The Relationship Between Caffeine Consumption and Sleep Quality in New Zealand Young Adults

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Marjial Angeli Judilla Hermanoche

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ABSTRACT

Background: Sleep is essential for promoting optimal health, well-being, and performance, but in today's modern world, sleep is becoming increasingly difficult to prioritise in our daily routines. It has been well documented that insufficient (quantity and quality) sleep is associated with a plethora of adverse consequences, including reduced cognitive functioning and physical performance, increased psychological distress, and increased risk of developing chronic diseases. Research suggests that short sleep (≤6 hours per night) is becoming increasingly common among young adults, and it appears that many are using caffeine to try and offset the effects of their sleep loss. Laboratory studies have shown that caffeine reduces sleep efficiency and sleep quality, prolongs sleep onset latency, shortens total sleep length and alters sleep architecture by reducing the amount of deep (slow-wave) sleep attained. Information on the sleep quality of young adults in New Zealand is required to determine whether there is a cause for concern and whether there may be a link between sleep quality and caffeine usage.

Aim: This cross-sectional study examined sleep quality in healthy young adults and the associations between sleep quality and caffeine consumption.

Method: Previously validated Caffeine Consumption Habits (CaffCo) and Pittsburgh Sleep Quality Index (PSQI) questionnaires were administered to 192 young adults (aged 18–25 years) via the online survey software, Qualtrics.

Results: Most young adults (98.4%) consumed caffeine in some form. The average daily caffeine intake was 159.6 $mg \cdot day^{-1}$, with coffee being the primary contributor. A high prevalence of poor sleep quality (85.9%) was observed in the study population. Furthermore, the majority of young adults (87.5%) slept less than 7 hours per night, the minimum amount advised for optimal health and well-being by scientific experts. Daily caffeine consumption was not associated with sleep quality ($p > 0.05$). Compared to working young adults, students with employment (OR 3.07; CI 1.02 – 9.25) and without employment (OR 3.52; CI 1.32 – 9.42) were more likely to experience poor sleep quality.

Conclusions: These findings demonstrate that poor sleep quality is widespread among New Zealand young adults. More research is required to determine the reasons for this phenomenon. Young adults, especially students prone to irregular sleep-wake schedules, would benefit from sleep education. Additionally, consumer education should be improved in light of the expanding market of caffeine-containing products to ensure that caffeine is ingested safely and within recommended limits.

Keywords: caffeine, caffeine consumption, sleep quality, sleep health, young adults, New Zealand.

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LIST OF ABBREVIATIONS

BMI	Body mass index
CaffCo	Caffeine Consumption Habits Questionnaire
CNS	Central nervous system
FFQ	Food frequency questionnaire
EEG	Electroencephalography
EMG	Electromyography
EOG	Electrooculography
ESFA	European Food Safety Authority
FSANZ	Food Standards Australia New Zealand
ipRGCs	Intrinsically photosensitive retinal ganglion cells
MELAA	Middle Eastern, Latin American, and African
$mg \cdot day^{-1}$	Unit for milligrams consumed per day
NREM	Non-rapid eye movement
NSF	National Sleep Foundation
NZ	New Zealand
PSQI	Pittsburgh Sleep Quality Index
REM	Rapid eye movement
RTD	Ready-to-drink
SCN	Suprachiasmatic nucleus
SE	Sleep efficiency
SOL	Sleep onset latency
SWA	Slow wave activity
SWS	Slow wave sleep
TIB	Time in bed
TST	Total sleep time
US	United States
WASO	Wake after sleep onset
WHO	World Health Organization

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CHAPTER 1 INTRODUCTION

1.0 Background

Sleep is inextricably linked to all vital processes and functions in the human body (Amici et al., 2014), and is the foundation of physical health (Gao et al., 2022; Luyster et al., 2012), mental health (Hamilton et al., 2007; Scott et al., 2021), cognition (Walker, 2009) and performance (Venter, 2012). Although individual sleep needs may differ (Chokroverty, 2017; Watson et al., 2015), it is generally recommended that most young adults require, on average, between 7 to 9 hours of sleep per night (Hirshkowitz et al., 2015). A growing body of research strongly indicates that insufficient (quantity or quality) sleep can have detrimental effects on health, functioning and well-being at an individual, interpersonal, and societal level. For example, one study found that chronic sleep restriction (simulated by 4 or 6 hours of sleep per night for 14 consecutive days) caused significant and dose-dependent neurobehavioural deficits, including increased attention lapses, delayed working memory and slowed cognitive processing (Van Dongen et al., 2003). Furthermore, researchers noted that those experiencing sleep restriction typically underestimated the severity of these accumulated impairments (Van Dongen et al., 2003). Epidemiological evidence also indicates that habitual short sleep duration (<7 hours per night) is associated with an increased likelihood of developing chronic diseases such as type 2 diabetes (Shan et al., 2015), obesity (Cappuccio et al., 2008), hypertension (Gangwisch et al., 2006), as well as all-cause mortality and cardiovascular events (Yin et al., 2017). It has been proposed that short sleep negatively affects the degree, nature and resolution of partner conflicts, thus potentially impacting relationships (Gordon & Chen, 2014). Short sleep and sleep disorders are also associated with reduced performance, absenteeism, increased risk of occupational injuries (Rosekind et al., 2010; Swanson et al., 2011), human-error-related accidents (Dinges, 1995; Vikram et al., 2008) and motor vehicle crashes (Connor et al., 2002; Horne & Reyner, 1995; Tefft, 2018); all of which place a significant financial burden on society (Hafner et al., 2016; Hillman et al., 2018).

Some researchers have hypothesised that sleep-related outcomes may be better predicted by sleep quality rather than quantity (Bin, 2016; Kohyama, 2021). The literature lacks a consensus definition of sleep quality, although it has traditionally been described as a person's satisfaction with their sleep experience (Krystal & Edinger, 2008). Other researchers have characterised the term by its components, such as sleep latency, nocturnal awakenings, sleep efficiency, etc. (Ohayon et al., 2017). Despite decades of research highlighting the need for adequate, good-quality sleep (Mukherjee et al., 2015; Ramar et al., 2021; Rechtschaffen, 1998), it appears that our contemporary lifestyles frequently place a higher priority on other activities (Basner et al., 2007). Some academics have argued that widespread cultural shifts, such as longer work and commute durations, prolonged nightlife and around-the-clock usage of electronics, may be somewhat accountable for people's failure to get enough, good quality sleep (Luyster et al., 2012; Ogilvie & Patel, 2018).

