

Chapter 6

Sleep Disturbances, Body Mass Index, and Eating Behavior

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INTRODUCTION

There is increasing recognition that sleep and eating behaviors are related. The evidence for this association arises from clinical manifestations of sleep and eating disorders and from empirical findings using clinical and community samples.

The evidence that sleep might modulate eating comes from longitudinal and cross-sectional studies exploring the effects of sleep difficulties on eating disturbance/body mass index (BMI). These studies analyze the effect of sleep restriction on eating behaviors and weight/obesity, nocturnal sleep-related eating disorder (NSRED) and its comorbidity with eating disorders and obesity, and also sleep difficulties and eating behavior disturbance in subjects from the general population. Conversely, evidence on a link between eating disturbance/BMI and sleep difficulties also arises from longitudinal and cross-sectional studies

exploring the modulation effect of eating behaviors/BMI on sleep disturbance in clinical settings of eating disorders (ED) patients, in subjects with night eating syndrome, in overweight/obese subjects and general population subjects. The association between eating and sleep disturbance might be bidirectional, as suggested by two studies with university students (Bos et al., 2013; Soares et al., 2013). The bidirectional association is not observed in respect to BMI. There is no overlap between eating disturbances and BMI with respect to their association with sleep disturbance. These results and those from other studies raise the question on eating disorders and weight overlapping regarding their association with sleep difficulties. We also explored psychological and neuroendocrine mechanisms that have been implicated in the relation between sleep and eating disturbances. With respect to psychological mechanisms, we paid special attention to the hypothesized mediation role

of psychological arousal (Soares et al., 2013; Preedy, Patel, & Le, 2013), which was empirically explored in a sample of university students.

Clinical and research implications from these findings were examined.

STUDIES EXPLORING THE EFFECT OF SLEEP DIFFICULTIES ON THE MODULATION OF EATING DISTURBANCES/BMI

Short/Long Sleep Duration and Weight: Findings from Epidemiological, Population-Based Cohort Studies and Laboratorial Studies

Since the last part of the twentieth century, the trend of weight gain with a prevalence of increasing obesity and metabolic disease risk (e.g., type 2 diabetes) has accompanied nightly sleep decrease in the Western world (e.g., Killgore et al., 2013).

Several literature reviews of epidemiological studies on sleep restriction and weight link revealed that short (and, less frequently, long) sleep duration is associated with and is a risk factor for greater weight gain and obesity in children and adults (e.g., Cappuccio et al., 2008) or in specific age ranges throughout adulthood (Gangwisch, Malaspina, Boden-Albala, & Heymsfield, 2005). However, prospective cohort studies produced mixed findings, with some studies confirming that short as well as long sleep duration increased the risk for weight gain/obesity. Other studies found opposing results and suggested that only current short sleep was associated with obesity, and, therefore, sleep restriction was a correlate but not a predictor of weight gain/obesity (Anic, Titus-Ernstoff, Newcomb, Trentham-Dietz, & Egan, 2010; Lauderdale et al., 2009; Stranges et al., 2008).

Laboratory studies on behavioral and neuroendocrine mechanisms underlying sleep restriction and weight gain showed that sleep restriction induces metabolic disturbances (e.g., impaired glucose tolerance; increased plasma cortisol) and changes in the levels of appetite regulation hormones, specifically by increasing ghrelin (an orexigenic hormone released from the stomach) and decreasing leptin (an anorexigenic hormone released from adipocytes) (e.g., Spiegel, Tasali, Penev, & Van Cauter, 2004). These changes might promote hunger and affect the person's macronutrient preferences, eating behaviors, and patterns, leading to weight gain/obesity. Thus, experimental studies showed that sleep deprivation is associated with increased self-reported hunger and appetite (e.g., Spiegel et al., 2004), increased caloric intake (e.g., St-Onge et al., 2011), and greater consumption of and preference for caloric-dense and palatable foods, specifically for foods rich in carbohydrates (e.g., Nedeltcheva et al., 2009; Spiegel et al., 2004) and fats

(e.g., St-Onge et al., 2011), including snacks (Nedeltcheva et al., 2009), sweets, salty foods, and starchy food (Spiegel et al., 2004).

Short sleep duration also might promote weight gain by increasing the frequency of meals and by a later circadian time of calorie consumption, such as consuming extra calories in the evening, at dinner, and during late night hours/early morning (e.g., Spaeth, Dinges, & Goel, 2013). Other factors such as health-related behaviors (physical inactivity and consumption of alcohol and tobacco), illness, use of medication, and psychological distress, which are associated with both short and long sleep duration, might contribute to weight increase/obesity (Theorell-Haglow, Berglund, Janson, & Lindberg, 2012).

Sleep Difficulties and Eating Behavior Disturbance/BMI in Convenience Samples of Subjects from the General Population

Two cross-sectional studies with two convenience samples of undergraduate students (Lopes et al., 2011; Soares et al., 2011) and one population based study with a retrospective design (Trace et al., 2012) suggested that current sleep difficulties are associated with current eating behavior disturbances and a lifetime history of eating disorders.

Soares et al. (2011), in a sample of university students of both genders, showed an association between sleep difficulties and eating behavior disturbance, particularly bulimic behaviors (BB). Both male and female insomniacs also revealed an odds ratio for BB higher than good sleepers. The association between sleep difficulties and social pressure to eat (SPE) is observable in males and the association between sleep difficulties and diet concerns (DC) is less consistent and only observable in females (Soares et al., 2011). BMI was correlated negatively with global sleep difficulties (Sleep Difficulties Index (SDI)), difficulties of initiating sleep (DIS), and insomnia symptoms, but it was not a significant predictor.

In university students of both genders, Lopes (2011) used three measures of subjective sleep restriction (sleep duration, sleep needs, and sleep deficit) and confirmed the association between lower sleep needs (<6h sleep) and increased BMI in males but not in females. In a subsample of 303 females, eating behavior disturbances were also explored and female short sleepers (<6h sleep) revealed higher levels of DC than females who usually slept more than 8h, but no significant differences were found with respect to BMI between groups. The results also showed that sleep deficit was a predictor of eating behavior disturbances, particularly of BB. Although the associations between sleep duration and DC and between sleep deficit and global eating disturbance were also significant, they were mediated by self-reported psychological/mental health. With respect to BMI, although it was associated with

and predicted by high levels of global eating disturbances, BB, lower levels of SPE, and poor physical health, it was not associated with sleep restriction in females.

A lifetime history of binge eating can be a risk factor for increasing prevalence of current sleep difficulties (not getting enough sleep, sleeping poorly, problems of falling asleep, feeling sleepy during work or free time, and disturbed sleep) in women from the general population, after controlling for lifetime history of depression and obesity status (Trace et al., 2012). After controlling for lifetime depression, only some sleep difficulties (early awakening and restless sleep) were not associated with binge and obesity status, which suggests that having a lifetime diagnosis of depression contributes to the association with some but not all sleep difficulties.

Nocturnal Sleep-Related Eating Disorder and Eating Disturbance/BMI

Other evidence that sleep is associated with disordered eating behavior comes from NSRED, which is characterized by a combination of sleep disturbances and abnormal eating at night. Nocturnal sleep-related eating disorder consists of a state of partial arousal from sleep, occurring within the first 3 h after sleep onset, followed by rapid episodes of ingestion of food (that can include eating in a sloppy manner or eating unusual combinations of food or inedible substances) described as out of control. Sometimes this arousal state is described as a confusional state or of half-awake or completely asleep, and in the following morning memory of the episode could be impaired (partial or total amnesia).

Nocturnal sleep-related eating disorder has also often been shown to be associated with lifetime and current eating disorder diagnosis (Schenck, Hurwitz, Bundlie, & Mahowald, 1991; Schenck, Hurwitz, O'Connor, & Mahowald, 1993) and with weight gain and a high prevalence of overweight/obesity (e.g., Schenck et al., 1991, 1993; Winkelman, 1998).

In subjects who were referred to sleep disorder clinics, the prevalence of NSRED was between 0.5% and 5% (Winkelman, Herzog, & Fava, 1999). In subjects with NSRED, anorexia nervosa with nocturnal bulimia was found in 10.5% (2 of 19) and nightly sleep-related binge eating in 84% by Schenck et al. (1993). A lifetime history of an ED was found in 10.5% and in 34.8% of patients (Schenck et al., 1991; Winkelman, 1998).

In subjects with eating disorders, NSRED was found in 16.7% of ED outpatients and 8.7% of ED inpatients (Winkelman et al., 1999). Gupta (1991) observed that 31% of bulimic females had NSRED with partial amnesia two or three times per month.

Studies on the prevalence of NSRED in undergraduate students showed rates between 0.6% (Goldin & Rosen, 1997) and 4.7% (Winkelman et al., 1999).

