Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in
Endocrine and Metabolic Research

Review

Meal timing, sleep, and cardiometabolic outcomes

Michelle Rogers[1,2], Alison M. Coates[1,2] and Siobhan Banks[1]

Abstract

Circadian misalignment is commonly experienced by shift workers due to night-time wake, day-time sleep, and eating around the clock. These changes in sleep and eating patterns away from traditional timings can cause metabolic disturbances and have been associated with elevated cardiometabolic disease risk in shift workers. This review summarizes and discusses the recent evidence linking meal timing, sleep, and metabolic challenges with a focus on the impact of fasting/feeding length and timing/frequency of consumption. While some impact of meal timing/composition on sleep was found by older studies, more recent work has focused on how meal timing contributes to circadian disruption and cardiometabolic derangement.

Addresses

[1] Behaviour-Brain-Body Research Centre, UniSA Justice & Society, University of South Australia, Adelaide, South Australia, Australia

[2] Alliance for Research in Exercise, Nutrition and Activity Research Concentration, UniSA Allied Health & Human Performance, University of South Australia, Adelaide, South Australia, Australia

Corresponding author: Banks, Siobhan (Siobhan.Banks@unisa.edu.au)

Current Opinion in Endocrine and Metabolic Research 2021, **18:**128–132

This review comes from a themed issue on **Endocrinology of Sleep**

Edited by **Peter Liu** and **Judith Carroll**

For complete overview of the section, please refer the article collection - Endocrinology of Sleep

Available online 22 March 2021

https://doi.org/10.1016/j.coemr.2021.03.006

Keywords

Meal timing, Sleep, Circadian misalignment, Shiftwork, Metabolism.

Introduction

Normal coordination of 24-hour physiological processes depends on internal clocks. There is a master clock in our brain and peripheral clocks in organs such as the liver, pancreas, muscle, and adipose tissues. The master clock coordinates periods of wake/sleep and feeding/fasting, and peripheral clocks generate 24-h oscillations of energy storage and utilization [1]. When properly aligned, these clocks optimally regulate metabolism and behavior across the day and night. Light entrains the central master clock. Clocks in peripheral organs are influenced by environmental cues, the most important being feeding/fasting cycles. Differential sensitivity of clocks across the body to external and internal entraining signals allows dynamic shifts in some rhythmic processes, whereas others remain tied to the prevailing day/night cycle [2].

Metabolic disturbances appear rapidly in response to misaligned central and peripheral clocks. Short-term clock desynchrony in healthy individuals [3] increases postprandial glucose, a result of inadequate pancreatic insulin secretion [4], and inverts the cortisol profile [3]. This underscores the importance of a synchronized circadian system for healthy metabolic function. Meal timing plays an important role in this desynchrony; irregular patterns of fasting and feeding can uncouple the master and peripheral clocks [1]. In humans, night-time eating has been found to shift circadian rhythms in core body temperature [5]. It has also been found that when daily energy intake is apportioned such that the majority of calories are ingested late in the day, there is an increased risk of obesity [6]. Eating at night is also associated with higher glucose excursions and concomitantly greater insulin levels, compared with an equivalent meal in the morning [7], and a meal during the night compared with no food overnight is associated with decreased glucose tolerance to a standard breakfast the following morning [8].

With our current 24/7 society, more and more people are sleeping less and eating around the clock. It is important to explore meal timing, meal frequency, and meal composition and how they might impact sleep and health outcomes. Therefore, the aim of this paper is to review studies in humans exploring the relationships between meal timing, sleep (quantity and quality), and metabolic disorders such as obesity and impaired glucose tolerance.

Meal timing, sleep, and obesity

Studies have shown that irregular meal timing negatively impacts metabolic health and is associated with an increased risk of obesity [9]. Obesity and unhealthy eating habits have been associated with poor sleep [10]. Previous studies have explored associations between individual foods [11], nutrients [12], and sleep outcomes, but few studies have explored the timing of food consumption and sleep and the impact on metabolic health. Cross-sectional data suggest that energy consumption later in the day and during the night is associated with weight gain [13,14]. Shift workers commonly show changes in meal patterns, skipping more meals and consuming more food at unconventional times, putting this group at increased risk of a range of chronic conditions associated with this behavior modification [15]; however, it is important to consider that multiple demographic and lifestyle factors contribute to this [16]. Hence, ideally, the timing of caloric consumption, as well as the quality and quantity of food consumed, would all be recorded when considering the relationship between food patterns, disruption of circadian rhythms and sleep patterns, and metabolic outcomes.

