



# An Overview of the Relationship Between Meal Timing and Sleep

## Yeme Zamanı ile Uyku Arasındaki İlişkiye Genel Bir Bakış

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### Abstract

Sleep is a crucial aspect of maintaining overall health, yet its mechanisms remain incompletely understood. Sleep deprivation has been linked to numerous social, mental, and physical issues, prompting investigations into various treatment methods. Among these, dietary factors such as meal content and timing have garnered attention. While much of the literature suggests that eating close to bedtime disrupts sleep quality, recent findings propose that considering dietary content may yield different outcomes, potentially enhancing certain sleep parameters. This study seeks to examine the association between meal timing and sleep parameters, aiming to shed light on this complex relationship.

**Keywords:** Sleep, diet, eating time, sleep parameters

### Öz

Uyku, genel sağlığın korunmasında çok önemli bir unsur olmasına rağmen uykunun mekanizmaları tam olarak anlaşılamamıştır. Uyku yoksunluğunun çok sayıda sosyal, zihinsel ve fiziksel sorunla ilişkilendirilmesi, çeşitli tedavi yöntemlerinin araştırılmasına yol açmıştır. Bunlar arasında öğün içeriği ve zamanlaması gibi beslenme faktörleri dikkat çekmektedir. Literatürün çoğu yatma saatine yakın yemek yemenin uyku kalitesini bozduğunu öne sürerken, son bulgular diyet içeriğinin dikkate alınmasının farklı sonuçlar verebileceğini ve potansiyel olarak belirli uyku parametrelerini artırabileceğini öne sürmektedir. Bu çalışma, yeme zamanlaması ile uyku parametreleri arasındaki ilişkiyi incelemeyi ve bu kompleks ilişkiyi aydınlatmayı amaçlamaktadır.

**Anahtar Kelimeler:** Uyku, diyet, yeme zamanı, uyku parametreleri

### Introduction

Sleep is a multifaceted process vital for maintaining overall health and well-being. It serves as a crucial period where communication with the external environment ceases, allowing for the repair and rejuvenation of both the endocrine and nervous systems.<sup>1</sup> Optimal sleep encompasses numerous factors, including sufficient duration, high-quality rest, proper timing, and the absence of any underlying sleep disorders.<sup>2</sup> Conversely, sleep deprivation refers to an insufficiency in quantity, structure, or quality of sleep, often leading to aberrant sleep patterns. Prolonged sleep deprivation can detrimentally impact health and significantly diminish one's overall quality of life.<sup>2</sup>

Chronic sleep deprivation is recognized for its correlation with elevated cortisol and reduced testosterone levels.<sup>3</sup> Elevated cortisol levels are linked to various public health concerns including depression, anxiety, hypertension, obesity, type 2 diabetes, and increased inflammatory markers associated with psychiatric disorders.<sup>4,5</sup> While there exist recommended sleep durations for maintaining health, it's understood that

individuals may require sleep at varying times across different life stages. Certain demographics such as infants and the elderly are particularly susceptible to inadequate sleep.<sup>2,6</sup> A meta-analysis by Grandner and Drummond<sup>7</sup> in 2007 revealed that both insufficient and excessive sleep duration among the elderly independently heightened the risk of cardiovascular disease and cancer-related mortality. Such risks have been attributed to sleep fragmentation within this age cohort.<sup>7,8</sup> Sleep fragmentation is believed to play a significant role in modulating leptin and ghrelin levels, crucial stimulators of sleep duration, energy expenditure, and appetite.<sup>9,10</sup> Studies indicate that chronic sleep deprivation or consistently short sleep durations are associated with reduced leptin levels and heightened ghrelin levels.<sup>11</sup> The focus of this current review is to explore the impact of meal timing on sleep parameters such as quantity, effectiveness, and phases.

### Stages of Sleep

Sleep is a dynamic process comprising slow wave sleep [non-rapid eye movement (REM)] and REM stages. These phases

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develop sequentially during the sleep cycle. Roughly 20-25% of total sleep time is dedicated to REM sleep, while 70-75% is allocated to non-REM sleep.<sup>12</sup> The typical duration of non-REM and REM sleep cycles in adults falls within the range of 90-100 minutes.<sup>13</sup> However, in cases of sleep deprivation or disorders, the duration and sequence of these phases may vary, and individuals may struggle to enter REM sleep altogether.<sup>14</sup> Non-REM sleep encompasses stages ranging from 1 to 3 (NREM 1 to NREM 3), with NREM 1 (N1) representing the lightest stage and NREM 3 (N3) indicating the deepest stage of sleep within this continuum.<sup>15</sup>