STUDIES EXPLORING EATING BEHAVIOR DISTURBANCES/BMI EFFECT ON MODULATION OF SLEEP DIFFICULTIES

Studies in ED patients, patients with night eating syndrome (NES), and subjects from the general population suggested that sleep might be modulated by disordered eating/BMI. Body mass index is considered a proxy of eating disorders; it is included in ED diagnostic criteria and BMI cutoffs are used to define overweight/obesity (Figure 1).

Eating Disorders and Sleep

Eating disorders, namely anorexia nervosa (AN), bulimia nervosa (BN), and binge eating disorder (BED) (APA, 2013), are characterized by severe eating behavior disturbance and nutritional deviance.

Core features of AN are (1) persistent restriction of energy intake and maintenance of excessively low body weight considering the age, height, sex, developmental trajectory, and physical health; (2) intense fear of gaining weight or becoming fat or persistent behavior that interferes with weight gain (APA, 2013; ICD-10, 1992); and (3) disturbance in self-perception of weight or shape and undue influence of body weight or shape on self-evaluation. ICD-10 also includes the loss of sexual interest or potency in men and amenorrhea in post-menarche women (ICD-10, 1992). Amenorrhea is part of DSM-IV-TR (APA, 2002) AN criterion but is excluded from DSM5 (APA, 2013).

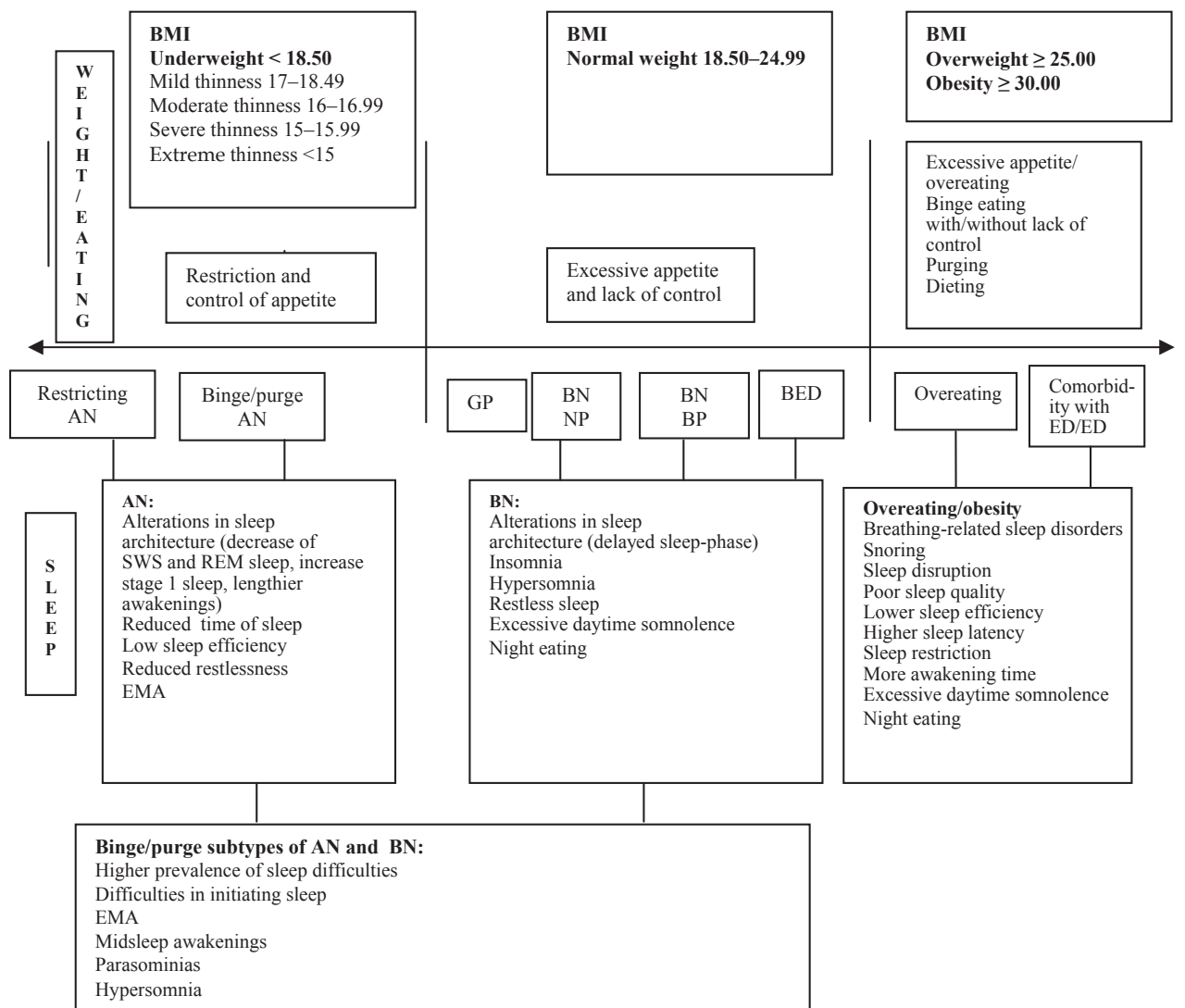
Although clinical judgment is necessary to evaluate a body weight below normal or below the minimal expected level (DSM-V, criterion A), BMI is used to operationalize the levels of thinness severity for adults (BMI (kg/m²) for low weight <18.5; BMI for thinness ≤17.0) (APA, 2013) (Figure 1) or the corresponding BMI-for-age percentiles for children and adolescents (APA, 2013 criterion A).

The essential features of BN are recurrent episodes of binge eating accompanied by a lack of control over feeding, and use of inappropriate weight gain compensatory behaviors.

There are two subtypes of AN (APA, 2002): the restricting subtype (AN-R) is characterized by excessive caloric restriction whereas the binge-eating/purging subtype (AN-BP) is characterized by binge eating and purging. Also, two subtypes of BN are described, purging (BN-P) and non-purging (BN-NP), during current episodes of BN.

Binge eating disorder is characterized by recurrent episodes of consumption of unusually large amounts of food in a discrete period of time, while feeling that eating is out of control in the absence of extreme weight control behaviors, as seen in BN. Binge eating is a symptom of BED and can be also a symptom of BN, AN-BP subtype, and NES.

Although AN and its subtypes, BN and its subtypes, and BED involve different eating behavior disturbances, a common



BMI = body mass index (kg/m^2); AN = anorexia nervosa; BN = Bulimia nervosa; BN NP = Bulimia nervosa - non purging; BN BP = Bulimia nervosa - binge purging; BED = Binge eating disorder; BMI = Body mass index; GP = Eating behavior disturbances in the general population subjects; EMA = Early morning awakening; SWS = Slow wave sleep; REM = Rapid eye movement sleep.

FIGURE 1 The continuum of eating disorders and weight and associated sleep difficulties.

characteristic of AN patients is the maintenance of severe caloric deficits necessary to continue low weight, whereas BN and BED patients usually maintain weight in a normal range or may even gain weight (Figure 1).

Clinical observations of AN patients' sleeping habits considered that usual symptoms are interrupted sleep and early morning waking (Crisp, Stonehill, & Fenton, 1971; Dally, 1969). Less frequently, initial insomnia might occur in anorectic patients. Anorectic binge-eating/purging subtype patients (AN-B/P) may also have initial insomnia and nocturnal sleep waking to overeat (Dally, 1969).

Objective sleep studies of sleep characteristics in AN patients with low body weight showed alterations in sleep

architecture, such as decreased amounts of slow wave sleep (SWS) (Lacey, Crisp, Kalucy, Hartman, & Chen, 1975), reduction of rapid eye movement (REM) sleep (Delvenne, Kerkhofs, Appelboomfondu, Lucas, & Mendlewicz, 1992; Lacey et al., 1975), insomnia, especially early morning waking, reduced sleeping time, especially in the last 4 h of the night, reduced restlessness (Lacey et al., 1976), low sleep efficiency, and lengthier awakening (Delvenne et al., 1992).

More often than controls, BN patients report insomnia, specifically difficulty falling asleep and early morning awakening, restless sleep and excessive daytime sleepiness (Latzer, Tzischinsky, Epstein, & Klein, 1999). Bulimics (BN and BED) also have sleep disruptions for binge eating

at night after having fallen asleep, with total or partial amnesia the next morning or total awareness of the episode. Studies with objective sleep measures (actigraphic records) showed they tend to fall asleep and wake up in the morning about 1 h later than healthy controls, which was related to binge-purge, particularly in the evening or at night (Latzer et al., 1999). However, some studies using objective sleep measures of sleep did not replicate these findings and showed no significant differences in sleep characteristics between AN and BN subjects and healthy controls (Lauer, Krieg, Riemann, Zulley, & Berger, 1990). With respect to electroencephalogram (EEG) sleep laboratory studies, Hudson et al. (1987) found only a trend toward increased REM density in the first REM period among bulimic subjects compared with controls, which was not confirmed by others. Levy, Dixon, and Schmidt (1987) found no significant differences between BN and AN patients and healthy control subjects with respect to REM sleep, and Walsh, Gotez, Roose, Fingeroth, and Glassman (1985) found no significant sleep differences between normal weight bulimic patients and controls.