Young adulthood (ages 18–25) is a crucial developmental stage during which several lifestyle behaviours are formed (Stroud et al., 2015) that can significantly impact one's quality of life (Pilcher et al., 1997) and improve or worsen health outcomes in the long term (Harris, 2010). Studies have shown that this age group frequently exhibits irregular sleep-wake schedules and experiences sleep restriction (Batten et al., 2020; Lund et al., 2010), and there are growing concerns that sleep disorders such as insomnia are prevalent and rising (McArdle et al., 2020; Sivertsen et al., 2019). Youngstedt et al. (2016) observed that during the past 20 years, there had been an increase in the prevalence of short sleep (≤6 hours per night), especially among young adults (aged 18–27 years) and more recently conducted research has found that poor sleep quality is also commonly observed in this demographic (Almojali et al., 2017; Becker et al., 2018a; Mohamed et al., 2020). Several adverse repercussions have been linked to short, poor-quality sleep, including lower academic performance (Chen & Chen, 2019; Gomes et al., 2011), increased risk-taking and sensation-seeking behaviours (Rusnac et al., 2019; Taghvaee & Mazandarani, 2022) and increased risk of psychological problems such as depression and anxiety (Dickinson et al., 2018; Regestein et al., 2010). Researchers have suggested several factors that may compromise sleep quantity and/or quality in young adults, including increased academic and social demands, increased independence, and greater access to drugs and other illicit substances (Taylor et al., 2013; Wang & Bíró, 2021). However, emerging research indicates that consuming caffeine may have a significant yet underappreciated impact on sleep (Batten et al., 2020; Lohsoonthorn et al., 2013; Young et al., 2020).

Caffeine is the most widely consumed psychostimulant in the world (Temple et al., 2017). It is rapidly and completely absorbed (Blanchard & Sawers, 1983), often reaching peak plasma concentrations within 45 minutes of ingestion (Smith, 2002). However, depending on the individual, this may vary between 15 and 120 minutes (Fredholm et al., 1999; Marks & Kelly, 1973). Caffeine achieves its well-known stimulating effects through various mechanisms, but predominantly through the antagonism of adenosine (A_1 and A_{2A}) receptors in the brain (Davis et al., 2003). Adenosine concentrations rise during prolonged wakefulness (Basheer et al., 2004) and have been suggested to be a homeostatic regulator of the inclination to fall asleep (Reichert et al., 2022). Thus, caffeine increases sensations of alertness by preventing adenosine from suppressing neuronal activity in the wake-promoting system (Reichert et al., 2022). Caffeine in low to moderate doses (up to about 300 $mg \cdot day^{-1}$ (McLellan et al., 2016)) has been shown to enhance cognitive functioning (McLellan et al., 2016; Nehlig, 2010; Smith, 2002) and physical performance (Duncan et al., 2013; Graham, 2001). However, doses higher than 400 $mg \cdot day^{-1}$ have been reported to potentially increase the risk of negative consequences, such as restlessness, anxiety, irritability, muscle tremor, insomnia, nausea and gastrointestinal upset (Kaplan et al., 1997; Nawrot et al., 2003). There is considerable interindividual heterogeneity in caffeine responses due to several factors such as age (Swift & Tiplady, 1988), gender (Temple & Ziegler, 2011), genetics (Childs et al., 2008; Yang et al., 2010), lifestyle (Nehlig, 2018) and caffeine habituation (Evans & Griffiths, 1992; Lara et al., 2019). However, scientific committees and experts concede that doses of up to 400 $mg \cdot day^{-1}$ are typically safe for most people and have a low risk of producing overtly adverse side effects in healthy adults (ESFA Panel on Dietetic Products Nutrition and Allergies (NDA), 2015; Nawrot et al., 2003).

Although it is generally acknowledged that sleep is the physiological function most sensitive to the effects of caffeine (Dews, 1982; Nehlig, 1999), it is also one that may be frequently overlooked by people in terms of how it affects their sleep timing and quality. For instance, many people might not be aware that caffeine has an average half-life of 4 to 6 hours in healthy adults (Benowitz, 1990; White et al., 2016). This means that its stimulating effects may persist long after ingestion, sometimes even after they are no longer needed or desired. Additionally, caffeine interferes with its own clearance, and higher/succeeding doses lengthen the elimination half-life (Denaro et al., 1990; Kaplan et al., 1997). Caffeine use has been associated with prolonged sleep onset latency, reduced total sleep time and sleep efficiency, worsened perceived sleep quality and diminished slow wave (deep) sleep (see review by Clark and Landolt (2017)). Previous studies have also shown that this is especially true when caffeine is consumed close to bedtime (Carrier et al., 2007; Drake et al., 2013; Drapeau et al., 2006). Research also indicates that caffeine and sleep have a bi-directional relationship. Caffeine is often consumed to combat drowsiness or fatigue, but it can also negatively affect the timing and architecture of sleep the subsequent night, which encourages more caffeine to be consumed the following day (O'Callaghan et al., 2018; Reichert et al., 2021). Thus, a self-reinforcing ‘caffeine cycle’ emerges as a result (Roehrs & Roth, 2008; Snel & Lorist, 2011), making some individuals believe that they must take the stimulant in order to perform optimally.

Young adults’ caffeine consumption has garnered attention, with particular concern about the implications for caffeine’s advantages being regularly touted in contrast to its disadvantages. For example, among this demographic, caffeine use is frequently associated with staying up late to finish a big project or study for an exam (Attila & Çakir, 2011; Lohsoonthorn et al., 2013), increasing energy, improving focus/performance or combatting lack of sleep (Attila & Çakir, 2011; Malinauskas et al., 2007). As a result of the focus placed on these benefits, young adults may believe that a higher dose leads to better outcomes or may even be persuaded to misuse caffeine. Previous research suggests that young adults do not typically monitor their caffeine consumption levels (McIlvain et al., 2011) and are generally unaware of the safe caffeine intake limits (Cormier et al., 2018). Another study reported that young individuals were not overly concerned about the effects of caffeine (Ludden & Wolfson, 2010), which may indicate that they are uninformed of the potentially adverse impacts the stimulant may have (Shochat, 2012). In light of these findings, it is essential to investigate whether young adults’ caffeine consumption habits affect their sleep.

1.1 Study Justification

Sleep is a biological necessity, yet it is commonly sacrificed in our modern lifestyles to accommodate personal and work schedules (Attila & Çakir, 2011; Basner et al., 2007; Calamaro et al., 2009). Young adults may be more susceptible than middle-aged or older adults to irregular sleep-wake schedules and experience the adverse consequences of insufficient sleep. International research in this population has estimated the prevalence of poor sleep quality to be anywhere from 31% (Li et al., 2020) to 87% (Mohamed et al., 2020). To the author's knowledge, young adults' sleep quality has not yet been explored in the New Zealand context. It is therefore important to ascertain the magnitude of the issue in our unique multicultural environment.