The initial two stages of non-REM sleep (N1, N2) are commonly referred to as superficial sleep, while the third stage (N3) is recognized as slow-wave sleep, characterized by deep restorative sleep. REM sleep, also known as paradoxical sleep due to its desynchronized electroencephalography activity, is where most dreams occur.<sup>15</sup> Despite various theories, the biological function of REM sleep remains elusive.<sup>16</sup> However, it is understood that REM sleep serves to periodically activate the brain during both development and sleep without causing full wakefulness.<sup>17</sup> Additionally, REM sleep is implicated in memory consolidation, neuronal plasticity, excitability, and emotional processing.<sup>18-20</sup> Between 10-35% of the population experiences difficulty falling asleep or maintaining sleep.<sup>21</sup> Insomnia, a prevalent sleep disorder, is characterized by inadequate, insufficient, or non-restorative sleep despite sufficient time spent in bed. Studies in our country have found the prevalence of insomnia among various groups to range from 6.1% to 12.56%.<sup>22-24</sup> Addressing sleep hygiene is crucial in managing sleep disorders. External factors such as artificial lighting, caffeine consumption, sedentary lifestyle, inconsistent bedtime routines, and excessive screen time are known to disrupt sleep patterns.<sup>1,25,26</sup>

### **Circadian Rhythm, Sleep and Nutrition**

The circadian rhythm plays a crucial role in coordinating the physiological and biological processes that occur within an organism over a 24-hour period. It serves as an internal clock that regulates various functions, including metabolism and behavior. At its core, this rhythm is governed by an autonomous clock situated in the suprachiasmatic nucleus (SCN) of the hypothalamus, often referred to as the "master clock". Light serves as the primary synchronizing agent for this central clock, which also coordinates secondary clocks located in peripheral tissues.<sup>27</sup> These secondary clocks are influenced by external cues such as nutrition and sleep, which act as "zeitgebers", or timekeepers.<sup>28,29</sup>

Clock genes like BMAL-1 and Period (PER) play a pivotal role in the molecular framework of circadian timing, functioning as transcriptional activators at the heart of the process. These genes operate within a feedback loop controlled by the SCN.<sup>30,31</sup> Disruptions to the circadian rhythm can occur if environmental and behavioral cues are misaligned with the endogenous rhythm governed by the SCN.<sup>27</sup>

Food intake, energy utilization, and energy storage patterns across the 24-hour cycle are intricately regulated by a neuro-endocrinological system. Within this system, numerous

hormones are released with distinct circadian rhythms and overlapping metabolic functions.<sup>32</sup> Hormones sensitive to food intake, such as insulin, leptin, ghrelin, and adiponectin, exhibit circadian release patterns influenced by both the internal circadian rhythm and external factors such as meal timing and light-dark cycles.<sup>33,34</sup> For instance, ghrelin levels typically surge during the day and peak in the evening, contributing to the sensation of hunger experienced later in the day.<sup>35</sup> Conversely, thermogenesis, the process of generating heat and increasing post-meal energy expenditure, tends to be more pronounced in the morning compared to the evening, indicating a greater expenditure of calories following breakfast.<sup>36,37</sup> Studies conducted in mice have shown that nocturnal food intake can induce a significant 12-hour shift in peripheral clock activity, akin to the effects observed in humans working night shifts. However, this shift in clock activity is not mirrored in the central clock.<sup>38</sup> The timing of food intake, particularly consuming meals later in the day or close to bedtime, has been linked to increased body weight.<sup>39,40</sup> Observational studies have indicated that individuals with shorter sleep durations tend to consume more fat or processed carbohydrates.<sup>41</sup> In a study by Heath et al.,<sup>42</sup> it was reported that a high carbohydrate and low protein intake were associated with reduced sleep efficiency in shift-working nurses. However, no specific correlation was found regarding the relationship between bedtime meals and sleep quality after night shifts.<sup>42</sup>

### **Does Meal Timing Affect Sleep Time and Quality?**

Described as a lack of sleep hygiene, various factors such as artificial lighting, caffeine consumption, sedentary lifestyle, inconsistent bedtime routines, and excessive screen time contribute to unhealthy sleeping conditions. Among these factors, food choices and meal timing, particularly consuming meals close to bedtime, stand out as significant determinants affecting certain aspects of sleep quality. Numerous studies have explored the relationship between meal skipping, meal content, and sleep disorders. For instance, Kim et al.<sup>43</sup> conducted a prospective cohort study involving women aged 35-74 years, revealing that increased snack consumption was associated with shorter sleep duration. Additionally, individuals with shorter sleep duration were more likely to skip breakfast compared to those with optimal sleep duration.<sup>43</sup> Another study analyzing data from the National Health and Nutrition Examination Survey between 2005 and 2010 examined participants' eating behaviors and sleep patterns. It found that only a small percentage of short sleepers consumed breakfast, while these individuals tended to consume more energy from snacks and meals consumed after 20:00. Notably, short sleepers had higher sugar and caffeine intake from beverages, particularly among women. However, the total number of eating episodes and overall energy intake were not correlated with sleep duration.<sup>41</sup> Research investigating the relationship between meal timing and sleep quality has yielded diverse findings. Iao et al.<sup>44</sup> examined the impact of meals consumed 1, 2, and 3 hours before bedtime on sleep in participants aged 15-85 from an American survey. Their study revealed that consuming food 1