Subjective and objective sleep problems are also associated with BED (Tzischinsky, Latzer, Epstein, & Tov, 2000). Binge eating disorder in obese patients was associated with self-reported snoring, midsleep awakenings, excessive daytime somnolence, sleepiness, and restless sleep (Tzischinsky et al., 2000). Objective sleep assessment by actigraphs revealed that BED patients had significantly lower sleep quality than normal-weight non-binge eater control subjects, as indicated by sleep efficiency, true sleep time, longest episode of continuous sleep, minutes awake during sleep, and minutes of zero activity counts (Tzischinsky et al., 2000).

Only a few studies take into account BN and AN subtypes. The study by Delvene, Kerkhofs, Appelboomfondu, Lucas, and Mendlewicz (1992) is an exception. A comparison in EEG variables of AN patients and controls revealed that AN patients had reduced REM sleep and a comparison of AN restricting and bulimic subtypes revealed that bulimics anorectics had an increase in stage 3 sleep. A recent transversal study of Kim and colleagues (Kim et al., 2010) using self-reported sleep measurements explored the difficulties of falling asleep, midsleep awakening, early morning awakening, parasomnia, and hypersomnia across different ED categories and subtypes in a sample of female ED patients. Sleep disturbances were reported by 50.3% of ED patients, the most common of which were difficulties in initiating (32.5%) and maintaining sleep (17.75%). Although there was no significant difference between AN and BN patients in global sleep disturbance prevalence (58.3% versus 57.3%), those with binge-eating/purging subtypes had significantly more sleep disturbances (56.8% versus 34.1%) irrespective of having an AN/BN diagnosis. Kim et al. (2010) showed that binge and purgative behaviors are particularly relevant to eating disturbances and

sleep difficulties irrespective of AN or BN diagnosis. Both AN-B/P and BN-P were associated with more severe eating disturbances and a higher prevalence of difficulties in initiating sleep, early morning awakening, parasomnias, and hypersomnia than AN-R, BN-NP, and ED not otherwise specified (ED-NOS). Moreover, a higher prevalence of midsleep awakenings were observed in AN-B/P subjects compared with AN-R, BN-NP, and EDNOS, and in BN-P subjects compared with AN-R and BN-NP. These findings suggest a strong association between sleep disturbance and disordered eating, particularly in bulimic/purgative behaviors. Sleep disturbances in ED are also associated with high clinical severity of ED symptoms (Kim et al., 2010), including a high prevalence of binge eating and vomiting, and high levels of global eating disturbances (Eating Disorders Inventory–2 total scores) (Kim et al., 2010). Alterations in the sleep patterns of AN patients may be due to endocrine and metabolic disturbances related to the pursuit of thinness; to nutritional deficits, starvation, and consequent weight loss; and particularly to the occurrence of overeating and purging, as suggested by Kim et al. (2010). On the other hand, the overeating and purgative behaviors in subjects with BB may cause rapid metabolic and neuroendocrine changes that lead to abnormal sleep patterns. Future research on sleep in ED patients might consider ED subtypes.

Night Eating Syndrome and Sleep

The association between eating behavior disturbance and sleep difficulties is also supported by NES, which is characterized by recurrent episodes of night eating, as manifested by eating after awakening from sleep or excessive food consumption after the evening meal (APA, 2013) (Table 1). Moreover, objective measures of sleep showed that this pattern of disordered eating occurs during non-REM sleep and is associated with low sleep efficiency (Wal, 2012).

It was first described in obese female patients by Stunkard, Grace, and Wolff (1955). Since then, its criteria have been revised and modified several times because they were not consensual. Therefore, a group of experts who recently met during the First International Night Eating Symposium proposed a set of diagnostic criteria for NES (Allison et al., 2010) to be tested in research and clinical practice (Wal, 2012) (Table 1). In 2013, the NES diagnostic category was included in the fifth edition of the *Diagnostic Manual of Mental Disorders* (DSM-5) (APA, 2013) within the category Other Specified Feeding or Eating Disorder, which is proposed to be used in situations in which the symptom presentation does not meet the criteria for any specific feeding and eating disorder (Table 1).

Night eating syndrome is often a long-lasting problem (Wal, 2012) that can occur in normal weight, overweight/obese subjects, in subjects with current or lifetime eating disorder diagnoses, and in those with sleep disorder diagnoses.

TABLE 1 Night Eating Syndrome Characteristics

Group of Experts (Allison et al., 2010) ^a	DSM-5 (APA, 2013)
(A.) Daily pattern of eating, characterized by significantly increased intake in the evening and/or nighttime, as manifested by:	Recurrent episodes of night eating, as manifested by eating after awakening from sleep or by excessive food consumption after the evening meal
(A.1.) Evening hyperphagia (consuming at least 25% of food intake after the evening meal and/or at least two episodes of awakenings with nocturnal eating per week) and/or	
(A.2.) Episodes of awakenings with nocturnal eating	
(B.) Presence of awareness and recall of evening and nocturnal eating episodes must be observed	There is awareness and recall of eating
(C.) Three of the following five symptoms must be present for an NES diagnosis:	–
(C.1.) Morning anorexia (lack of desire to eat in the morning and/or omission of breakfast on four or more mornings per week)	
(C.2.) Strong urge to eat between dinner and sleep onset and/or during the night	
(C.3.) Sleep symptoms (sleep onset and/or maintenance insomnia on four or more nights per night)	
(C.4.) The person must believe that one must eat to initiate or return to sleep	
(C.5.) Frequently depressed mood and/or worsened mood in the evening	
(D.) Functioning impairment or significant distress associated with the disorder	Night eating causes significant distress and/or impairment in functioning
(E.) Maintenance of the disorder for at least 3 months	–
(F.) The disorder must also not be secondary to substance abuse/dependence, medical disorder, medication, or another psychiatric disorder	The disordered pattern of eating is not better explained by binge eating disorder or another mental disorder, including substance use, and is not attributable to another medical disorder or to an effect of medication
–	The night eating is not better explained by external influences such as changes in the individual's sleep-wake cycle or by local social norms

^aGroup of Experts Meeting, during the First International Night Eating Symposium.

In a sample of women undergoing treatment for obesity, Peixoto (2013) showed that 57% of subjects revealed morning anorexia, 1.2% consumed more than 50% of daily food in the evening, 62.9% have the urge to snack after dinner, 6.7% have cravings or urges to eat when they wake up at night, and 7.9% need to eat to get back to sleep when they wake at night (Night Eating Questionnaire (NEQ), Allison et al., 2008). In these patients, night eating (NEQ total score) was positively associated with short sleep duration, sleep deficit, insomnia, and daytime somnolence (Peixoto, 2013).

The prevalence of NES in obese weight loss patients generally ranges from 4.3% to 15% (Colles, Dixon, & O'Brien, 2007; Kuldau & Rand, 1986) but may exceed from 26% (Rand

and Kuldau, 1993) to 64% (Stunkard et al., 1955). Allison et al. (2006), using a semi-structured interview, found that 1.9% of obese presurgery candidates met diagnostic criteria for a strict definition of NES and 8.9% across all definitions of NES; but its prevalence may exceed 42% in these patients (Wal, 2012).

In referrals to an eating disorders clinic over 3 years Tzischinsky and Latzer (2004) found that 5% met diagnostic criteria for NES. Moreover, the prevalence of NES among patients with BED was 16%, among patients with BN 9%, and among patients with AN binge-purge type 0% (Tzischinsky & Latzer, 2004). Stunkard et al. (1996) also observed a similar prevalence of NES (15%) in women with BED. In women reporting binge eating at least once a week, the prevalence of NES was 37% (Colles et al., 2007).

The prevalence of NES ranged from 0.4% to 1.5% in adult community samples of all weights (Rand & Kulda, 1986; Rand, Macgregor, & Stunkard, 1997) and was 1.1% in children aged 5–6 years (Lamerz et al., 2005). In general population subjects, NES was associated with more eating disturbances, sleep difficulties, and psychopathology. Night eating syndrome was associated with a different circadian distribution of food intake, more severe disordered eating, body image concerns, sleep disturbance, greater depressed mood, perceived stress, decreased quality of life, and more frequent Axis I comorbidity, specifically anxiety, mood, and substance use disorders (Lundgren, Allison, O'Reardon, & Stunkard, 2008). In clinical samples of psychiatric outpatients, the prevalence of NES was 12.3% (Lundgran et al., 2006).