The relationships between patterns of food intake sleep and increased adiposity have been shown in a representative sample of Australian adults to be sex-dependent [17]. Food intake was captured by two 24-hour recalls collected during the cross-sectional 2011−2012 Australian National Nutrition and Physical Activity Survey, and participants reported their total sleep duration on the night before the survey in minutes. Three patterns labeled ‘conventional’, ‘later lunch’, and ‘grazing’ were identified. The conventional pattern was characterized by eating occasions occurring at conventional mealtimes in Australia (e.g. lunch at 1200 hours and dinner at 1800 hours and between-meal snacks at 1000 hours and 1500 hours). The later lunch pattern was similar to the conventional pattern, with the exception of lunch that occurred 1 hour later. The grazing pattern was characterized by a higher frequency of eating occasions, a low probability of food consumed at conventional mealtimes and a greater probability of food consumption occurring into the evening (e.g. after 2000 hours). Grazing patterns were associated with elevated adiposity in women, while men with a conventional temporal eating pattern of breakfast, lunch, and dinner had a significantly higher BMI. Daily sleep time did not differ between men and women who followed a conventional eating pattern, and interestingly this group also had a longer sleep time compared with those who followed a grazing pattern. These data highlight the importance of capturing temporal meal patterns so that tailored advice can be provided to help combat elevated adiposity.

The volume, nutrient composition, and total caloric load of meals in the evening must also be considered in the context of meal timing impacting sleep and metabolism. A study in males with obesity and with obstructive sleep apnoea reported that higher amounts of food intake during the evening period reduced sleep quality (lower sleep efficiency and more apnea-hypopnea events) [18]. Sleep is known to decrease digestive function [19], and a greater gastric volume during the night may cause discomfort and might contribute to less deep sleep [20]. A recent paper showed that consuming a high energy but slowly digestible meal (protein + saturated fat-rich) at 2200 hours (1 hour prior to bedtime) led to disturbed sleep in healthy young males, while consuming an easily digestible meal (rich in starch and sugar forms of simple carbohydrates) matched for calories and with the same timing relative to bedtime, did not impair sleep [21]. These findings should be replicated in women, factoring in the menstrual phase and also in people with obesity to determine whether these findings are consistent or exacerbated. Furthermore, exploring other nutrient profiles may allow for healthy food options to be promoted to those who have little choice but to eat close to bedtimes, such as shift workers who often have limited eating opportunities at standard meal times and reduced opportunities for sleep resulting in compressed proximity of meals and sleep.

The patterns linking sleep, meal timing, and adiposity, however, have not been consistently observed in all studies. For example, the China Health and Nutrition Survey reported longer sleep duration was associated with lower BMI [22], while another cross-sectional study found that meal timings and sleep were not independently associated with BMI [23]. The author suggests this could be due to the selection of a healthy population, who slept 7 hours, with intermediate chronotypes.

Ha and Song [24] assessed the associations of meal timing and frequency with obesity and metabolic syndrome. Meal frequency was inversely associated with abdominal obesity in men only, and longer fasting duration was associated with obesity. Independent of the number of eating episodes at night, and nightly fasting duration, morning eating was associated with a lower prevalence of metabolic syndrome than no morning eating. But less sleep was associated with metabolic syndrome and obesity.

Some of the mixed results may be due to how meal timing is defined. A study in adults with mild to severe obstructive sleep apnoea, considered the range of food intake patterns, including the total amount consumed, the eating duration as proposed, and the proximity of food consumption with sleep duration and latency [25]. A late consumption of food pattern was associated with significantly higher energy intake compared to an early eating pattern. Individuals who ate dinner early and had an eating duration <12 hours reported better self-reported sleep duration than individuals who ate late and individuals with eating duration >12 hours. Individuals who ate an early breakfast had higher self-reported sleep duration than those who ate a late breakfast. Furthermore, a later dinner was positively associated with poor sleep quality. In this same study, people with a shorter eating window (under 12 hours) compared with those with a longer eating window also had a significantly lower BMI. This study highlights how different deviation of meal timing can change the resulting relationships between variables.

Meal timing, sleep timing, and metabolic effects

Evidence from observational studies suggests that eating and sleeping outside of normal times is associated with a greater risk of obesity and an adverse metabolic profile; however, observational studies have struggled to isolate the independent effects of meal timing and sleep as typically later sleepers also have short sleep duration and food intake is also later [6]; and short sleep duration has been shown in several studies to be associate with greater energy intake [12,26,27].

