Nutrition, Metabolism and Cardiovascular Diseases 35 (2025) 104014

Contents lists available at ScienceDirect

Nutrition, Metabolism and Cardiovascular Diseases

journal homepage: www.elsevier.com/locate/nmcd

Invited Review

Obesity and sleep disorders: A bidirectional relationship

Michela Figorilli [a], Fernanda Velluzzi [b], Stefania Redolfi [a,*]

[a] Sleep Disorder Research Center, Department of Medical Sciences and Public Health, University of Cagliari, Cagliari, Italy
[b] Obesity Unit, Department of Medical Sciences and Public Health, University of Cagliari, Cagliari, Italy

ARTICLE INFO

Handling Editor: G Targher

ABSTRACT

Aims: Obesity and sleep disorders are highly prevalent conditions with profound implications for public health. Emerging evidence highlights a bidirectional relationship between these two conditions, with each exacerbating the other in a complex interplay of behavioral, physiological, and hormonal mechanisms. Sleep deprivation and poor sleep quality contribute to energy imbalance through dysregulation of appetite hormones (e.g., leptin and ghrelin), increased caloric intake, and reduced physical activity. Conversely, sleep disorders such as obstructive sleep apnea syndrome (OSAS), insomnia, and restless leg syndrome (RLS) are significantly more common in individuals with obesity.

Data synthesis: This review explores the pathophysiological mechanisms underlying this relationship, including the roles of inflammation, autonomic dysregulation, and neuroendocrine pathways. Sleep loss exacerbates metabolic syndrome components, including insulin resistance and dyslipidemia, further perpetuating weight gain. Similarly, obesity-induced sleep disorders lead to pro-inflammatory states, vascular dysfunction, and sympathetic overactivation, compounding cardiometabolic risks. Specific conditions like OSA and RLS are examined as models of this interdependence, emphasizing their shared pathways and clinical implications.

Conclusions: The bidirectional link between obesity and sleep disorders underscores the importance of integrating sleep assessment and management into obesity treatment strategies. Addressing this relationship could mitigate the progression of cardiometabolic comorbidities and improve overall health outcomes. Moreover, the intertwined dynamics between obesity, sleep disorders, and mental health—mediated by inflammatory pathways, hormonal dysregulation, and neurobehavioral factors—highlight the critical need for integrated treatment approaches targeting physical, psychological, and sleep-related dimensions to enhance health and quality of life.

1. Introduction

The global obesity epidemic represents one of the most pressing public health challenges of the 21st century, with profound implications for morbidity, mortality, and healthcare systems. Obesity is not only a risk factor for a wide range of chronic conditions, including cardiovascular disease, diabetes, and cancer, but also closely linked to sleep disorders, which have emerged as significant contributors to poor health outcomes. Among these, obstructive sleep apnea (OSA) and insomnia stand out due to their high prevalence and substantial impact on cardiometabolic health.

Sleep plays a vital role in metabolic regulation, energy balance, and overall health. However, the relationship between obesity and sleep is bidirectional: obesity predisposes individuals to sleep disorders through multiple physiological and anatomical mechanisms, while poor sleep quality and untreated sleep disorders can exacerbate weight gain and metabolic dysfunction. This cyclical interaction creates a complex web of pathophysiological interdependencies, requiring a nuanced understanding of the underlying mechanisms and clinical manifestations.

This review aims to explore the intricate connections between obesity and sleep disorders, with a focus on OSA and insomnia. It will examine the epidemiology, pathophysiology, clinical features, cardiometabolic consequences, and current treatment modalities for these conditions. By synthesizing the latest evidence, the review seeks to highlight key insights and identify gaps in knowledge, ultimately guiding future research and improving clinical management for individuals affected by obesity and sleep disorders.

This article is part of a special issue entitled: One Health published in Nutrition, Metabolism and Cardiovascular Diseases.

* Corresponding author. Sleep Disorder Research Center, Department of Medical Sciences and Public Health, University of Cagliari, Cagliari, Italy.
E-mail address: stefania.redolfi@unica.it (S. Redolfi).

https://doi.org/10.1016/j.numecd.2025.104014
Received 25 January 2025; Received in revised form 7 March 2025; Accepted 10 March 2025
Available online 15 March 2025

2. Obesity

Obesity is a chronic, progressive, and relapsing metabolic disease characterized by excessive fat accumulation that impairs health and quality of life. Its prevalence has increased globally, reaching epidemic proportions [1] also affecting the paediatric population. Moreover, childhood obesity tends to persist into adulthood, typically increasing in severity over time [2].