Night eating syndrome is also more common among patients with insomnia (Wal, 2012); its prevalence in subjects who were referred to sleep disorder clinics is 5% (Spaggiari et al., 1994) or 6% (Manni, Ratti, & Tartara, 1997).

Obesity and Sleep

Obesity is a general medical condition characterized by an excess of fat mass in the body. This accumulation of adiposity results from an imbalance between energy intake and energy expenditure. In Western societies obesity has reached epidemic proportions and continues to have alarming increases worldwide in both adults and children (e.g., Finucane et al., 2011); it is one of the major concerns for health according to the World Health Organization (WHO).

Body mass index (BMI = weight (kg)/height (meters)²) is a widely used measure to evaluate global body fat masses. Body mass index is highly and positively correlated with measures of body fat distribution (e.g., circumferences of waist and hips, abdominal sagittal diameter) and therefore is similarly associated with risks of metabolic complications and diseases. Body mass index cutoffs (WHO) are used to define overweight (BMI 25–29.9) and obesity (BMI ≥ 30) (Figure 1). Overweight/obesity could have many causes and contributing factors (e.g., genetic factors, low physical activity, availability of fast food in Western societies) and eating disorder behaviors can be included among these factors. Low control of food intake, eating patterns, and eating preferences of obese subjects might favor an increase in energy intake, leading to weight gain. They usually eat larger amounts of food than they perceive. Many overweight/obese individuals display eating disorder behaviors such as night eating, dieting, fasting, laxative and diuretic misuse, vomiting, binge eating (e.g., Duncan et al., 2007; Peixoto, 2013), and repeated cycles of restricted diet and overeating, leading to weight fluctuations and/or weight gain. In a sample of obese women, Peixoto (2013) found a high prevalence of eating disorder behaviors: 27.8% showed binge eating episodes with loss of control overeating, 1.5% had vomiting, 5.6% used laxatives to lose weight,

and 16% had excessive/compulsive physical exercise to control weight gain. Weight and shape concerns were frequent and 78% of subjects tried to restrict food amounts, 40% of these in all days during the month. A high percentage of BN patients were overweight/obese (e.g., Masheb & White, 2012).

Binge eating disorder is also frequent (Allison et al., 2006). Moreover, a lifetime diagnosis change/crossover might occur. Binge eating is a risk factor for obesity (De Zwaan, 2001) and overweight/obesity may precede BED (Reas & Grilo, 2007) and is a risk factor for BN (Fairburn, Welch, Doll, Davies, & O'Connor, 1997). In addition, the comorbidity between obesity and an ED (BN or BED) confers higher clinical severity to obesity with respect to disordered eating symptoms, sleep disturbance, and psychopathology (e.g., Tzinshinsky & Latzer, 2006).

Overweight and obesity also are often associated with sleep disturbances such as breathing-related sleep disorders (e.g., obstructive sleep apnea (OSA)/hypopnea) in children (Redline et al., 1999) and adulthood (ICSD, 1990), frequent snoring, sleep disruption, difficulties initiating or maintaining sleep, early morning awaking, not getting enough sleep/restless sleep, poor sleep quality (e.g., Peixoto, 2013; Trace et al., 2012; Tzinshinsky & Latzer, 2006), sleep restriction (e.g., Cappuccio et al., 2008; Peixoto, 2013), sleep disruption for eating (e.g., Allison et al., 2006; Schenck et al., 1991), excessive daytime somnolence (EDS) (e.g., Bixler et al., 2005; Resta et al., 2001), feeling sleepy during work or free time, not enough rest, and the need to nap (Trace et al., 2012). Some of these sleep difficulties can be considered risk factors for overweight/obesity (e.g., short sleep duration, NES, NSRED) or a consequence of it (e.g., OSA). Trace et al. (2012) also indicated that most sleep problems of obese women remained significantly associated with obesity when controlling for lifetime depression (all, excluding early awakening and not getting enough sleep).

In objective sleep measures, obese subjects revealed more sleep problems than normal weight controls, including lower sleep efficiency, higher sleep latency, and more awakening time during sleep (Tzinshinsky & Latzer, 2006).

Eating Behavior Disturbances and Sleep Modulation in General Population Subjects

Research on disordered eating and sleep disturbance modulation in community samples is scarce and most of it is cross-sectional.

In the 1950s, a starvation study showed that severe and prolonged dietary restriction in healthy male volunteers can lead to severe physical and psychological problems, including food preoccupation, binge eating episodes, sleep disruption, and a decreased need for sleep (Keys et al., 1950). Makino, Hashizume, Yasushi, Tsuboy, and Dennerstein (2006) in a sample of college students showed that global eating

disturbances and distorted body perception were associated with short sleep duration. [Ohayon and Hong \(2002\)](#) in a sample of subjects from the general population showed that eating before going to sleep was associated with sleep disruption and with non-restorative sleep, and [Veldi, Aluoja, and Vasar \(2005\)](#) in a sample of medical students found that awakening owing to nocturnal eating was associated with poor sleep quality. In a community sample of young adult females, [Seigel, Broman, and Hetta \(2004\)](#) found an association between reports of insomnia, eating disturbances, and concern about body image. Frequent attempts to reduce weight, body image dissatisfaction, feelings of being overweight, fear of becoming fat, binge eating episodes, and the impulse to vomit were significantly associated with difficulties maintaining sleep and with the perception of restless sleep.

Only longitudinal studies are informative about the direction of the causal relationship between sleep and eating problems. In a study of women assessed during and after pregnancy, [Ulman et al. \(2012\)](#) showed that DSM-IV BED symptoms before and/or during pregnancy are associated with sleep problems during pregnancy and with dissatisfaction with sleep 18 months after childbirth.

LONGITUDINAL STUDIES IN GENERAL POPULATION SUBJECTS EXPLORING THE BIDIRECTIONAL ASSOCIATION BETWEEN SLEEP AND EATING DISTURBANCES/BMI: OUR CONTRIBUTION

Two prospective studies on the association of eating and sleep disturbance and BMI might clarify their bidirectionality ([Bos et al., 2013](#); [Soares et al., 2013](#)).

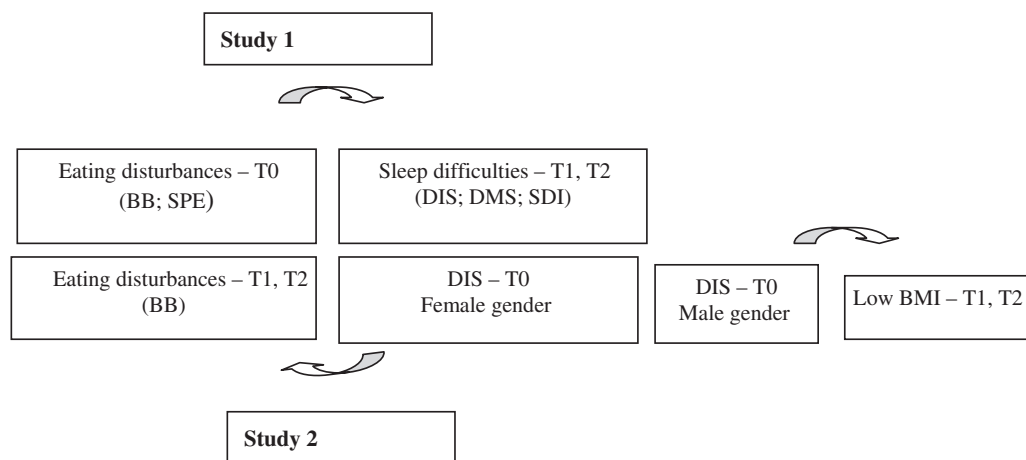
They were performed in the same sample of 870 university students (mean age, 19.59 years; standard deviation, 1.61 years; range, 17–25 years) with both genders represented ($n=544$). These studies comprised three assessment stages: baseline (T_0 ; time 0); 1 year (T_1 ; time 1), and 2 years after the baseline (T_2 ; time 2). At each stage, subjects completed the same measures ([Bos et al., 2013](#)).

Study 1

[Bos et al. \(2013\)](#) explored whether eating disturbances/BMI were predictive of sleep difficulties over time ([Figure 2](#)). This study showed that subjects with more severe global disorders of eating at baseline (particularly BB and SPE) revealed more DIS, DMS, and SDI at all stages of the study (baseline, T_1 , and T_2) compared with students with less severe eating-disordered behaviors. Concerning DC, the association with sleep disturbances was less robust. Nevertheless, the group with more severe DC and behaviors at baseline revealed more overall sleep difficulties (SDI) over time than the group with less severe DC. Moreover, the groups with persistent insomnia, remission, and onset of sleep difficulties at T_1 and T_2 revealed more disordered global eating behaviors and more BB and SPE at baseline compared with good sleepers.