To help tease out the independent effects, a small controlled crossover study in healthy adults with overweight/obesity tested the influence of meal timing and sleep on food intake [28]. Sleep duration was controlled, but the timing of sleep altered. The timing of food consumption was determined based on wake-up time, but participants could choose what and how much they ate, providing a real-world lens to the study but increasing the variability in responses between participants and conditions. Hormones related to satiety and food intake were impacted by altering sleep and mealtimes with ghrelin, leptin, and glucagon-like peptide 1 all affected, suggesting that the alignment of sleep and meals may have an impact on both food choice and energy balance [28]. Participants, however, did not experience any adverse effects on insulin sensitivity or glucose tolerance [29], which differs from findings from a previous study in simulated shift workers, who experience increased glucose responses to a meal tolerance test when food was consumed during the night, and their sleep was also shifted to the daytime [8].

A recent study that controlled sleep and exercise, keeping them constant, found that altering meal timing alone to a late or early pattern impacted metabolism [30]. Participants completed two eight-week counterbalanced conditions, a daytime eating pattern (intake limited to 0800 hours−1900 hours) and a delayed (intake limited to 1200 hours−2300 hours). The authors found that the daytime eating condition, compared to the delayed eating condition, promoted weight loss and improved glucose metabolism. These studies show that manipulating meal timing and sleep have consequences for health, suggesting that both could be targets for behavioral modification.

Altering meal timing to improve glucose metabolism

A parallel, laboratory-based study was conducted to test the effects of eating a meal at night versus not eating at night (fasting) on glucose regulation during simulated shiftwork in healthy young males [8]. Participants underwent four nights of simulated shiftwork where sleep (7 hours time in bed) was during the day and work at night. Fasted bloods were collected, and participants also completed meal tolerance testing before and after the circadian disruption. Sleep was not different between groups, and fasting glucose and insulin were not altered by day or condition; however, when examining the impact of the conditions on meal tolerance, there were significant effects of day and condition × day for glucose AUC, with increase glucose AUC observed solely in the night eating group. It has also been recently tested as to whether the size of the meal at night can mediate this effect [31]. These data show that altering the timing of meals to only during the daytime hours can lessen the impact of circadian misalignment of sleep on metabolism due to shiftwork [8].

Intermittent fasting/feeding

Intermittent fasting or time-restricted feeding (TRF) has been associated with many cardiometabolic benefits in rodent models, but evidence from humans is in its infancy. The purported benefits on body weight and glycemia, cardiometabolic risk markers, and oxidative stress parameters associated with TRF reviewed recently [32,33]; however, very few of these studies also examined sleep parameters or simply report sleep as part of general daily activity monitoring e.g. energy expenditure, number of steps, and time spent lying down [37].

Ramadan fasting provides a real-world model of intermittent fasting. During the month of Ramadan, observers have a shift in their food consumption from mainly the daytime to the dark hours between sunset and dawn. Studies that have been conducted in non-constrained environments where no controls have been included to account for lifestyle changes, caloric intake, and nocturnal meal timings have reported rapid and significant delays in bedtime and rising time [38,39]. When studies have accounted for sleep/wake schedule, sleep duration, light exposure, caloric consumption, meal timings, and energy expenditure, no changes in circadian rhythm during fasting were observed [40].

Roky et al. [39] assessed intermittent fasting during Ramadan on sleep patterns in a non-constrained environment. They assessed sleep patterns in eight healthy males at baseline (15 days before Ramadan) and the start and end of Ramadan. Meals were consumed during the evening between 1800 hours and 2230 hours. They found that sleep onset was delayed, which may be related to the late occurrence of meals. In addition to increased sleep latency and decreased sleep time there were also modifications to sleep architecture, stage 2 sleep increased, and REM sleep decreased. These changes are consistent with those seen in sleep restrictions. These authors also postulated that another possibility to explain the increased sleep latency might be a physiological adaptation to the presence of food. In a rodent model, feeding can induce an increase in extracellular histamine concentrations in the hypothalamus [41], and direct stimulation of the hypothalamus with histamine in cats is able to elevate wakefulness [42].

