Eating Behaviours in Night Shift Workers:

A Systematic Review

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ABSTRACT

Background: Globally, the increasing demand for 24–hour production and services has resulted in approximately 20% of the workforce in industrialised countries engaging in night shift work, either in a rotating or fixed shift schedule. Night work is associated with an increased risk of cardiometabolic diseases, including obesity, cardiovascular disease, and type 2 diabetes. This is partly due to an altered shift schedule causing circadian disruption and sleep loss, which can impair metabolic regulation, as well as changes in eating behaviours that may further contribute to these effects. Understanding these different eating behaviours will help inform the design of future interventions with the intention of mitigating these associated risks.

Aim: To systematically review scientific literature and examine the broad range of eating behaviours experienced by night workers in both fixed and rotating schedules.

Method: A comprehensive literature search was conducted using PubMed, Scopus and Discover (an aggregated host database that indexes Medline, Academic Search Premier, CINAHL and APA PsycINFO), to identify quantitative evidence. A total of 1468 studies were retrieved, and after the screening process, 22 studies were included in the review. A narrative synthesis was then conducted to summarise eating behaviours across four domains: *what* night workers are eating, *when* they are eating, *where* they are eating, and *why* they are deciding to eat, with comparison made with day workers on rotating or fixed shift schedules.

Results: Overall diet quality was poor, with increased intakes of saturated fats, sugar and sodium exceeding recommended levels, and dietary fibre remaining below daily recommendations. The average 24-h energy intake did not differ between day and night shifts within rotational schedules. However, night shift workers exhibited irregular meal timing, increased snacking/eating at night, and higher consumption of discretionary food compared with day shift workers.

Conclusion: The results of this review suggest that the impact of circadian disruption in addition to unhealthy eating behaviours may contribute to the relationship between night work and chronic metabolic diseases.

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DEDICATIONS

Lastly, I dedicate this thesis to the strong women in my life, the survivors (you know who you are) who don't back down in times of adversity and just keep pushing forward.

And to my son Jasper, anything is possible….

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CHAPTER 1 INTRODUCTION

Over the past two decades, the structure of the global workforce has undergone significant changes (James et al., 2017). Traditionally, work hours were confined to standard daytime schedules, typically defined as Monday to Friday between 08:00-09:00 and 17:00-18:00 (Arlinghaus, 2019; Moreno et al., 2019). However, the rise of a '24-hour society' (James et al., 2017) has significantly altered requirements for the organisation of work and workers. Shift work has been introduced as a solution by allowing continuous productivity over a 24-hour working day (Gao et al., 2020; James et al., 2017) or outside standard working hours (Arlinghaus, 2019). Shift work is common practice in contemporary society, especially in sectors that require 24-hour operations, including transportation, manufacturing, emergency services, rescue operations and health services (Gao et al., 2020). Across the different shift work schedules, night shifts are considered the most deleterious and physiologically disruptive (Costa, 1996; Ker et al., 2010; Silva & Costa, 2023) and are associated with an increased risk of chronic metabolic conditions (Gan et al., 2015; Ho et al., 2022; Xi et al., 2025).

Healthy eating can be challenging for shift workers, especially night shift workers, due to irregular shift schedules and the shift work environment(Gupta, Coates, et al., 2019) The shift work environment typically limits accessibility to healthy food by providing limited food options onsite and inadequate food storage and equipment. This can result in a reliance on vending machines and pre-packaged convenience foods at mealtimes (Gupta, Coates, et al., 2019) Irregular shift schedules alter meal patterns and food intake and the quantity and quality of food are typically compromised, which can overall impact health outcomes (Bonham et al., 2016).

1.1 Who works shift work?

Globally, a significant proportion of the workforce is engaged in night shift work. It is estimated that in Europe, about one worker out of five works night shifts (Eurofound, 2015). More specifically, it is estimated that approximately 25% of the workforce in the United States, 20% in Europe, and approximately 16% in Australia are shift workers (Clark et al., 2023). While recent statistics on the number of shift workers in New Zealand are not available, a large study conducted with blood donors from 1998 to 1999 found that shift work accounted for 21% of the employed population (Fransen et al., 2006).

1.2 Definitions of shift work

There is no agreed or consensus definition of shift work in the international literature (Knutsson, 2004). Most definitions of shift work describe either (a) the way shift work is organised (e.g., work schedules in which a worker replaces another in the same job within a 24-hour period) or (b) work that falls outside of normal daytime working hours (i.e., outside 8-9am and 5-6pm). In the scientific literature, shift work has typically been defined as *occurring when any portion of work overlaps with the hours 6pm-8am* (Arlinghaus, 2019; Costa, 2016; Grzywacz, 2016). This broad definition has been used as the basis for the work presented in this thesis.

Shift work patterns are diverse and encompass different:

- shift types: morning (early and very early), evening (late) and night shifts.
- types of shift schedules: fixed, rotating, or irregular schedules

The main shift type that will be examined within this thesis is the night shift, which is typically defined as a work period of no less than 3 hours that includes time worked between 12.00am and 05.00am (International Labour Organisation, 1990).

Night shift schedules may be classified as either fixed or rotating. Fixed schedules refer to arrangements in which workers are assigned to the same shift type for all their work periods (Costa, 2016). In contrast, rotating shift schedules involve periodic changes in work hours, such as transitions from evenings or night shifts to day shifts, and/or schedules where the employee has rotating days off between pay periods(Presser, 2014). Both fixed and rotating shift patterns may differ in their design in relation to shift durations and shift types, as well as the start and end times of individual shifts. Rotating shift patterns can differ in their direction of rotation and speed of rotation. These different aspects of shift work patterns can have different impacts on workers' health and performance (Arlinghaus, 2019; Moreno et al., 2019).

1.3 Definition of eating behaviours

Many aspects of eating are known to change or have the potential to change for individuals who perform night shift work (Gupta, Coates, et al., 2019). These include:

1. *What* people eat (for example, meal constitution, including calories, nutrients, and food groups);
2. *When* people eat (for example, 24-hour meal timing);
3. *Where* people eat (for example, location, home, work or staffroom);
4. *Why* people choose to eat in the way they do (for example, meal availability, meal options, and decision-making related to what, when and where workers eat, and other food-related choices).

These different aspects of eating may be captured with the term 'eating behaviours.' However, as with shift work, there is no agreed definition of what constitutes eating behaviours. Within the literature, there are numerous definitions that focus on aspects of decision-making related to food intake including that eating behaviours are "food choices that are moderated by consumption trends, personal preferences, specific diets and calorie counting" (González-Monroy et al., 2021), or "the way in which individuals eat […]determined by environmental, social, and biological factors, such as cooking skills, taste preferences, family eating habits, and knowledge of healthy eating"(Maneschy et al., 2022). The present thesis has broadly focused on eating and eating behaviours, addressing the aspects of "what, when, and where" individuals eat, as well as the decisions behind their eating behaviours ("why").

1.4 Challenges associated with night shift work

Although night shift work offers benefits for employees, such as increased flexibility and better remuneration (Clark et al., 2023), it also presents significant challenges, particularly from a physiological, functional, and health perspective (Arlinghaus, 2019; Bonham et al., 2016; Costa, 2016; Gupta, Coates, et al., 2019). Night shift workers frequently experience sleep loss (Åkerstedt & Wright, 2009), disruptions to the circadian body clock and circadian rhythms (circadian disruption), (James et al., 2017) impaired functioning (Folkard & Tucker, 2003), and poorer health outcomes (Kecklund & Axelsson, 2016; Vyas et al., 2012). These disruptions not only affect physiological functioning and wellbeing, but also influence daily behaviours that are closely associated with metabolic health.

1.5 Eating behaviours in night shift workers

Among the behaviours affected by night shift work are eating behaviours. Night shifts lead to changes in eating behaviours due to a combination of psychosocial, physiological, and environmental factors at both an organisational and individual level (Gupta, Coates, et al., 2019). At the organisational level, the workplace environment influences eating behaviours of workers through changes in food availability at different times of the day, as well as by creating barriers to making healthy food choices due to limited food storage facilities, cooking equipment, or food options (Gupta, Coates, et al., 2019; Marko et al., 2023; Vyas et al., 2012). Further, rest break times within shift work schedules influence when food is consumed (Allen et al., 2023). On an individual level, psychosocial factors may influence eating behaviours at and away from work. For example, eating may be influenced by a desire to socialise with co-workers rather than a response to hunger (Anstey et al., 2015), further shaping food choices and meal timing. At home, eating may be affected by the person's prioritisation of food intake (e.g., choosing when to eat or having meals as a family) and other activities (e.g., leisure, sleep, household requirements and community commitments)(Gupta, Coates, et al., 2019). Physiological factors related to eating behaviours include disruption to homeostatic mechanisms for metabolism and digestion (Taheri et al., 2004). Disruption to these mechanisms impacts the ability to metabolise and digest food effectively, which then affects satiety and hunger cues. This can lead to changes in food preferences, with night workers (including those in rotating schedules) reported to have higher intake of oil and fats and discretionary foods compared to day workers (Souza et al., 2019).

1.6 Why is it important to understand eating behaviours in night shift workers?

Understanding and modifying eating behaviours in night shift work through evidence-based research has the potential to improve health and performance outcomes (Gupta et al., 2022). Although many scientific studies have explored eating behaviours in shift workers, few reviews have been conducted that capture the broad range of research available. The most recent reviews identifying the impact of shift work on eating behaviours have included a systematic review and meta-analysis by Clark et al. (2023), which examined only dietary intake in rotating shift work, and a scoping review by Gupta et al. (2019) that explored what and when shift workers eat and what influences their decision-making. Clark et al. (2023) only examined one aspect of eating behaviours, dietary intake and concluded that rotating shift workers tend to have more frequent meals, increased snacking, and a higher intake of discretionary foods compared to day workers (Clark et al., 2023). However, the sole focus on rotating shift workers and dietary intake leaves a gap in understanding the broader range of eating behaviours among shift workers, including those engaged in night shift work, in both rotating and fixed shift schedules. In their review, Gupta, Coates, et al. (2019) emphasised the importance of examining the content, size, type, and timing of meals to develop more effective and achievable dietary interventions and highlighted the need for further research that incorporates the impact of social and environmental factors in the workplace on eating behaviours.

1.7 Study justification

Previous reviews have largely examined eating behaviours among a broad group that encompasses all types of shift workers (including early, late and night shifts; and rotating and irregular schedules) (Bonham et al., 2016; Hemmer et al., 2021; Souza et al., 2019). To date, only one systematic review has focused exclusively on night shift workers. Cayanan et al. (2019) examined eating in night workers in both real-world and simulated settings; however, their review was limited to dietary intake alone. Consequently, literature focused specifically on night shift workers that has examined the broader aspects of eating behaviours, such as meal timing, frequency, duration and quality in addition to dietary intake, has not been systematically reviewed. The systematic review presented in this thesis addresses this gap by evaluating eating behaviours among night shift workers and during night shifts, including workers on fixed and rotating schedules. Given that night shift workers represent a vulnerable population, with stronger associations observed between those engaged in night work and adverse health outcomes compared to other shift types (Boivin et al., 2022; Gan et al., 2015; Pepłońska et al., 2019), this review has substantial relevance. Evaluating eating behaviours broadly is essential when designing targeted and evidence-based dietary interventions that meet the needs of night shift workers.

1.8 Purpose of the research

The overall aim of this thesis is to systematically review the literature that examines the broad range of eating behaviours experienced by night workers.

The objectives of this thesis are to:

1. Identify eating behaviours observed in night shift workers
2. Examine how eating behaviours differ in night workers compared with day workers
3. Explore what factors that influence eating behaviours in night shift workers

1.9 The structure of the thesis

This thesis is organised into four chapters. Chapter 1 has introduced the topic, outlining the background, justification of the study, and aims and objectives of the research. Chapter 2 presents a comprehensive literature review, examining scientific findings that explain the challenges associated with night shift work as well as the mechanisms for why people's eating behaviours change when engaged in night shift work and the implications of those changes. Chapter 3 presents a systematic review of the scientific literature published in the last 10 years that has examined eating behaviours in night shift workers. Chapter 4 offers a summary of the research findings, highlighting strengths and limitations of the review, and provides evidence-based recommendations aimed at supporting night shift workers at both the individual and organisational level.

1.10 Researcher contributions

Contributors	Contribution to the Thesis
Megan Wright MSc Nutrition and Dietetics Candidate	Primary researcher and thesis author; developed PROSPERO application for systematic review in collaboration with supervisors; conducted systematic review of literature, including screening of titles, abstracts and full-text articles in line with PRISMA guidelines; conducted quality assessment of selected articles; synthesised literature for review; developed each of the thesis chapters.

Dr Karyn O'Keeffe Primary Supervisor Sleep/Wake Research Centre, School of Health Sciences, College of Health, Massey University	Provided supervision throughout the research process in collaboration with MSc Candidate, developed and submitted the systematic review protocol to PROSPERO; assisted with article selection for review; assisted with quality assessments of selected articles; provided guidance during synthesis of articles for systematic review and development of thesis chapters.
Margo van den Berg Co-Supervisor Sleep/Wake Research Centre, School of Health Sciences, College of Health, Massey University	Provided supervision throughout the research process; developed PROSPERO application for systematic review in collaboration with main supervisor, assisted with article selection for review; assisted with quality assessments of selected articles; provided guidance during development of thesis chapters.

CHAPTER 2 LITERATURE REVIEW

Shift work requires working against our biology, resulting in significant impacts on sleep and the circadian timekeeping system (Boivin et al., 2022). These impacts create challenges for obtaining sufficient good-quality sleep, achieving and sustaining optimal functioning during waking hours, and maintaining good health and well-being (Moreno et al., 2019). Shift work, therefore, has implications for overall health and well-being, as well as performance and safety (Kecklund & Axelsson, 2016; Van Dongen et al., 2003).

Humans spend approximately one third of their day asleep(Aminoff et al., 2011). Sleep is an essential biological need in humans, like breathing air or drinking water (Rechtschaffen et al., 1989). Regular, sufficient, good quality sleep is needed to maintain optimal health (Ohayon et al., 2017) and has a fundamental role in many physiological processes, including cellular repair (Assefa, 2015), toxin removal (Inoué et al., 1995), immunity (Opp & Krueger, 2015), memory consolidation (Marshall et al., 2006), and hormone secretion (Czeisler & Klerman, 1999).

Humans are diurnal; their innate physiology and behaviour are organised around a daily cycle of being active during daylight hours and sleeping during dark hours (i.e., at night) (Foster & Kreitzman, 2017). Throughout the 24-hour day, humans experience fluctuations in a number of processes, including both physical and mental functioning, which are expressed as rhythmic patterns of rising and falling activity levels and known as circadian rhythms. These intrinsic circadian rhythms are not simply the result of 24-hour changes in the physical environment caused by the earth's rotation; they originate from an endogenous circadian timekeeping system (Schwartz & Klerman, 2019). The circadian system enables humans to anticipate and prepare for the environmental changes associated with day and night, ensuring that appropriate physiological, behavioural, and biochemical actions are performed at optimal times, including the timing of sleep and wake and meal intake (Rea et al., 2008).

2.1 Sleep

2.1.1 Sleep health

Sleep duration requirements vary across the lifespan, between individuals, and night to night (Ohayon et al., 2017).However, internationally recognised guidelines recommend that most adults aged 18-64 years obtain 7-9 hours of sleep within each 24-hour period (Hirshkowitz et al., 2015; Watson et al., 2015), although some people may only need 6 hours and some may need as many as 10 hours of sleep within a 24-hour period. Habitual sleep durations of less than 7 hours are associated with poorer health outcomes (Chaput et al., 2020) whereas regularly sleeping for 7-9 hours per night has been linked to increased longevity and improved functioning (Sen & Tai, 2023; Siegel, 2009).

In his seminal paper, Buysse et al, (2014) highlighted the importance of considering overall sleep health, rather than the single concept of sleep duration. Sleep health is conceptualised as being multidimensional and is generally accepted to be comprised of six measurable dimensions of equal importance (Buysse, 2014; Hale et al., 2019; St-Onge et al., 2025). These six dimensions are defined below:

1. Satisfaction with sleep: A person's assessment of whether they are satisfied or dissatisfied with their sleep. This assessment is irrespective of other subjective sleep characteristics, such as perceived continuity or duration of sleep.
2. Alertness during waking hours: A person's ability to remain alert throughout their waking hours without experiencing sleepiness.
3. Timing of sleep: The placement of sleep within a 24-hour period.
4. Sleep efficiency: How easy it is to fall asleep or return to sleep.
5. Sleep duration: The total amount of sleep obtained within a 24-hour period.
6. Sleep Regularity: The stability of a person's bed and rise times across days.

Although not included in current models of sleep health as a standalone construct (St-Onge et al., 2025), sleep quality is generally considered to be comprised of both objective and subjective aspects of sleep. These aspects include sleep structure, sleep efficiency, and sleep satisfaction. Good sleep quality has been characterised by the following parameters, (Ohayon et al., 2017): falling asleep within 30 minutes of going to bed, waking less than three times per night, spending no more than 20 minutes awake after sleep onset and spending at least 85% of the time in bed asleep.

2.1.2 Sleep loss

Sleep loss occurs when an individual's sleep needs are not met across one or more dimensions of sleep health, including inadequate duration, poor quality, or irregular sleep patterns (Jan et al., 2010). Over time, sleep loss can lead to adverse neurological (Palma et al., 2013), and physiological outcomes (Hidayat et al., 2025; Sallinen & Kecklund, 2010).

Physiologically, chronic sleep loss is associated with adverse outcomes across multiple body systems (Sallinen & Kecklund, 2010), including cardiovascular (Grandner et al., 2012), endocrine and immune systems (Aldabal & Bahammam, 2011) as well as the central nervous system (Kim, 2025), which regulates alertness, reaction time and mood.