Obesity is a critical health issue, as it is associated with an increased risk of mortality and morbidity, particularly from cardiovascular and metabolic diseases. Furthermore, a higher prevalence of respiratory, hepatobiliary, renal, neurodegenerative, psychiatric, osteoarticular diseases, and some forms of cancer has been reported in patients with obesity [3]. In addition, social stigma is common, with patients often being viewed as entirely responsible for their condition, leading to harmful consequences for both their physical and psychological health [4].

The current definition of obesity is based on the measurement of Body Mass Index (BMI), which is the ratio of body weight to the square of height (kg/m^2). A BMI between 18.5 and 24.9 kg/m^2 is considered normal, a BMI between 25 and 29.9 kg/m^2 indicates overweight, and a BMI of 30 kg/m^2 or higher defines obesity [5]. However, BMI has two main limitations. Firstly, it does not account for body composition, specifically the distinction between fat mass and lean mass, and fails to recognize sarcopenic obesity, the coexistence of excess fat and low lean mass, which exacerbates the health risks of obesity [6]. Secondly, it does not reflect fat distribution. It is well established that cardiometabolic risk is more closely associated with visceral, centrally located, and ectopic adiposity, due to its unique metabolic and inflammatory activity [7]. Integrating BMI assessment with a measure of visceral fat, even an indirect one, such as waist circumference, provides a more accurate estimation of obesity-related cardiometabolic risk [8]. Furthermore, the waist-to-height ratio (WHtR) has recently been proposed as a more accurate measure of central or visceral adiposity, with the advantage of applying the same threshold across the entire population [9].

The heterogeneous pathogenesis of obesity involves genetic, epigenetic, environmental, psychological, and behavioral factors, whose complex interplay results in a chronic positive energy imbalance leading to weight gain over time [10].

In this context, while excessive food intake and low physical activity level are well-known contributors, emerging evidence highlights the importance of other factors. Among these, the composition of the gut microbiota and its modulation by dietary patterns and lifestyle play a key role in regulating host metabolism [11,12].

Another aspect that has gained researchers' attention as a modulator of lifestyle and a potential pathogenetic factor for obesity is sleep. Following a similar trend to that of obesity, the prevalence of sleep disorders has progressively increased in the last decades. Specifically, reduced sleep duration and decreased restorative sleep have been reported in both children and adults and a bidirectional relationship with obesity has been hypothesized. On the one hand, poor-quality sleep can negatively impact energy balance through various hormonal and behavioral mechanisms, promoting weight gain and metabolic alterations. On the other hand, obesity may predispose individuals to sleep disorders [13].

Based on this evidence, it has been suggested that sleep assessment be included in the multidimensional approach to obesity and obesity treatment be integrated with measures to correct sleep abnormalities [13].

3. Sleep disturbances promote obesity

Recent evidence indicates that sleep disturbances, including short sleep duration, disrupted sleep, and poor-quality sleep, are associated with an increased risk of cardiometabolic diseases, such as obesity, insulin resistance, type 2 diabetes, arterial hypertension, and dyslipidemia. These conditions, in turn, increase the risk of major cardiovascular events, including ischemic stroke and myocardial infarction [14]. Moreover, it has been suggested that insufficient sleep may accelerate biological aging, which could contribute to an increased risk of morbidity and mortality. In this regard, a recent study involving a large sample of adults aged 56–100 years found that individuals with short sleep duration and insomnia, particularly when occurring in combination, had an accelerated epigenetic age compared to healthy sleepers [15].

Short sleep duration affects approximately 25–30 % of adults and 35 % of children and adolescents despite recommendations for regular and adequate sleep to promote good health [16]. More specifically, the American Academy of Sleep Medicine (AASM) recommends 7–9 h of sleep per night for adults [17], while the optimal sleep duration is 9–12 h for children aged 6–12 years and 8−10 h for adolescents aged 13–17 years [18]. According to the AAMS criteria, short sleep is defined as ≤ 6 h of sleep per night for adults (Watson N.F.2015b), < 8 h for adolescents aged 13–17 years, and <9 h for children aged 6–12 years [18]. It has been observed that in a substantial proportion of individuals, both adults and adolescents, insufficient sleep represents a chronic condition, referred to as habitual short sleep duration (HSSD), which may lead to an increased cardiometabolic risk [19]. Despite some evidence of heterogeneity across studies, an association between HSSD and the risk of hypertension has been reported among individuals under 65 years of age [20]. Adults with HSSD have about a 30 % higher risk of developing type 2 diabetes mellitus compared with regular sleepers [21], while in younger individuals, short sleep duration has been associated to later insulin-resistance [22]. Moreover, a community-based study of 15,227 US Hispanic/Latino adults, consistent with other research, found the strongest association with diabetes, in short sleepers with insomnia. However, this association became non-significant after adjusting for BMI, suggesting that obesity plays a key mediating role [23].