In contrast, Almeneessier, BaHammam [40] assessed the effect of diurnal intermittent fasting during and outside the month of Ramadan on circulating inflammatory cytokines and sleep in healthy males in a tightly regulated study caloric intake (fixed caloric intake (35 kcal/kg/24 h) and a fixed proportion of proteins, fats, and carbohydrates) and conducted all testing in controlled a laboratory setting on four occasions. During their stay, participants fasted from dawn to sunset. During a non-fasting baseline visit, participants received three meals; dinner at 2030 hours, breakfast at 0715 hours, and lunch at mid-day. During Ramadan intermittent fasting, the distribution of meals was different to the earlier study by Roky et al. [39], such that, during daytime fasting visit, a light meal was served at sunset, followed by dinner at 2100 hours and a predawn meal 30 min before dawn time. The authors found diurnal intermittent fasting significantly reduced the levels of cytokines, especially IL-1β, and IL-6 reflecting a reduction in inflammatory status. Interestingly they found no differences in total sleep time, sleep efficiency, arousal index, stage shifts, and sleep latency.

A recent pilot study of a 10-hour TRF intervention for 12 weeks in people with metabolic syndrome reported reduced caloric intake, improved cardiometabolic risk factors (reduced weight, lipids, blood pressure although only modest effects on glucose regulation), and increased morning restfulness but modest changes in indirect measures of sleep from actigraphy [34]. The lack of change in sleep quality is similar to that observed by Gabel et al. [35] in participants with obesity who completed an 8-hour TRF intervention for 12 weeks. While TRF interventions hold promise as an effective strategy for weight management [36], the evidence to support improvements in sleep parameters is inconsistent, and further studies are needed.

Conclusion

Recent findings exploring meal timing, metabolic changes, and sleep have focused on implications for obesity and metabolism, the impact of fasting/feeding length, and frequency of consumption. It is clear that populations who have altered eating and sleep patterns suffer from increased prevalence of obesity [43] and are at increased risk of cardiometabolic complications linked to impaired metabolism [44]. While 24-hour operations are vital for many industries and the development of shift workers, and the recommendations focus on many aspects, including shift length and patterns [45], the impact of worker health should also consider both the timing of food and sleep [46]. Ideally, workers can be educated to make simple, sustainable changes to their food patterns, including quality, frequency, and timing of food intake, which has the potential to help limit many of the sleep and metabolic disturbances associated with shiftwork.

Funding

This paper did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. We have been funded in the past for projects that have examined meal-timing, macronutrients, sleep, and cognitive performance. Funding in the last 5 years includes for Alison Coates: Consultancy fees/honoraria – Nuts for Life, Bega, Dried Fruit Council of Australia; Grants–Almond Board of California, Almond Board of Australia, International Nut and Dried Fruit Council, NHMRC, National Institute for Forest Products Innovation, Australian Dental Research Foundation, Pork CRC: Cooperative Research Centre for High Integrity Australian Pork. And for Siobhan Banks: Grants–Harmony Gold Mining, NHMRC, DST Group, Thales UK, USA Naval Post Graduate School, SafeWorkSA, Lockheed Martin Australia, Defence Innovation Partnership.

Conflict of interest statement

Nothing delared.

References

Papers of particular interest, published within the period of review, have been highlighted as:

* of special interest
** of outstanding interest

1. Bass J: **Circadian topology of metabolism**. *Nature* 2012, **491**:348–356.
2. Bechtold DA, Loudon AS: **Hypothalamic clocks and rhythms in feeding behaviour**. *Trends Neurosci* 2013, **36**:74–82.
3. Scheer FA, *et al.*: **Adverse metabolic and cardiovascular consequences of circadian misalignment**. *Proc Natl Acad Sci USA* 2009, **106**:4453–4458.
4. Buxton OM, *et al.*: **Adverse metabolic consequences in humans of prolonged sleep restriction combined with circadian disruption**. *Sci Transl Med* 2012, **4**:129ra43.
5. Krauchi K, *et al.*: **Alteration of internal circadian phase relationships after morning versus evening carbohydrate-rich meals in humans**. *J Biol Rhythm* 2002, **17**:364–376.
6. Baron KG, *et al.*: **Role of sleep timing in caloric intake and BMI**. *Obesity (Silver Spring)* 2011, **19**:1374–1381.
7. Leung GKW, Huggins CE, Bonham MP: **Effect of meal timing on postprandial glucose responses to a low glycemic index meal: a crossover trial in healthy volunteers**. *Clin Nutr* 2019, **38**:465–471.
8. ** Grant CL, *et al.*: **Timing of food intake during simulated night shift impacts glucose metabolism: a controlled study**. *Chronobiol Int* 2017, **34**:1003–1013.