Sleep loss has profound metabolic consequences and is a recognised risk factor for weight gain and other metabolic disturbances (Markwald et al., 2013; Patel & Hu, 2008). Several mechanisms have been proposed to explain this association, including alterations in the appetite-regulating hormones, leptin, and ghrelin. Studies have demonstrated that sleep loss reduces circulating levels of the satiety hormone leptin, while increasing levels of the hunger-stimulating hormone ghrelin (Spiegel et al., 2004), thereby promoting increased appetite and energy intake. (Patel & Hu, 2008) In addition to effects on appetite regulation, sleep loss has been linked to acute changes, such as reduced insulin sensitivity and impaired glucose metabolism (van Dijk et al., 2019; Zuo et al., 2012). An early study in which participants were restricted to 4 hours in bed each night for

5 nights found a 24% reduction in insulin sensitivity (Spiegel et al., 1999), highlighting a mechanism by which sleep loss increases the risk of developing type 2 diabetes

Sleep loss alters brain function, impacting a broad range of brain and cognitive abilities. A large body of literature has consistently demonstrated that sleep loss leads to significant performance deficit across a broad range of neurocognitive functions, particularly those involved in vigilant attention, such as motor response, working memory, decision making and self-regulation (Hidayat et al., 2025). Consequently, sleep loss is associated with an increase in accidents and errors within the workplace setting, due to slower reaction times and increased levels of fatigue(Van Dongen et al., 2003). Together, these findings illustrate the importance of adequate sleep in daily life, and that maintaining a consistent sleep routine and schedule is imperative for overall health and wellbeing.

2.2 Regulation of sleep and wake

Sleep-wake behaviour is regulated by two independent mechanisms interacting with each other: the homeostatic sleep drive and the circadian system (Borbély, 1982). Together, these mechanisms determine when we sleep (sleep timing), how long we sleep for (sleep duration) and the structure of sleep.

The homeostatic sleep drive reflects a process of increasing sleep need or pressure (manifesting as sleepiness) as we spend time awake and a dissipation of that sleep pressure across the sleep period (Czeisler, 2007; Mongrain et al., 2006). The homeostatic process regulates how much sleep we get and the structure of our sleep, such that when we stay awake for extended periods, this homeostatic pressure becomes more pronounced, leading to an increased proportion of deep sleep and potentially longer sleep duration (Dijk et al., 2000). The circadian system (discussed in section 2.3 below) regulates alertness and sleepiness, thereby producing cycles of sleep and wakefulness over a 24-hour period. It is easiest to sleep when the homeostatic drive for sleep is high and the circadian system is promoting sleepiness. Conversely, it is most difficult to sleep when homeostatic pressure for sleep is low and/or the circadian system is promoting alertness.

In normal circumstances, the sleep-wake cycle is regulated by the circadian system and the homeostatic sleep drive to produce sleep at night of sufficient duration and quality. However, several factors, such as shift work, social obligations, international travel, the use of alarm clocks, and exposure to artificial light outside of daylight hours, can disrupt normal regulation. Night shift work, the focus of this thesis, creates challenges for both the circadian system and the homeostatic sleep drive and is discussed more in Section 2.4

2.3 The circadian system

The word 'circadian' is derived from the Latin meaning 'about a day'(McHill & Butler, 2024). Circadian rhythms refer to approximately 24-hour cycles in physiological, biochemical and behavioural processes (Berry & Wagner, 2015). These rhythms are ubiquitous and represent a fundamental feature of biological functioning across nearly all life forms, including humans (Burns et al., 2024). They are governed by the circadian system, a hierarchical network of endogenous clocks distributed across tissues, organ systems and individual cells throughout the body (Dibner et al., 2010).

The circadian system is organised hierarchically, with a central 'master clock' located in the suprachiasmatic nuclei (SCN) of the anterior hypothalamus, and peripheral clocks present in multiple organ systems, including skeletal muscle, liver, heart, lungs and gastrointestinal tissues (Sletten et al., 2020). The SCN coordinates circadian rhythms throughout the body through two mechanisms: directly regulating circadian rhythms in multiple processes, and synchronising its activity with peripheral clocks via signalling pathways, including the secretion of the hormones melatonin and cortisol.

The SCN comprises two clusters of neurons that exhibit an intrinsic rhythm of neuronal firing that is slightly longer than 24 hours (approximately 24.2 hours on average) (Berry & Wagner, 2015; Boivin et al., 2022). This endogenous rhythm persists in the absence of external time cues (Vitaterna et al., 2001). In contrast, the circadian activity of peripheral clocks tends to dampen without central coordination, and therefore these clocks require synchronisation with the SCN to maintain stable rhythmicity (Albrecht, 2012). Under optimal conditions, the SCN, peripheral clocks, and the physiological rhythms they generate are aligned with one another and with the external 24-hour light-dark cycle (Johnston, 2014). This temporal alignment ensures that circadian-regulated processes, including the sleep-wake cycle, hormone secretion, metabolism, core body temperature regulation, and cognitive and physical performance, occur at biologically appropriate times of the day and night (Czeisler, 2007; Meyer et al., 2022; Serón-Ferré et al., 2013; Valenzuela et al., 2008).

To remain synchronised with the external environment, the SCN relies on environmental and behavioural time cues known as *zeitgebers* (German for "time giver") (Aschoff, 1954). This process of alignment is termed entrainment. Light is the dominant zeitgeber for the SCN and entrains the central clock via a dedicated non-image-forming retinal pathway involving intrinsically photosensitive retinal ganglion cells (ipRGCs) (Berson et al., 2002). These cells transmit photic information directly to the SCN through the retinohypothalamic tract (Dibner et al., 2010). Additional zeitgebers influencing the SCN, include physical activity and social interaction (Lewis et al., 2018). Exposure to zeitgebers can shift the circadian system to an earlier or later phase, depending on the timing of exposure.

While the SCN is primarily entrained by light, peripheral clocks are particularly sensitive to non-photic cues, especially feeding behaviour. Evidence from time-restricted feeding (TRF) studies demonstrates that peripheral clocks in the liver, pancreas, gut and adipose tissue can be independently entrained by feeding time (Ruddick-Collins et al., 2020) and macronutrients, metabolic enzymes, and hormones may also function as entrainment signals for peripheral tissues. Aligning food intake with the active phase (daytime) supports circadian-regulated metabolic processes, whereas consuming food during the rest phase (night-time) disrupts circadian alignment and impairs metabolic regulation (Potter et al., 2016)

2.3.1 Circadian disruption

Circadian disruption has been defined as "disturbances, deregulation, or issues that negatively affect circadian function" (Fishbein et al., 2021). It typically arises from misalignment between the endogenous circadian phase (the timing of the cycle) and an environmental or behavioural cycle (Vetter, 2020), or from uncoupling between the central clock in the SCN and the peripheral clocks across different organs (Sletten et al., 2020; Vetter, 2020).

In modern 24/7 societies, circadian disruption has become increasingly prevalent (Baser et al., 2025). Common environmental and lifestyle factors that disturb the circadian system include: (1) light exposure during the night (i.e., the rest phase) (Schibler, 2006), (2) food intake during the night (McHill & Butler, 2024), and (3) sleep disruption (Lauren & Hoon-Ki, 2020).

Being exposed to light in the evening shifts the circadian cycle of the SCN later (phase delay). Similarly, exposure to bright light during the first half of the night, before the nadir of the core body temperature rhythm, alongside avoidance of light in the morning, can induce phase delay (Gooley, 2017; Van Cauter et al., 1994). Conversely, being exposed to light in the early morning, after the core body temperature minimum, can shift the circadian system earlier (phase advance) (Cyr et al., 2022; Lewy et al., 1995; Smith & Eastman, 2012).

Shift work, of particular relevance to this thesis, represents a major form of circadian disruption because work hours are irregular and often scheduled at night. As a result, physiological rhythms, including body temperature, hormones and behavioural cycles, become misaligned with environmental cues (Horowitz et al., 2001; Sharma et al., 2016). Shift workers, particularly night shift workers, are often required to remain awake and alert, and eat and sleep during the night, while simultaneously being exposed to artificial light during the night. These behavioural and environmental factors reinforce circadian misalignment by opposing the day-oriented behaviour promoted by the light-dark cycle and disrupting alignment between the central and peripheral clocks.

2.3.2 Implications of circadian disruption for health and functioning

Circadian disruption has significant implications for both physiological health and daily functioning (Boivin et al., 2022). Misalignment between circadian rhythms and environmental (i.e., light-dark) or behaviour cycles (i.e., sleep-wake, fast-fed, physical activity) impairs metabolic regulation, leading to hormonal imbalance and dysregulation of key metabolic processes, contributing to an increased risk of insulin resistance and type 2 diabetes (Gan et al., 2015; Kianersi et al., 2024; Knutson et al., 2017; Spiegel et al., 1999; Windred et al., 2024), and cardiovascular disease (Chellappa et al., 2019; Moon et al., 2023; Nuszkiewicz et al., 2025; Torquati et al., 2017). Circadian misalignment also disrupts neuroendocrine pathways and may promote systemic inflammation, resulting in increased risk of various cancers (Beckett & Roden, 2009; Haus & Smolensky, 2013; Torquati et al., 2017). In addition to its metabolic and oncogenic implications, circadian disruption affects cognitive and psychological functioning and is associated with mood disturbances, including depression and anxiety (Driesen et al., 2010; Messman et al., 2024; Salgado-Delgado et al., 2011; Silva et al., 2017). Collectively, these implications highlight that circadian disruption affects multiple systems throughout the body and has multifaceted impacts on health and functioning.

2.4 Shift work

As discussed in Chapter 1, there is no consensus definition of shift work. Most definitions describe it as work that falls outside the standard working day of 8-9am to 5-6pm. A night shift is typically considered as a work period of no less than 3 hours, which overlaps with the period of 12am to 5am (International Labour Organisation, 1990). Night work can occur in fixed schedules, in which workers are assigned to the same shift type for all their work periods (Costa, 2016), and rotating schedules, in which the scheduled work periods ‘rotate’ in a forward or backwards direction (Presser, 2014).

2.4.1 Shift work and sleep loss

Sleep loss and poor quality sleep are prevalent among shift workers and represent a significant health concern, with up to 75% of the shift working population affected (Akerstedt, 1988; Åkerstedt & Wright, 2009; Tune, 1968). A substantial body of evidence indicates that night shift workers, whether working fixed or rotating schedules, have a higher prevalence of disturbed sleep (Åkerstedt et al., 2008; Åkerstedt et al., 2010; Conway et al., 2008), and a reduced total sleep duration to approximately 4-6 hours of sleep within a 24-hour period (Åkerstedt & Wright, 2009; Boivin et al., 2022; Kecklund & Axelsson, 2016; Pilcher & Coplen, 2000). The factors contributing to sleep loss in night workers include irregular work schedules that disrupt the homeostatic and circadian mechanisms regulating sleep, extended periods of wakefulness that reduce the time available for sleep within a 24-hour period and environmental disturbances such as daytime noise and light, which make it more difficult to fall and stay asleep.

Irregular shift schedules contribute to sleep loss by requiring workers to sleep at times of the day when they are biologically programmed to be awake and remain awake during periods when sleep propensity is high. This misalignment between behavioural demands and the endogenous sleep-wake cycle reduces both sleep duration and sleep quality (Boivin et al., 2022). For night shift workers, attempting to sleep during the daytime after a night shift is particularly challenging, and the majority of night shift workers experience difficulties achieving adequate sleep due to problems falling asleep and remaining asleep. (Åkerstedt et al., 2010).

The circadian system has an important influence on sleep duration and quality; its daily fluctuations in alertness produce periods during the 24-hour circadian cycle when alertness is high (i.e., sleep propensity or sleepiness is low) and periods when alertness is low (i.e., sleepiness is high)(Dijk et al., 1992). In turn, these fluctuations create ‘windows’ that can facilitate or hinder sleep, making it easier to fall asleep or more difficult to fall asleep at particular times during the 24-hour day. Strogatz (1986) demonstrated that two of these key endogenous circadian windows occur approximately 8 hours before (at approximately 8pm) and 6 hours after (at approximately 10am) the core body temperature minimum (which typically occurs around 4am). Attempting to sleep during these periods can impair the ability to fall asleep and remain asleep (Gooley, 2016; Lavie, 1986; Strogatz, 1986), and may truncate the sleep of night shift workers. The latter of these windows, occurring in the late morning to early afternoon, can shorten the sleep of night shift workers who are trying to sleep during the daytime after a night shift, as the circadian system is promoting alertness and overcomes the falling homeostatic drive for sleep. The other of these windows, occurring around 8pm is termed the 'evening wake maintenance zone' or 'forbidden sleep zone,' and typically occurs 2-3 hours before sleep onset. During this period, the circadian system promotes alertness, temporarily countering the building homeostatic drive for sleep, and making it difficult to stay asleep or fall asleep (Lavie, 1986; Zeeuw et al., 2018). Studies indicate that the drive for alertness during this 3-4 hour window is potent enough to delay sleep onset, even in individuals who have been awake for 37 hours (Folkard, 2008; Zeeuw et al., 2018). Individuals entrained to the day-night cycle and sleeping at night are unaffected by the 'evening wake maintenance zone' as it occurs before usual sleep onset. Shift workers, however, may be trying to sleep during this period, particularly if they are working early morning shifts or attempting to nap before starting a night shift. In these circumstances, a worker is unlikely to be able to fall asleep, potentially resulting in a shorter daily sleep duration.

Extended wakefulness is common amongst night shift workers due to the structure of their shift schedules (Baulk et al., 2006; Dorrian et al., 2011). This frequently occurs when transitioning from a day shift or day off directly onto a night shift (Marot et al., 2021). In these situations, many night workers remain awake from the time they rise in the morning prior to their first night shift, without having a preparatory sleep before their shift commences (Dorrian et al., 2011). Night shift workers have been shown to experience extended periods of wakefulness exceeding 20 hours during the transition from a day shift to the first night shift in a rotating shift schedule.

(Marot et al., 2021). Only around 50% of workers report having a preparatory sleep before starting a night shift. (Dorrian et al., 2011). Several factors may contribute to this behaviour, including daytime noise and light, prioritising family and social commitments over sleep(Chung et al., 2009), as well as a lack of sleepiness prior to the shift, which may partly reflect the influence of the 'evening wake maintenance zone' These extended wakefulness periods increase fatigue and sleepiness during the subsequent night shift (Axelsson & Kecklund, 2016).

As a consequence of sleep loss from truncated sleep and increased homeostatic sleep drive, sleepiness during night shifts becomes a pronounced problem, with prevalence rates reported at 50% during night shifts compared with 5% during day shifts (Sallinen & Kecklund, 2010). This heightened sleepiness increases the risk of falling asleep at work (Åkerstedt et al., 2010; Sallinen & Kecklund, 2010), and is associated with a greater risk of accidents (Philip & Åkerstedt, 2006).

2.4.2 Shift work and circadian disruption

One of the primary causes of circadian disruption is working non-standard hours (Kervezee et al., 2020). These work patterns disrupt the circadian system by desynchronising regular behavioural cycles, including sleep and wake, rest, activity, and fasting and feeding from the light-entrained SCN master clock (Kosmadopoulos et al., 2020b), with workers continually exposed to external cues promoting (re)orientation with the biological day (Boivin et al., 2022). During night shift schedules, exposure to light occurs during the biological night when a worker would normally be sleeping, food intake occurs during biologically inappropriate hours, and wakefulness occurs during periods typically reserved for sleep (Vetter, 2020). As light primarily entrains the SCN while food intake acts as a major zeitgeber for peripheral clocks, exposure to these conflicting time cues can lead to misalignment between the SCN and peripheral clocks, as well as misalignment between the SCN and the environmental day-night cycle (Boivin, 2022).

Night workers often consume food during the night-time hours (Shaw et al., 2019). Physiologically, this poses a challenge because the circadian system prepares metabolic and digestive processes for feeding during the daytime, rather than the evening or night. For example, gastric emptying and gastrointestinal motility tend to peak during the morning, and glucose metabolism is more efficient earlier in the day. In contrast, during the evening and night, gastric motility slows, and metabolic processes become less efficient, reflecting a physiological period more conducive to fasting and metabolic restoration (Thaiss et al., 2014).

Peripheral clocks found in the heart, kidney, liver, pancreas, adipose tissue and gastrointestinal tract can be independently entrained by food intake (Damiola et al., 2000; Stokkan et al., 2001). This is particularly evident in the liver, a key metabolic organ that metabolises carbohydrates, proteins and fats (Rui, 2014). The liver responds to food more rapidly than other peripheral organs. Moreover, feeding cycles can entrain the peripheral clock in the liver independently of both the SCN master clock and the light-dark cycle (Hatori & Panda, 2015; Stokkan et al., 2001).

2.5 Eating behaviours

2.5.1 The importance of eating behaviours in the context of health and wellbeing

Healthy eating is integral for human health and wellbeing, impacting metabolic processes, mental health, and disease risk (Tischner & Malson, 2012). For optimal health, healthy eating comprises life-stage appropriate proportions of macro- and micronutrients, as well as hydration to support physiological needs without excessive intake. Macronutrients (i.e., carbohydrates, fats, and proteins) provide energy, which is necessary for cellular functioning. Micronutrients (i.e., vitamins and minerals) are also essential and required in trace amounts to support growth, development, and metabolism (Skerrett & Willett, 2010).

Unhealthy eating is typically characterised by a diet high in saturated fats, processed foods, sodium, and sugar, and deficient in essential nutrients, such as minerals, vitamins and fibre. Unhealthy eating is associated with an increased risk of non-communicable diseases (NCDs), including CVD, diabetes, and obesity (Waxman, 2003). These diseases are considered the leading causes of death and disability throughout the world, with rates of obesity in adults more than doubling since 1990 (Smith & Smith, 2016). The cause of this is undoubtedly multifactorial, including non-modifiable factors such as genetics (Thaker, 2017) and environment, as well as modifiable lifestyle factors, such as diet, physical activity (Masood & Moorthy, 2023), and sleep(Muscogiuri et al., 2019). When assessing dietary choices at an individual level, it is important to consider the different behavioural aspects of an individual's eating, including why, when and under what circumstances individuals consume food.