The relationship between short sleep duration and obesity has been investigated in several studies, which are predominantly cross-sectional and rely largely on self-reported assessments of sleep duration. The main findings of these studies, including several reviews and metanalysis, indicate that individuals with HSSD have a higher BMI compared to those with normal sleep duration [20]. Specifically, the sleep-obesity relationship appears to be more pronounced among very short sleepers ($\leq$5 h of sleep per night) [24]. Furthermore, a longitudinal association between short sleep and obesity has been observed in children, adults, and the elderly, although the evidence in adults is more mixed, primarily due to methodological issues, such as self-reported data [25].

3.1. Age differences

The elderly is characterized by a high prevalence of obesity, which contributes to and exacerbates age-related diseases, such as cardiovascular, metabolic, and musculoskeletal disorders. Moreover, a decrease in average sleep duration has recently been reported in Chinese older adults [26]. However, there are few studies on the relationship between sleep and obesity in older adults. A meta-analysis of 15 studies, involving a total sample of over 52,000 individuals aged 60 and above, reported a significant correlation between short-sleep duration and overweight or obesity. This result was observed in both cross-sectional and cohort studies conducted in developed countries that used objective methods to assess sleep duration. In contrast, no correlation was found in studies conducted in developing countries such as those in Asian regions or in studies that used self-reported methods to assess sleep duration. However, the scarcity of prospective studies remains a limitation, highlighting the need for further research on this topic [27].

3.2. Sex differences

Several studies have reported some sex-related differences in sleep

characteristics. Women tend to sleep longer but experience more frequent nocturnal awakenings and generally have poorer sleep quality than men. On the other hand, men tend to have a later sleep onset and experience more social jetlag. A recent meta-analysis, including six longitudinal cohort studies with a large sample size, examined the influence of sex on the relationship between short sleep duration and obesity. It found a significant association, with no differences between men and women. However, consistent with other studies, the main limitation of this study is its reliance on self-reported sleep duration [28].

3.3. Underlying mechanisms

Although the evidence is somewhat conflicting, the mechanisms underlying the relationship between insufficient sleep duration and obesity involve changes in the appetite-regulating hormones, particularly reduced leptin levels and increased ghrelin levels, leading to a predominantly orexigenic signal [29]. Additionally, alterations in orexin levels have been observed, but their exact role in this context remains unclear [29]. Moreover, short sleep duration promotes hyperactivation of the hypothalamic–pituitary–adrenal (HPA) axis, leading to increased cortisol secretion. Elevated cortisol levels stimulate food intake, particularly driving food choices toward palatable high energy foods, rich in simple sugars and saturated fats. Furthermore, cortisol promotes the expansion of visceral fat which, through the secretion of pro-inflammatory cytokines, contributes to the chronic inflammatory status typical of visceral obesity [30,31]. It is well established that abdominal and visceral obesity are more strongly associated with cardiometabolic complications than BMI alone [32].

A recent meta-analysis of seven cohort studies evaluated the relationship between short sleep duration and abdominal obesity, measured as waist circumference in six studies and waist-to-hip ratio in one study. Despite the limitation of self-reported sleep duration, the results showed a significant association. Specifically, short sleepers had an 8 % increased risk of abdominal obesity confirming findings from a previous meta-analysis of 21 cross-sectional studies [33].

Studies involving experimentally induced sleep restriction have observed a reduction in insulin sensitivity, although the underlying mechanisms remain unclear. A role of hypercortisolism and circadian rhythm misalignment has been hypothesized. Moreover, it has been proposed that sleep restriction could activate brain areas specifically related to hedonic eating, such as the nucleus accumbens, thalamus, insula and prefrontal cortex leading to an increased desire for and consumption of palatable foods [34]. A possible change in the gut microbiota linked to circadian rhythm alterations has also been described. Reduced microbiota diversity and altered composition could be additional explanations for the metabolic abnormalities in HSSD [35].