Of the numerous biological, lifestyle and social factors (Grandner, 2019; Ohida et al., 2001) associated with sleep health, caffeine consumption has been recognised as one significant (Irish et al., 2015), yet controllable behaviour (Shochat, 2012). Given the well-known 'benefits' of caffeine, it is not surprising that people of all ages regularly ingest the stimulant (Tran et al., 2016). However, there are growing concerns that adolescents and young adults, in particular, are more prone to overconsume (Bertasi et al., 2021; Reid et al., 2016) or even misuse caffeine (Ferré, 2013) than older adults. Studies also suggest that young adults may be becoming more dependent on caffeinated products to compensate for insufficient sleep (Sanchez et al., 2013), and some may have misconceptions about caffeine usage, such as the notion that it can be used as a substitute for sleep (Lee et al., 2009). The lack of understanding of how caffeine affects sleep timing and quality among young adults highlights the importance of better education to help protect consumers from unnecessary harm. Furthermore, most research investigating the link between caffeine and sleep has been conducted in laboratories (Carrier et al., 2007; Drake et al., 2013; Drapeau et al., 2006), and more data is required on the effects of habitual caffeine consumption on sleep in naturalistic settings.

1.2 Purpose of the Research Study

1.2.1. Aim

This study aimed to determine the association between caffeine consumption and subjective sleep quality and the prevalence of poor sleep quality among healthy New Zealand young adults (aged 18 to 25 years old).

1.2.2. Objectives

1. Determine the prevalence of poor sleep quality among healthy young adults
2. Evaluate the associations between caffeine consumption and subjective sleep quality
3. Determine the differences in caffeine consumption between good and poor sleepers

1.3 Structure of Thesis

This thesis contains four key chapters with additional appendices and references. Chapter One introduces the research topic and outlines the background and justification of the study. This chapter also includes the study aims, objectives, and researcher contributions. Chapter Two reviews the current literature on the relationship between caffeine consumption and sleep quality, primarily focusing on the young adult population. Chapter Three consists of the research manuscript, including an abstract, introduction, methods, results, discussion, and conclusions. This has been formatted for publication in the Journal *Nutrients*. Chapter Four summarises critical findings and recommendations, including the strengths and limitations of the study, the research impact of the work presented and prospects for future research. The appendices contain the study advertisement poster, ethics approval, participant information sheet, Caffeine Consumption Habits (CaffCo) and Pittsburgh Sleep Quality Index (PSQI) questionnaires, and supplementary information and results.

1.4 Researchers' Contributions

Table 1.1 Researchers' contributions to the thesis study.

Researcher	Contribution
Marjial Hermanoche School of Sport, Exercise and Nutrition	Author of thesis. Research proposal, study design and conceptualisation, ethics application, literature review, participant recruitment and data collection, data entry and statistical analysis with corresponding discussions and conclusions, thesis manuscript preparation.
A/Prof Kay Rutherfurd-Markwick School of Health Sciences	Provided supervision with the study design and conduct of research, ethics application, data analysis, chapter writing including editing and revising, and manuscript preparation.
Dr Karyn O'Keeffe School of Health Sciences	Provided supervision with the study design and conduct of research, ethics application, data analysis, chapter writing including editing and revising, and manuscript preparation.
Prof Ajmol Ali School of Sport, Exercise and Nutrition	Provided supervision with the study design and conduct of research, ethics application, and data analysis.
Prof Carol Wham School of Sport, Exercise and Nutrition	Provided supervision with the study design and conduct of research.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

The following chapter reviews the current literature on caffeine and sleep and their bi-directional relationship. Firstly, background on the importance of sleep and an exploration of sleep health. Following this, the fundamentals of sleep architecture and sleep regulation are summarised, with a brief mention of chronotypes. Sleep duration and the consequences of short sleep, as well as sleep quality and its measurements are then covered. Sleep trends in young adults are highlighted where research is available. Subsequent sections examine caffeine research, beginning with caffeine sources and their content. An overview of caffeine intake levels, patterns and recommendations follows. Caffeine pharmacokinetics and pharmacodynamics are then discussed, with an outline of factors affecting the caffeine response and withdrawal. Finally, the review's main focus, caffeine's impact on sleep, is evaluated. An overview of critical knowledge gaps on the subject is provided at the conclusion of this chapter.

2.2 The Importance of Sleep

Although we spend approximately one-third of our lives asleep (Saper et al., 2010), there remains much to be understood about the mechanisms and purposes of this biological phenomenon (Ezenwanne, 2011). The current understanding of the importance of sleep has resulted from cross-sectional (Carpi et al., 2022; Gangwisch et al., 2013; Okano et al., 2019) and longitudinal studies (Shi et al., 2018; Wang et al., 2020; Yin et al., 2017) that have investigated the relationships between sleep characteristics and health, well-being and performance outcomes, and experimental studies (Schuld et al., 2005; Scott et al., 2021; Wang et al., 2022) exploring the mechanisms underlying those relationships. Together, these studies have highlighted that sleep of sufficient duration, continuity and depth, without disease or disruption, is crucial for supporting optimal health (Goel et al., 2013) and ensuring efficient functioning of important processes such as learning and memory (Gais & Born, 2004; Walker et al., 2002), emotional regulation (Palmer & Algano, 2017; Vandekerckhove & Wang, 2017), immunity (Besedovsky et al., 2012; Del Gallo et al., 2014) and hormone and energy balance (Kim et al., 2015; Spiegel et al., 2004). Studies on sleep deprivation in rats (Everson et al., 1989; Rechtschaffen et al., 1989) and an inherited condition (known as Fatal Familial Insomnia) imposing unrelenting insomnia on afflicted persons (Fiorino, 1996; Lugaresi et al., 1986) show that insufficient sleep can have serious consequences (discussed in Section 2.5.1) or even result in death. Therefore, much like other physiological needs such as eating, breathing and reproducing, sleep is essential for life.

Sleep Health

The term “sleep health” is an important construct in sleep research yet lacks a consensus definition in the literature. In a seminal paper, Buysse (2014) proposed that sleep health be defined as “a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being”. According to Buysse’s model, subjective satisfaction with sleep, appropriate sleep timing, adequate sleep duration, sleep efficiency and/or continuity, and the ability to sustain alertness during waking hours are the five key dimensions of sleep health, which can be measured subjectively or objectively in any individual (Buysse, 2014). The definition acknowledges that sleep health is a process or state that exists on a continuum, and what is attributed as “good” or “poor” may vary according to the individual and their circumstances. For the purpose of this review, I will primarily be focusing on the dimensions of sleep duration (Section 2.5) and sleep quality (Section 2.6) in young adults.