What individuals eat and the food choices they make is crucial because they are directly linked to health outcomes. Food choices can be influenced by the availability and accessibility of food. Poor dietary decisions can lead to insufficient intake of essential vitamins, minerals, and both macro- and micronutrients(Gush et al., 2021). In turn, this leads to nutrient deficiencies, which compromise physiological functions and result in poorer health outcomes (Bailey et al., 2015).

When we eat is a crucial element of healthy eating. Optimal meal timing is fundamental for ensuring synchrony between circadian clocks and rhythms, ultimately maintaining metabolic homeostasis. Eating meals at suboptimal times, such as during the evening or night, disrupts these endogenous feeding rhythms, and the ability to maintain homeostasis is impaired (Pickel & Sung, 2020).

Where people eat and where the food source comes from have a profound impact on a person's dietary intake (Gupta, Coates, et al., 2019), especially when considering the impact of the work environment. In some work settings, there are limited options for both obtaining food and finding a suitable place to prepare and eat it. The options for purchasing food can be limited to vending machines or staff cafeterias, and there may be limited equipment in staff rooms to reheat home-brought food, all of which impacts dietary decisions (Gupta, Coates, et al., 2019).

Why we eat and the motivation behind choosing to eat is associated with both physiological and environmental factors(Qualls-Creekmore et al., 2020). Physiologically, hunger, satiation, satiety, and tiredness are associated with the need to eat and the decision to eat. Environmentally, work schedules with allocated break times, social norms that include set meal patterns (e.g., breakfast, lunch, and dinner) and social engagements, can override the physiological drive of hunger, highlighting the role that environmental and social factors can have on shaping our decision-making around food intake and eating behaviour.

2.5.2 Eating behaviours in night shift workers

Eating behaviours among night shift workers are significantly altered due to a broad range of physiological and enviro-social factors associated with working during the night (Crispim et al., 2007; Gordon et al., 1986; Lowden et al., 2010). Irregular schedules disrupt the circadian system and contribute to sleep loss, both of which are known to influence metabolic regulation and dietary behaviour (Boivin et al., 2022). As a result, several aspects of eating behaviours may be affected, including meal timing, energy intake, frequency of eating, food preferences and decision-making regarding food choices.

Importantly, the workplace environment plays a critical role in shaping the dietary choices of night workers. During night shifts, access to food is often more limited than during daytime hours, and available options might be limited to convenience food, such as that found in vending machines. In addition, workplace facilities may not provide appropriate equipment, such as refrigerators or microwaves, to store or reheat food. This may limit workers' ability to consume healthier meals prepared at home, thereby influencing what is eaten overall.

A wide body of literature highlights the implications of these changes to eating behaviours; they ultimately lead to a higher propensity for the development of nutritionally related diseases(Crispim et al., 2007; Lennernäs et al., 1994), such as type 2 diabetes(Gottlieb et al., 2005; Kawakami et al., 2004; Nilsson et al., 2004), dyslipidaemia, and obesity and altered metabolism of food(Ishizaki et al., 2004; Karlsson et al., 2001; Karlsson et al., 2003; Lowden et al., 2001; Parkes, 2002).

2.5.3 Sleep loss and eating behaviours

Chronic sleep loss is increasingly recognised as a factor that can alter eating behaviours, and night shift workers provide an important population in which to study this association (Crispim et al., 2007). Evidence suggests that these changes may occur through both physiological and behavioural pathways. Physiologically, sleep loss may influence metabolic processes that regulate appetite, food preferences, energy intake and snacking behaviour (Cheng & Chan, 2025). These physiological changes may subsequently influence behavioural responses, affecting what individuals choose to eat, when they eat, and the motivations underlying their food choices.

A growing body of literature suggests an association between sleep loss and increased hunger alongside reduced feelings of fullness and satiety (Akhlaghi & Kohanmoo, 2025; Zhu et al., 2019). For example, one study demonstrated that extending sleep from 5.6 hours to 7.1 hours led to a 14% decrease in overall appetite and a 62% decrease in sweet and salty food (Tasali et al., 2014). These findings suggest that insufficient sleep may promote an increase in appetite and energy intake.

One proposed mechanism underlying these changes involves the disruption of appetite-regulating hormones, particularly leptin and ghrelin. Under normal physiological conditions, these hormones work in synchrony to regulate feeding behaviour (James et al., 2017) and maintain energy balance (Schwartz et al., 2003). Both hormones follow a diurnal rhythm that is largely regulated by the circadian feeding-fasting cycle. During fasting periods, ghrelin, an orexigenic, short-acting hormone, is secreted from the gut and signals to the hypothalamus to stimulate hunger and promote food intake. Postprandially, satiety signals are mediated by hormones such as leptin and insulin, which suppress appetite and promote energy expenditure (Schwartz et al., 2003).

Although the precise effect of sleep loss on these hormonal pathways is not fully understood, numerous studies suggest that sleep loss disrupts this hormonal balance, resulting in decreased leptin concentrations and elevated ghrelin (Leibel, 2002; Mullington et al., 2003; Spiegel et al., 2004; Taheri et al., 2004; Van Cauter et al., 2008). This hormonal profile may contribute to increased hunger and reduced satiety. Supporting this, Spiegel et al. (2004) found that sleep loss in men was associated with an increase of 28% in ghrelin levels and a reduction in leptin levels of 18%, increased appetite of 23%, heightened hunger of 24%, and a stronger preference for high-carbohydrate foods. Notably, this change in food preference was observed under conditions of sleep restriction and not during adequate sleep.

Sleep loss has been shown to not only increase appetite but also preference for food containing more calories and higher in sugar (Akhlaghi & Kohanmoo, 2025; Taheri et al., 2004). Spiegel et al. (2004) showed that appetite for energy-dense, high carbohydrate foods increased by 33-45% when experiencing sleep restriction. By contrast, appetite for fruit and vegetables and high protein food was less impacted. Additionally, further studies have demonstrated that sleep loss may lead to individuals consuming lower mean energy intake from main meals, alongside higher intake from snacks and increased snacking frequency (Kant & Graubard, 2014; Lee, 2017; Nedeltcheva et al., 2009).

Sleep loss may affect when eating occurs(Kant & Graubard, 2014), with evidence showing that individuals suffering from sleep loss (obtaining less than 6 hours of sleep a night) eat during a wide window of time (early morning to late evening) with extra energy mostly consumed during the evening hours (Duraccio et al., 2022; Herzog et al., 2012; McHill & Wright, 2017; Nedeltcheva et al., 2009; Spaeth et al., 2013). Nedeltcheva et al (2009) found that healthy adults restricted to 5.5 hours of sleep per night for 14 nights consumed more calories from snacks during the night-time(19:00-07:00) compared to when they had 8.5 hours of sleep (Nedeltcheva et al., 2010). Of note, 24-hour energy intake remained the same between the two conditions. Similarly, Spaeth et al. (2013) observed that participants subjected to only 4 hours of sleep per night had a greater consumption of fat during night-time hours (22:00-03:59). Collectively, these findings suggest that sleep loss leads to more time and more opportunity to eat, shifting energy intake towards later hours (Chaput & Dutil, 2016).

A meta-analysis examining experimentally induced short sleep over five or more nights (less than 5 hours of sleep per night) found an increase in energy intake of approximately 204 kcal per day (Fenton et al., 2021) Interestingly, studies examining single-night deprivation did not observe this effect, suggesting that increased energy may occur after a threshold of cumulative sleep loss is reached (Cheng & Chan, 2025).

Evidence has demonstrated an association between sleep loss and/or poor quality sleep and an increased risk of type 2 diabetes (Lombardo et al., 2020; Spiegel et al., 2009), largely due to alterations in glucose metabolism. Glucose regulation involves a balance between the distribution and the utilisation of glucose by tissues such as muscles, adipose tissue, and the brain. Effective regulation maintains blood glucose within a narrow range and prevents the development of hypoglycaemia and hyperglycaemia (Crispim et al., 2007; Spiegel et al., 2005). During the night, normal sleep contributes to metabolic regulation by slowing glucose metabolism as the body enters a fasting state. This effect primarily occurs during the first half of the night when deep restorative sleep predominates (Spiegel et al., 2009). During this time, cerebral glucose uptake declines and peripheral tissues, including skeletal muscles, require less glucose, leading to reduced glucose utilisation.

Experimental evidence supports the role of sleep in glucose regulation. For example, Spiegel et al. (1999) examined the metabolic consequences of sleep loss in a group of healthy men whose sleep was limited to 4 hours per night for six consecutive nights, followed by a period of sleep extension of 12 hours for six consecutive nights. Glucose tolerance was approximately 40% lower following sleep restriction compared with the sleep extension condition, reaching levels typically observed in ageing people suffering impaired glucose tolerance (Spiegel et al., 1999). When glucose regulation is impaired in this way, the body becomes less efficient at regulating blood glucose following carbohydrate consumption, which over time may lead to type 2 diabetes. This mechanism explains why night shift workers have a 16% higher risk of developing type 2 diabetes compared to regular day workers(Gao et al., 2020).

2.5.4 Circadian disruption caused by eating behaviours.

As discussed in section 2.3, the circadian system is a hierarchical 24-hour timing system that regulates daily rhythms in behaviour and metabolism through the SCN and peripheral clocks located in various tissues and organs. Consequently, the body responds differently to the same food eaten depending on the time of day it is consumed, showing diurnal variation in glucose tolerance, insulin sensitivity and other metabolic processes. Food intake is a zeitgeber (time cue) that entrains circadian clocks to the external environment and significantly influences peripheral clocks in metabolic tissues such as the liver, gut, pancreas and adipose tissue.

Eating during the night can lead to misalignment between the SCN and the peripheral clocks (Bass & Takahashi, 2010), disrupting key metabolic processes and contributing to glucose intolerance, reduces insulin sensitivity, and increases the risk of obesity (Berg et al., 2009; Bertéus Forslund et al., 2002; Wang et al., 2014). Conversely, greater intake earlier in the day, particularly during the morning and midday, may be protective against overweight and obesity (Beccuti et al., 2017; Berg et al., 2009; Summerbell et al., 1996).

In addition to sleep, glucose regulation is strongly influenced by circadian rhythmicity (Van Cauter et al., 1991; Van Cauter et al., 1997). Glucose tolerance, defined as the ability to metabolise glucose and return blood glucose levels to baseline(Knutson & Van Cauter, 2008), follows a circadian pattern similar to hormones involved in appetite regulation, such as ghrelin and leptin. Glucose tolerance is typically higher in the morning and lower in the evening, indicating that the body metabolises glucose more efficiently earlier in the day (Knutson & Van Cauter, 2008). This rhythmicity persists even in the absence of sleep or food intake, demonstrating regulation by the endogenous circadian system(Van Cauter et al., 1997).

Inefficiency of glucose metabolism in the evening is partly attributed to decreased insulin sensitivity, meaning that cells respond less effectively to insulin secretion and greater amounts are required to regulate blood glucose levels. At the same time, insulin secretion is reduced, further impairing glucose tolerance. (Van Cauter et al., 1997).

While meal composition is important for health, the timing of food intake is also a key consideration; however, optimal timing remains unclear, and further research is needed in this area.

2.6 Conclusion

Night shift workers as a population are disproportionately associated with a higher risk of chronic metabolic diseases, including obesity, cardiovascular disease and type 2 diabetes. This increased risk is largely attributed to disruption to the circadian system, which can lead to sleep loss and a desynchronised sleep-wake cycle. As a result of sleep loss and circadian disruption, eating behaviours may change, including alterations in meal timing, food preference, and energy intake. Therefore, it is fundamental to night shift workers' eating behaviours to understand how they change and potentially contribute to adverse metabolic health outcomes and to inform the development of targeted interventions and recommendations aimed at mitigating this disparity.

Despite growing evidence on the implications of night shift work, an important gap remains in examining eating behaviours more broadly. Much of the existing literature focuses on individual aspects of dietary behaviour, rather than considering multiple dimensions known to change in night shift workers, such as what individuals eat, *when* they eat, *where* they eat and *why* people eat. For example, a recent review evaluating night shift workers primarily examined individuals' dietary outcomes such as energy intake and food type (Cayanan et al., 2019), rather than exploring multiple behavioural dimensions of eating simultaneously. Similarly, Clark et al. (2023) evaluated dietary patterns but only assessed dietary intake (food quality, food frequency, and energy intake). While they found higher energy intake among rotating shift workers compared to regular daytime schedules, the mean energy intake of the day shift compared with the night shift within a rotating shift schedule did not differ significantly. Souza et al. (2019) conducted a systematic review examining the effects of shift work on eating habits and reported changes in meal timing, food preferences and increased consumption of unhealthy foods. Although this review evaluated eating behaviours more broadly, it did not examine night shift workers exclusively as a population, highlighting a gap in understanding eating behaviours within this group.

CHAPTER 3 EATING BEHAVIOURS IN NIGHT SHIFT WORKERS: A SYSTEMATIC REVIEW

Abstract

Background: Globally, a substantial proportion of the workforce engages in night shift work, which is associated with an increased risk of obesity and cardiometabolic diseases. Circadian misalignment resulting from night work may impair metabolic regulation, while eating behaviours may further significantly contribute to modulating these effects. **Objective**: The aim of this review is to systematically review the literature that examines the broad range of eating behaviours experienced by night workers. ***Methods***: A systematic review was conducted searching PubMed, Scopus and Discover (an aggregated host database that indexes Medline, Academic Search Premier, CINAHL and APA PsycINFO), to identify quantitative evidence. A total of 1468 studies were retrieved and assessed for eligibility of which 22 studies met the inclusion criteria. ***Conclusion:*** Among night workers, overall diet quality was poor, with saturated fats, sugar and sodium exceeding recommended guideline levels. Total 24-hour energy intake did not differ between day and night workers within a rotating schedule. Night workers showed more irregular meal timing, increased night-time eating, and a greater consumption of discretionary foods.

The citation format for chapter three has been formatted in accordance with the Appetite Journal guidelines, as I intend to submit this chapter for publication in Nutrients.

3.1 Introduction

The structure of the traditional work schedule has changed significantly due to the demands of a modern 24/7 society. Traditionally, standard working hours were Monday to Friday between

08:00–09:00 and 17:00 -18:00. However, due to changing expectations and demands of modern-day society, shift work has been introduced as a solution. Shift work is typically defined as work performed outside the hours of 08:00 to 18:00, with workers replacing one another within a 24-hour schedule (Arlinghaus et al., 2019). It consists of different shift types (e.g., early, late, night) and schedules, including fixed, rotating, or irregular schedules. It is estimated that approximately 20% of workers in industrialised countries engage in shift work across various industries, including transportation, healthcare, manufacturing, and services (including hospitality) (Ker et al., 2010). Compared to day work or standard working hours, shift work is associated with an increased risk of several diet- related chronic metabolic conditions, including cardiovascular disease (CVD) (Ho et al., 2022; Xi et al., 2025), obesity (Liu et al., 2018) and type 2 diabetes (T2DM) (Xie et al., 2024).

Of shift work schedules, night shift work is the most physiologically disruptive. There is no consensus definition of night shift work, with definitions varying considerably across the literature and often reflecting local legal frameworks rather than standardised scientific definitions (Hemmer et al., 2021; Parent-Thirion et al., 2017). However, it has commonly been defined as a work period of no less than three hours that overlaps with the period between of 00:00 and 05:00 (EU Working Time Directive, 2003; International Labour Organisation, 1990). Night work encompasses both fixed schedules, in which workers are assigned to the same shift type for all their work periods (Costa, 2016), and rotating schedules, in which work periods 'rotate' in a forward or backwards direction (Presser, 2014). Individuals working night shifts suffer the most deleterious effects due to profound misalignment of work and sleep schedules with the endogenous human circadian system and are consequently at greater risk of developing chronic metabolic conditions(Silva & Costa, 2023).

Humans are diurnal, meaning they are biologically adapted to be active during the day and sleep during the night (Boivin et al., 2022). Hormone production and metabolic functions are closely aligned with this circadian rhythm, enabling the body to be metabolically primed for food intake and energy utilisation during the day. At night, sleep represents a predominantly anabolic state, during which metabolic processes are not optimised for food intake and typically coincide with prolonged fasting. Overnight, blood glucose levels decline, and glucose utilisation is prioritised for the central nervous system, supporting tissue growth and repair. Consequently, skeletal muscles exhibit a reduced capacity to process and respond to glucose during the night (Lowden et al., 2010).

Night shift workers typically sleep during the day, and eat during the evening or night when metabolism is not optimally aligned for nutrient intake. This misalignment in the timing of sleeping and eating with the circadian system leads to sleep loss and circadian disruption. Studies have reported that night shift workers obtain less than the recommended duration of sleep averaging 4-6 hours of sleep within a 24-hour period (Åkerstedt & Wright, 2009). Shift work, including night work, contributes to circadian disruption. Sleeping during the day and working and eating during the night, desynchronises regular behavioural cycles, including sleep and wake, rest and activity, and fasting feeding cycles (Kosmadopoulos et al., 2020b). Sleep loss and circadian disruption are associated with significant impairment in health and functioning and have been linked to altered eating pattens leading to adverse metabolic outcomes. (Costa, 1996).

Previous studies suggest that during night shifts, meal timing is adjusted to align with work hours and scheduled breaks, which may extend opportunities for food intake and reduce time spent in a fasting state (Shaw et al., 2019). As a result, a significant proportion of daily energy is consumed in the evening which can impair digestion and nutrient absorption, and is associated with obesity, a major risk factor for type 2 diabetes and CVD. CVD and metabolic disorders are among the leading causes of death worldwide and contribute substantially to the global disease burden (Xi et al., 2025). Currently, in industrialised countries, approximately 20% of workers engage in night shift work with numbers projected to rise in the coming years (Boivin & Boudreau, 2014; Cayanan et al., 2019).

