of numbers of subjects in the present study.

On the other hand, when the presence or absence (below and above the cut off values) of each JIC component were compared in terms of sleep quality as per the cut off value for global scores of PSQI, it is observed that even in metabolically healthy subjects, notable contributions of biochemical parameters are seen toward bad sleep [Figure 2]. Similarly, the majority of bad sleepers are having worse anthropological and clinical parameters [Figure 2].

Global PSQI score showed a positive correlation with age, BMI, waist circumference, fasting blood sugar, and triglycerides but a negative correlation with DBP and HDL [Table 2]. These values signify that poor sleep quality demonstrated by higher PSQI score worsens with age, obesity grade, and components of metabolic health.

The correlations coefficients of measured parameters of the two groups with the age of subjects are shown in [Table 3]. The age of subjects showed a positive correlation with all the metabolic components except HDL. BMI and waist circumference were also positively correlated with age. Significant associations were found for the global PSQI score, BMI, waist circumference, SBP, FBS, and TGL.

Figure 3 demonstrates an increasing trend of more positive components of JIC with progressing age of the study subjects.

**Discussion**

The present study was conducted to compare sleep quality in the two phenotypes of obesity: MAO and MHO. Based on anthropometry and metabolic profile, the recruited obese subjects were classified into study groups: MHO \((n = 53)\) and MAO \((n = 47)\). The sleep quality of the participants was assessed using the Pittsburgh Sleep Quality Index.

In the present study, subjects of older age presented with significantly deranged metabolic health components as compared to their younger counterparts. The subjects of

| Joint interim criteria (JIC) | BMI | WC | SBP | DBP | FBS | TGL | HDL |
|----------------------------|-----|----|-----|-----|-----|-----|-----|
| PSQI global score          | 0.274* | 0.298* | 0.215* | −0.013 | 0.122 | 0.161 | −0.059 |

BMII = Body mass index; WC = Waist circumference; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; FBS = Fasting blood sugar; TGL = Serum triglyceride; HDL = Serum high-density lipoprotein cholesterol, *indicates \(P < 0.05\), \(n = 100\)

| GS = PSQI global score; BMI = Body mass index; WC = Waist circumference; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; FBS = Fasting blood sugar; TGL = Serum triglyceride; HDL = Serum high-density lipoprotein cholesterol, *indicates \(P < 0.05\), \(n = 100\) |

| GS | BMI | Joint interim criteria (JIC) |
|----|-----|----------------------------|
| WC | SBP | DBP | FBS | TGL | HDL |
| Age 0.249* | 0.440* | 0.453* | 0.424* | 0.122 | 0.423* | 0.312* | −0.022 |

**Table 2: Correlation of PSQI global score, BMI, and components of Joint Interim Criteria with the age of the subjects**

**Table 3: Correlation of PSQI global score, BMI, and components of Joint Interim Criteria with the age of the subjects**

**Figure 1:** Box and Whisker plot for the Global scores of PSQI in subjects grouped as per the numbers of positive Joint Interim Criteria components. Numbers of subjects are shown in large blue dots with numbers presented in respective heights from the baseline.

**Figure 2:** Percentage stacked column of individuals based on the distribution of their sleep quality. Each column represents the distribution of subjects as per single positive components of Joint Interim Criteria (JIC).
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MHO were found to be younger as compared to the subjects of MAO. In corroboration with current findings, a study on the US population presented that the prevalence of MHO decreased with age, 68% MHO in adolescents, 54% MHO in the 19–44 year age group, and 24% MHO in the 45–85 years age group. The systemic review by Rey-Lopez et al. also accorded the similar trend of decreasing metabolic health with age. Interestingly, significant positive correlations of WC, SBP, FBS, and TGL have been noticed with age of the subjects without classifying them in metabolic groups. Therefore, with progressing age, metabolic profile is also deteriorating along with advancing degree of obesity. Observation of the current study suggests that most of the obese are susceptible to metabolic threats and they may reach the category of MAO eventually, if not intervened.

Ageing presents with altered glucose levels and defective lipid metabolism along with increasing visceral fat tissue deposits. In addition to this, accumulations of senescent cells or their byproducts may be involved in the process through increased oxidative stress, evoked tissue fibrosis, upgraded endothelial dysfunction, and elevated levels of inflammatory cytokines. All these factors culminate in a chronic inflammatory state with decreased insulin sensitivity and adipose tissue dysfunction. However, possible contributory role of increased sedentary living and surplus carbohydrate-rich and fat-rich food consumption compromising dietary fibers intake cannot be excluded. Thus, markers of abnormal metabolic profile—hyperglycemia, high levels of bad cholesterol, and decreased levels of good cholesterol—could be associated with ageing, and also can contribute in the worsening of the obesity status and sleep performance.

The present study also demonstrated significant higher values of BMI and WC of MAO subjects. As already suggested WC changes could be used as a measure of central obesity, which positively correlates with the appearance of obesity-related complications. Present study apprises the correlation of BMI, which shows grades of obesity, with metabolic complications associated with obesity. In agreement with earlier report, the observations made by the current observation bespeak about the relationship between the grades of obesity and metabolic health. Based on National Health and Nutrition Examination Survey III (NHANES III), Willett et al. reported a close association of BMI with body fat percentage \( (r = 0.19) \). In addition, BMI showed close and positive associations with markers of metabolic health like FBS, TGL, and negative associations with HDL. In line with the current report, they have also observed a positive association between BMI and SBP. Similar findings were also reported by Hunter et al. and proposed BMI as a good indicator for predicting TGL, HDL levels, markers of obesity-related metabolic health, and SBP.