Results in this healthy sample suggest that fasting at night may limit the metabolic consequences of simulated night work. Further study is needed to explore whether matching food intake to the biological clock could reduce the burden of type 2 diabetes in shift workers.

9. Pot GK, Almoosawi S, Stephen AM: **Meal irregularity and cardiometabolic consequences: results from observational and intervention studies**. *Proc Nutr Soc* 2016, **75**:475–486.

10. Muscogiuri G, *et al.*: **Obesity and sleep disturbance: the chicken or the egg?** *Crit Rev Food Sci Nutr* 2018, **59**: 2158–2165.

11. Norouzi M, *et al.*: **The association between sleep pattern and nutrients intake pattern in healthy overweight and obese adults**. *Sleep Biol Rhythm* 2018, **16**:55–61.

12. Markwald RR, *et al.*: **Impact of insufficient sleep on total daily energy expenditure, food intake, and weight gain**. *Proc Natl Acad Sci U S A* 2013, **110**:5695–5700.

13. Bo S, *et al.*: **Consuming more of daily caloric intake at dinner predisposes to obesity. A 6-year population-based prospective cohort study**. *PloS ONE [Electronic Resource]* 2014, **9**, e108467.

14. Wang J, *et al.*: **Timing of energy intake during the day is associated with the risk of obesity in adults**. *J Hum Nutr Diet* 2014, **27**:255–262.

15. Souza RV, *et al.*: **The effect of shift work on eating habits: a systematic review**. *Scand J Work Environ Health* 2019, **45**: 7–21.

16. Gupta CC, *et al.*: **The factors influencing the eating behaviour of shiftworkers: what, when, where and why**. *Ind Health* 2019, **57**:419–453.

17. Leech RM, *et al.*: **Temporal eating patterns: associations with nutrient intakes, diet quality, and measures of adiposity**. *Am J Clin Nutr* 2017, **106**:1121–1130.

18. de Melo CM, *et al.*: **Relationship of evening meal with sleep quality in obese individuals with obstructive sleep apnea**. *Clin Nutr ESPEN* 2019, **29**:231–236.

19. Tahara Y, Shibata S: **Chronobiology and nutrition**. *Neuroscience* 2013, **253**:78–88.

20. Crispim CA, *et al.*: **Relationship between food intake and sleep pattern in healthy individuals**. *J Clin Sleep Med* 2011, **7**: 659–664.

21. Uçar C, Özgöçer T, Yõldõz S: **Effects of late-night eating of easily-or slowly-digestible meals on sleep, hypothalamo-pituitary-adrenal axis, and autonomic nervous system in healthy young males**. *Stress Health* 2021, https://doi.org/10.1002/smi.3025. Online ahead of print.

22. Liu X, *et al.*: **The associations between carbohydrate and protein intakes with habitual sleep duration among adults living in urban and rural areas**. *Clin Nutr* 2018, **37**:1631–1637.

23. Marinac CR, *et al.*: **Associations between timing of meals, physical activity, light exposure, and sleep with body mass index in free-living adults**. *J Phys Activ Health* 2019, **16**: 214–221.

24. Ha K, Song Y: **Associations of meal timing and frequency with obesity and metabolic syndrome among Korean adults**. *Nutrients* 2019, **11**.

25. ** do Vale Cardoso Lopes T, *et al.*: **Eating late negatively affects sleep pattern and apnea severity in individuals with sleep apnea**. *J Clin Sleep Med* 2019, **15**:383–392.

This study found that individuals who ate dinner early and had an eating duration <12 hours reported higher self-reported sleep duration than in individuals who ate late. Individuals who ate an early breakfast were also found to have higher self-reported sleep duration than those who ate a late breakfast.

26. Spaeth AM, Dinges DF, Goel N: **Effects of experimental sleep restriction on weight gain, caloric intake, and meal timing in healthy adults**. *Sleep* 2013, **36**:981–990.

27. Nedeltcheva AV, *et al.*: **Sleep curtailment is accompanied by increased intake of calories from snacks**. *Am J Clin Nutr* 2009, **89**:126–133.

28. St-Onge MP, *et al.*: **Sleep and meal timing influence food intake and its hormonal regulation in healthy adults with overweight/obesity**. *Eur J Clin Nutr* 2019, **72**(Suppl 1):76–82.