Given these considerations, and the health disparity observed among shift workers, particularly night shift workers it is critical to develop a clearer understanding of this population's dietary behaviours, as changes in eating behaviours represent a plausible contributing factor to the increased risk of metabolic diseases.

Such knowledge is essential for developing targeted dietary interventions and evidence-based recommendations to mitigate the adverse health consequences associated with night shift work. To date, few systematic reviews have broadly evaluated eating behaviours exclusively among night shift workers. Recent reviews (Bonham et al., 2016; Clark et al., 2023) have focused on specific aspects of eating behaviours, such as energy intake and dietary patterns and/or rotating shift workers without isolating night shift exposure.

The overall aim of this systematic review is to examine the broad range of eating behaviours experienced by night workers in both fixed and rotating schedules. The objectives of this review are to:

1) Identify eating behaviours observed in night shift workers

2) Examine how eating behaviours differ in night workers compared with day workers

3) Explore what factors influence eating behaviours in night shift workers.

3.2 Methods

A systematic review was conducted to identify the eating behaviours of night shift workers engaged in both fixed and rotating schedules. The protocol for the systematic review was registered on PROSPERO (ID PROSPERO 2025 CRD420251042474), and the review has been reported according to the Preferred Items for Systematic reviews and Meta-analysis statement (PRISMA) (Liberati et al., 2009) and methodology outlined in Pati and Lorusso (2017).

3.2.1 Definition of terms

Eating behaviours were conceptualised across four key domains: *what* night workers are eating (e.g., meal composition), *when* they are eating (e.g., 24-hour meal timing), *where* they are eating (e.g., at home, work, staffroom), and *why* they are deciding to eat (e.g., decision making about what, when and where and other food related choices).

For the purpose of this review, night shifts were defined as at least 3 hours of work between the hours of 00:00 and 05:00 (EU Working Time Directive, 2003; International Labour Organisation, 1990). To allow for a more comprehensive understanding of how night shift work influences overall eating behaviours, the review included all tools used to assess eating behaviours and night work, and examined energy behaviours across the entire 24-hour period.

3.2.2 Search Strategy

To be as inclusive as possible, a broad range of databases across relevant disciplines was systematically searched for relevant studies. A search of PubMed and Scopus was conducted on April 23, 2025, and on 12 May 2025, Discover (an aggregated host database) was used to search Medline, Academic Search Premier, CINAHL and Complete APA PsycINFO. In consultation with an experienced university research librarian, a search string was developed that encapsulated each main concept (i.e., eating behaviours and night shift work) with truncation to capture plural and singular forms of related words, as well as the use of the Boolean operators OR and AND. The final search string was:

(“rotat* shift*” OR “rotat* shift work*” OR “night shift*” OR “night shift work*” OR “night work*”AND ("eating pattern*" OR "eating behavio*" OR "feeding pattern*" OR "dietary habit*" OR "feeding behavio*" OR "dietary behavio*" OR meal*). The search strategy was adapted to different requirements for each database used.

A separate search string, 'night work feeding behaviour', was developed and used to identify studies in the PubMed database that aligned with MeSH terms.

3.2.3 Inclusion Criteria

Screening was conducted using a two-staged screening process and all reasons for exclusion were documented in the PRISMA flow diagram, Figure 1. We included studies based on the following inclusion criteria: 1) Peer-reviewed articles with quantitative findings published in English between the 1st January 2015 to 31st of March 2025; 2) Observational studies, or intervention studies where baseline information was available; and 3) Studies conducted with healthy working adults who were within the age range of 18 – 65-year-olds. Review articles, including scoping, narrative and systematic reviews and meta-analyses, studies that did not present original research, and intervention studies where eating behaviours were evaluated only after the intervention was given were excluded.

The studies were screened for eligibility using the Population-Exposure-Comparator- Outcome-study (PECOS) framework.

Table 1. PECOS framework for study eligibility

Criteria	Definition
Population:	Healthy adult workers (≥18 years)
Exposure:	Night work (fixed/permanent or rotating night shifts)
Comparison:	Day work (standard hours, e.g., 08:00–18:00)
Outcomes:	Eating behaviours (what, when, where, why, how)
Study design:	Observational

3.2.4 Study selection

All studies retrieved during the search process were exported into EndNote. Duplicates were removed by MW. Abstracts and titles of deduplicated articles were then screened by two independent reviewers (100% were screened by MW; 50% screened by KO and 50% by MVDB) using the Population-Exposure-Comparator- Outcome- study (PECOS) framework for the inclusion criteria. If agreement was not reached between two reviewers, the records were discussed with a third reviewer (KO or MVDB, as appropriate) to reach a consensus on eligibility. In cases where suitability could not be determined based on title and abstract, full text articles were retrieved and assessed against the inclusion criteria.

After all titles and abstracts were reviewed and a consensus reached, full-text articles were retrieved for all records noted as being eligible to confirm their inclusion in the review. Screening of full-text articles was conducted by MW and KO. Any uncertainties regarding inclusion were discussed with a third independent review (MVDB). Subsequently, a secondary manual search of the reference lists of all included studies was conducted to identify studies that may be eligible for review. These studies were then assessed against the full set of inclusion criteria, including the specified publication date. Studies published outside this date range were excluded, even if they appeared relevant in terms of content or methodology.

3.2.5 Data extraction

Data from the included studies were extracted by one reviewer (MW), with ongoing consultation with an independent reviewer (KO). Extracted data included study design, location, number of participants and percentage of female participants, shift type (including start and end times) and schedule, the study's primary outcome(s), occupational context, dietary assessment tool, aspect of eating behaviours evaluated, and main findings relating to eating behaviours. Findings from the included studies were collated, described, and presented in Table 2, with conclusions drawn based on the evidence. When data were missing, study authors or sponsors were contacted via email to obtain extra information. Studies were excluded from the overall findings if no response was received after a second attempt. Studies that reported eating behaviours specifically during night work with a rotating shift pattern were included in this systematic review.

3.2.6 Quality assessment

The eligible studies were critically appraised for quality and risk of bias using the Joanna Briggs Institute (JBI) critical appraisal tool(Aromataris et al., 2015). This appraisal involves assessing the methodological quality of the included study and determining the extent of bias in the study's design, conduct and analysis (Joanna Briggs Institute JBI, 2020). Methodological quality is reported in Table 3. However, it did not influence the inclusion or exclusion of the studies. In accordance with the standardised protocol, two reviewers (MW, KO) independently conducted risk of bias assessments of all eligible studies using the appropriate JBI assessment checklist for the study design. In each checklist, methodological factors were designated as Yes, No, Unclear, or Not Applicable, and the results were qualitatively assessed. If any discrepancies in assessments occurred, they were discussed by MW and KO with the intention of mitigating the occurrence of reporting errors. Any discrepancies that could not be resolved were discussed with a third reviewer (MVDB).

3.2.7 Data Synthesis

Due to the high heterogeneity in the measurement and categorisation of both shift work and eating behaviours between studies, a meta-analysis was deemed non-feasible, and outcomes were synthesised and presented narratively.

3.3 Results

Figure 1 summarises the study selection process for the systematic review. After conducting the initial database searches and the removal of 1099 duplicates, 369 studies were retrieved. After title and abstract screening, the full text records of 95 eligible studies were retrieved for further assessment. As shown in Figure 1, 73 studies were excluded. Twenty-two studies were identified as meeting the inclusion criteria and were included in the review. A manual evaluation of the reference lists of the eligible studies did not result in any additional studies for inclusion in the review. Although four studies present in the reference list were relevant in terms of content and methodology, they were published before 2015 and therefore excluded (Balieiro et al., 2014; Reeves et al., 2004; Waterhouse et al., 2003; Zverev, 2005). Correspondence by email was made to the co-author of one study (Hulsegge et al., 2020) to obtain extra information from a supplementary table. The requested table was provided. The PRISMA flow diagram below shows the selection process for the 22 studies.

Figure 1: PRISMA flow diagram for identification of studies for inclusion.

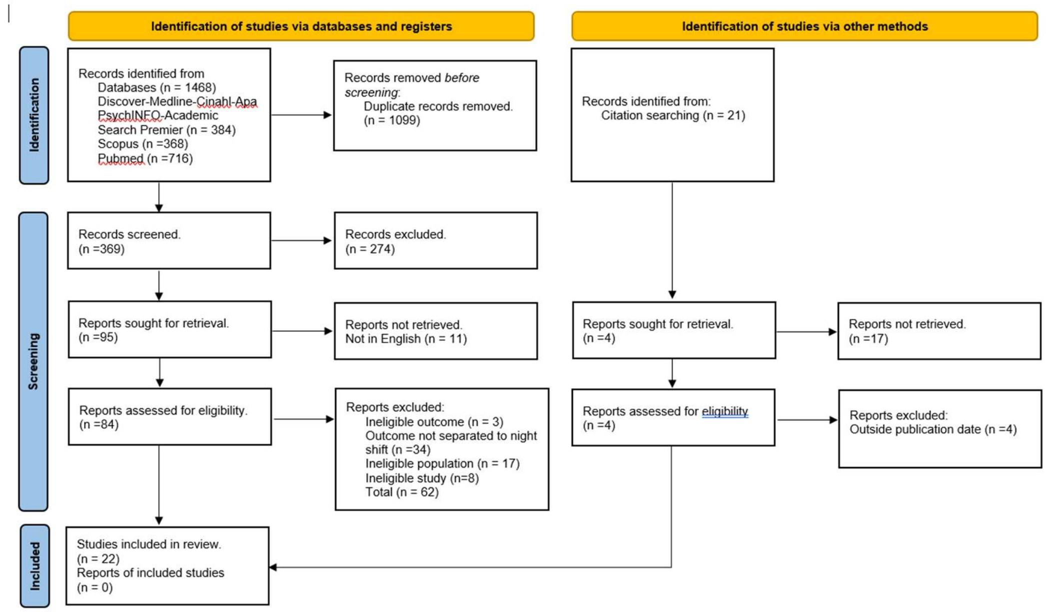


Table 2. Summary of the characteristics of included studies

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator, if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Allen et al. (2023) UK	Within subject Mixed method	127 (% not specified)	103	Rotating schedule: early, day, late, afternoon (NS: 20:00–03:59 Late: 12:00-19:59 DS 04:00-11:59)	Eating behaviours	Police officers	3 x online mandatory questionnaires **	•Diet quality •Barriers to healthy eating	•49% reported that night shift (NS) most challenging and negatively affected their diet compared to other shifts. •Diet quality was significantly lower during NS compared to rest days. (mean = 27.4) compared with rest days (mean = 31.0; $p < 0.001$). •Two main barrier factors for healthy eating: 1)Personal and social (motivation and social support) 2)Physical (time, access and cost) (PCA, 51.6% variance; $\alpha = 0.72$)	Descriptive statistics for DS and NS Statistical Comparison of NS, DS, and rest day
Beebe et al. (2017) USA	Between subject	103 (98%)	53 (Comparator: DW 50)	Fixed schedule: day, night (NS: 18:00-06:00 20:00-03:59 04:00- 11:59)	Sleep quality	Nurses working at community hospital	Food frequency questionnaire (DHQII) and Total HEI-2010 score	•Diet quality.	•No statistically significant difference in diet quality between day workers (DW) and night workers (NW). •Both groups showed poor diet quality, with low scores out of 10 for optimal intake: fatty acids (DW 4.20; NW 5.14), whole grains (DW 2.18; NW 2.28), and sodium (DW 3.66; NW 3.67), with no significant differences.	Statistical comparison of DW and NW
Bonnell et al. (2017) Australia	Within subject Mixed method	55 (2.4%)	19	Rotating schedule: 2 days, 2 nights followed by 4 days off	Eating behaviours	Firefighters, including a mixture of recruit (<1y) or experienced	2 recalls (12 h each covering 24h) using †24-hours USDA multiple pass conducted by phone with dietitian.	• MI and EI • Eating occasions	•No significant difference in total 24hr EI between day shift (DS) and night shift (NS). •No Significant difference in MI between NS and DS •NS median 24h %TEI: protein 21%, Saturated fat 12.5%, CHO 43.8% •Sugar (%EI) was higher during 24h period that included a NS compared with 24h period that included DS (16.8% vs 15.5% EI; p = 0.036) • Higher proportion of discretionary snacks consumed at work during NS (31%) than DS (24%) – e.g., chocolate, ice cream, pastries •Significantly fewer foods and a greater energy density on NS than DS (p < 0.001) over 24h and during work. •75-80% of those on NS ate cooked meals from home compared with 30-35% of those on DS	Descriptive Statistics of DS, NS Statistical comparisons of NS and DS.

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator, if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Chang (2024) South Korea	Within subject	117 (94%)	117	Rotating schedule: day, evening, night (Start and end time not specified)	Eating behaviours	Nurses working in medical ward, surgical ward, intensive care unit (ICU) and emergency room.	1 x Questionnaire to record eating and rest times on each shift type.	•Meal and break timing	•Mean mealtime was longest during night shift (NS) (16.3 ± 17.3 min). •Break time was longest for NS (24.9 ± 26.4 min), compared to DS (7.6 ± 10.9 min). •Mealtime and breaktime were less than 30minutes on all shifts.	Descriptive statistics of DS and NS
de Rijk et al. (2023) Netherlands	Within subject	128 (92%)	128	Rotating schedule: Only night assessed. (NS: 22:00 and 23:15 – 07:00 and 08:30)	Objective and subjective alertness	Nurses recruited from 3 hospitals	1 x per month for 3 months. 24-h dietary recall (24h intake from the evening meal prior to the first night shift until the evening meal after the night shift)	•EI and MI •Eating occasions	•Median of 3.3 eating occasions during NS •TDEI%; Night shift higher in CHO, and mono and disaccharides (52.3%) and lower in protein and fat compared with whole-day intake (47%) (p<0.001) •Total EI during NS: 618 ± 230 kcal, compared with 1,697 ± 504 kcal across whole day.	Descriptive statistics of NS only and NS whole-day. Statistical Comparison of the NS only and the whole day when on NS.
de Rijk et al. (2021) Netherlands	Within subject	118 (100%)	118	Rotating schedule: Only NS assessed (NS: 22:00 and 23:15 – 7:00 and 08:30)	Objective and subjective alertness GI complaints	Nurses recruited from 3 different hospitals	1 x per month for 3 months. 24 -h dietary recall (24h intake from the evening meal prior to the first night shift until the evening meal after the night shift)	•EI • Eating occasion	• Median of 6 eating occasions during 24hr and 2.5 eating occasions during night shift only. Mean total 24-h EI was 1656 ± 450 kcal, of which 610 kcal (IQR 455–737) was consumed during NS. •Mean kcal per eating occasion was 175 kcal during night shift only.	Descriptive statistics of NS

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator, if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Dobrzyńska et al. (2019) Poland	Between subject	300 (100%)	100 (Comparator: Morning shift 100 Afternoon shift 100)	Shift schedule: Not specified (Start and end time not specified)	CVD markers and dietary nutrients that may increase risk.	Not specified	Duration not specified. 24 -hour dietary recall according to national institute of food and nutrition (NIFN). Face to face with each participant	•EI and MI •Eating occasions.	•NW had 3 meals (n =47) and 4 meals (n = 29). •NW had significantly higher, protein (%), and carbohydrates than those on morning or afternoon shifts •NW 24h EI 1457kcal	Descriptive statistics and statistical comparison of permanent morning shift, afternoon shift and night workers (NW).
Della Torre et al. (2020) Switzerland	Within subject Mixed method	65 (0%)	57 (Comparator: DS: 57 Unspecified: 8	Rotating schedule: day, night, recovery day, days off (NS 20:00-06:00)	Eating behaviours	Airport firefighters, police officers and international airport workers	5 or 6 consecutive day using e-CA electronic mobile-based food record to log day by day by 8-h periods. (validated)	•EI and MI •Nutrient and food group intake •PNNS-GS scores	•No difference in MI between DS and NS •No difference in EI between DS and NS •Energy intake increased slightly across 1 → 2 → 3+ nights (2221 → 2423 kcal; p = 0.54) •Both DS and NS consumed below the recommended % TEI for all food groups' •NS: (% of median TEI) SFA was 13.9%, Fibre17.8g. DS: SFA was 13.2% Fibre 20.5% •Energy intake was lower on days following night shifts, corresponding with healthier dietary scores. •NS: Highest proportion of energy intake occurred between 1–9pm (53%), with 18% consumed overnight (9pm–5am). •DS: Highest proportion of energy intake occurred between 5am–1pm (48%), with 8% consumed overnight (9pm–5am). NS; 6.6 eating occasions over 24h. DS: 7 eating occasions over 24h PNNS-GS score: 1 night (5.95) 2 nights (6.46) 3 nights (6.75).	Descriptive Statistics of NS, DS and recovery day. Statistical comparison of single NS with consecutive NS