Additionally, the group with sleep onset difficulties over time revealed more DC at baseline than did good sleepers.

This study also revealed that BB and SPE are the predictors of long-term difficulties of initiating and maintaining sleep and of persistent insomnia. However, BMI was not a significant predictor of eating disturbances and of sleep difficulties over time ([Bos et al., 2013](#)).



The findings from [Bos et al. \(2013\)](#) and [Soares et al. \(2013\)](#) studies; BB = Bulimic behaviours, SPE = Social Pressure to Eat; DIS = Difficulties in initiating sleep; DMS = Difficulties in maintaining sleep; SDI = Sleep Difficulties Index; BMI = Body Mass Index; T0 = Time 0/baseline; T1 = Time 1/one year after; T2 = Two years after

FIGURE 2 Bidirectional association between sleep and eating disturbances/BMI.

Study 2

Soares et al. (2013) explored whether sleep difficulties are predictive of eating disturbances/BMI (Figure 2). Findings revealed that insomniacs at baseline showed consistently more severe disordered global eating behaviors, DC, BB, and SPE over time (at T_1 and T_2) and also a lower BMI at T_2 than good sleepers. This study also revealed that female gender and DIS at baseline were predictors of BB over time. DC, SPE, and global eating disturbances predictors were less consistent over time. In respect to BMI, consistent predictors overtime were male gender and DIS at baseline.

Results from both of these studies substantiate the bidirectional association between sleep and eating disturbances, particularly difficulties initiating sleep and BB. In contrast, a dual directionality between BMI and sleep disturbance was not observed and only difficulty initiating sleep and male gender were predictive of low BMI.

BODY MASS INDEX VERSUS EATING BEHAVIOR DISTURBANCES ASSOCIATIONS WITH SLEEP

BMI and Eating Disturbances

There is evidence from the literature that BMI is associated with disordered eating in clinical samples and in general population subjects, and BMI is often considered a proxy for eating problems and nutritional deviance. In fact, BMI cutoffs are part of the operational diagnostic criteria of AN (DSM-5, 2013) and are used to define obesity and its severity (WHO). Weight is also part of BN and BED, and maintenance of normal range weight, weight fluctuations, and a tendency to gain weight or to be obese characterize them (Figure 1). With respect to the association between body weight/BMI and sleep patterns findings from literature are mixed; some studies confirm this association and others do not.

Weight/BMI and Sleep

As described in this chapter, several clinical and research findings support an association between underweight (e.g., AN), overweight/obesity, and weight fluctuation (e.g., weight loss, weight gain as observed in BN and in the general population) and sleep problems.

The relation between weight and sleep is supported by experimental studies on the impact of weight gain/loss on sleep with animal models (Guan, Vgontzas, et al. 2008; Jacobs & McGinty, 1971), with healthy males from the general population (Keyes, 1950), and with clinical samples of psychiatric patients, AN patients, and obese patients (e.g., Bixler et al., 2005; Crisp et al., 1971; Dixon, Schachter, & O'Brien, 2001; Resta et al., 2003).

In psychiatric outpatients, weight loss is associated with reduced duration of sleep, more broken sleep, and early waking; inversely, weight gain is associated with longer duration of sleep, unbroken sleep, and later waking (Crisp & Stonehill, 1973). A consistent finding from research is that weight loss in AN patients is accompanied by an increase in sleep difficulties such as insomnia, particularly with middle and terminal insomnia (Crisp & Stonehill, 1973), and with a decreased amount of total sleep (Crisp et al., 1971). Conversely, weight gain weight/restoration in anorexics is accompanied by subjective improvements in sleep (increase in sleep duration and decrease of wake time), confirmed by studies with objective sleep measures (Lauer & Krieg, 2004). More specifically, the last one revealed that weight gain is associated with improvements in sleep continuity and sleep architecture (Lauer & Krieg, 2004): namely, with a decrease in intermittent awake time, an increase in the amount of REM sleep (Lacey et al., 1975; Lauer & Krieg, 1992; 2004), and a reduction in NREM stage 3 sleep for the benefit of stage 4 sleep (Lauer & Krieg, 1992). Improvement in NREM was found to be less consistent with some authors confirming its occurrence. Some authors found them (Lauer & Krieg, 2004) while others did not (Lauer & Krieg, 1992), and they were shown to be unstable throughout weight recovery (Lacey et al., 1975). However, Delvene et al. (1992) in a study with AN, BN, and control subjects, found that sleep EEG variables were not significantly correlated with BMI. A general finding emerged of a relationship between weight loss and weight gain, longer duration of sleep, unbroken sleep, and later waking with weight recovery in ED patients.

In community samples, evidence of BMI/weight and sleep link is mixed. Some studies showed significant positive associations between having a high BMI (e.g., being overweight/obese) and, for example, nocturnal awakening, insomnia, excessive daytime somnolence, less need for sleep in males, and short and long sleep duration (e.g., Bjorvatn et al., 2007; Cappuccio et al., 2008; Gangwisch et al., 2005; Lopes, 2011; Ohayon & Hong, 2002; Oyahon & Vecchierini, 2005; Rosmaninho, 2011).

Even an inverse association between BMI and sleep difficulty and sleep duration was reported (Soares et al., 2011; Soares et al., 2013; Xiang et al., 2009) in two studies performed on university students (Soares et al., 2011; Soares et al., 2013) and on females (but not in males) from the general population of China (Xiang et al., 2009).

However, there are also several studies with clinical samples of ED, obese patients, NED patients (e.g., Delvenne et al., 1992; De Zwaan, Burgard, Schenck, & Mitchell, 2003; Lauer & Krieg, 2004; Peixoto, 2013), and persons from the community whose findings did not indicate an association between BMI and sleep problems (e.g., Lamerz et al., 2005; Rand et al., 1997; Seigel et al., 2004).

Eating Disturbances, Weight/BMI and Sleep Difficulties

An additional finding from the literature is that disordered eating and weight/BMI could be differently related to sleep disturbances, as suggested by findings from studies exploring both disordered eating behaviors and BMI and sleep difficulties in the same sample.

In a sample of obese women undergoing treatment for obesity, [Peixoto \(2013\)](#) found no significant associations between BMI and sleep duration, sleep needs, sleep deficit, insomnia, and daytime somnolence (DS) although these sleep difficulties were associated with eating disturbance. Using other anthropomorphic measures of body adiposity considered to be more accurate for evaluating central obesity, such as abdominal sagittal diameter and neck circumference, the author found that they were positively associated with self-reported sleep deficit and sleep needs, respectively. However the correlations were poor.

In the transversal study of [Soares et al. \(2011\)](#), low BMI did not contribute significantly to an explanation of sleep difficulty and to the likelihood of reported insomnia symptoms in both genders. Regardless of this, sleep difficulties were associated with and were significant predictors of eating disturbances in both genders, and subjects with insomnia symptoms of both genders also revealed more disordered eating behaviors and consistently more BB.

[Lopes \(2011\)](#) in female university students found that BMI was not significantly associated with sleep restriction. However, sleep deficit, BMI, and self-reported poor psychological/mental health were shown to have a significant contribution to BB explanation. Sleep deficit and sleep duration also were predictive of DC and global eating disturbances, but were mediated by poor psychological/mental health.

Considering the two studies that explored the bidirectional association between sleep and eating disorders ([Bos et al., 2013](#); [Soares et al., 2013](#)), findings indicated a consistent bidirectional association between disordered eating behaviors, particularly BB, and sleep disturbances over time, particularly DIS. In contrast, a dual directionality between BMI and sleep disturbances was not observed. Therefore, low BMI is not a significant predictor of sleep difficulties over time ([Bos et al., 2013](#)), even though sleep difficulties at baseline and male gender were predictive of lower BMI over time ([Soares et al., 2013](#)).

The different association between BMI and sleep difficulties and between eating behaviors and sleep indicate that BMI may not be a good proxy for eating disturbances or their association with sleep disturbances. Therefore, it is possible that BMI may cluster with disordered eating behaviors and nutritional deviance, particularly at the extremes of disordered eating and weight continuum, corresponding these extremes to AN and obesity. However, this is not the case in ED such as BN, BED and EDNOS, which

are characterized by the maintenance of a normal range weight or by weight fluctuations or even a tendency to gain weight in consequence of cycles of restricted diet and overeating, despite the occurrence of severe disordered eating.