hour before bedtime increased sleep duration during the week, with female participants experiencing an average of 35 minutes longer sleep time and male participants 25 minutes longer. Furthermore, both short and long sleep durations, as well as post-sleep wakefulness rates, decreased as the interval between eating and bedtime widened.<sup>44</sup>

In a study involving 793 university students and young adults, Chung et al.<sup>45</sup> investigated the effect of meals consumed within 3 hours of bedtime on sleep quality and duration. They found a positive relationship between meal timing and night awakenings, though this association was not linked to shorter sleep duration.<sup>45</sup> Conversely, a study focusing on male participants with obstructive sleep apnea (OSA) revealed that higher food intake in the evening was associated with lower sleep efficiency, reduced NREM percentage, increased arousal, and a higher apnea-hypopnea index (AHI).<sup>46</sup> Another study examined the relationship between traditional meal timing and sleep parameters in individuals with OSA. Participants were categorized based on meal timing habits as early eaters, late eaters, or those skipping meals. The findings indicated associations between dinner timing and sleep latency, AHI, and poor sleep quality. Breakfast and lunch timing were also linked to various sleep parameters, with late eaters showing significantly poorer sleep quality and increased daytime sleepiness compared to early eaters.<sup>47</sup>

Furthermore, Choi et al.<sup>48</sup> discovered that individuals who frequently skipped breakfast and consumed late-night meals were more likely to experience poor sleep quality, with a high prevalence of OSA observed in this group.

Similarly, Crispim et al.<sup>49</sup> investigated the relationship between food intake and sleep patterns in healthy male and female participants. They found that consuming oily foods close to bedtime was negatively associated with REM sleep and sleep onset latency. Additionally, nocturnal fat intake was linked to sleep efficiency and latency in women, while nightly caloric intake correlated with sleep latency and efficiency in women. Overall, eating close to bedtime was inversely related to sleep quality variables.<sup>49</sup>

The glycemic index (GI) of foods, which measures how quickly they affect blood sugar levels, plays a significant role in meal timing and its impact on sleep. High GI foods are known to induce hyperinsulinemia, leading to increased insulin levels in the bloodstream. Tryptophan, an amino acid found in food, competes with other large neutral amino acids. Consumption of high GI foods results in an increased ratio of tryptophan to large neutral amino acids. This occurs because high GI foods stimulate insulin secretion, which helps transport tryptophan across the blood-brain barrier. Consequently, tryptophan can enter the brain and contribute to the production of serotonin

and melatonin, neurotransmitters involved in regulating sleep.<sup>50</sup> In a study investigating the effects of consuming high and low GI foods four hours before bedtime, 12 healthy male participants were provided with either a high-GI or low-GI meal. The study found that consuming a high-GI meal four hours before bedtime reduced the time it took to fall asleep compared to a meal consumed one hour before bedtime.<sup>51</sup> In contrast, Gangwisch et al.<sup>52</sup> reported that high GI foods were associated with increased insomnia over a three-year period in postmenopausal women. They observed that consuming fruits with higher fiber content instead of fruit juice was linked to a lower prevalence of insomnia. Afaghi et al.<sup>53</sup> conducted a study in 2008 to evaluate the effects of a short-term very low-carbohydrate diet on sleep parameters in healthy individuals with ideal body weight and no sleep problems. They found that the percentage of REM sleep relative to total sleep time was significantly reduced during the very low-carbohydrate diet compared to a control night.<sup>53</sup> Additionally, a study assessing the effects of consuming tryptophan-enriched cereal at breakfast and dinner on the sleep of children with neurological disorders revealed increases in sleep efficiency and duration among the children.<sup>54</sup>

Proteins have been a focus of investigation in studies examining bedtime dietary intake and its impact on sleep. Park et al.<sup>55</sup> conducted a cross-sectional study to explore the relationship between the timing and nutritional characteristics of food consumed before bedtime and the sleep quality of night-shift nurses. Their findings indicated that a shorter duration between meals led to objectively measured longer total sleep time. Additionally, the study concluded that consuming a protein-enriched meal or a higher total calorie intake close to bedtime improved certain sleep parameters. In contrast, Lowden et al.<sup>56</sup> reported that consuming more than 20% of one's daily calories before bedtime had a negative effect on sleep. Similarly, a study involving hospital shift workers found a tendency to deviate from normal circadian rhythms as the total calorie intake from bedtime meals increased.<sup>56</sup>