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator, if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Flanagan et al. (2020) England	Within subject Mixed method	20 (100%)	20	Rotating schedule Morning, afternoon, evening and night (Morning 07:00 – 13:00 NS 21:00–07:00)	Eating behaviours	Hospital nurses and midwives	14-day self-administered Food diary. Dietary intake data were analysed using Nutritics v5.09	•EI •Eating occasions •Meal timing	•No significant difference in total daily EI between NS and non-night shift. •NS: Eating occasions peaked between 23:00–24:00 h, with a secondary peak between 04:00–05:00 h on Night 1, 03:00–04:00 h on night 2. •NS: Highest proportion of EI occurred between 21:00-07:00h (466.5 ± 419 vs 126.8 ± 102.0 kcal for non-night shift. representing 29.8% ± 5.1% vs 8.2 ± 5.2% of 24hr EI. •EI was significantly higher as a proportion of daily calories consumed during the night on night 2 (42.3%) vs night 1 (27.3%, $p = 0.037$) with CHO 38.1% of TDEI in night 2 and 25.4% in night one. •NS: TDEI% (Night 1 vs Night 2) CHO; 25.4%±16.6% vs 38.1%±30.2%, Fat; 169.2±160.0 vs 157.6±200.1, Protein; 20.5%±17.2%vs 28.9%±23.8%	Descriptive statistics of NS, non-night shifts Statistical comparison of NS and non-night shifts
Kosmadopoulos et al. (2020a) Canada	Within subject	31 (17%)	24 (Comparator: DW 21)	Rotating schedule: day, evening, and night (DS: 07:00–16:00 or 07:00–19:00 h NS: 22:30–07:30 h, 23:00–08:00 h, or 19:00–07:00 h)	Sleep-wake times	Police officers	Recorded 4 different day types using a Smartphone to photograph all food and beverage intakes classification of meals using movisensXS smartphone application	•MI •EI distribution •Meal timing	•No significant differences between DW and NW MI and EI across 24 h. •NW consumed more energy at night (30.3% of daily intake) than on rest days (2.2%) or day shifts. •Meals were significantly more dispersed during NS than rest days or DS, with most calories consumed within the first 4 h post-waking. •NW Peak eating time 16:00 – 20:00 and 04:00 – 08:00 •Rest days peak eating times were 1200-16:00 and 16:00 - 20:00 •DW 16:00-20:00 and 08:00-12:00 •NW and DW: Caloric range of meals was mostly 100 to ≤500kcal (40.4% and 39.9%) •NW had more snacks/24h (30.5%) compared to DW (27.8%)	Descriptive statistics of DW and NW Statistical Comparison of DW and NW

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator, if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Lotti et al. (2025) Italy ℂ	Between subjects	322 (56.9%)	94 (Comparator: Non shift worker 156 Morning/afternoon shift workers DW 72)	Rotating schedule: not clearly specified (Start and end times not specified)	-Sleep quality -Mental health	Convenience sample of population	7-day Self-reported Standardised weighted dietary record (WDR)	•Adherence to Mediterranean diet. •Eating occasions •EI	•No differences observed between DW and NW adherence to the Mediterranean diet or total 24 h EI. •Non- shift workers had significantly better adherence to Mediterranean diet compared to day or night workers on a rotating shift schedule. •DW %TEI: SFA; (29.55 ± 13.20) Fibre; (18.67 ± 9.34), CHO; (44.93 ± 8.17) •NW %TEI: SFA; (31.67 ± 11.02), Fibre; (17.18 ± 7.52) CHO; (44.99 ± 7.68)	Descriptive statistics of DW and NW Statistical Comparison of DW and NW
Hulsegge et al. (2020) Netherlands	Between Subject	485 (83.3%)	83 (Comparator: DW 212)	Rotating schedule: day evening night (DS: 08:00–16:30 or 08:30-17.00. NS: 23:00 – 07:30)	Eating behaviours	Healthcare workers from 6 hospitals	3-day self-reported food diary. Including one work free day.	•Eating occasions	•No difference in snack frequency (3), eating episodes (6.0), high-quality snacks (1.0), and low-quality snacks (1.0) between DW and NW. .	Statistical Comparison of DW and NW
Majumdar et al. (2023) India	Within subject	80 (100%)	80	Rotating schedule morning, night (DS: 08:00–20:00 NS 20:00–08:00)	Psychological symptoms Sleep quality	Nurses from government hospital and 2 nursing homes	Diet Survey using 24-h recall method taken for 15 days	•Meal timing •Meal gaps	•NW had a mean first meal at 09:03 ± 00:32 and last meal at 18:46 ± 08:36, with high variability. •Overnight fasting lasted 09:42 ± 01:54. Meal gaps were 1–2: 05:24 ± 00:43, 2–3: 05:08 ± 01:21, and 3–4: 04:50 ± 01:03. For comparison, •DW had a mean first meal at 06:27 ± 00:28 and last meal at 22:00 ± 00:47, overnight fasting 08:57 ± 00:55, with meal gaps of 1–2: 01:10 ± 00:25, 2–3: 07:30 ± 00:40 and 3–4: 04:18 ± 01:26.	Descriptive statistics of DW and NW
Marot et al. (2021) Brazil	Within Subject	30 (0%)	30	Rotating schedule: morning, afternoon, night (NS: 00:00-08:00 DS: 08:00-16:00)	Eating Behaviours	Miners	10 consecutive days 24-h recall. Multiple pass method	•Eating duration •EI •MI	•Higher energy intake and longest eating duration observed first night of NS after 24h free (3410 ± 235 kcal) 20.7 ± 1.2 compared to 12.3 ± 0.3 h and 12.9 ± 0.4h during DS. •Longer eating duration associated with extended wakefulness. No statistical difference in MI between different shift patterns and different eating durations. •NW showed a significantly earlier first meal and eating midpoint than all shifts •Timing of last meal on night shift is not different from the other shift.	Descriptive statistics of DW and NW Statistical Comparison of DW and NW

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator , if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Marot et al. (2023) Brazil	Within subject	30 (0%)	30	Rotating schedule: morning, evening, night (NS: 00:00-08:00 DS: 08:00 -16:00)	Eating Behaviours	Miners	10 consecutive days 24-h recall. Multiple pass method	•Meal timing. •EI •Eating occasions	•No significant difference in total EI across shift schedules. •NW consumed slightly more meals than DW (4.4 vs 4 meals for sequential shifts). • NW had higher % of energy intake between 00:00–03:59 h compared to DW. •Timing of last meal on night shift is not different from the other shift. No significant difference in time and energy of largest meal between shifts •NW had an earlier first meal and eating midpoint compared to DW, first and last meals occurred at 05:52 ± 0:42 h and 20:34 ± 0:11 h, with the highest-calorie meal at 14:38 ± 1:24 h. •DW first and last meals were 08:16 ± 0:28 h and 21:00 ± 0:11 h, with the highest-calorie meal at 16:05 ± 0:51 h.	Statistical Comparison of DW and NW
Molzof et al. (2017) USA	Between subject	17 (100%)	9 (Comparator: DW 8)	Rotating schedule: (DS: 07:00-19:00 NS: 19:00-07:00)	Metabolic risk factors	Nurses	8 day self-reported 24-hr intake. Including 3 consecutive night shifts or day shifts	•EI and MI •Meal Timing	•NW (working) distributed energy consumption between 18:00-09:00 DW (working) had peak consumption between 12:00-15:00 •NS (off work) and DS (off work) had similar high food consumption 18:00-21:00. •No differences in DW or NW 24-h body-weight-adjusted energy and macronutrient intake.	Descriptive statistics of DW and NW
Park et al. (2023) South Korea	Within subject	128 (93.8%)	128	Rotating schedule: 2-3 consecutive night shifts every 10 to 12 days (NS: 22:00 - 07:00)	Sleep quality/ sleep latency and fatigue levels.	Nurses at a University hospital	Self-reported one -night intake. CAN-Pro 5.0 program used	•EI and MI before bed	•Mean macronutrient composition per bedtime meal was 12.8 ± 6.6% protein, 27.5 ± 15.3% fat, and 59.5 ± 18.5% carbohydrates and total calorie 428.2 ± 262.2 kcal •Time interval between meal and sleep 1.43±1.18h	Descriptive statistics of NW

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator, if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Saggi et al. (2023) Australia	Mixed Method	79 (84.8%)	23	Rotating, fixed or variable schedules -part time or full time with at least 3 consecutive shifts. (NS: start after 17:00 and spanning midnight, no end time DS: start before 12:00, end before 00:00)	Eating behaviours	Nurses working in a range of clinical areas	4-day food diary DEBQ using digital diary "Easy diet diary" recorded on 4 different days- work day, non-workday, 1st day shift, last day of shift	• EI and MI	•Protein 82.5-93.3g/day •Total fat: highest on first shift workday (79.0g) •Saturated fat: peaked on first shift workday (31.5g) •Carbohydrates: Highest on pre-shift non-shift •Sugar: Increased during last shift (69.3g) and post shift non-workday (69.7g)	Descriptive statistics of NW
Samhat et al. (2020) Lebanon	Within Subject	307 (67.1%)	307	Rotating schedule (NS: Summer (20.00 – 05.00 Winter 19.00 – 06.00) At least 2 shifts weekly	Body weight and obesity indicators Physical activity levels	Nurses from 5 different hospital working in different care hospitals	EPIC-Norfolk FFQ adapted for face-to-face. Consisting of 7 food groups and 5 beverages. Compared to the recommended frequencies set by the Lebanese Food Pyramid guidelines.	•Meal timing •discretionary food intake	•78.2% of nurses had irregular meals. •During night shifts, 50% increased snacking ($p = 0.015$), consuming potato chips (34.4%), fruits (11.8%), and baked goods (3.8%). •Fruit and vegetable intake was significantly below recommendations (~1 serving/day vs 3 recommended). •Intake of fat, sweets, and energy drinks was significantly above recommended levels. •45.3% brought homemade dishes for dinner, 29.6% preferred to consume fast food.	Descriptive statistics of NW Statistical Comparison of NW evaluated against recommended guidelines.

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator, if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
Shaw et al. (2019) Australia	Within subject	22 (72.7%)	22	Rotating, split, or fixed NS schedules. (NS: 01.00 – 06.00)	Eating behaviours	Healthcare, Transport and Other	4-day food diary with two-night shifts, one day, (If any) and one day off.	• EI and MI •Eating occasions •Recommended servings	•No difference in total 24-h energy intake. •During NS, 30% of eating occasions occurred between 23:00–07:00 compared to 7% DS/day off •NW: mean TEI%: Total Fat; 36.8%, SFA; 14.2%, Sugar; 17.8%, Protein; 19.9%, CHO; 40.8%, Fibre 21.9g/day •Total sugar intake (% of total energy) was significantly higher during NS (p = 0.025), while saturated fat intake was significantly lower (13.8 vs 15.7) compared to days/off (p = 0.030). •NW consumed half of their recommended serves for fruit, vegetables, whole grains, and dairy. •No difference in eating occasions between NW and DW/day off •No significant difference in recommended serves across food groups on nights vs days/off; largest effect size for grains (d = −0.32). •Eating occasions for NS were lower in energy content on average (1661 kJ) compared with DS/off (1933 kJ). •NW eat around the clock with no extended fasting window during the night. On DS they return to typical eating pattern	Descriptive statistics of DW/days off shift and NW Statistical Comparison of DS/Days off shift and NS
Silva et al. (2017) Brazil	Within Subject	34 (Not specified)	34	Fixed Night shift (NS: 18:30- 06:30)	Anxiety levels Sleep quality	Security guards from a public university	6 non-consecutive day food diary. (3 days after night shift and 3 days after regular sleep)	•Meal timing •Meal response	Breakfast; 7.48 ± 1.14 Lunch; 12.57 ± 1.04 Dinner; 20.51 ±1:19 •Hunger varies in the same individuals as their work routine changes. •Hunger before lunch and breakfast was lower after night shifts (6.56 ± 1.79) compared with after night sleep (6.13 ± 1.66, p = 0.007).	Descriptive statistics of NS Statistical Comparison of NS

Author Name Year and Country	Study Design	Total N (% Female)	N of Night Workers (Comparator , if relevant)	Type of Shift Schedule (Start and End Times of Shifts)	Study's Primary Outcome	Occupational Context	Dietary Assessment Tool(s)	Eating Behaviour Outcome(s)	Main Eating Behaviour Findings	Extracted Statistics on Eating behaviours
(Silva et al., 2022) Brazil	Between subject	81 (0%)	52 (Comparator: DW:29)	Fixed day shift and fixed night schedules (DS: Start range: 06:00 - 08:00. End range: 15:00 and 17:00. NS: Start range 21:00 and 23:00 – End range 06:00 and 07:00)	Eating behaviours	Military police officers	three non-consecutive days. Dietary record of Analysis through Dietpro software	• Meal timing •Eating duration •Nightly fasting •Caloric midpoint •24hr EI and MI intake	•NW showed a later eating time for the last meal ($p < 0.001$) NW:23.1 h, DW: 20.5 h Later timing of the last meal was positively associated with higher 24-h energy intake in both day workers (β = 0.352; $p = 0.044$) and night workers (β = 0.424; $p = 0.002$). Later last meal timing was also associated with higher 24-h protein intake in both day (β = 0.451; $p = 0.013$) and night workers (β = 0.536; $p < 0.001$). •NW: later last meal timing was associated with higher CHO (β = 0.346; $p = 0.016$) and fat intake (β = 0.286; $p = 0.042$). •NS had a higher number of meals in 24h (4.1) compared with day (3.9), but no significant difference ($p = 0.185$) •Eating duration was longer for NS (14.4 h vs 12.1 h, $p < 0.001$) •Nightly fasting was shorter in NS (7.3 h vs 10.0 h, $p < 0.001$) •Caloric midpoint occurred later in NS (15.9 h vs 14.8 h, $p = 0.037$) •Protein intake was higher in NS (575.6 kcal vs 444.9 kcal, $p = 0.020$; 5.8 vs 4.7 kcal/kg, $p = 0.038$) No significant differences were observed for total EI, carbohydrate, or fat intake.	Descriptive statistics of NW and DW Statistical Comparison of NW and DW.

Abbreviations: EI, energy intake; MI, macronutrient intake; CHO, carbohydrate; SFA, saturated fatty acids; %TEI, percentage of total energy, GI; gastrointestinal complaints; CVD, cardio-vascular disease:
USDA, United States Department of Agriculture; PNNS-GS, Programme, National Nutrition Santé - Guideline Score, diet quality index with a score ranging from 1 to 12 (12 being the healthiest) measures how closely an individual's diet aligns with national dietary recommendations.
Shift schedules were defined as either rotating or fixed. NS, night shift, a work period occurring at night within a rotating or fixed schedule; NW, night worker, a person engaged in either a rotating or fixed shift schedule; DS, day shift, a work period occurring during standard daytime hours within a rotating or fixed schedule; DW, day worker, a person engaged in day work only
EB, eating behaviour; REAP-S, Rapid Eating Assessment for Participants (REAP-S), higher scores indicate better diet quality; DII, Dietary Inflammatory Index, EPIC and Norfolk; European Prospective Investigation into Cancer and Nutrition-(Norfolk, England), Total HEI-2010 score, healthy eating index assesses how well aligned a diet is with dietary guidelines for Americans.

ℂ(Lotti et al., 2025): shift schedule not clearly defined, non shift workers appear to be those who are not engaged in any shift work schedule, the remaining workers appear to be engaged in a rotating schedule, some of which include night shifts

** The three validated questionnaires included: Perceived Personal, Social and Environmental Barriers to Weight Maintenance, REAP-S, and Food Choice Questionnaire (FCQ)
† Dietary intake assessed using the USDA multiple-pass 24-hour dietary recall method, a structured interview involving repeated passes through the previous day to improve recall accuracy.

3.3.1 Characteristics of Included Studies

The characteristics of the included studies are summarised in Table 2. Across the 22 studies, 12 countries were represented, including Brazil (n=4); Australia and Netherlands (n=3 each); the United States of America (USA), United Kingdom (UK) and South Korea (n=2 each); and Lebanon, Poland, Switzerland, Canada, Italy and India (n=1 each). All studies were observational and employed a cross-sectional study design. Five were conducted as a prospective study (de Rijk et al., 2023; de Rijk et al., 2021; Kosmadopoulos et al., 2020a; Silva et al., 2017) and four used mixed-method approaches. Nursing was the predominant occupational group examined, accounting for 50% of the included studies, followed by emergency services personnel, which included police officers and firefighters and represented 23% of the studies.

Study sample sizes ranged from 17 to 485 participants. Most studies (n=14) had samples that were predominantly female, with five studies including exclusively female participants(de Rijk et al., 2021; Dobrzyńska et al., 2019; Flanagan et al., 2020; Majumdar et al., 2023; Molzof et al., 2017), whereas four studies included only male participants (Della Torre et al., 2020; Marot et al., 2023; Marot et al., 2021; Silva et al., 2022). One study did not report on the gender distribution (Park et al., 2023).

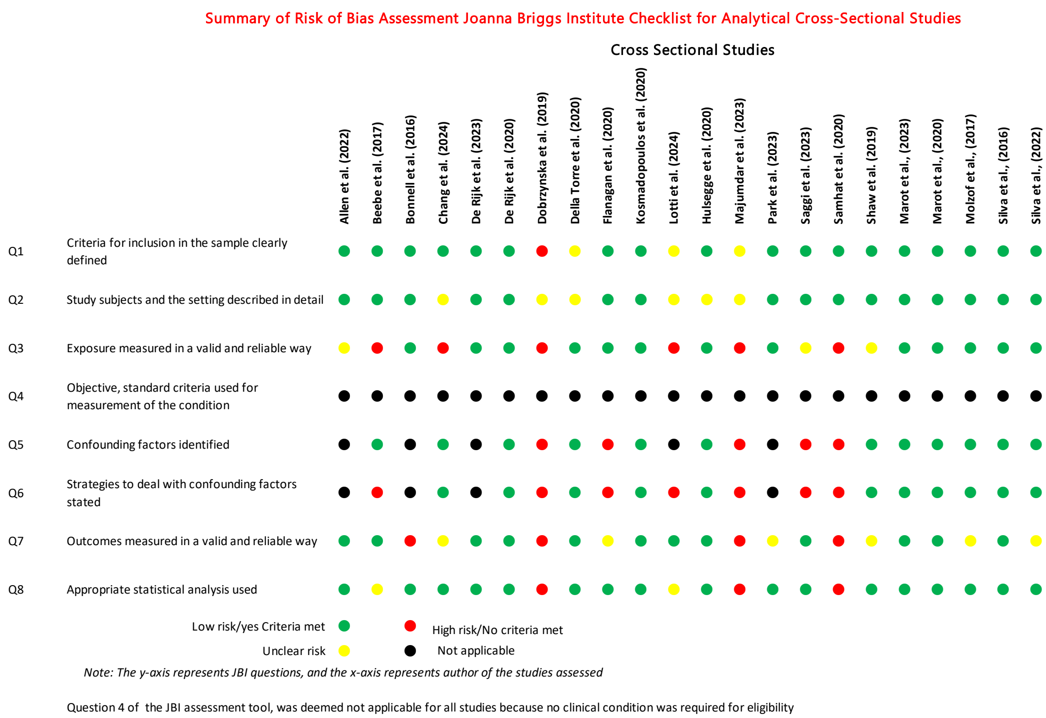
A range of dietary assessment methods were used, including 24-hour food recall, online questionnaires, food diaries, standardised weighted dietary record (WDR), mobile phone apps and food photography. The 24-hour recall was the most commonly used method (n=10 studies) (Bonnell et al., 2017; de Rijk et al., 2023; de Rijk et al., 2021; Della Torre et al., 2020; Dobrzyńska et al., 2019; Majumdar et al., 2023; Marot et al., 2023; Marot et al., 2021; Molzof et al., 2017; Park et al., 2023), followed by food diaries (n=6) (Flanagan et al., 2020; Hulsegge et al., 2020; Saggi et al., 2023; Shaw et al., 2019; Silva et al., 2017; Silva et al., 2022). The duration of dietary measurements varied across studies, ranging from a single night of recording (Park et al., 2023), two 12-hr recalls covering 24-hr (Bonnell et al., 2017), to 15 days (Majumdar et al., 2023).