POTENTIAL MECHANISMS OF ASSOCIATION

Psychological Correlates of Eating Behavior Disturbances and Sleep Problems

Sleep and eating disturbances are complex phenotypes with a multifactorial, biopsychosocial determination that are not yet completely known. In a previous study ([Soares et al., 2013](#)) using a transdiagnostic perspective that is considered a first step toward assessing common and specific processes of psychopathology, we suggested that psychological arousal might have a role in the bidirectional association between eating disturbance and sleep difficulties ([Soares et al., 2011](#)) ([Figure 2](#)). Some personality traits (e.g., perfectionism; neuroticism, impulsivity, novelty seeking), maladaptive cognitive processes and attributional styles, maladaptive mechanisms of coping with stress, emotion regulation mechanisms, and affective dysregulation (e.g., tendency to experience anxiety, hostility, and depressive affect) might contribute to an increase in the impact of life events and stress, and to the determination/intensification of psychophysiological arousal ([Soares et al., 2013](#)). This might be related to psychological distress, including negative affect, sleep, and eating disturbances. In fact, previous studies showed that stress and sleep disruption are completely mediated by psychophysiological arousal ([Morin, Rodrigue, & Ivers, 2003](#)) and that stress and psychological negative states (e.g., negative affect; anxiety and depression) interfere with efforts to maintain a restricted diet ([Stice, 2001](#)) and are related to overeating, a preference for sweet and fat food ([Adam & Epel, 2007](#)), emotional eating, loss control over eating, and binge eating episodes ([Stice & Shaw, 2002](#)). Intensification or maintenance of psychophysiological arousal can be observed by a feedback process, by worries or concerns about sleep disruption and daytime consequences, and by feelings of failure and concerns about one's loss of control over eating and weight and shape ([Soares et al., 2013](#)) ([Figures 3 and 4](#)).

With the goal of exploring contributing factors to pre-sleep arousal (Portuguese version of the Pre-sleep Arousal Scale (PSAS)) ([Azevedo et al., 2010](#)) and the mediating role of pre-sleep arousal on the association of eating and sleep disturbance, we performed a study on a sample of 468 unmarried female medical and dentistry students, aged 17–24 years (data not published).

Results showed that introversion (Eysenk Personality Inventory–12), negative affect (Profile of Mood States), worries interfering with sleep (loss of sleep over

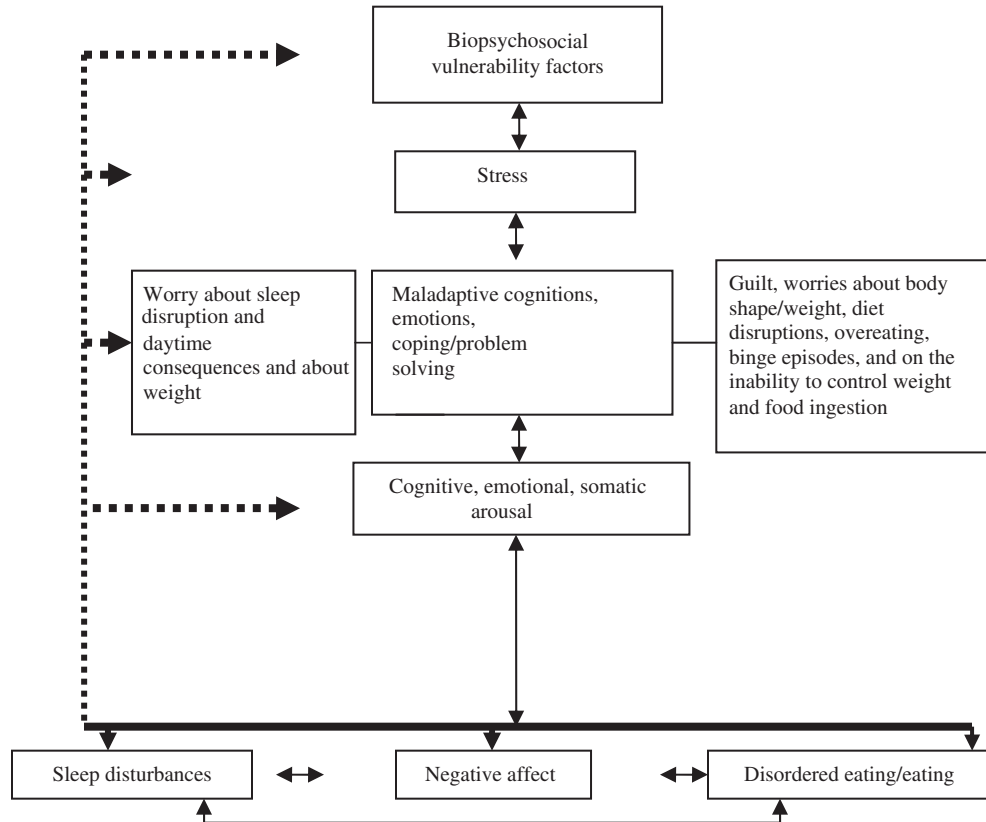


FIGURE 3 Model of possible biopsychosocial factors related to both disordered eating and sleep difficulties.

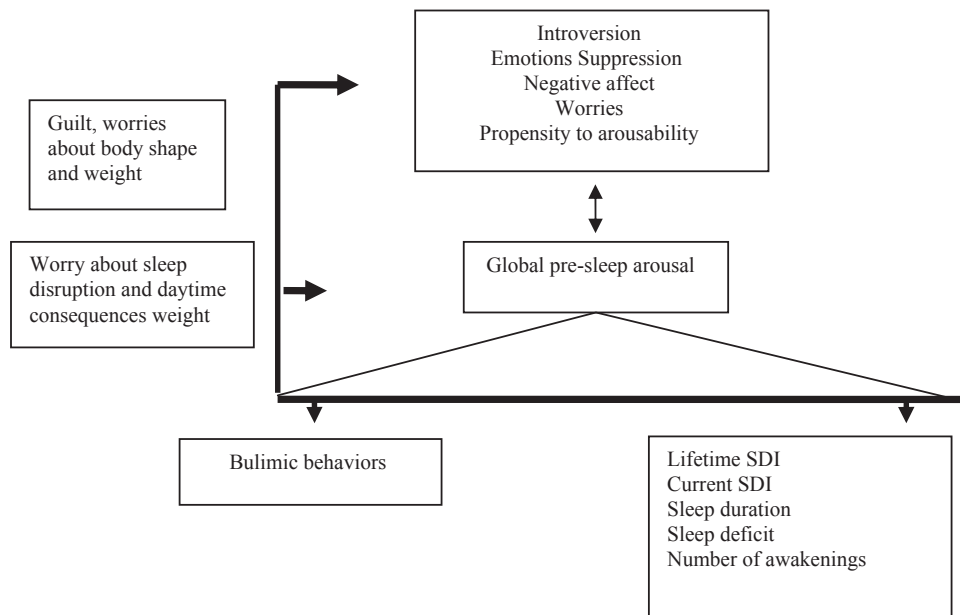


FIGURE 4 Mediation role of pre-sleep arousal in the association of eating and sleep disturbance (including our findings).

worries), arousal propensity (Arousal Pre-Sleep Scale), and emotion suppression (Emotions Regulation Questionnaire) were the PSAS total score significant predictors in a model that explained 41.2% of its variance. Unexpected results

were that perfectionism and impulse strength were not significant predictors of pre-sleep arousal.

As we hypothesized, the global pre-sleep arousal (PSAS total score) was independently associated with both

eating disturbances (Eating Attitudes Test–25) (Pereira et al., 2008) and sleep difficulties. Global pre-sleep arousal was significantly associated with global eating disturbances and BB dimension and with sleep duration, sleep deficit, sleep depth and quality, sleep latency, number of awakenings from sleep, difficulties initiating and maintaining sleep, and excessive daytime somnolence. Because DC, SPE, and BMI were not associated with global pre-sleep arousal, mediation analysis was not performed with respect to these dimensions. Because BB was associated with pre-sleep arousal and both of these were associated with global sleep difficulties (SDI), lifetime and current difficulties initiating and maintaining sleep, sleep duration, sleep quality, sleep flexibility, number of night awakenings, and sleep deficit mediation analyses were performed between BB and these sleep problems using PSAS total score as a mediator.

Results from mediation analysis confirmed the partial mediation role of global pre-sleep arousal (PSA–total score) in the association between BB and sleep duration and its total mediation in the association between BB and both lifetime and current global sleep difficulties (SDI), number of sleep awakenings, and sleep deficit. The mediating role of pre-sleep arousal was not significant in the association of BB with sleep quality and sleep flexibility (Figure 4).