2.3 Sleep Architecture

Sleep architecture refers to the basic structural organisation of sleep stages that an individual experiences on any given night (Hirshkowitz, 2004). The two types of sleep, non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep, distinguished by their distinct electroencephalographic (EEG) activity and physiological manifestations (Carskadon & Dement, 2011), are hypothesised to carry out different functions (Abel et al., 2013; Hutchison & Rathore, 2015). NREM sleep is further divided into three stages (N1–N3 sleep) on a continuum of relative depth based on the arousal threshold required to awaken someone from sleep (Assefa et al., 2015). N1 and N2 sleep are considered light stages of sleep, from which a person can be easily woken from (Guion & Avis, 2011; Markov & Goldman, 2006). N3 sleep, commonly known as “slow-wave sleep” (SWS), is the deepest stage of sleep characterised by the presence of high amplitude slow wave EEG activity (SWA) (Guion & Avis, 2011; Hirshkowitz, 2004). REM sleep is distinguished by periodic bursts of rapid eye movements, heightened central nervous system (CNS) activity, postural muscle atonia and twitching of the extremities (Guion & Avis, 2011; Purves et al., 2001; Siegel, 2005).

Sleep stages are experienced in a cyclical progression from NREM sleep to REM sleep that typically includes a transition from N1 to N2 to N3 sleep, followed by a period of REM sleep (Carskadon & Dement, 2011). Each sleep cycle lasts for 90 minutes on average; however, cycles can vary between 70 and 120 minutes in length (Markov & Goldman, 2006; Memar & Faradji, 2018). A sleep period usually includes 4–6 sleep cycles that increase in length and change in structure as the sleep period progresses (Hirshkowitz, 2004). N3 sleep predominates in the first half of the night (Markov & Goldman, 2006), whereas REM sleep dominates in the last third of the night (Guion & Avis, 2011; Siegel, 2005). Overall, NREM sleep comprises most of the total sleep period, accounting for about 75–80% (50–60% in N1 and N2 sleep, 15–20% in N3 sleep), and REM sleep for 20–25% of the sleep period (Carskadon & Dement, 2005; Hirshkowitz, 2004). Sleep architecture may be affected by factors such as age, gender, medications, drug or alcohol use, and sleep disorders (Deatherage et al., 2009; Sharma & Kavuru, 2010).

2.4 Sleep Regulation

Humans are primarily diurnal, which implies that we spend the day active and the night sleeping (Andreatta & Allen, 2021), with the exception of shift workers or those who intentionally vary their schedules. Sleep duration and timing are governed by the circadian timekeeping system and the homeostatic sleep drive, known as ‘The Two-Process Model’ of sleep (Borbély, 1982; Borbély et al., 2016). Both processes are independent of one another but work interactively to generate consolidated periods of alertness and sleep from day to day (Deboer, 2018; Fisk et al., 2018). Disturbances to either process may affect the initiation or maintenance of sleep (sleep propensity) or waking performance (Fisk et al., 2018).

The circadian system comprises a central master pacemaker residing in the suprachiasmatic nucleus (SCN) of the hypothalamus in the brain (Borbély, 1982; Borbély et al., 2016) and peripheral circadian clocks located in various tissues throughout the body (Richards & Gumz, 2012). Through a range of neuronal, humoral and physical outputs, the SCN generates overt rhythms in behaviour and physiology with a ~24-hour periodicity that are known as circadian rhythms (Schibler, 2008). Although the SCN's endogenous cycle length (free running period) is typically somewhat longer than 24 hours (Crowley et al., 2007), circadian rhythms like the sleep-wake cycle (Crowley et al., 2007), are synchronised (entrained) to the 24-hour day/night cycle in response to time signals (zeitgebers) in the environment (Figueiro, 2017). Light is the circadian system's most important zeitgeber (Fisk et al., 2018), with the intrinsically photosensitive retinal ganglion cells (ipRGCs) providing the SCN with information about the time of day (Zele et al., 2011). When timed immediately after or just prior to normal wake times, light exposure causes circadian rhythms to shift earlier (phase advance), whereas light exposure in the evening shifts the circadian rhythm later (phase delay) (Crowley et al., 2018).

The homeostatic sleep drive (sleep pressure) (Borbély, 1982; Borbély et al., 2016) transmits information about prior sleep/wake conditions rather than the time of day (Carskadon, 2011), and is primarily mediated by the neuromodulator adenosine (Landolt, 2008). Adenosine concentrations rise with each hour of wakefulness and diminish after a period of sleep (Basheer et al., 2004; Huang et al., 2011), and help to instigate sleepiness by suppressing neuronal activity in the wake-promoting system (Bjorness & Greene, 2009; Porkka-Heiskanen et al., 2002). Thus, sleep pressure is typically highest around usual bedtime and lowest when waking up in the morning (Markov & Goldman, 2006). After a time of sleep restriction or inadequate sleep to meet one's needs, the homeostatic sleep drive also promotes prolonged sleep length and greater sleep intensity (Borbély et al., 1981; Landolt, 2008).

2.4.1. Chronotypes

The term 'chronotype' refers to variations in personal circadian preference for the timing of sleep and waking activity within a 24-hour day (Almoosawi et al., 2019). Morning type individuals ("larks") prefer to have earlier bed and rising times and function more optimally in the morning, whereas evening types ("owls") prefer to sleep and wake up later and operate better towards the latter part of the day (Adan et al., 2012). A person's chronotype can be influenced by several factors, including genetics (Archer et al., 2003; Katzenberg et al., 1998), age (Fischer et al., 2017; Randler et al., 2017), gender (Randler & Engelke, 2019; Tonetti et al., 2008) and the environment such as light exposure (Porcheret et al., 2018; Roenneberg et al., 2003). Chronotypes also affect behaviour traits and outcomes with studies having shown that evening types are more likely than morning types to have unhealthy dietary and lifestyle habits (e.g., smoking and alcohol use) (Adan, 1994; Fabbian et al., 2016), poorer health (Knutson & von Schantz, 2018) and academic performance (Enright & Refinetti, 2017), as well as irregular sleep schedules and sleep-related issues (Bodur et al., 2021; Fabbian et al., 2016).

Throughout adolescence, there is a biological shift towards later circadian preference (phase delay) that persists into young adulthood and peaks at around 20 years of age (Carskadon et al., 1993; Roenneberg et al., 2004). Additionally, it has been proposed that the accumulation of homeostatic sleep pressure slows during puberty (Jenni et al., 2005; Taylor et al., 2005), which may encourage adolescents and young adults to prolong their wakefulness later into the night and delay their bedtimes (Crowley et al., 2007). These intrinsic developmental changes in sleep-wake regulation can sometimes conflict with the early wake-up times required by school or jobs (Carskadon, 2011), leading young people to restrict the amount of sleep they get. As a result, sleep debt is more prone to accumulate during these years (Lack, 1986; Phillips et al., 2017). The misalignment between one's regular sleep-wake schedule with one's biological clock is coined as 'social jet lag' (Wittmann et al., 2006), and has been linked to several adverse consequences such as poor sleep quality (Gangwar et al., 2018), increased daytime sleepiness (Giannotti et al., 2002) and higher caffeine/nicotine use (Bodur et al., 2021; Taillard et al., 2003).