Eleven studies examined eating behaviours as the main outcome (Allen et al., 2023; Bonnell et al., 2017; Chang, 2024; Della Torre et al., 2020; Flanagan et al., 2020; Hulsegge et al., 2020; Marot et al., 2023; Marot et al., 2021; Saggi et al., 2023; Shaw et al., 2019; Silva et al., 2022), with the remaining studies investigating a sleep-related outcome (e.g., sleep duration, quality) (Beebe et al., 2017; de Rijk et al., 2021; Majumdar et al., 2023; Park et al., 2023), alertness levels (de Rijk et al., 2023; de Rijk et al., 2021), physiological symptoms, (Lotti et al., 2025; Majumdar et al., 2023; Silva et al., 2017), physical activity levels and body weight (Samhat et al., 2020), and metabolic risk factors (Molzof et al., 2017). In many, eating behaviours were evaluated as a factor that may contribute to the primary outcome rather than being the primary focus of the study.

3.3.2 Quality Assessment

The quality assessment results for each study can be found in Table 3.

Table 3. Summary of risk assessment



Most studies demonstrated a low risk of bias. A high risk of multiple bias was identified in four studies (Dobrzyńska et al., 2019; Lotti et al., 2025; Majumdar et al., 2023; Samhat et al., 2020). The primary contributors to high risk were poor measurement of exposures (e.g., incomplete reporting of: night shift schedules, start and finish times of shifts, and shift frequency) and limitations in outcome measurement, such as non-validated dietary assessment tools, reporting periods shorter than 14 days, or unclear measurement definitions (Gibson & Ferguson, 2008; Ma et al., 2009). Notably, two studies had methodological considerations that may affect comparability. Lotti et al. (2025) described the eating behaviours of morning, afternoon, and night-shift workers without clearly specifying their shift start and end times, while others, such as Saggi et al. (2023), imprecisely classified day workers as working morning (starting before

12:00) or afternoon (starting after 12:00 and finishing before 00:00) shifts, encapsulating some day workers in those working non-standard hours. While appropriate statistical analyses were used in the majority of the studies, confounding factors were not always clearly identified or adjusted for (Beebe et al., 2017). Overall, the quality assessment indicated substantial heterogeneity across study design, measurement techniques for assessing eating behaviours, and participant groups. This variability supported the decision not to conduct a meta-analysis, but instead to provide a narrative synthesis of the review findings.

3.3.3 Shift schedules and eating behaviours.

Across the included studies, five studies (de Rijk et al., 2023; de Rijk et al., 2021; Park et al., 2023; Samhat et al., 2020; Silva et al., 2017) focused solely on the eating behaviours of night shift workers within a rotating shift schedule. Thirteen studies compared eating behaviours between day and night shift workers within a rotating shift schedule (Allen et al., 2023; Bonnell et al., 2017; Chang, 2024; Della Torre et al., 2020; Flanagan et al., 2020; Huggins et al., 2022; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Majumdar et al., 2023; Marot et al., 2023; Marot et al., 2021; Molzof et al., 2017; Shaw et al., 2019), and two studies compared night shift workers and day shift workers engaged in a fixed schedule (Beebe et al., 2017; Silva et al., 2022). Notably, one study did not report the type of schedule worked (Dobrzyńska et al., 2019).

As indicated earlier, eating behaviours were conceptualised across four domains: *what* night workers are eating (e.g., meal composition), *when* they are eating (e.g.,24-hour meal timing), *where* they are eating (e.g., at home, work, staffroom), and *why* they are deciding to eat (e.g., decision making about what, when and where and other food related choices). The following reporting of findings is organised across these domains.

3.3.4 What night shift workers eat: Energy intake, macronutrient distribution, food choices, and diet quality.

What night shift workers eat was the most assessed eating behaviour within the included studies. It was examined across multiple dimensions, including energy intake, macronutrient composition, percentage of total daily energy intake (%TDEI), diet quality, and food choices.

3.3.4.1 Energy intake

Energy intake was evaluated in 14 studies (Bonnell et al., 2017; de Rijk et al., 2023; de Rijk et al., 2021; Della Torre et al., 2020; Dobrzyńska et al., 2019; Flanagan et al., 2020; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Marot et al., 2023; Marot et al., 2021; Molzof et al., 2017; Saggi et al., 2023; Shaw et al., 2019; Silva et al., 2022). Reporting of energy intake differed between studies and included the total intake in 24 hours (Bonnell et al., 2017; Della Torre et al., 2020; Flanagan et al., 2020; Kosmadopoulos et al., 2020a; Lotti et al., 2025), during the work shift only (de Rijk et al., 2023; de Rijk et al., 2021; Flanagan et al., 2020), across consecutive night shifts (Marot et al., 2021), in a single meal (Kosmadopoulos et al., 2020a), and in a meal consumed before the sleep period after a night shift (Park et al., 2023). Most comparisons were conducted between night and day workers within rotating schedules, with one study comparing workers in fixed day and night schedules(Silva et al., 2022). One study used a percentage of basal metabolic rate as a proxy measure for energy intake (Kosmadopoulos et al., 2020a). Eight studies compared total 24-hour energy intake between morning/day and night shifts within rotational shift schedules(Bonnell et al., 2017; Della Torre et al., 2020; Flanagan et al., 2020; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Marot et al., 2023; Saggi et al., 2023; Shaw et al., 2019), while one study by Silva et al. (2022) conducted comparisons between different workers in fixed day and night schedules. Across all of these studies, no meaningful differences in total 24-hour energy intake were observed between night and day shifts. Notably, Bonnell et al. (2017) reported no significant difference in energy intake between night and day shifts, despite unequal shift duration (a 14-hour night shift vs a 10-hour day shift).

Three studies reported energy intake across the night shift only (de Rijk et al., 2023; de Rijk et al., 2021; Flanagan et al., 2020). Flanagan et al. (2020) reported a mean intake of 466.5 ± 419.1 kcal during a 10-hour night shift (21:00-07:00) compared with 126.8 ± 102.0 kcal consumed by day shift workers during the same overnight period (Flanagan et al., 2020). The remaining two studies reported total energy intake during a 9-hour night shift, with a similar mean intake of 618 ± 230 kcal (de Rijk et al., 2023) and 610 kcal(de Rijk et al., 2021).

Three studies reported an increase in energy intake among night shift workers (Flanagan et al., 2020; Marot et al., 2021). This included two studies which examined energy intake across consecutive night shifts, with one reporting total 24-hour energy intake (Della Torre et al., 2020) and the other reporting night shift intake as a percentage of total energy (Flanagan et al., 2020). Both observed an incremental increase from night 1 to night 2, with a significant difference in energy intake reported only during the night shift hours of a 24-hour day (Flanagan et al., 2020). The third study compared 24-hour energy intake across consecutive shift days within a rotating pattern and reported that the highest intake (3410 ± 235 kcal) occurred on the first day following 24 hours off, with a night shift coinciding with approximately 21-hours of wakefulness (Marot et al., 2021).

Two studies reported mean energy intake during each eating occasion. de Rijk et al. (2021) examined 9-hour night shifts only and found a mean intake of 175 kcal per eating occasion. Kosmadopoulos et al. (2020a) reported that most workers consumed between 100 ≤ 500 kcal during meals on both night and day shifts, with 40.4% of night shift meals and 39.9% of day shift meals falling within this range.

3.3.4.2 Macronutrient intake

Macronutrients (carbohydrates, proteins, and fats) are the primary contributors to energy intake. Eleven studies reported macronutrient intake and macronutrient intake distribution as a percentage of total energy intake (Bonnell et al., 2017; de Rijk et al., 2023; Della Torre et al., 2020; Dobrzyńska et al., 2019; Flanagan et al., 2020; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Marot et al., 2021; Shaw et al., 2019; Silva et al., 2022). All the studies reported intake of primary macronutrients (carbohydrates, fat, and protein). Six studies additionally reported fibre intake(de Rijk et al., 2023; Della Torre et al., 2020; Dobrzyńska et al., 2019; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Shaw et al., 2019), and saturated fat (Bonnell et al., 2017; de Rijk et al., 2023; Della Torre et al., 2020; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Shaw et al., 2019). Three studies reported sugar intake as a percentage of total energy intake (Bonnell et al., 2017; de Rijk et al., 2023; Shaw et al., 2019), and two studies reported 24-hour sodium intake (Della Torre et al., 2020; Lotti et al., 2025).

Eight studies compared 24-hour macronutrient intake between day and night shifts in those working rotating schedules (Bonnell et al., 2017; Della Torre et al., 2020; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Marot et al., 2021; Molzof et al., 2017; Shaw et al., 2019; Silva et al., 2022), with five using within-subject (Bonnell et al., 2017; Della Torre et al., 2020; Kosmadopoulos et al., 2020a; Marot et al., 2021; Shaw et al., 2019), and three comparing intake between subjects (Lotti et al., 2025; Molzof et al., 2017; Silva et al., 2022). The remaining studies examined macronutrient intake among night shift workers only, either across consecutive night shifts or by comparing the proportion of total daily energy intake consumed during the night shift period vs the rest of the day. One study additionally reported the macronutrient composition of meals consumed before sleep following a night shift (Park et al., 2023).

Among the eight comparative studies, six found no significant difference in 24-hour macronutrient intake between night and day shifts (Bonnell et al., 2017; Della Torre et al., 2020; Kosmadopoulos et al., 2020a; Lotti et al., 2025; Marot et al., 2021; Molzof et al., 2017). Of the two that reported differences, one observed higher protein intake in night shift workers compared to day shift workers (575.6 kcal vs 444.9 kcal, $p = 0.020$), with no significant differences in carbohydrate or fat intake(Silva et al., 2022). The other study by Shaw et al.

(2019) found higher total sugar (19.1% vs 15.0% p=0.025) and lower saturated fats (13.8% vs 15.7% p = 0.030) (Shaw et al., 2019)in night workers.

Among the three studies examining sugar intake as a percentage of total energy intake, all reported increased intake among night workers. Two studies found a significantly higher proportion of total energy derived from sugars across a 24-hour period during night shift compared to day shift (16.8% vs 15.5%, p=0.036) (Bonnell et al., 2017; Shaw et al., 2019). One study observed that during a 9-hour night shift, the proportion of energy derived from mono and disaccharides was significantly higher compared with 24-hour intake (52.3%vs 47%, p<0.001) (de Rijk et al., 2023).

All studies, except one by Marot et al. (2021), reported that total fat intake was above 30% of 24-hour energy intake, with five studies finding it was ≥35%. Five of the six studies found that observed values for saturated fat (SFA) intake were ≥12.5% of total energy intake (Bonnell et al., 2017; Della Torre et al., 2020; Lotti et al., 2025; Shaw et al., 2019), while one study reported 11.6% (Kosmadopoulos et al., 2020a). Two studies found 24-hour sodium intake was 3001mg/day (Della Torre et al., 2020) and 1784mg/day (Lotti et al., 2025). Among the six studies evaluating fibre intake, all reported mean intakes below 22g/day, ranging from 13.5g (Dobrzyńska et al., 2019) to 21.9g (Shaw et al., 2019).

Across all studies, mean protein intake ranged from 16.9%(de Rijk et al., 2023) to 21.4%(Bonnell et al., 2017) and carbohydrate intake ranged from 43.2% (Bonnell et al., 2017) to 55% (Marot et al., 2021). One study comparing macronutrient intake across two consecutive night shifts found no significant differences in carbohydrate, fat or protein intake, but a trend towards increasing carbohydrate (Night 1: 212.8 ± 177.6 kcal; Night 2:264.1 ± 228.6) and decreasing fat (Night 1: 169.2 ± 160.0 kcal; Night 2: 157.6 ± 200.1 kcal) (Flanagan et al., 2020) intake was observed.

Three studies reported the median macronutrient intake during the night shift period (Bonnell et al., 2017; de Rijk et al., 2023; Kosmadopoulos et al., 2020a). Over a 14-hour night shift, Bonnell et al. (2017) observed that the intake of protein was 23.1%, carbohydrate (43.2%), total fat (29.2%), saturated fat (11.9%) and sugars (15%). Over a 9-hour shift, de Rijk et al. (2023) found that protein intake was 15.6%, carbohydrate (52.3%) total fat (29.2%), saturated fats (12.3%), carbohydrate (52.3%), with a total fibre intake of 8.4g Kosmadopoulos et al. (2020a) reported protein intake of 18.9%, carbohydrate (45.9%), fat (35.3%), and total sugars (19.9%), over a 9-hour shift.

3.3.4.3 Snacking and discretionary foods

Four studies observed an increase in snacking behaviour among night shift workers compared to day shift workers within a rotating schedule (Bonnell et al., 2017; Hulsegge et al., 2020; Kosmadopoulos et al., 2020a; Samhat et al., 2020). Hulsegge et al. (2020) found that only night shift workers of a median age of 40 years or older had a higher frequency of snacks during the night shift; among night shift workers, the frequency of total snacks was higher than on work-free days (Hulsegge et al., 2020). Although of low methodological quality, Samhat et al. (2020) examined snacking in nurses engaged in rotating night work and reported that during night shifts, 78.5% had irregular meal patterns, which contributed to a decrease in complete meals during the day ($p =< 0.05$) and an increase in the number of snacks at night ($p =< 0.05$). The composition of meals was primarily sweets (50%), potato chips (34.4%), fruits (11.8%), and baked goods (3.8%) (Samhat et al., 2020). Bonnell et al. (2017) observed that, among firefighters working rotating schedules, a greater proportion of discretionary food was consumed during night shifts compared to day shifts (24% for day workers and 31% for night workers). These discretionary foods included chocolate, ice cream and sweet pastries. Kosmadopoulos et al. (2020a) observed a small increase in the proportion of snacks consumed during a 24-hour period that included a night shift (30.5%) compared to a 24-hour period that included a morning shift (27.8%); however, this difference did not reach significance ($p=0.739$).

3.3.4.4 Diet quality

The diet quality of night workers was reported in four studies (Allen et al., 2023; Beebe et al., 2017; Della Torre et al., 2020; Lotti et al., 2025). Beebe et al. (2017) evaluated diet quality among night working and day working nurses using the Healthy Eating Index-2010(HEI-2010), which provides an overall diet quality score from dietary intake data. No significant differences were observed between nurses on fixed day shift and fixed night shift schedules. However, overall diet quality was suboptimal across both groups, with low scores (out of 10) for fatty acids (DS 4.20; NS 5.14), whole grains (DS 2.18; NS 2.28), and sodium (DS 3.66; NS 3.67). Importantly, however, there was no adjustment for covariates in this study.

Allen et al. (2023) assessed the diet quality of police officers using the Rapid Eating Assessment for Participants-Short (REAP-S) when on night shifts, day shifts and rest days within a rotating schedule. Median diet quality scores did not differ significantly between night and day shifts. However, diet quality was significantly lower during night shifts (mean = 27.4) compared with rest days (mean = 31.0; $p < 0.001$).

Among workers on rotating shift schedules, Lotti et al. (2025) assessed Mediterranean diet adherence using the validated Medi-Lite questionnaire (possible scores range from 0-18; higher scores indicate greater adherence). No significant differences were observed between day shifts and night shifts. However, non-shift workers had significantly greater adherence compared with night shift workers (7.6±2.3 vs 8.1±2.2, p<0.05).

Della Torre et al. (2020) examined diet quality across consecutive night shifts using the PNNS-Guideline Score (PNNS-GS), a 0-15 point index assessing adherence to the French national dietary guidelines. Mean scores were low across both nights and did not differ substantially between night 1 and night 2 (Night 1: 5.95± 1.39 vs Night 2: 6.46±1.52).

3.3.4.5 Fruit and vegetable intake

Four studies assessed fruit and vegetable intake per day (Della Torre et al., 2020; Lotti et al., 2025; Samhat et al., 2020; Shaw et al., 2019), with three studies assessing intake against country-specific dietary guideline recommendations (Della Torre et al., 2020; Lotti et al., 2025; Shaw et al., 2019). Three studies examining intake within rotating shift schedules reported no significant difference in daily fruit and vegetable intake between day and night shifts. However, three studies observed that consumption was lower than recommended. One study examined night shift workers exclusively (Samhat et al., 2020), and found that mean fruit (1.15 servings) and vegetable intake (1.25 servings) were significantly lower than the daily recommendations outlined in the Lebanese food pyramid (i.e., 3 servings/day; $p < 0.001$).

Shaw et al. (2019) evaluated fruit and vegetable intake in night shift workers and found that they consumed 0.7 of the recommended fruit serves and 0.6 of the recommended vegetable serves.