Another mechanism linking short sleep duration and weight gain is the negative impact of insufficient sleep on lifestyle, which leads to both increased food intake and decreased physical activity. These behaviors can be considered a consequence of a prolonged wakeful period, associated fatigue and increased energy needs. However, a chronic positive energy balance may lead to weight gain and related complications over time [34].

4. Sleep disorders in obesity

4.1. Respiratory sleep disorders

4.1.1. OSA in obesity

4.1.1.1. Epidemiology. Obstructive Sleep Apnea (OSA) is a prevalent disorder characterized by recurrent episodes of upper airway obstruction during sleep, leading to intermittent hypoxia, autonomic fluctuation, and sleep fragmentation [36]. Obesity is a significant risk factor for OSA, with half of patients with OSA being obese [37]. The prevalence of OSA increases with BMI, and weight gain has been associated with the development and progression of OSA [38]. Conversely, weight loss has been shown to reduce the severity of OSA [38]. The apnea-hypopnea index (AHI) is the primary measure of OSA severity, representing the number of apneas and hypopneas per hour of sleep. Evidence suggests a strong correlation between AHI and BMI, with increasing body weight associated with a higher frequency of respiratory events during sleep. Epidemiological studies indicate that a 10 % weight gain is linked to a 32 % increase in AHI, while a 10 % weight loss can reduce AHI by 26 % [39,40].

4.1.1.2. Pathophysiology. The pathogenesis of OSA in obese individuals is multifactorial, involving both anatomical and physiological factors. Obesity leads to increased fat deposition in the neck and pharyngeal structures, resulting in a reduced upper airway lumen and increased collapsibility during sleep [41–43]. Fat deposition in the abdomen may decrease lung volume, longitudinal tracheal traction forces and upper airway wall tension contributing to pharyngeal airway collapsibility [44–46]. The rostral fluid shift, characterized by the redistribution of fluid from the lower extremities to the upper body during sleep, has been implicated in pathogenesis of OSA, particularly in conditions associates to fluid overload [47]. This mechanism may be especially relevant in obese patients due to various factors promoting fluid overload and daytime accumulation in the legs, including the high prevalence of resistant arterial hypertension, heart failure, renal insufficiency, venous insufficiency, and sedentary lifestyle. In addition, obese patients may exhibit reduced activity or responsiveness of the upper airway dilator muscles, diminishing their ability to maintain airway patency during sleep [43]. Obesity-related hormones and cytokines such as leptin may impair the neuro-anatomical interactions and promote respiratory instability, thereby predisposing to OSA [48].

Conversely, OSA may promote weight gain or make it more difficult to lose weight by inducing changes in appetite control mechanisms. These include a decrease in serum leptin and increase in serum ghrelin concentrations, altered cognitive control, and reward pathways, thus increasing preference for energy-density foods with high hedonic value [49]. Additionally, OSA is associated to daytime sleepiness which can promotes physical inactivity and energy expenditure reduction, thereby adding to the risk of weight gain. This bidirectional relationship creates a cycle where obesity leads to OSAS, and untreated OSAS can promote further weight gain due to poor sleep.

4.1.1.3. Clinical manifestations. Recent studies of community-based populations have highlighted the diverse clinical manifestations of OSA, underscoring the importance of comprehensive evaluation. They reveal four primary symptom clusters: disturbed sleep/insomnia, minimal symptoms, excessive daytime sleepiness and moderate sleepiness [50]. About 40–60 % of OSA patients report sleepiness, which is linked to conditions like hypertension and cardiovascular disease [51]. In obese patients, factors like poor sleep hygiene, other disorders, and systemic conditions can contribute to EDS independently of OSA, underscoring its complex causes [52]. Women with OSA are often underdiagnosed due to their presentation with atypical symptoms such as asthenia, fatigue, and mood disturbances, which are frequently attributed to menopause or mood disorders rather than sleep-disordered breathing. However, the gender bias in OSA diagnosis tends to diminish as the risk increases for women during perimenopause and menopause, likely due to hormonal changes that contribute to airway collapsibility and fat redistribution, making OSA more prevalent and severe in this population [53].