2.5 Sleep Duration

Sufficient sleep (both quantity and quality) is necessary to function optimally during the day and maintain good health (Watson et al., 2015). Ideal sleep needs (or a person's daily requirements) can vary between individuals due to several factors such as gender, genetics, stress, physical activity and illness (Chokroverty, 2017; Watson et al., 2015), as well as the stage in lifespan (Ohayon et al., 2004). Scientific panels and authorities (Hirshkowitz et al., 2015; Watson et al., 2015) concede that most young adults (aged 18–25 years) generally need between 7–9 hours of sleep each night. However, some individuals may only require 6 hours, while others may require as many as 10–11 hours (Hirshkowitz et al., 2015).

A growing body of research has suggested that the amount of time we spend sleeping may be decreasing in favour of other waking activities (Basner et al., 2007), especially as we shift towards a more 24/7 society (Luyster et al., 2012). Cultural trends such as lengthy commutes, extended workdays and around-the-clock use of electronic devices have been theorised to contribute to people's inability to obtain sufficient sleep (Luyster et al., 2012; Ogilvie & Patel, 2018). Additionally, stimulants like caffeine have enabled people to extend their wakefulness (Meredith et al., 2013) beyond the traditional day/night cycle. Contradictory findings about changes in sleep duration, however, call into doubt the notion that our culture is becoming more and more sleep-deprived. Some research has indicated an increase in the prevalence of short sleepers (Ford et al., 2015; Zomers et al., 2017), with one United States (US) study showing that one in three adults routinely failed to get the minimum amount (7 hours each night) of sleep recommended (Liu et al., 2016). However, other studies have reported either an increase (Basner & Dinges, 2018) or no appreciable changes in sleep duration (Bin et al., 2013; Robbins et al., 2020). In New Zealand, a recent study (Lee & Sibley, 2019) reported that more than a third (37%) of adults (aged 18+) obtained less than 7 hours of sleep daily. Furthermore, a higher incidence of short sleepers has also been noted among Māori (Paine & Gander, 2016) and Pacific peoples (Lee & Sibley, 2019), mainly as a result of socioeconomic and health-related inequities (Paine & Gander, 2016).

Mounting research indicates that it is becoming more common for young adults to experience inadequate sleep (Hershner & Chervin, 2014) and sleep disorders (Gaultney, 2010; Sivertsen et al., 2019), which raises concerns that sleep-related issues are manifesting earlier in life. One study demonstrated that the majority (86%) of students (mean age 20.4 years) report waking in the morning feeling unrefreshed, indicating that they are generally falling short of their sleep needs (Gaultney, 2010).

Instead of making sleep a priority, young adults may regard it as a flexible commodity that can be adjusted to fit around other social commitments (Batten et al., 2020). For example, one study (Machado et al., 1998) found that college students' waking time on weekdays is often dictated by school (85%), employment (47%), or other external influences (48%), as opposed to waking up after a sufficient quantity of sleep has been attained. Overall, it is generally acknowledged that many young adults may be more prone to have irregular sleep-wake schedules (Gaultney, 2010; Lund et al., 2010; Machado & Suchecki, 2016), particularly as a result of factors such as late-night technology use (Joshi et al., 2022), caffeine intake (Patrick et al., 2018; Sanchez et al., 2013), and insufficient knowledge and practice of good sleep hygiene (Al-Kandari et al., 2017; Suen et al., 2010).

2.5.1 Consequences of Short Sleep

Every element of our physical (Clement-Carbonell et al., 2021), neurobehavioural (Lim & Dinges, 2010; Pilcher & Huffcutt, 1996), and psychological (Baglioni et al., 2016) health and well-being suffers when we don't obtain sufficient sleep. Mounting research indicates that habitual short sleep (<7 hours each night) can have detrimental effects on human cognition, notably on attention, processing speed and working memory (Choudhary et al., 2016; Cunningham et al., 2018; Van Dongen et al., 2003). Additionally, individuals are believed to lose the ability to judge the severity of their impairment as a result of these effects (Belenky et al., 2003; Van Dongen et al., 2003), which are hypothesised to accumulate dose-dependently from night to night (Van Dongen et al., 2003). Evidence also indicates that lack of sleep heightens stress reactivity and emotional sensitivity (Minkel et al., 2012; Rosales-Lagarde et al., 2012), which has increased attention to the critical function that sleep plays in emotional brain processes (Killgore, 2010; Walker, 2009).

A plethora of research has demonstrated that short sleep increases daytime sleepiness (Giannotti et al., 2002), distractions (Anderson & Horne, 2006), and the likelihood of "microsleeps" (Goel et al., 2009), which are brief episodes of sleep during which the capacity to respond to external stimuli is completely suspended (Poudel et al., 2014). Studies have found that prolonged wakefulness causes cognitive and performance impairments that are comparable to those that occur when a person is driving over the legal alcohol driving limit (Lamond & Dawson, 1999; Williamson & Feyer, 2000). This presents a significant risk for safety in the real world, and it is perhaps not surprising that short sleep has been linked to adverse outcomes such as decreased workplace productivity, absenteeism and injuries (Rosekind et al., 2010; Swanson et al., 2011), human-error-related accidents (Dinges, 1995; Vikram et al., 2008) and motor vehicle crashes (Connor et al., 2002; Horne & Reyner, 1995; Tefft, 2018).

Young adults may be more vulnerable to the negative neurobehavioural effects of short sleep than older adults. One study (Zitting et al., 2018), demonstrated that younger adults (aged 18–27 years) displayed higher drowsiness-related neurobehavioural performance deficits than older adults (aged 55–70 years), including more attention lapses and microsleeps. Furthermore, a wealth of literature has shown that short sleep has a variety of negative effects on young adults including lower academic performance (Chen & Chen, 2019; Gomes et al., 2011), increased risk-taking and sensation-seeking behaviours (Rusnac et al., 2019; Taghvaee & Mazandarani, 2022), increased risk of psychological problems such as depression and anxiety (Dickinson et al., 2018; Regestein et al., 2010) and increased suicidal ideation and attempts (Becker et al., 2018b; Vail-Smith et al., 2009).