Psychological and mental health (e.g., depression and anxiety disorders) also might have a role in the interrelation of eating and sleep disturbance (Soares et al., 2013) but it was not explored.

Feeding Behavior, Sleep, and Arousal: Neurobiologic Mechanisms

Evidence from multiple sources indicates that sleep and metabolism are largely regulated by the same brain circuits, and that these circuits are also part of stress response and reward systems, with the hypothalamus playing a central role in the modulation of these multiple interacting homeostatic processes and mechanisms (Adamantidis & de Lecea, 2008; Boutrel & de Lecea, 2008).

The lateral hypothalamus area (LH) has a key role in the regulation of ingestive behavior and sleep–waking regulation. Some peptides are expressed in the brain only by neurons in this area: melanin concentrating hormone (MCH) and hypocretins 1 and 2 (Hcrt 1/Hcrt 2) (also known as orexins A and B) (Sakurai et al., 1998). Activation of Hcrt neurons has postsynaptic excitatory properties, whereas MCH neurons are thought to have the opposite effect (Sakurai, 2007).

Hypocretin neurons have widespread projections throughout the brain, especially to areas involved in energy homeostasis, arousal, and brain reward (Boutrel & de Lecea, 2008), including the cortex, hippocampus, amygdala, nucleus accumbens, histaminergic tuberomammillary nucleus (TMN), thalamus, ventral tegmental area (VTA), locus coeruleus (LC), and raphe. In turn, afferents to these

neurons project from multiple areas linked to the regulation of the sleep–wake cycle, energy homeostasis, and motivation such as the basal forebrain, bed nucleus of the stria terminalis, lateral septum, preoptic area, and posterior hypothalamus (Yoshida, McCormack, Espana, Crocker, & Scammell, 2006).

Melanin concentrating hormone neurons have numerous roles, and their involvement in feeding behavior and energy homeostasis is well documented (Pissios, Bradley, & Maratos-Flier, 2006). Melanin concentrating hormone has acute short-term orexigenic properties and the MCH system is up-regulated after fasting. Available evidence demonstrates that activation of the MCH system decreases energy expenditure.

Appetite is regulated by the interaction between metabolic and hormonal signals in the central nervous system, mainly in the LH. This brain region regulates energy homeostasis (i.e., food intake and metabolism) by sensing circulating hormones (e.g., leptin and ghrelin) and by integrating autonomic, endocrine, and environmental signals into coherent goal-directed behaviors such as feeding (Adamantidis & de Lecea, 2009). Leptin is a satiety hormone produced by adipose tissues that inhibits hypothalamic arcuate neurons that coexpress neuropeptide Y (NPY) and agouti-related peptide (AgRP) and activate proopiomelanocortin (POMC) neurons that also coexpress cocaine- and amphetamine-related transcripts (CART). In contrast, ghrelin, a hormone from the digestive tract, has the opposite effect and is appetite-stimulating. Thus, activation of POMC/CART and NPY/AGRP neurons induces anorexigenic and orexigenic properties, respectively.

With respect to the association between sleep and ingestive behavior, we know that sleep duration and the length of a sleep–wake cycle are inversely correlated with brain metabolic rate across species (Savage & West, 2007). Also, sleep disturbances (e.g., sleep reduction) are associated with hormonal imbalances that may result in metabolic disorders, including obesity and diabetes (Knutson & Van Cauter, 2008). In this context, epidemiological studies have shown a strong association of short sleep duration with lower leptin and higher glucose and ghrelin levels (Chaput, Després, Bouchard, & Tremblay, 2007; Taheri, Lin, & Mignot, 2004). Such peripheral signals activate NPY/AgRP neurons and inhibit POMC/CART neurons (Abizaid & Horvath, 2008). This result in a feeding signal, which may be responsible for the higher BMI and increased incidence of type 2 diabetes reported after protracted sleep disturbance (Penev, 2007).

Thus, according to Adamantidis and de Lecea (2008), the Hcrt and MCH systems have an antagonistic function in sleep and metabolism. Activation of the Hcrt system promotes wakefulness and induces energy expenditure. In contrast, the MCH system is thought to promote energy conservation and to be a sleep-promoting system, possibly by inhibiting arousal centers of the brainstem and posterior

hypothalamus or by activating sleep-promoting neurons of the anterior hypothalamus (Adamantidis et al., 2008; Modirrousta, Mainville, & Jones, 2005; Verret et al., 2003).

The scope of functions in which the Hcrt system is implicated largely exceeds the regulation of sleep and eating. Multiple evidence has shown that the Hcrts are critical for the maintenance of arousal. By arousal, we mean a state of heightened cortical responsiveness to sensory input mediated by activation of the ascending reticular formation located in the brainstem, accompanied by an increase in physiological activity (Adamantidis & de Lecea, 2009).

Behavioral arousal is a key component of the stress response and recent data indicate that the hypocretinergic system may also be a component of response of the hypothalamo–pituitary–adrenal (HPA) axis. Activation of the HPA axis consists of increased release of corticotropin-releasing factor (CRF) from the paraventricular nucleus of the hypothalamus (PVN), stimulating adrenocorticotropin hormone (ACTH) secretion from the pituitary, which afterward increases secretion of adrenal corticosteroids.

Intracellular recordings of Hcrt neurons indicate that CRF, which is responsible for initiating the central stress response, directly depolarizes hypocretinergic cells (Winsky-Sommerer et al., 2004). This effect is likely mediated through CRF-R1.

The fact that Hcrt deficiency results in narcolepsy in humans, dogs, and rodents suggests that the Hcrt system is particularly important in the maintenance of wakefulness (Tsujino & Sakurai, 2009). The brain of narcoleptic patients is practically devoid of Hcrt-producing neurons (Thannickal et al., 2000) and Hcrt peptide infusion promotes wakefulness (Sakurai, 2007).

Close partners in the regulation of wakefulness are noradrenergic, serotonergic, and histaminergic neurons (Anaclet et al., 2009; Passani, Giannoni, Bucherelli, Baldi, & Blandina, 2007). The last is particularly important and regulates basic homeostatic and higher functions including cognition and circadian and feeding rhythms. Furthermore, one of the major outputs of the Hcrt system that promotes wakefulness is direct activation of histaminergic neurons that are localized exclusively in the TMN, in the posterior hypothalamus. This area of hypothalamus has only recently been recognized as an important waking center (Lin, Sergeeva, & Haas, 2011).

Thus, in addition to their crucial role in stabilizing the sleep–wake cycle, enhanced Hcrt neuronal activity could promote feeding behavior, arousal, and increased energy expenditure acting in part via activation of several mechanisms, including the activation of arousal centers in the brain and increasing sympathetic tone. It is possible that these mechanisms could also be activated via cognitive arousal.

The Hcrt system is also a major component of natural reward associated with feeding behavior, and its activation

can increase hedonic feeding (Adamantidis & de Lecea, 2008). It is possible that sleep and metabolism are also regulated through reward pathways of the brain. Hypocretins and MCH might interact with brain reward pathways to modulate arousal and food-seeking behaviors (Boutrel & de Lecea, 2008; Georgescu et al., 2005). This suggests a pathophysiological role for these circuits in patients with night eating syndrome (NES), NSRED, and narcolepsy, who have sleep perturbation associated with night feeding (Chabas et al., 2007).

The Hcrt and MCH systems, acting in concert with other neurotransmitter systems (serotonergic, histaminergic, dopaminergic, and noradrenergic), are at the heart of different homeostatic functions, illustrating the intricate relationship between wakefulness, stress reactivity, feeding, and reward systems. Therefore, those systems may constitute potentially new targets for therapeutic interventions in sleep disorders, eating disorders, addiction, and emotional problems (Tsujino & Sakurai, 2009).

DISCUSSION

Sleep disturbances, disordered eating behaviors, and BMI are interrelated. There are numerous findings in the published literature supporting the association between eating and sleep disturbances in animal models, as well as in clinical populations of eating disorders and obesity patients, in patients with NES/disorders, and in patients with sleep problems, as well in community samples. Therefore, it is time to explore their bidirectional association and mediation factors.

Results from two recent studies in healthy student populations substantiate the bidirectional association between sleep and eating disturbances (Bos et al., 2013; Soares et al., 2013). Difficulties in initiating sleep (and female gender) at baseline were significant predictors for global eating disturbances and BB 1 and 2 years later (Soares et al., 2013); conversely, BB and social pressure to eat are predictors for overall sleep disturbance, difficulties initiating and maintaining sleep, and persistent insomnia over time (Bos et al., 2013). The interrelation between DC and sleep difficulties was less consistent over time (Bos et al., 2013; Soares et al., 2013).