29. Pizinger T, *et al.*: **Pilot study of sleep and meal timing effects, independent of sleep duration and food intake, on insulin sensitivity in healthy individuals**. *Sleep Health* 2018, **4**:33–39.

30. Allison KC, *et al.*: **Prolonged, controlled daytime versus delayed eating impacts weight and metabolism**. *Curr Biol* 2021, **31**:650–657 e3.

31. * Gupta CC, *et al.*: **Subjective hunger, gastric upset, and sleepiness in response to altered meal timing during simulated shiftwork**. *Nutrients* 2019, **11**:15.

This study investigated the impact of altering food timing on subjective responses by examining consumption of a snack or meal at night during simulated shiftwork. It was found that participants reported less sleepiness after the snack compared to after the meal. Gastric upset did not differ between conditions.

32. Liu K, Liu B, Heilbronn L: **Intermittent fasting: what questions should we be asking**. *Physiol Behav* 2020, **218**:1–8.

33. Waldman HS, Renteria LI, McAllister MJ: **Time-restricted feeding for the prevention of cardiometabolic diseases in high-stress occupations: a mechanistic review**. *Nutr Rev* 2019, **78**:459–464.

34. Wilkinson MJ, *et al.*: **Ten-hour time-restricted eating reduces weight, blood pressure, and atherogenic lipids in patients with metabolic syndrome**. *Cell Metab* 2020, **31**. p. 92-104.e5.

35. Gabel K, *et al.*: **Effect of 8-h time-restricted feeding on sleep quality and duration in adults with obesity**. *Appl Physiol Nutr Metab* 2019, **44**:903–906.

36. Pellegrini M, *et al.*: **Effects of time-restricted feeding on body weight and metabolism. A systematic review and meta-analysis**. *Rev Endocr Metab Disord* 2020, **21**:17–33.

37. Hutchison AT, *et al.*: **Time-restricted feeding improves glucose tolerance in men at risk for type 2 diabetes: a randomized crossover trial**. *Obesity (Silver Spring)* 2019, **27**:724–732.

38. BaHammam A, *et al.*: **Circadian pattern of sleep, energy expenditure, and body temperature of young healthy men during the intermittent fasting of Ramadan**. *Appetite* 2010, **54**: 426–429.

39. Roky R, *et al.*: **Sleep during Ramadan intermittent fasting**. *J Sleep Res* 2001, **10**:319–327.

40. * Almeneessier AS, *et al.*: **The effects of diurnal intermittent fasting on proinflammatory cytokine levels while controlling for sleep/wake pattern, meal composition and energy expenditure**. *PloS ONE [Electronic Resource]* 2019, **14**, e0226034.

This study aimed to assess the effect of intermittent fasting during and outside of the month of Ramadan on interleukin (IL)-1β, IL-6, and IL-8, while controlling confounding variables such as sleep/wake pattern, sleep length and quality, meal composition, etc. This study found intermittent fasting led to decreased plasma levels of cytokines (IL-1β, IL-6, and IL-8) across 24 hours. Intermittent fasting had no effect on the circadian patterns of the measured cytokine.

41. Itoh Y, Oishi R, Saeki K: **Feeding-induced increase in the extracellular concentration of histamine in rat hypothalamus as measured by in vivo microdialysis**. *Neurosci Lett* 1991, **125**: 235–237.

42. Lin JS, Sakai K, Jouvet M: **Hypothalamo-preoptic histaminergic projections in sleep-wake control in the cat**. *Eur J Neurosci* 1994, **6**:618–625.

43. Zhang Q, *et al.*: **Association between shift work and obesity among nurses: a systematic review and meta-analysis**. *Int J Nurs Stud* 2020:103757.

44. Shaw E, *et al.*: **The impact of time of day on energy expenditure: implications for long-term energy balance**. *Nutrients* 2019, **11**.

45. Garde AH, *et al.*: **How to schedule night shift work in order to reduce health and safety risks**. *Scand J Work Environ Health* 2020, **46**:557–569.

46. * St-Onge MP, *et al.*: **Meal timing and frequency: implications for cardiovascular disease prevention: a scientific statement from the American Heart association**. *Circulation* 2017, **135**: e96–e121.

This paper proposed research definitions for eating occasions. Eating with attention to the timing and frequency of meals could lead to healthier lifestyle and cardiometabolic risk factor managemen