Short sleep has also been linked to a multitude of adverse health outcomes, including an increased risk of chronic diseases such as hypertension (Gangwisch et al., 2013; Gottlieb et al., 2006), cardiovascular disease (Ayas et al., 2003; Nagai, 2010), metabolic disorders including obesity (Wu et al., 2014; Zhou et al., 2019) and diabetes (Gangwisch et al., 2007; Shan et al., 2015), immune suppression (Cohen et al., 2009; Patel et al., 2012) and all-cause mortality (Cappuccio, D'Elia, et al., 2010; Yin et al., 2017). There is also growing evidence supporting that sleep and health are interrelated in a bi-directional manner, with inadequate sleep potentially causing or worsening a range of physical and mental diseases and vice versa (Zee & Turek, 2006). Although getting regular long sleep (>9 hours) is less common than getting short sleep (<6 hours) and, therefore, less of a concern, studies have shown a U-shaped relationship between sleep duration and chronic diseases (Cappuccio, D'Elia, et al., 2010; Gottlieb et al., 2006; Shan et al., 2015), emphasising the "optimal" range of 7–9 hours (Hirshkowitz et al., 2015).

2.6 Sleep Quality

Although there is no widely accepted definition of sleep quality in the literature, some researchers have described it in relation to how satisfied a person is with their sleep experience (Krystal & Edinger, 2008). Other researchers have characterised sleep quality by rating specific sleep parameters such as sleep onset latency (SOL), total sleep time (TST), sleep efficiency (SE) and wake after sleep onset (WASO), taken from various self-report measures (Buysse et al., 1988; Ohayon et al., 2017). The National Sleep Foundation (NSF) defines good sleep quality for young adults as a sleep efficiency (the percentage of time spent asleep while in bed) of 85% or higher, falling asleep in less than 30 minutes, waking up no more than once during the night, and, spending less than 20 minutes awake after initially falling asleep (Ohayon et al., 2017).

Growing research demonstrates that sleep quality is more predictive of health and performance outcomes than sleep quantity (Cappuccio, D'Elia, et al., 2010; Chandola et al., 2010; Kohyama, 2021). Good sleep quality is associated with a variety of beneficial properties, such as having better self-control (Liu et al., 2020), improved mental state (Scott et al., 2021) and greater life satisfaction (Ness & Saksvik-Lehouillier, 2018; Shin & Kim, 2018). Conversely, poor sleep quality is linked with negative outcomes such as increased fatigue and irritability (Nelson et al., 2022), daytime sleepiness and impaired focus (Alapin et al., 2000), as well as decreased resilience to stress and greater sensitivity to psychological disorders (Edéll-Gustafsson et al., 2002). Additionally, the importance of a person's sleep hygiene, or their sleep habits, in influencing their quality of sleep is becoming more evident (Brick et al., 2010; Yazdi et al., 2016). Adopting healthy lifestyle practices such as regular exercise, consistent bed- and waking times, limiting daytime naps, and avoiding caffeine, nicotine, and alcohol close to bedtime can all help to improve sleep quality (Irish et al., 2015).

Concerns have been raised regarding how widespread poor sleep quality is in the young adult population, with estimates of its prevalence ranging between 31–87% in this demographic (Table 2.1). However, given the well-established awareness that various influences, including biological (Ohayon et al., 2004), sociocultural (Knutson, 2013) and other external factors (Altun et al., 2012) can affect sleep experiences, it is not surprising that estimates vary greatly between regions and countries. Additionally, differences in study methods, such as sample size and confounding factor management (e.g., screening for sleep disorders, mental/physical illnesses, and drug or alcohol use), can also impact results (Ohayon et al., 2004). Few studies have examined sleep quality among New Zealanders; however, one recent study (Gibson et al., 2022) indicated that 45% of adults (aged 20–85) experienced worsened sleep quality after the country's first enforced COVID lockdown in 2020. The authors (Gibson et al., 2022) ascribed this to elements such as reduced physical activity, limited sunlight exposure and elevated feelings of anxiety/depression.

Table 2.1 provides an overview of the population studies evaluating the prevalence of poor sleep quality among young adults. Studies were included where participants were healthy young adults (mean age between 18–25 years), and the Pittsburgh Sleep Quality Index (PSQI) was utilised to assess sleep quality (where a global PSQI score of >5 indicated "poor sleep quality"). Studies investigating adolescents, adults (mean age above 25 years) or the elderly were not included, nor were studies where the prevalence (%) of poor sleep quality was not reported.

Table 2.1: Summary of studies on the prevalence of poor sleep quality in young adults. Studies were included if participants were healthy young adults (aged 18–25 years) and the PSQI was used to assess sleep quality. Studies on adolescents, adults or the elderly, or in which the prevalence (%) of poor sleep quality was not reported, were excluded. Studies are arranged alphabetically according to first author.

Reference	Origin	Study design	Sample (n, cohort, age)	Prevalence of poor sleep quality (%)	PSQI global score (mean ± SD)
Ahmed et al. (2020)	Bangladesh	Cross-sectional	*n* = 332, university students, 21.6 ± 1.7 y	67	6.0 ± 2.8
Ahrberg et al. (2012)	Germany	Longitudinal,	*n* = 144,		
		Pre-exam	medical students,	59	6.3 ± 2.6
		Exam period	22.4 ± 2.5 y	29	4.6 ± 2.3
		Post-exam		8	3.1 ± 1.9
Aldhawyan et al. (2020)	Saudi Arabia	Cross-sectional	*n* = 842, university students, 18.4 ± 0.7 y	75	Not stated
Alkhatatbeh et al. (2020)	Jordan	Cross-sectional	*n* = 1422, young adults, 21.0 ± 2.5 y	63	5.9 ± 3.2
Almojali et al. (2017)	Saudi Arabia	Cross-sectional	*n* = 263, medical students, 21.9 ± 1.4 y	76	7.1 ± 3.8
Becker et al. (2018a)	United States	Cross-sectional	*n* = 7626, university students, 19.1 ± 1.4 y	62	Not stated
Bodur et al. (2021)	Turkey	Cross-sectional	*n* = 661,	66	Not stated

			university students, 21.4 ± 1.38 y		
Carpi et al. (2022)	Italy	Cross-sectional	*n* = 1279, university students, 23.4 ± 2.5 y	65	8.7 ± 5.2
Di Benedetto et al. (2020)	Australia	Cross-sectional	*n* = 355, university students, 20.0 ± 1.5 y	62	Not stated
Fatima et al. (2016)	Italy	Cross-sectional	*n* = 3778, young adults, 20.6 ± 0.9 y	58 (all) 65 (F) 50 (M)	Not stated
Gómez-Chiappe et al. (2020)	Colombia	Cross-sectional	*n* = 414, university students, median age 21 y	59	Not stated
Hershner and O'Brien (2018)	United States	Longitudinal, Pre-intervention*	*n* = 54, university students, 21.9 ± 4.1 y	85	6.1 ± 2.8 (C) 6.6 ± 2.9 (I[†])
Lemma et al. (2012)	Ethiopia	Cross-sectional	*n* = 2230, university students, 21.6 ± 1.7 y	53	Not stated
Li et al. (2020)	China	Cross-sectional	*n* = 6284, university students, 19.7 ± 1.5 y	31	4.5 ± 2.5
Lohsoonthorn et al. (2013)	Thailand	Cross-sectional	*n* = 2854, university students, 20.3 ± 1.3 y	48	5.8 ± 2.5
Lund et al. (2010)	United States	Cross-sectional	*n* = 1125,	66	6.7 ± 3.1 (F)