Lotti et al. (2025) found that only 17% of night workers achieved the recommended intake of fruit per day (>2 servings/day), and 19% consumed >2.5 servings of vegetables a day. Della Torre et al (2020) reported a combined mean fruit and vegetable intake of 2.49 servings/day.

3.3.5 When night workers eat: Meal timing and eating occasions.

Exploration of when workers eat included the time of meals, the number of eating occasions, and eating duration, as well as caloric midpoint, which is the time of day at which 50% of the total daily calories have been consumed.

3.3.5.1 Time of meals

Meal timing was reported in eight studies (Chang, 2024; Flanagan et al., 2020; Kosmadopoulos et al., 2020a; Majumdar et al., 2023; Marot et al., 2023; Molzof et al., 2017; Shaw et al., 2019; Silva et al., 2022), all of which observed a redistribution of energy intake among night workers from daytime hours into the night shift period.

Compared with day shifts, workers on night shift had multiple peak eating window times across the 24-hour period. Although findings were broadly comparable, the defined measurement window differed between studies. Reported peak intake times for night workers typically included meals consumed shortly before a night shift and during the early part of the night shift: between 23:00-24:00 and 04:00-05:00 (Flanagan et al., 2020),16:00-20:00 and 04:00-08:00(Kosmadopoulos et al., 2020a), 00:00-03:59 (Marot et al., 2023), 00:00-03:00 and 15:00-18:00 (Molzof et al., 2017), and between 18:00-20:00 (dinner) and 02:00-04:00 (Shaw et al., 2019). In contrast, peak eating times among day workers were concentrated within daytime hours, and most food was consumed between 12:00-20:00 (Kosmadopoulos et al., 2020a) and between 12:00-15:00 (on a work day) (Molzof et al., 2017). Notably, one study examining eating among fixed day and fixed night shift workers on their days off found that their meals with the highest mean total food intake occurred between 18:00 and 21:00 for both types of workers (Molzof et al., 2017). A comparable pattern was observed by Flanagan et al. (2020), who reported that when working a rotating schedule, a greater proportion of 24-hour energy intake occurred between 17:00-21:00 on non-night shifts compared to night shifts (Flanagan et al., 2020).

3.3.5.2 Eating occasions

Nine studies reported the number of meals night workers consumed (Bonnell et al., 2017; de Rijk et al., 2023; Dobrzyńska et al., 2019; Flanagan et al., 2020; Hulsegge et al., 2020; Kosmadopoulos et al., 2020a; Marot et al., 2023; Shaw et al., 2019; Silva et al., 2022). Seven of these compared 24-hour intake during night shift with day work (Bonnell et al., 2017; Dobrzyńska et al., 2019; Hulsegge et al., 2020; Kosmadopoulos et al., 2020a; Marot et al., 2023; Shaw et al., 2019; Silva et al., 2022). Of these, four reported no significant differences in the number of meals consumed over a 24-hour period (Hulsegge et al., 2020; Marot et al., 2023; Shaw et al., 2019; Silva et al., 2022). Among the remaining studies, two observed that night workers consumed significantly fewer meals (Bonnell et al., 2017; Kosmadopoulos et al., 2020a). In contrast, Dobrzyńska et al. (2019) found that a greater number of meals were consumed by night workers; however, this study was of poor quality, and the finding should be interpreted with caution.

Kosmadopolus et al. (2020) observed that the mean number of meals consumed over a 24-hour period differed significantly between day and night shifts (6.3 vs 5.9 meals, respectively). Similarly, Bonnell et al. (2017) reported fewer eating occasions (of solid food only) during a 24-hour period that included a night shift (6.4 vs 6.56 meals), alongside a significantly greater overall energy density of the diet during night shifts. Notably, when examining the number of meals during work time only (a 14-hour night shift), night workers had a greater number of eating occasions compared with day shift workers (a 10-hour day shift) (8.68 vs 8.95 meals).

Marot et al. (2023) examined the number of meals consumed across a 10-day rotating shift schedule and found no significant difference between day and night shifts; however, on days off, participants had significantly more meals than during night shifts (4.4±0.3 vs 3.6±0.3) ($p=0.020$).

Flanagan et al. (2020) examined the number of eating occasions across two consecutive night shifts and found no significant difference in the number of eating occasions during the night shift between night 1 and 2. de Rijk et al. (2023) examined eating occasions among fixed night shift workers only during a night shift and reported a median of 3.3 (IQR:2.3-4) eating occasions.

3.3.5.3 Eating Window

Daily eating windows (defined as the time between the first and last eating occasion) were examined in five studies (Chang, 2024; Kosmadopoulos et al., 2020a; Majumdar et al., 2023; Marot et al., 2021; Silva et al., 2022). Across all studies, the duration between the first and final eating occasion over a 24 h period was significantly longer on night shift days compared to day shift days or days off. The longest eating window was 20.7 ± 1.2 hours and was observed when on night shifts within a rotating shift schedule. Notably, this long eating window was observed when the night shift was preceded by daytime hours free of work (i.e., due to extended hours of wakefulness before the first night shift) (Marot et al., 2021).

3.3.5.4 Caloric mid-point

Three studies observed the mid-point of caloric intake among night shift workers. Kosmadopoulos et al. (2020a) examined caloric mid-point within a rotating schedule, and Silva et al. (2022) in a fixed schedule. Both found that compared with day work, night shift work was associated with a later mid-point. In contrast, Marot et al. (2023) observed an earlier caloric mid-point when on night shifts in a rotating schedule, attributing it to an earlier timing of the first meal.

3.3.6 Why night shift workers eat in the way they do: decision making about eating

Very few studies explored the reasons why night workers eat in the way they do, such as their decision-making regarding what, when and where they eat, as well as other food-related choices. Two studies examined work-related meal choices during the night shift (Bonnell et al., 2017; Samhat et al., 2020). Bonnell et al. (2017) used 24-hour dietary recall and found that night workers consumed a substantially higher proportion (75-80%) of cooked main meals and a lower proportion of easy-to-prepare meals compared to day workers. Takeaway meals were consumed at similar frequencies and in low proportions across both day and night shifts (Bonnell et al., 2017). When examining night shifts only in a rotating schedule,Samhat et al. (2020) observed that 45.3% of workers brought homemade dishes for dinner and 29.6% preferred to consume fast foods.

Hunger, enjoyment of eating and satiety were found to vary significantly across meals (breakfast, lunch and dinner) (Silva et al., 2017). However, these factors were not significantly influenced by whether workers were working a night shift or a day shift when they could sleep at night.

A mixed method study of police officers working rotating schedules evaluated barriers to healthy eating. From quantitative data, they identified two main barrier factors for those working night shifts: *personal/social* and *physical barriers.* Night shift workers' decisions to eat were influenced by work-related time pressure, fatigue, limited availability of healthy foods during night hours, and social influences at work, which often resulted in reliance on convenience foods or takeaway meals. However, these findings needed to be interpreted with some caution, as a small proportion of participants (n=19; 16%) were shift workers who did not work nights but were included in the grouped results for day workers (Allen et al., 2023).

3.3.7 Where night shift workers eat, location

No studies evaluated the locations where night shift workers consumed their meals.

3.4 Discussion

The purpose of this review was to evaluate the broad range of eating behaviours experienced by night workers in both fixed and rotating shift schedules across four key domains: *what* night workers are eating (e.g., meal composition), *when* they are eating (e.g., 24-hour meal timing), *where* they are eating (e.g., at home, work, staffroom), and *why* they are deciding to eat (e.g., decision making about what, when and where and other food related choices. This was achieved by examining 22 studies and evaluating night workers' eating behaviours and how they differed when compared with day workers or day shifts within fixed or rotating schedules. The majority of the reviewed research focused on what night shift workers eat, followed by when they eat. Fewer studies examined why food choices were made, and no studies within this review quantitatively evaluated where eating occurred, likely due to the contextual nature of this aspect of eating.

Overall, the findings indicate that night shift work is associated with changes in eating behaviours. Consistent with previous reviews (Cayanan et al., 2019), total energy intake did not differ between day workers and night workers within rotational shifts. However, food consumption was more frequent and spread 'around the clock', extending into night-time hours, which can cause circadian misalignment. Further, intake of key nutrients essential for cardiovascular health and overall wellbeing were below recommended dietary guideline levels. Conversely, nutrients and food types associated with increased risk of CVD and type 2 diabetes exceeded recommended levels. Lastly, key considerations when interpreting the findings from the studies were low methodological rigour and limitations in the reporting and definitions of key terms, which compromised the robustness of the overall findings.

3.4.1 What night shift workers eat

What night workers ate was the most commonly evaluated aspect of eating behaviours, including assessment of 24-hour energy intake, macronutrient intake as a percentage of total energy intake, diet quality and discretionary food intake. As mentioned earlier, the findings from this review showed no difference in 24-hour energy intake between night and day shift workers within rotational schedules. This finding is consistent with recent systematic reviews that have included meta-analyses (Bonham et al., 2016; Cayanan et al., 2019), as well as earlier studies (de Assis et al., 2003; Morikawa et al., 2008; Pasqua & Moreno, 2004). Evidence supporting this observation dates back several decades; for example, one of the earliest studies conducted in 1979, evaluating a small sample of refinery workers using an eight-week food diary, reported no difference in total energy intake between shift workers and day workers (Reinberg et al., 1979). Collectively, these findings suggest that total intake may not adequately capture differences in eating behaviours among night shift workers. Therefore, examining broader aspects of dietary behaviour, such as meal timing, location of food consumption and decision making around food choices, may provide greater insight into how night shift work influences eating behaviours.

Macronutrient intake (protein, carbohydrate and total fat) did not differ substantially between night and day shift workers within a rotating schedule, and was reported within the internationally accepted Adequate Distribution Macronutrient Range (ADMR) (carbohydrate 45–65%, protein 15–25%, and total fat 20–35%) (Lowden et al., 2010; Ministry of Health, 2017). However, further evaluation of other essential nutrient intake values in relation to dietary guidelines suggests a notable reduction in essential nutrients among night shift workers. Night shift workers, who are already predisposed to an increased risk of metabolic disease due to circadian disruption and sleep loss, may face an increased cumulative risk because of the suboptimal nutrient intake identified in this review.

Across all night workers, the percentage of energy derived from saturated fat and free sugars exceeded recommended nutrient reference values (i.e., SFA ≤10% and free sugar 5-10%), 24-hour sodium intake surpassed the Suggested Dietary Target of ≤ 2000mg/day, while dietary fibre intake was below Adequate Intake recommendations (i.e., 30g/day for men and 25g/day for women), and substantially lower than the dietary targets recommended for individuals at increased cardiometabolic risk (i.e., 38g/day for men and 28g/day for women). These findings align with previous research demonstrating higher intakes of saturated fats and sugars, as well as suboptimal dietary fibre intake, among shift workers (Hemiö et al., 2015; Lowden et al., 2010; Phoi et al., 2025; Souza et al., 2019).

Dietary fibre is a key component of a healthy diet, with adequate intake supporting metabolic health through glucose and lipid regulation, promoting colonic health through maintenance of a healthy gut microbiome, and contributing to overall wellbeing (Barber et al., 2020). Given that fruit and vegetables are major contributors to overall dietary fibre intake, their consumption is an important consideration. Within this review, three studies assessed fruit and vegetable intake against recommended guidelines, and across all studies, intake was below the recommended daily amounts for both day and night workers within rotational shift patterns.

Based on this, the corresponding low dietary fibre intake observed among night shift workers in this review was not unexpected.

Looking ahead, future research examining dietary intake in night shift workers should prioritise assessing key nutrients and micronutrients associated with metabolic health (i.e., saturated fatty acids, sugar intake, sodium, and fibre), particularly given this population's predisposition to metabolic diseases. Within this review, only two studies assessed sodium intake, while six assessed dietary fibre and saturated fatty acid intake among the 11 studies that evaluated macronutrients, highlighting the need for further studies adopting this approach.

Targeted evaluation of these key nutrients in research may provide valuable insight into additional dietary risks among night shift workers and support the development of targeted nutritional interventions. Such strategies may include redistributing dietary energy intake by shifting consumption away from saturated fats, simple sugars and sodium towards higher quality carbohydrate sources, with particular emphasis on fibre-rich foods, including fruit and vegetables (Phoi et al., 2025).

Night shift workers demonstrated a greater frequency of snacking compared with day shift workers, with a larger contribution from discretionary food. This aligns with findings from earlier studies (Assis et al., 2003; Lennernäs et al., 1993), which similarly reported increased snacking and a high fat intake from convenient foods among night workers. Both physiological and environmental factors likely contribute to this overall unhealthy eating behaviour. From a physiological mechanistic perspective, appetite regulation follows an endogenous circadian rhythm characterised by greater hunger and food intake during the biological day (active phase), and reduced intake during the biological night and early morning when homeostatic pressure for sleep is high and the circadian system promotes night time activities (Lowden et al., 2010; Waterhouse et al., 2003). Eating during the night, therefore, occurs at a time when metabolic processes are not optimally aligned for food intake. Furthermore, sleep loss and circadian disruption, both inherent in night workers (Åkerstedt & Wright, 2009), may dysregulate key appetite-regulating hormones, such as ghrelin and leptin, which play central roles in the control of hunger, satiety, and energy balance(Buxton et al., 2012; Kervezee et al., 2020; St-Onge et al., 2012). These alterations may alter food preferences and promote an increase in the consumption of discretionary food (Heath et al., 2012). Environmental factors may also contribute to these behaviours, with qualitative research suggesting that workplace context can reinforce snacking and discretionary food consumption. For example, qualitative research reports that nurses (who represent the majority of participants in this review) often forgo scheduled breaks and rely on convenience foods due to high workload demands (King et al., 2009), the need to maintain alertness (Horton Dias & Dawson, 2020), social norms of celebrating (Marko et al., 2023) and limited access to healthy food options (Allen et al., 2023; Horton Dias & Dawson, 2020; Marko et al., 2023).

As mentioned in the reviewed study by Marot et al. (2023), in Brazil, especially in industries such as mining, employers participating in the Worker Food Program (PAT) commonly provide one main meal during the work period. In 2015, the program had 236,970 registered companies, covering 19.5 million workers (Torres et al., 2020). Within this review, there were four studies conducted in Brazil. This workplace policy demonstrates that eating behaviours can be significantly influenced by contextual factors beyond work schedules alone. Consequently, such factors should be transparently reported in research, including detailed information regarding what meals are provided and when, as employer-provided onsite meals can determine multiple aspects of eating behaviours, and this may influence study findings (Assis et al., 2003).

3.4.2 When night shift workers eat

The timing of food intake among night shift workers was assessed through meal timing, number of eating occasions, eating duration and caloric midpoint. Collectively, the results demonstrated a clear redistribution of energy intake toward night-time hours, reflecting the alignment of food consumption with the night shift schedule. For the most part, peak eating window times reflected consumption of meals before a night shift and during early morning hours, typically between 02:00 and 05:00. This altered meal timing in night shift workers is relevant to the association between night shift work and an increased risk of CVD and other metabolic diseases (Brown et al., 2013; Jakubowicz et al., 2013; Marot et al., 2023). Of particular relevance is that the metabolic response to a meal is not independent of meals consumed before or after (Al-Naimi et al., 2004). Therefore, for night shift workers who commonly consume a low calorie snack during the night shift after having a main meal (dinner) prior to the start of work, this eating pattern may lead to higher postprandial triacylglycerol concentrations and detrimental effects on LDL cholesterol (Hibi et al., 2012).

Additionally, glucose tolerance is highest in the morning when the body is preparing for food intake, and decreases at night when the body enters a fasting state. Eating during this fasting state leads to circadian disruption and disturbs key metabolic processes contributing to glucose intolerance, reduced insulin sensitivity and further increased risk of obesity (Berg et al., 2009; Bertéus Forslund et al., 2002; Wang et al., 2014), CVD and type 2 diabetes (Gan et al., 2015; Kianersi et al., 2024; Knutson et al., 2017; K. Spiegel et al., 1999; Windred et al., 2024).

Peak eating times for day workers followed a diurnal pattern where food was mostly consumed between 12:00 and 21:00, with a greater proportion of energy intake consumed between 17:00 and 21:00, reflecting dinner being the largest meal consumed during the day. This diurnal eating pattern supports circadian physiology and promotes metabolic health, as food is consumed within a consistent 8-12 hour daytime window when the body is better prepared to metabolise, absorb, and digest nutrients more efficiently(Mangoonian et al., 2022).

This review demonstrated that extended periods of wakefulness and longer eating windows are associated with increased energy intake, suggesting that total energy intake may be affected by shift scheduling (Marot et al., 2021; Silva et al., 2022). These findings are supported by earlier research by Spaeth et al. (2013), who reported that adults experiencing chronic sleep loss and later bedtimes may be more susceptible to weight gain due to greater caloric intake and increased consumption of calories during the night. One proposed explanation for this increase is that remaining awake for longer periods, particularly overnight, provides greater opportunity and time to eat (Chaput, 2010; Spaeth et al., 2013). However, further research is needed to clarify this relationship.

Overall, these findings suggest that the increased risk of cardiometabolic diseases among night shift workers may not be solely the result of energy intake and poor diet quality, which are commonly recognised contributors within the wider population (Castro-Barquero et al., 2020). Instead, the cumulative redistribution of food consumption to night-time hours may play a key role.

3.4.3 Why night shift workers eat

Within this review, the synthesis was limited to quantitative evidence; therefore, findings explaining contextual factors, such as why night shift workers choose to eat, were limited. The available evidence suggested that decisions around eating may be influenced at both an individual level, such as satiety, enjoyment of eating or hunger, and an organisational level, including workplace-related constraints such as fatigue, time pressure, social influences at work and limited access to healthy food options during night shifts. These factors may lead workers to choose fast food and discretionary foods due to their convenience and accessibility. However, further research incorporating qualitative evidence is needed to better understand the contextual factors influencing why night shift workers choose to eat.