4.1.1.4. Cardiometabolic consequences. In obese individuals OSA exacerbates the risk of cardiometabolic disorders. In fact, intermittent

hypoxia and increased sympathetic activity associated to OSA contribute to elevated blood pressure and hypertension [54]. OSA independently contributes to glucose intolerance and insulin resistance, compounding metabolic risk in obese patients [55]. Additionally, altered lipid metabolism has been observed in OSA patients, further increasing cardiovascular risk [56]. Moreover, there is an increased incidence of coronary artery disease, heart failure, and arrhythmias in patients with OSA [54]. Furthermore, both OSAS and obesity often result in poor sleep quality, which worsens metabolic issues. The synergistic effect of obesity and OSA amplifies these risks, necessitating prompt recognition and management.

4.1.1.5. Treatment modalities. Weight loss through lifestyle modification, pharmacotherapy, or bariatric surgery can lead to significant improvements in OSA severity. Sustained weight reduction is associated with decreased AHI and improved symptoms [57]. Evidence suggests that significant weight reduction through bariatric surgery leads to notable improvements in OSA severity. A meta-analysis demonstrated that bariatric surgery results in a substantial decrease in BMI, with an associated reduction in the AHI. However, post-surgical outcomes vary, and some patients continue to exhibit moderate to severe OSA despite significant weight loss [58]. Recent studies have highlighted the potential of incretin-based therapies (e.g., GLP-1 and GLP-1/GIP receptor agonists such as semaglutide and tirzepatide) in weight management and OSA improvement. The SURMOUNT-OSA trial reported a significant reduction in both body weight and AHI following tirzepatide treatment, with some patients achieving near-complete resolution of OSA [58].

Continuous positive airway pressure (CPAP) remains the gold standard treatment for OSA, providing pneumatic splinting of the airway to prevent collapse. In obese patients, CPAP has been shown to significantly decrease the frequency of apneas and hypopneas, improve daytime sleepiness, enhancing alertness and quality of life, and lower blood pressure, contributing to better cardiovascular outcomes [59]. However, the persistence of obesity despite effective OSA control through CPAP limits its impact on symptoms, cardiometabolic risk, and overall quality of life.

Adherence to CPAP therapy can be challenging, with some patients experiencing discomfort or intolerance. For these patients, several alternative options are available, although these therapies are generally less effective in obese patients [60]. Alternative treatments to CPAP therapy include mandibular advancement devices, which are effective for mild to moderate OSA and preferred for their comfort and convenience; positional therapy, which reduces OSA severity in positional-dependent cases but often suffers from poor long-term compliance; and surgical procedures, such as uvulopalatopharyngoplasty or maxillomandibular advancement, which may be appropriate for patients with anatomical airway abnormalities but have variable outcomes. Additionally, early studies on hypoglossal nerve stimulation show promise in reducing OSA severity, though long-term efficacy data are not yet available.

4.1.2. Obesity hypoventilation syndrome

Obesity hypoventilation syndrome (OHS) represents a significant intersection of obesity and respiratory sleep disorders, defined by the triad of obesity, daytime hypercapnia (arterial carbon dioxide tension $\geq$45 mmHg), and respiratory sleep disorders, with exclusion of other causes of hypoventilation [61]. OHS is closely linked to OSA, with approximately 90 % of OHS patients exhibiting OSA, underscoring the synergistic pathophysiology of these conditions [62]. The respiratory dysfunction in OHS is multifactorial, including mechanical constraints from excess adiposity, impaired respiratory muscle function, and a diminished ventilatory drive exacerbated during rapid eye movement (REM) sleep [62,63]. Notably, leptin resistance, often observed in obesity, may contribute to the attenuated central respiratory drive [64]. Beyond the respiratory implications, OHS is associated with systemic cardiometabolic comorbidities, including pulmonary hypertension, heart failure, and type 2 diabetes, which collectively exacerbate morbidity and elevate mortality risk [65–67]. Management of OHS emphasizes a multimodal approach, combining positive airway pressure (PAP) therapies - CPAP for OHS with severe OSA and non-invasive ventilation (NIV) for cases dominated by hypoventilation - with lifestyle interventions targeting weight reduction [68–70]. Despite these interventions, the long-term prognosis remains guarded, necessitating further research into integrative therapeutic strategies [71]. The bidirectional relationship between obesity and sleep is particularly evident in OHS, where sleep-disordered breathing not only emerges as a consequence of obesity but also perpetuates metabolic dysfunction, highlighting the need for comprehensive management addressing both conditions.