			university students, 20 ± 1.3 y		7.2 ± 3.2 (M)
Mah et al. (2018)	United States	Cross-sectional	*n* = 628, collegiate athletes, 19.6 ± 1.3 y	42	5.4 ± 2.5
Mishra et al. (2022)	India	Cross-sectional	*n* = 284, medical students, 20.6 ± 1.1 y	45	5.8 ± 3.3
Mohamed et al. (2020)	Saudi Arabia	Cross-sectional	*n* = 303, medical students, 21.6 ± 1.4 y	87	Not stated
Paudel et al. (2022)	Nepal	Cross-sectional	*n* = 212, medical students, ≥18 y	38 (all) 44 (F) 35 (M)	5.4 ± 3.3 (all) 5.9 ± 3.5 (F) 5.1 ± 3.2 (M)
Safhi et al. (2020)	Saudi Arabia	Cross-sectional	*n* = 326, medical students, 21.9 ± 1.7 y	76	7.4 ± 3.7
Sanchez et al. (2013)	Peru	Cross-sectional	*n* = 2458, university students, 20.9 ± 2.6 y	56 (all) 58 (F) 52 (M)	Not stated
Shrestha et al. (2021)	Nepal	Cross-sectional	*n* = 168, university students, 21.6 ± 1.5 y	30	4.2 ± 2.2
Wondie et al. (2021)	Ethiopia	Cross-sectional	*n* = 576, medical students, 21.5 ± 2.4 y	62	Not stated
Yazdi et al. (2016)	Iran	Cross-sectional	*n* = 285,	58 (all)	

			medical students, 22.8 ± 1.7 y	52 (F) 63 (M)	5.8 ± 0.9 (F) 6.6 ± 1.1 (M)
Young et al. (2020)	United States	Cross-sectional	*n* = 462, young adult women, 22.9 ± 0.5 y	45	5.7 ± 2.9
Zunhammer et al. (2014)		Longitudinal, Pre-exam Exam period Post-exam	*n* = 142, university students, 22.2 ± 2.5 y	 34.5 53.3 21.4	 5.0 ± 2.5 6.3 ± 2.8 4.1 ± 2.4

Abbreviations: F = Females, M = Males, C = Control subjects, I = Intervention subjects
*Participants' sleep quality prior to sleep education intervention
†Participants who undertook the sleep education intervention

2.6.1 Measuring Sleep Quality

There are several methods used to evaluate sleep quality in the literature despite there being no widely accepted definition of the term. The gold standard for objectively measuring sleep is Polysomnography (PSG), a laboratory-based tool that captures brain (electroencephalography), muscle (electromyography) and eye movement (electrooculography) activity (Van de Water et al., 2011). This procedure, however, is time-consuming, expensive and not widely available (Escourrou et al., 2000; Natsky et al., 2021). Wrist-worn actigraphy, a well-regarded alternative for PSG, monitors activity and rest patterns and predicts sleep characteristics using specialised algorithms in computer software programs (Martin & Hakim, 2011). Although it is non-invasive and can be utilised in naturalistic settings over multiple nights (Van de Water et al., 2011), actigraphy is limited by estimation errors in naps, SOL (Martin & Hakim, 2011), TST and SE (Blackwell et al., 2008).

Subjective assessments (e.g., retrospective questionnaires and prospective sleep diaries) are frequently used in epidemiological research because they are easy to administer, readily available and show high participant compliance (Fabbri et al., 2021). Currently available questionnaires that assess sleep quality include the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1988), Leeds Sleep Evaluation Questionnaire (LSEQ) (Parrott & Hindmarch, 1980), Sleep-50 Questionnaire (Spoormaker et al., 2005) and Mini Sleep Questionnaire (MSQ) (Zoomer et al., 1985). However, the questionnaires in and of themselves are highly variable, with some focused on particular aspects of sleep quality e.g., nocturnal awakenings (Spoormaker et al., 2005) or feelings of refreshment (Parrott & Hindmarch, 1980), while others are based on sleep parameters e.g., SOL and TST (Buysse et al., 1988). One obvious disadvantage of questionnaires is that they rely on self-report, which can be unreliable and show up as either a poorer impression of sleep compared to objective data or a better experience of sleep when there is actual sleep disturbance (Edinger et al., 2000). Overall however, questionnaires are valued for having strong psychometric properties, high internal consistency and test-retest reliability (reviewed by Fabbri et al. (2021)), and effective as a general evaluation to identify whether additional screening and/or treatment may be necessary (O'Donnell et al., 2009). Researchers have advocated for the use of both objective and subjective metrics to help minimise limitations and inconsistencies (Zhang & Zhao, 2008).

2.7 Caffeine Sources and their Content

Caffeine (1, 3, 7-trimethylxanthine) is the most widely consumed psychostimulant in the world (Temple et al., 2017). It occurs naturally in more than 60 different plant species (Barone & Roberts, 1996), such as coffee beans (*Coffea Arabica and Coffea robusta),* tea leaves *(Camelia siniensis)*, cacao beans *(Theobroma cacao)*, guarana berries *(Paullinia cupana)*, kola nuts *(Cola acuminate)* and yerba mate *(Ilex paraguariensis)* (Heckman et al., 2010). Common sources of caffeine include coffee, tea, chocolate, and kola (soft) drinks, and in recent years, energy drinks and sports drinks/supplements have also become popular (Heckman et al., 2010; Nehlig, 2018). Additionally, many prescription and over-the-counter (OTC) medications and dietary supplements also contain caffeine as an ingredient (Frary et al., 2005; Temple et al., 2017).

Most dietary caffeine comes from caffeinated beverages, with coffee often accounting for the majority of people's total caffeine intake (Drewnowski & Rehm, 2016; Mitchell et al., 2014). The average caffeine content in a standard cup of coffee is 83 mg for instant coffee, 100 mg for plunger (drip) and 120–210 mg for espresso (see Appendix E.2). The amount of caffeine in other products can range from negligible amounts of a few milligrams per serving, as in chocolate and some confectionary (Dews, 1982), to higher levels in energy drinks (50 to 500 mg) and some medications e.g., paracetamol and some pain relievers (30 to 65 mg) (Liu et al., 2011; Temple et al., 2017). Even decaffeinated products still contain trace amounts of caffeine (Chin et al., 2008; McCusker et al., 2006).