Both of these studies suggested that the interrelation between disordered eating and sleep difficulties consistently involves BB and difficulties in initiating sleep. The association between sleep difficulties and BB was confirmed by studies in clinical samples of AN and BN patients (e.g., Kim et al., 2010), in undergraduate students (Lopes et al., 2011; Soares et al., 2011), and in young females from the general population (Seigel et al., 2004). In a study on subjects with an eating disorder, Kim et al. (2010) observed an association between sleep difficulties and eating disturbances, particularly bulimic/purgative symptoms, irrespective of the AN or BN diagnosis

(Kim et al., 2010). In a study on young adult females, Seigel et al. (2004) showed that body image dissatisfaction, feelings of being overweight, fear of becoming fat, repeated attempts to reduce weight, and bulimic/purgative behaviors such as binge eating and the impulse to vomit after eating were significantly associated with difficulties in maintaining sleep and with non-restorative sleep. Studies with university students also confirm the role of sleep difficulties in eating disturbance modulation, difficulties in initiating sleep (Soares et al., 2011), and sleep debt (Lopes et al., 2011) particularly related to eating-disordered behaviors and especially to BB. A lifetime history of BE was also found in persons with current sleep problems (Trace et al., 2012), and previous and current BED symptoms were associated with current sleep problems and prospectively with dissatisfaction with sleep (Ulman et al., 2012).

Globally, these findings on eating and sleep association suggest that sleep and eating problems may cluster together (Tzischinsky & Latzer, 2004; Winkelman et al., 1999) throughout a continuum of severity.

In contrast, bidirectionality between BMI and sleep disturbances was not observed. Sleep difficulties at baseline are associated with current and long-time lower BMI (Soares et al., 2011; Soares et al., 2013), but the inverse association is not confirmed. Lower BMI is not a significant predictor of sleep difficulties over time (Bos et al., 2013).

Reports on the association of sleep and BMI in clinical samples and in community samples are mixed and do not show consistent associations between sleep patterns and body weight/BMI. However, the inverse association between sleep difficulties and BMI (Bos et al., 2013; Soares et al., 2013) is unexpected considering the findings of most studies on sleep restriction and weight/obesity, which revealed that short/long sleep and weight increase/obesity are associated (e.g., Cappuccio et al., 2008; Gangwisch et al., 2005). These findings suggest that non-clinical samples of young adults from the general population behave in the same way as clinical samples of AN patients (Dally, 1969). These results may also indicate that difficulties initiating or maintaining sleep and short sleep duration may not correlate (Kripke, Garfinkel, Wingard, Melville, & Marler, 2002), and consequently, their association with weight/obesity may be different. Nevertheless, our findings were similar to those of Xiang et al. (2009), which revealed that Chinese female short sleepers (not males) had lower BMI than medium and long sleepers, after controlling for age and psychiatric disorders.

An additional finding from these two studies exploring the bidirectionality (Bos et al., 2013; Soares et al., 2013) is that BMI and eating disturbances did not overlap with respect to sleep disturbance prediction. Studies simultaneously exploring an independent association of BMI and eating disturbances with sleep disturbances in the same sample might clarify whether BMI is always a proxy for

eating disturbances in this association. Results from these studies are in line with our findings. They also indicated a high positive association between BMI and disordered eating, although both of these are differently related to sleep disturbances.

Therefore, there is a continuum of weight, from underweight/severe thinness to overweight/extreme obesity (Figure 1). This continuum of weight is accompanied by several eating disturbances and disorders: AN-R, AN-BP, BN-NP, BN-P, BED, ED-NOS, obesity, obesity with comorbid eating disorders, and disordered eating behaviors in subjects from the general population (Figure 1). The overlap between eating disturbances and BMI might be higher in the extremes of the weight continuum: namely, AN and obesity. This overlap might be lower in BN, BED, and EDNOS patients, as well as in general population subjects with eating behavior disturbances, because in these subjects, disordered eating behaviors may be observed despite maintaining weight within normal ranges. This continuum of weight and eating disturbances might be accompanied by sleep difficulties (Figure 1). Therefore, BMI could not be a proxy of eating disturbances in their association with sleep disturbances, particularly in cases in which low overlap between both of these is observed. Thus, it may be possible that in our sample of healthy young adults from the general population, BMI and eating disturbances are differently related to sleep difficulties as a consequence of the low overlap between BMI and eating disturbances.

It is also possible that BMI and eating disturbances have different correlates/risk factors, as well as different mediators that might function as covariates/mediators/confounding factors in their link with sleep disturbances, such as, for example, age, gender, and physical and psychological/mental health. In fact, we found a different influence of gender on the association between sleep difficulties and, respectively, BMI (male gender) and eating disturbances (female gender) (Soares et al., 2013). A gender effect is also observed by Lopes et al. (2011) in a sample of university students, where high body mass index was associated with low sleep needs only in males, and by Xiang et al. (2009) in a representative sample from the Chinese general population, in which short sleep duration and BMI were only observed in females. The age might be a correlate or risk factor that can influence predictors and outcomes by its effect on BMI (increased with age), eating disturbances (higher risk and prevalence in adolescence and young adults), and sleep characteristics. Lopes (2011) found a robust association between poor physical health and BMI and between poor psychological/mental health and eating disturbances (BB were associated with both poor physical and psychological/mental health).

The observation that BMI is associated with eating disturbances but is not a proxy for eating disturbances on their association with sleep disturbances also might have

implications for research and clinical settings. One implication is that it will be useful to consider more than BMI cutoffs in the classification of obesity. This may require the definition of phenotypes that will simultaneously consider BMI or other measures of adiposity, the occurrence of disordered eating behaviors, and perhaps sleep problems. Sleep problems may also be involved in the maintenance of eating disturbances and in BMI prediction (Bos et al., 2013, Soares et al., 2013). The presence of sleep disturbance was an indicator of eating symptoms and behavior severity in ED patients (Kim et al., 2010). Sleep disturbance may also be an important clinical marker of disordered eating and could be useful in clinical settings, especially for ED in which patients denied eating symptoms (Kim et al., 2010). They may also be a secondary parameter of recovery (Kim et al., 2010).

Neurobiologic mechanisms involved in sleep and metabolism might explain the association or interrelation of sleep and eating behaviors. Sleep and metabolism are largely regulated by the same brain circuits, which are also part of reward systems and stress response, with the complex hypothalamic machinery underlying the interface between the sleep–wake cycle, feeding behavior, reward, arousal, and stress reactivity. Hypothalamic peptidergic neurons such as the orexin system interact with systems that regulate emotion, reward, and energy homeostasis. This might underline the association between negative emotions, eating under emotional conditions (binge eating episodes and emotional eating), and sleep difficulties/wakefulness.

We hypothesized in a previous study (Soares et al., 2013) that among psychological mechanisms, psychophysiological arousal might have a mediating role in the association between sleep difficulties and eating disturbance. Our study on the mediating role of pre-sleep psychological arousal in the association of eating and sleep disturbances revealed that pre-sleep arousal is a partial/or total mediator of BB and some sleep difficulties (lifetime and current overall sleep difficulties (SDI), sleep duration, sleep deficit, and number of awakenings) but not all. Particularly prone to pre-sleep psychological arousal are individuals with high propensity to arousability, high levels of introversion personality trait, negative affect, and suppression of emotions, revealing maladaptive cognitions such as worries interfering with sleep.

Therapeutic interventions addressing pre-sleep arousal and their correlates may lead to improvements in ED behaviors (e.g., BB), sleep difficulties, and interruption of the circular cycle of associations between both. This interruption can have reflexes in the predictive power of sleep in BMI modulation.

Another implication of our findings is that general practitioner clinicians and specialized clinicians should pay attention to the possibility of coexisting sleep and eating disturbances in ED patients, obese subjects, and subjects

from the general population. Effective prevention and clinical interventions in sleep and eating/weight areas might focus on both eating and sleep disturbances, and assess and intervene in both eating and sleep. This may involve resources and knowledge from both sleep and eating/obesity areas.

An additional implication is that prevention and clinical interventions focusing on disordered eating behaviors and sleep difficulties can ameliorate both and prevent a BMI increase or decrease. Treatment and prevention of ED might reduce sleep difficulties; conversely, a decrease in sleep difficulties might reduce the risk of ED and prevent weight gain or loss.

Studies on bidirectionality described here were performed on university students and our findings may not be generalized to other populations. Future longitudinal research on bidirectionality with other populations might contribute to knowledge in the areas of sleep and eating/weight. Investigations should control for the effect of some likely correlates, contributing factors, and mediators that may intervene in sleep and eating and their association, such as, for example, age, gender, physical and mental health, negative affect states, levels of stress, medication, health-related habits (e.g., alcohol, tobacco), patterns of eating close to bedtime, the macro-composition of nourishment, and the level of patients' activities.

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