4.2. Non respiratory sleep disorders

4.2.1. Insomnia

Insomnia is considered the most frequent sleep disorder, interesting up to 10 % of the adults in Europe [72]. According to the International Classification of Sleep Disorder third edition, insomnia is defined as a persistent difficulty of initiating and or maintaining sleep, including sleep fragmentation, or waking up to earlier than desired. These essential sleep features of insomnia must be associated with sleep dissatisfaction and diurnal complaints, namely fatigue, malaise, attention/concentration and/or memory impairment, mood disturbances and/or irritability, daytime sleepiness, behaviour problems, reduced motivation, and proneness for errors/accidents [73]. Thus, insomnia is nowadays recognized as a 24-h disease [73]. Insomnia is a heterogeneous clinical entity encompassing different phenotypes, often present in a single individual throughout his or her clinical history. Recently, a specific subtype of chronic insomnia with short sleep duration (ISSD) has been defined, with an objectively documented average sleep duration of less than 6 h per night [73]. ISSD has been considered a more severe phenotype associated with higher cardiovascular risk and morbidity compared to insomnia with normal sleep duration [74–78]. A recent meta-analysis has found no difference in BMI between insomniac patients with or without short sleep duration, and no association between ISSD and high BMI [77]. However, a certain degree of heterogeneity in the diagnosis of insomnia and in the assessment of sleep duration has been noted. Moreover, longitudinal studies have demonstrated that obesity was not associated with an elevated risk of future insomnia in comparison with individuals of a normal weight [79,80]. Conversely, the evidence supporting the association between insomnia and future obesity remains controversial and unclear [79,80].

To conclude, further longitudinal studies with large cohorts and standardized diagnostic criteria are required to assess the bidirectional relationship between insomnia and obesity. In addition, such studies should ascertain whether obesity represents a risk for future insomnia or, conversely, insomnia constitutes a risk factor for obesity.

4.2.2. Restless legs syndrome

Restless legs Syndrome (RLS) is a sensorimotor disorder characterized by and urge to move the legs, usually but not always associated with an unpleasant sensation in the inferior limbs, that begins or worsen during period of rest or inactivity in the evening or night, and these symptoms are partially or totally relieved by movement [73,81]. RLS has a prevalence of about 10 % in adult population, increasing with age [73]. The pathophysiology of RLS remains to be fully elucidated. RLS is a multifaceted complex disorder involving the dysregulation of various neural networks, including the mesolimbic and nigrostriatal dopaminergic pathways, GABA and glutamatergic transmission, iron metabolism, and the opioid system [82–84]. Moreover, a complex genetic and environmental background has been proposed as a risk factor for RLS. Different genome-wide association have identified different genetic

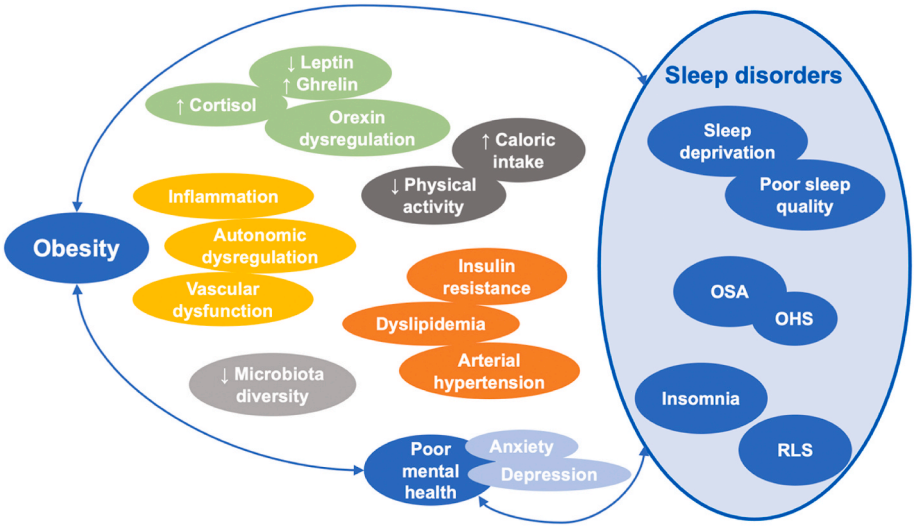

Fig. 1. Pathophysiological pathways regarding the bidirectional links between obesity, sleep disorders and mental health, including hormonal (green), behavioral, (dark grey) physiologic (yellow), cardiometabolic (orange) and microbiota (light grey) elements. OSA: obstructive sleep apnea; OHS: obesity hypoventilation syndrome. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

risk factor for RLS, linked to neurogenesis, network formation, synaptogenesis and axonal guidance [85–87].