3.4.4 Methodological considerations

3.4.4.1 Control group

Within this review, the majority of studies examined eating behaviours associated with day work within a rotating schedule and within-subject designs. The suitability of this control group is questionable, as working rotating schedules that include both day and night shifts have their own health challenges (van Drongelen et al., 2011). There may be limitations to this approach as the findings do not reflect the eating behaviours of individuals working standard working hours and might alter the results since permanent dayworkers tend to differ socially, economically and psychosocially. Therefore, studies in this area should carefully consider and define the control group (van Drongelen et al., 2011).

3.4.4.2 Definitions of eating behaviours and shift work

A significant methodological limitation across the studies included in this review was the inconsistent definitions used for terms related to eating behaviours and the classification of shift work, particularly regarding night shifts and day shifts. This lack of consistency and standardisation complicated the interpretation of the findings and limited the ability to make robust comparisons across the studies. Numerous studies classified dayworkers as those working only 'standard hours' to those working morning and/or afternoon shifts. Similarly, there were notable differences in the definition and description of both shift work and night shifts, particularly in relation to their start and finish times.

Since 2007, when the International Agency for Research on Cancer (IARC) classified shift work as carcinogenic (Straif et al., 2007). A large body of research has evaluated the associated adverse effects of shift work. Alongside this, IARC have established recommendations for defining and reporting shift work. The identified characteristics were considered integral to assess shift work in literature: 1) shift system (start time of shift, number of hours per day, rotating or permanent, and direction of a rotating system, regular or irregular); 2) years worked on a non-day shift schedule and cumulative exposure to the shift system over the subject's working life); 3) shift intensity; time off between work day and non-work day (Stevens et al., 2011). However, the heterogeneity observed across the studies in this review suggests that these key characteristics have not been applied.

3.4.4.3 Dietary assessment

Although dietary questionnaires such as 24-hour recalls, food records, and food frequency questionnaires are widely used in observational studies due to their feasibility and low cost (Willett, 2012), they are associated with inherent limitations due to the nature of self-reporting, making intake susceptible to memory loss, bias and underreporting of food that can affect the accuracy and comparability of dietary data (Vucic et al., 2009). In the context of night work, accurate assessment of usual dietary intake is particularly important, as the adverse health effects associated with shift work are chronic and arise following prolonged exposure. Consequently, short-term dietary assessments may inadequately capture habitual eating behaviours relevant to long-term health outcomes.

Within this review, methods of assessing dietary outcomes varied considerably across the included studies; the 24-hour recall was the most used dietary assessment tool (n=10), with few studies employing repeated measures over a sufficiently long duration to estimate usual intake. Previous evaluations have indicated that a minimum of 14 days of repeated 24-hour recall is considered necessary to provide a valid representation of habitual dietary intake (Gibson & Ferguson, 2008; Ma et al., 2009). However, only two of the reviewed studies met this criterion (Flanagan et al., 2020; Majumdar et al., 2023). Other reviewed studies either failed to report the duration of dietary assessment (Dobrzyńska et al., 2019) or relied on a single day or night of intake (Park et al., 2023), limiting the reliability and interpretability of their findings. This demonstrates how the selection of dietary methods should be guided by predefined study objectives, such as quantitative assessment of nutrient intake, assessment of the consumption of food or food groups, or evaluating dietary patterns (Willett, 2012), particularly in populations with irregular eating schedules such as night shift workers.

3.4.5 Limitations

Although there are clear advantages to quantitative research, such as enabling easier comparisons and being time-efficient, some aspects of eating behaviours are difficult to capture using quantitative methods alone. By limiting the scope of this review to quantitative evidence, valuable factors, such as evaluating barriers to healthy eating, have likely not been captured. A systematic review that includes studies with qualitative analysis of eating behaviours may provide additional insights. For example, five studies included in this review (Allen et al., 2023; Bonnell et al., 2017; Della Torre et al., 2020; Flanagan et al., 2020; Saggi et al., 2023) employed a mixed-method study design and reported qualitative findings that explored 'why' and 'how' shift workers make decisions to eat, including choices around what, when and where to eat. However, these findings were outside the scope of the present review and therefore could not be incorporated. Future research would benefit from conducting a mixed method systematic review to capture a broader and more in-depth understanding of eating behaviours, including contextual factors that underpin the decision to eat.

3.4.6 Conclusion

The findings of this review suggest that night shift work compromises eating behaviours, particularly in relation to the timing of food consumed and the type of food consumed. While total 24-hour energy intake did not differ between night and day workers, night workers had irregular meal patterns, increased night-time eating, and a greater consumption of discretionary food, saturated fat, and sugar. These alterations in eating behaviours may contribute to the increased risk of cardiometabolic diseases observed among night workers. Addressing modifiable risk factors, such as improving diet composition, and acknowledging non-modifiable factors, including circadian disruption, is critical for mitigating the adverse effects of night work and for developing targeted interventions and dietary advice for this vulnerable population. Future research should incorporate consistent and reliable methodologies to limit heterogeneity in study design and findings and consider mixed method designs to provide broader insights into eating behaviours.

CHAPTER 4 DISCUSSION

4.1 Summary of main findings

An extensive body of literature has identified an association between night shift work and increased risk of metabolic diseases, including CVD, type 2 diabetes (Gan et al., 2015; Kianersi et al., 2024; Knutson et al., 2017; Spiegel et al., 1999; Windred et al., 2024), and obesity (Berg et al., 2009; Bertéus Forslund et al., 2002; Wang et al., 2014). These chronic conditions are among the leading causes of morbidity and mortality worldwide and represent a significant burden on the healthcare system (World Health Organisation, 2023). Identifying typical eating behaviours among night shift workers may provide greater insight and understanding into factors contributing to these associated risks, thereby informing the development of targeted, evidence-based interventions aimed at mitigating adverse health outcomes in this at-risk workforce. Considering this, the primary aim of this thesis was to systematically review the available scientific literature with quantitative findings and examine the broad range of eating behaviours experienced by night workers. Three objectives helped to achieve this: 1) identifying eating behaviours among night shift workers, 2) Comparing differences in eating behaviours between night workers and day workers, and 3) identifying the factors that influence eating behaviours.

The systematic review identified that three aspects of eating behaviours were explored in the literature between 2015 and 2025: what night workers eat, when they eat and to a limited extent, why they eat. The context of where food was consumed had not been quantitatively examined. Two types of comparisons between day workers and night shift workers were identified in the literature; one was fixed day workers vs fixed night workers, and the other was a comparison of eating behaviours on night shift vs day shifts in a rotating pattern. Overall, no difference in 24-hour energy intake was observed between day and night workers or day shifts and night shifts. However, night shift workers demonstrated poor adherence to recommended guidelines, with intakes of saturated fat, sodium and sugar exceeding recommended values alongside inadequate intake of dietary fibre, reflecting low consumption of fruit and vegetables. In addition, night workers showed an increase in snacking and discretionary food intake compared with day shift workers. Temporal patterns differed significantly from day-oriented work, with night workers redistributing energy intake to night-time hours.

4.2 Research impact

Previous systematic reviews with a more limited focus have suggested no difference in total energy intake between night workers and day workers (Bonham et al., 2016; Cayanan et al., 2019). The findings of this review highlight the value of examining eating behaviours through a broad, multidimensional lens. Focusing on only one or a few aspects risks overlooking important factors that could be effectively targeted through intervention. The present research also adds to the knowledge and understanding of why night shift workers are at an increased risk of developing chronic metabolic diseases. Specifically, the observed changes in diet are likely to increase risks of adverse cardiovascular outcomes (Hooper et al., 2020) and insulin resistance (Roden & Shulman, 2019; Wali et al., 2020). Further, the redistribution of eating to night-time hours is likely to contribute to circadian disruption (Boivin et al., 2022; McHill & Butler, 2024), and therefore metabolic dysfunction (Basolo et al., 2021; McHill & Butler, 2024). The review's findings also suggest that improving health outcomes in this population requires targeted dietary guidelines and recommendations that address both the type and timing of food, alongside understanding the barriers to healthy eating that exist within occupational contexts. Further, the interventions need to occur in the workplace and target both the individual and organisational level of behaviour change (Huggins et al., 2022; McIntosh et al., 2023).

4.3 Strengths

To the authors' knowledge, this is the first systematic review to broadly examine eating behaviours solely among night shift workers. This focus is a key strength, as night shift workers are disproportionately affected by adverse health outcomes compared to those on other shift schedules.

Secondly, this research provides a comparison of the nutrient intake of night workers against New Zealand nutrient reference values and recommended guidelines, rather than solely comparing with day shift workers. Comparisons limited to dayworkers within rotating schedules often showed no difference; however, evaluating intake against evidence-based guidelines provides a more meaningful assessment of dietary adequacy, an approach not consistently used in previous reviews. By highlighting these dietary inadequacies, this review underscores the need for more targeted research focusing on fibre, sodium, sugar and saturated fat as target nutrients to assess. Such research would provide a stronger basis for understanding the dietary contributors to metabolic diseases among shift workers, particularly those engaged in night work.

A key observation from this review is that context matters and plays a crucial role in shaping eating behaviours among night workers, which may vary substantially depending on the nature of the work performed and the setting in which it is performed. For example, the spontaneous nature and lack of designated breaks for emergency response personnel, including police officers and emergency response nurses, may influence the type and quality of food consumed (Allen et al., 2023). This compares with roles that are less mentally and physically demanding and in a fixed setting, such as call centre work, where hours of work and task allocation might be more predictable. Predictable and/or stable work environments may allow for kitchen facilities and regular provision of higher quality food, as well as facilitate the preparation of higher quality food. In contrast, unpredictable work and changeable work environments can limit break opportunities and the ability to prepare nutrient-dense meals.

Finally, including all studies in the systematic review irrespective of their risk of bias as determined by the JBI assessment allowed us to describe and highlight methodological limitations across the literature. These observations provide guidance for future studies on the methodological aspects that need careful consideration. The review may act as a roadmap, potentially enhancing the quality of future research in this area.

4.4 Limitations

Despite its substantial value, one of the key challenges encountered in the review was the inconsistent definition and reporting of both eating behaviours and shift work schedules across studies. The terminology used to describe shift work varied considerably between studies, often relying on author-defined definitions, which made comparisons difficult. For example, imprecise definitions of day work meant that comparisons with night work were not equal. Notably, studies varied in their definition and description of day work, from "non shift work worker" to individuals following a regular daytime work schedule, to individuals who were day-oriented but may have been working rotating morning or afternoon shifts as part of their work schedule. These inconsistencies created challenges when comparing and interpreting results. In addition, the reporting of shift schedules was often incomplete, with some studies reporting only shift start times without specifying the total duration of the shift, making it difficult to align with our working definition of night shift work. Furthermore, several studies did not clearly report the duration of participants' exposure to night shift work. This is an important consideration given that the health consequences of working night shifts may differ substantially depending on whether exposure occurred over a short or long time period, and eating behaviours such as total energy intake and meal patterning differ when assessed over different time periods.

4.5 Individual and organisational recommendations for night workers

The present systematic review highlights opportunities for interventions to improve the eating behaviours of night shift workers. When providing recommendations, it is important to consider both the organisational level and individual level, as there is little value in supporting individuals to have healthy eating behaviours if the context in which they are working does not support those eating behaviours. This approach avoids placing blame on the individuals for non-adherence and instead highlights the influence of the organisation or employer.

4.5.1 Individual-level recommendations

Interventions and recommendations need to be feasible and appropriate to the lifestyle of shift workers to enable adherence (Phoi & Keogh, 2019)

1. Night workers should limit consumption of discretionary foods high in saturated fat, sugar and salt and replace these with snacks rich in dietary fibre (by selecting foods with higher fibre content per 100g from the nutrition panel) and protein, with target intakes of 20-25g at each meal and approximately 10g per snack. These protein values align with New Zealand's dietary guidelines, which support adequate protein distribution across the day to optimise satiety and support metabolic health.

Discretionary foods, including chocolate, sweets, sugar-sweetened soft drinks and processed meats, tend to be highly palatable, convenient, and affordable and are often seen in vending machines (Gupta, Coates, et al., 2019; Marot et al., 2023). They are strongly associated with obesity and other co-morbidity risk and contribute to a gut environment associated with inflammatory diseases, like cardiovascular disease (Crimarco et al., 2022). By replacing discretionary food options with ones that are high in dietary fibre, it helps to support a healthy gut biome and ensures a slow release of nutrients into the digestive tract while maintaining satiety and regulating blood glucose levels. Furthermore, high protein snacks are associated with lower postprandial glucose response and greater satiety compared with low protein, high carbohydrate meals (Davis et al., 2020).

2. It is recommended that dietary fibre intake be increased to 25-30g per day for healthy individuals and to 30-40g per day for individuals with diabetes or at increased risk of

cardiovascular disease. These intake levels are consistent with New Zealand Nutrient Reference Values and are associated with improved satiety, glycaemic control, reduced cholesterol, and overall support for the prevention of metabolic diseases.

Dietary fibre found in plant sources plays an important role in metabolic health and exists in two forms, each defined by the way it functions in your body (Barber et al., 2020). Soluble fibre, present in foods such as oats, legumes and fruit, has been shown to lower and delay glucose absorption, thereby improving glycaemic control. Insoluble fibre, found in wholegrain products, vegetables and fruit, contributes to increased satiety and may help reduce snacking behaviour. Increasing fibre through these sources can improve diet quality and metabolic outcomes.

3. It is recommended that night workers maintain a structured meal pattern across the day (e.g., breakfast, lunch and dinner) where possible. During the night shift, large meals or snacks (about 500kcal) should be replaced with a smaller snack of approximately 200kcal at around midnight.

Eating a snack-size portion of 200kcal rather than a meal size of 500kcal during night shift has been associated with reduced sleepiness and better performance and alertness (de Rijk et al., 2021), as well as reduced headaches and dizziness (Gupta, Centofanti, et al., 2019). From a metabolic perspective, consuming a snack at night is linked to more favourable glucose responses, whereas consuming meals during night shift has been shown to impair glucose tolerance at subsequent meals(Centofanti et al., 2018).

4. It is recommended that night workers eat prior to sleep, to avoid waking up from hunger. It is also recommended that a low calorie, high protein meal is consumed.

The proportion of protein in meals 2 hours prior to bed has been found to be positively associated with sleep efficiency among night workers (Park et al., 2023). This might be explained by the presence of the amino acid Tryptophan in some protein rich foods. Tryptophan promotes sleep and is abundant in milk, eggs, soybeans and chicken (Binks et al., 2020). Supporting this approach, research has also shown that a diet lacking in Tryptophan impairs overall sleep quality (Bhatti et al., 1998). Other foods may also benefit sleep. For instance, consuming cherries, which contain a high concentration of melatonin and serotonin, can improve sleep duration and quality (Garrido et al., 2013).

4.5.2 Organisational level recommendations

Workplace culture plays a critical role in shaping dietary behaviour, as health behaviours can be socially influenced, and the workplace environment is a strong predictor of individual dietary behaviour (Pettinger et al., 2004; Shimotsu et al., 2007). Workplaces should foster a supportive environment that encourages healthier eating through targeted initiatives and positive reinforcement. Promoting a culture of shared responsibility where both employees and managers are motivated to make healthier choices together builds camaraderie and a sense of unity, making commitments to health outcomes longer lasting.

5. Workplaces and organisations need to evaluate their environment and address key barriers to healthy eating. A primary barrier to healthy eating among night workers is limited access to healthy food. Organisations that provide food for workers should ensure nutritionally balanced meals that meet the energy demands of the workers. Similarly, workplaces need to ensure workers can purchase healthy alternatives in vending machines or workplace canteens (Navruz-Varlı & Mortaş, 2024).

6. Employers and organisations need to provide adequate break times for night shift workers, so they have sufficient time to eat. Additionally, staff rooms need to be adequately equipped with a fridge and microwave so food can be brought from home, stored appropriately and reheated.

7. Workplace educational strategies, such as seminars or workshops, should be provided to night workers during their work hours. These initiatives should be tailored to the health

literacy level of the workers and provide both general healthy eating education and targeted guidance on increasing fibre and protein intake at mealtimes, emphasis should be placed on encouraging consumption of low-calorie, high-fibre snacks, such as fruit and vegetables, to support a balance macronutrient intake and sustained energy release across the nightshift, while helping to minimise overall night time food intake (Phoi et al., 2025).

4.5.3 Future directions

Minimising food intake during the night has gained a lot of interest recently due to its potential to improve cardiometabolic health markers (Grant et al., 2017; Mangoonian et al., 2022; Ruddick-Collins et al., 2020). However, a recent systematic review reported inconclusive evidence regarding this approach, largely due to the small sample sizes and methodological limitations of the current literature (Koh et al., 2025). Beyond metabolic outcomes, there are additional factors other than adjusting energy intake that must also be considered. Qualitative evidence suggests that the feasibility of minimising eating at night remains a key challenge, as food is often used as a strategy to maintain camaraderie, increase alertness, support performance, and meet energy demands, particularly in physically demanding roles such as firefighters or miners (Huggins et al., 2022).

Looking ahead, future research should aim to establish best-practice approaches for the assessment and reporting of eating behaviours among night workers, including the design of the studies that accurately capture these behaviours. Alternate methods of data collection may be needed, given concerns regarding validity, whereby participants (particularly women) may alter or underreport dietary behaviours to avoid judgement (Scagliusi et al., 2003). Emerging approaches, such as the use of social media platforms, may offer valuable insight into perceptions and decision-making processes in research studies due to respondents being less influenced by social desirability bias, which may facilitate more honest and transparent reporting (McIntosh et al., 2023; Scagliusi et al., 2003).

Lastly, more studies are warranted that evaluate eating behaviours as their primary outcome. Within the present systematic review, the majority of studies did not evaluate eating behaviours as their primary outcome. Instead, it was commonly evaluated in conjunction with sleep, which has a known bidirectional relationship with eating and other aspects of metabolism. There is considerable potential to gain insights into eating behaviours in vulnerable populations, such as night shift workers, when eating behaviours are prioritised as the primary research focus and explored in-depth.

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