Another study evaluated the effects of two isocaloric diets with different protein and carbohydrate ratios on melatonin levels and sleep in healthy young men. The results showed that sleep latency decreased after consuming a low-protein, high-carbohydrate meal. Furthermore, the two diets influenced sleep staging, including the duration of REM sleep and N1 stage. It was observed that REM latency and cortical arousal increased with a high-carbohydrate diet but decreased with a low-carbohydrate, high-protein diet.<sup>57</sup> Overall, the relationship between eating time and sleep parameters has been extensively explored in the literature, as summarized in Table 1.

**Table 1. The relationship between meal timing and sleep parameters as explored in the literature**

Authors	Sample Size (n)	Results
Kim et al. <sup>43</sup>	27,983 participants, 35-74 aged female	-Individuals with short-term sleep patterns were more likely to skip breakfast compared to those with optimal sleep durations.
Kant and Graubard <sup>41</sup>	15,199 participants, 20-70 aged male and female	-Short-term sleepers had higher levels of sugar and caffeine in their diets, along with a higher percentage of energy derived from beverages (observed only in women), although the total number of eating episodes and overall energy intake were not linked to sleep duration.
Iao et al. <sup>44</sup>	124,239 participants, 15-65+ aged male and female	-Consuming food one hour before bedtime was associated with increased sleep duration during the week. -Both short and long sleep durations, as well as post-sleep wakefulness rates, decreased as the time interval between eating or drinking before bedtime increased.
Chung et al. <sup>45</sup>	793 participants, 18-29 aged male and female	-A positive relationship was observed between mealtime and night awakenings; however, this relationship did not correlate with shorter sleep duration.
de Melo et al. <sup>46</sup>	163 participants, 30-55 aged male	-Increased food intake in the evening was linked to lower sleep efficiency and a decreased percentage of non-rapid eye movement (NREM) sleep in individuals with obstructive sleep apnea.
Lopes et al. <sup>47</sup>	296 participants, 27-48 aged male	-Late meal timing was associated with poorer sleep patterns and quality, as well as increased apnea severity, compared to early meal timing in patients with obstructive sleep apnea.
Choi et al. <sup>48</sup>	4389 participants, ≥19 aged male	-Consuming nightly meals was associated with an increased risk of obstructive sleep apnea.
Crispim et al. <sup>49</sup>	52 participants, 19-45 aged male and female	-Eating close to bedtime was negatively correlated with sleep quality variables in healthy participants.
Afaghi et al. <sup>51</sup>	12 participants, 18-35 aged male	-High glycemic index foods consumed four hours before bedtime reduced sleep onset latency and facilitated faster sleep initiation compared to meals consumed one hour before bedtime in healthy volunteers.
Afaghi et al. <sup>53</sup>	14 participants, 18-35 aged male	-The percentage of REM sleep relative to total sleep time was significantly reduced during a very low-carbohydrate diet compared to the control night.
Galan-Lopez et al. <sup>54</sup>	1717 participants, 13-16 aged boys and girls	-Children with neurological disorders experienced increased sleep efficiency and duration with the consumption of tryptophan-enriched cereal at breakfast and dinner.
Park et al. <sup>55</sup>	128 participants, different aged male and female	-A short duration between meals objectively led to longer total sleep time. -Consuming a protein-enriched meal or a higher total calorie intake close to bedtime improved certain sleep parameters.
Saidi et al. <sup>57</sup>	24 participants, 19-25 aged male	-Sleep latency decreased following consumption of a low-protein, high-carbohydrate meal. -The two diets induced differences in sleep staging, including variations in the time spent in REM and N1 stages.

## Conclusion

Maintaining good sleep involves considering a variety of factors, and diet plays a significant role in this regard. The timing and content of meals consumed before bedtime have gained widespread attention in recent years. While some studies suggest that consuming a meal close to bedtime may disrupt sleep parameters, others propose that depending on the dietary content, the period between bedtime and meal consumption could enhance certain sleep parameters. The impact of diet on sleep onset latency and the REM phase of sleep is particularly noteworthy.

As research in this area continues to evolve, further investigations are necessary to fully elucidate how various nutrients affect sleep parameters and overall sleep architecture. By delving deeper into the intricate relationship between diet and sleep, we can uncover valuable insights that will contribute to enhancing

our understanding of optimal sleep practices and ultimately promote better sleep quality and overall well-being.

## Ethics

### Authorship Contributions

Concept: M.G.K., A.Y., Design: A.Y., Data Collection or Processing: M.G.K., Analysis or Interpretation: A.Y., Literature Search: M.G.K., Writing: M.G.K.

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