A recent meta-analysis has revealed that patients with obesity are susceptible to developing RLS, with a pooled odds ratio of 1.44 [88]. Additionally, female obese subjects exhibit a higher risk compared to their male counterparts, with an odds ratio of 1.42 [88]. Female predominance might be explained by iron changes and sex hormones regulation [89,90]. Didriksen et al. investigated the association between obesity and RLS after controlling for confounding lifestyle variables, such as smoking and alcohol consumption. Their findings demonstrated that, after adjusting for potential confounders, there appeared to be a positive association between obesity and RLS [91]. As demonstrated in the meta-analysis conducted by Zhao et al., obesity has been shown to be significantly associated with an elevated risk of systemic iron deficiency, and iron is an important cofactor in dopamine metabolism [92]. This heightened risk can impede the transportation of iron to the brain, resulting in conditions such as hypoxia and myelin loss [92,93]. These findings might explain the increased risk for restless legs syndrome (RLS) in obese individuals. In addition, a lower number of striatal dopamine D2 receptors has been observed in individuals with obesity, and this finding may contribute to an increased likelihood of developing restless legs syndrome (RLS) [88,94,95]. A large-scale prospective study indicated that obesity ($OR = 1.57$, $p < 0.0001$) and elevated cholesterol levels ($OR = 1.33$, $p = 0.002$), but not hypertension ($OR = 0.09$), exhibited a considerable correlation with an augmented probability of developing RLS [96,97].

Further large, prospective cohort studies are needed to ascertain the correlation between obesity and RLS. The findings indicate that maintaining a healthy body weight may offer a protective effect against RLS, particularly in women.

5. Obesity, sleep, and mental health

The intricate relationship between obesity, sleep disorders, and mental health underscores a bidirectional interplay with profound implications for health outcomes. This triad operates through shared biological mechanisms, including dysregulated inflammatory pathways, hormonal imbalances, and alterations in appetite-regulating hormones such as leptin and ghrelin [98]. For instance, obesity-associated systemic inflammation may heighten vulnerability to mood disorders and disrupt circadian rhythms, perpetuating a cycle of poor mental and physical health [99]. Similarly, psychopathological conditions also influence these interactions. Depression and anxiety, commonly comorbid with obesity, are linked to disordered sleep patterns and disrupted circadian biology [100]. Emerging research highlights the role of neuroinflammatory pathways in bridging these conditions, with elevated markers like interleukin-6 found across obesity, sleep disturbances, and mental disorders [101]. Furthermore, maladaptive behaviours such as emotional eating and sedentary lifestyles in response to stress exacerbate weight gain and further compromise sleep quality [100].

Integrated treatment strategies are critical in addressing these overlapping issues. Multimodal interventions targeting lifestyle modification, psychological support, and improved sleep hygiene hold promise for breaking the cycle of obesity and mental health decline. Future research should prioritize understanding the nuanced interconnections among these factors, paving the way for personalized therapeutic approaches aimed at optimizing both mental and physical well-being.

6. Conclusion

The bidirectional relationship between obesity and sleep disorders represents a critical public health challenge, with significant implications for cardiometabolic, mental, and overall health. Obesity predisposes individuals to sleep disorders such as OSA, insomnia, and RLS, while poor sleep quality and insufficient duration exacerbate weight gain through hormonal dysregulation, metabolic disturbances, and behavioural changes (Fig. 1). This cyclical interplay highlights the need for integrated, multidimensional approaches to assessment and management.

Current treatment modalities, including CPAP for OSA and lifestyle interventions for weight reduction, provide partial relief but often fail to address the underlying complexity of these interconnected conditions. Emerging evidence suggests that a personalized, holistic approach combining weight management, sleep hygiene, and psychological support can break the cycle of obesity and sleep disorders, thereby improving health outcomes and quality of life.

Additionally, the intricate links between obesity, sleep, and mental health demand further exploration to identify shared pathophysiological pathways and effective therapeutic strategies. Future research should focus on understanding these interconnections, optimizing adherence to therapies, and developing innovative interventions that simultaneously target obesity and sleep disorders. Such efforts are essential to mitigating the growing public health burden posed by these intertwined

conditions and fostering long-term well-being.

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