The MAO group of the present study were poor sleepers compared to MHO groups and a significant difference in their global PSQI scores was noted. The sleep disturbances score was significantly higher in MAO group, while other components like latency, duration, quality, and efficiency of sleep were higher but not statistically significant. Similarly, use of sleep medication and daytime dysfunction were also insignificantly higher in MAO group. However, these trends of higher scores for specific sleep components corroborate the sleep disturbance in MAO. These observations are in agreement with earlier observations. Because there are only limited studies related to the comparison of sleep in MHO and MAO subjects, the current study is unique in the use of a validated questionnaire. Using self-reported sleep duration as the only parameter, Hankinson et al. found significantly higher sleep duration in MAO women, but not in men, in comparison to respective MHO subjects. Similarly, another self-reported history-based study reported statistically insignificant differences between sleep duration and quality between MHO and MAO groups. However, Ryu et al. reported longer sleep duration in MHO individuals based on self-reported sleep history. In a recent study conducted by Al-Rashed et al., sleep quality was negatively correlated with obesity and metabolic markers related with obesity, which further supports the results of the present study.

The differences in the sleep of two groups could be attributed to differences in the age of subjects also. Elderly people are reported to have difficulty in falling asleep after waking up during the night, thereby experiencing sleep fragmentation, decreased sleep duration, and difficulty in maintaining sleep. The poor sleep of MAO might be a risk factor for their deranged metabolic profile as short sleep has been associated with upregulation of orexin hormones, sympathetic and adrenocortical activity along with growth hormone suppression. In obesity, there is an accumulation of fatty tissue, which eventually may lead to narrowing of the upper respiratory airway. These, along with contributions by partial collapses during sleep, result in episodes of apnoea and hypopnoea, and ultimately obstructive sleep apnoea syndrome. These breathing disorders of sleep might be the reason for fragmented sleep, decreased sleep efficiency, daytime fatigue and sleepiness, and increased sleep latencies in obese.
The positive association of PSQI global score with metabolic components, in the present study, signifies that poor sleep could be used as an indicator of abnormal metabolic profile. Even in the metabolically healthy subjects, notable contributions of biochemical parameters could be seen toward poor sleep. The current observations also emphasize on increasing age and BMI as important risk factors for deteriorating sleep quality as well as the metabolic health of subjects, as the majority of bad sleepers were having worsened anthropological and clinical parameters. In affirmation of the current observations, earlier reports on significant associations of PSQI global score with WC, BMI, serum insulin, and glucose levels suggested the influence of poor sleep on the metabolic health of subjects. Hung et al. found that the subjects who had metabolic syndrome scored higher PSQI scores and were poor sleepers. In the same study, positive associations of hyperglycemia and low HDL with PSQI were seen, which is similar to the findings reported here. In another study, Lou et al. observed high PSQI scores of subjects with impaired fasting glucose as compared to subjects with normal glycemic control. Our results also support the observations made by the Baependi heart study, in which a significant association was seen between high global PSQI scores and raised blood VLDL and triglycerides levels. Lu et al. studied the effects of both sleep quality and duration on the prevalence of metabolic syndrome in the Chinese population and observed that subjects with poor sleep quality had a high prevalence of metabolic components as compared to subjects with very good sleep quality. They also found a U-shaped association of metabolic syndrome with sleep duration. Thus, with increasing age, there is a progression of obesity and its metabolic consequences along with decreasing sleep quality.

To summarize, we found MAO group presented with poor overall sleep quality as well as high sleep disturbances score. Sleep health is a much needed but ignored aspect of complete well-being. With the current epidemic of obesity globally, good quality sleep should also be ensured in the management of obesity. Sleep assessment methods like PSQI, sleep diaries, etc., can be very easily administered at primary health care centers and community levels by physicians and health care workers to assess sleep health status of obese patients. Following which, measures like educating the population regarding sleep hygiene might be able to improve sleep and reduce the risks of metabolic complications associated with obesity. With the emergence of distinct phenotypes of obesity, different studies are being conducted by scientists to find clinical as well as genetic differences between MAO and MHO, but differences in sleep in these two phenotypes is a topic yet to be explored. Thus, the novelty of our study is that we compared the sleep quality in MAO and MHO population using PSQI, which is a standard and validated tool for sleep quality assessment.

**Future direction**

A PSQI study could be conducted as a follow-up study to understand the effects of good sleep practices on the metabolic status of obese. As this is a cross-sectional study, the independent causal effects of ageing and sleep on the deteriorating metabolic profile of obese remained unidentified. A prospective study may be conducted to identify the changes in the metabolic health of obese with ageing, along with PSQI to study the sleep changes associated with ageing in the population.

**Key message**

Sleep quality assessment and good sleep hygiene could be implemented as an adjunct therapy to reduce metabolic complications associated with obesity.

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Nil.

**Conflicts of interest**

There are no conflicts of interest.

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