Studies have shown that the quantity of caffeine found in sources, even of the same type, can vary significantly (Desbrow et al., 2019; McCusker et al., 2003; Reissig et al., 2009). For example, coffee generally contains more caffeine than tea (Barone & Roberts, 1996), although the typical amount of caffeine in a cup of instant coffee (83 mg) might vary by as much as half to twice that amount (Dews, 1982). The amount of caffeine present can be greatly influenced by the plant's geographical origin, the climate and other environmental variables that affect growth and harvesting (Cloughley, 1982; Matissek, 1997). Variations in caffeine concentration can also be attributed to other factors such as processing (e.g., the degree of roasting coffee beans) and preparation methods (e.g., brewing time), and the volume of the item (Barone & Roberts, 1996; Bunker & McWilliams, 1979; Mandel, 2002). An analysis of the caffeine content of Nespresso® pods (Desbrow et al., 2019), for instance, demonstrated that the amount of caffeine contained in each pod might differ by

51 to 162% from the amount stated by the manufacturer. This variation means that determining a person's caffeine intake is highly challenging, and some researchers have hypothesised that people may be consuming more caffeine than they realise (Gilbert et al., 1976; McCusker et al., 2003). Different approaches have been used in different studies to determine total caffeine consumption, and not all account for the complete range of caffeine-containing products that people are exposed to (Olechno et al., 2021; Thomson et al., 2014). Thus, research on population caffeine intakes is heavily debated with the premise that actual caffeine intakes are most likely under- or overestimated.

2.8 Caffeine Consumption Levels and Patterns

With an estimated 80% of people worldwide regularly using caffeine in some form (Samoggia & Rezzaghi, 2021), there is no doubt that its consumption is deeply ingrained in the cultural fabric of contemporary life. As the market for caffeine-containing products has expanded considerably in recent decades (Olechno et al., 2021; Reissig et al., 2009; Vegro & de Almeida, 2020), it is projected that consumption will continue to rise (Quadra et al., 2020; Temple et al., 2017). Some researchers even argue that complete non-consumers of caffeine are rare, since manufacturers are increasingly adding caffeine as a hidden ingredient to many products (Budney & Edmond, 2014; James & Rogers, 2005). Caffeine consumption levels and patterns differ according to age, gender and country (Dillon et al., 2019; Reyes & Cornelis, 2018; Verster & Koenig, 2018), and can be influenced by a number of factors including genetics, social/cultural behaviour and secular trends (Choi, 2020; Nehlig, 2018; Verster & Koenig, 2018).

Findings from the 2008/9 National Adults Nutrition Survey reported that in New Zealand, adults (aged ≥15 years) consumed on average 216 $mg \cdot day^{-1}$ (University of Otago and Ministry of Health, 2011), which is equivalent to about two cups of single shot espresso coffee per day (Appendix E.2). For young adults (aged 19–30), the average daily intake of caffeine is 194 $mg \cdot day^{-1}$ for males and 144 $mg \cdot day^{-1}$ for females (University of Otago and Ministry of Health, 2011). Coffee and tea are reported as the main sources of caffeine in the diet of New Zealand adults, whereas kola (soft) drinks, tea and biscuits are more popular among children and adolescents (Ministry of Health, 2003; University of Otago and Ministry of Health, 2011).

Some researchers have hypothesised that young adults (aged 18–25 years), especially university students, routinely consume more caffeine than the general population (Bertasi et al., 2021; Champlin et al., 2016), and at levels beyond what is thought to benefit function and performance (Malinauskas et al., 2007). For example, one study (McIlvain et al., 2011) indicated that university freshmen ingested on average 850 mg·day^{-1}, which is more than double the advised safe amount (discussed in Section 2.8.1). Studies show that students are frequently motivated to use caffeine to stay awake in order to study for an exam or finish a big project (Attila & Çakir, 2011; Lohsoonthorn et al., 2013; Malinauskas et al., 2007), and it is thought that high consumption may reflect a mechanism for coping with the increased academic and social demands young adults generally experience (Lohsoonthorn et al., 2013). Many studies have reported common reasons for caffeine consumption include combatting insufficient sleep, increasing energy, improving mood, alleviating stress and improving performance (Attila & Çakir, 2011; Mahoney et al., 2019; Malinauskas et al., 2007; Stachyshyn et al., 2021). It is also acknowledged that young people are highly engaged in the digital world (Villanti et al., 2017), and there is evidence to suggest that they are increasingly using caffeine to stay up later in order to use their electronic devices for longer (Calamaro et al., 2009).

2.8.1 Caffeine Intake Recommendations

Caffeine's use as a mild stimulant is typically considered safe when consumed in amounts that are within normal levels of intake (Heckman et al., 2010; Rodak et al., 2021; Temple et al., 2017). No reference range, such as an acceptable daily intake (ADI), has been established for caffeine use (Turnbull et al., 2016) due to the variables that alter interindividual caffeine responses (discussed in Section 2.11.1). The consensus among government authorities and expert scientific panels is that consumption of up to 400 mg day^{-1} is generally safe and poses minimal risk of producing overt, adverse side effects in healthy adults (Doepker et al., 2018; ESFA Panel on Dietetic Products Nutrition and Allergies (NDA), 2015; Nawrot et al., 2003; Wikoff et al., 2017). Safe levels are lower for pregnant women, who are recommended to keep intakes under 300 mg·day^{-1} (Nawrot et al., 2003).

2.9 Caffeine as an Adenosine Antagonist

Caffeine is well known for its ability to combat fatigue and drowsiness, as well as to foster increased focus and alertness (Nehlig et al., 1992; Smith, 2002). Caffeine's primary mechanism of action is mediated through the antagonism of adenosine A_1 and A_{2A} receptors located throughout the brain (Nehlig et al., 1992; Van Galen et al., 1992). Adenosine is an endogenous neuromodulator that decreases neural firing rate and inhibits the release of most excitatory neurotransmitters (Bjorness & Greene, 2009; Fredholm et al., 2005; Porkka-Heiskanen et al., 2002). The similarity of caffeine's molecular structure to adenosine allows it to occupy adenosine receptor sites, thus preventing adenosine from binding and exerting its sleep-inducing effects (Heckman et al., 2010). Caffeine also stimulates the release of norepinephrine, dopamine, and serotonin in the brain and increases circulating catecholamine levels (Benowitz, 1990) to promote arousal of the central nervous system i.e., increased wakefulness (Fiani et al., 2021; Nehlig et al., 1992). Genetic polymorphisms at the level of the adenosine A_{2A} receptor (ADORA2) can influence how an individual responds to a given dose of caffeine (Cornelis et al., 2007; Nehlig, 2018).

2.10 Caffeine Pharmacokinetics

In humans, caffeine is rapidly and completely absorbed from the gastrointestinal tract, with almost 100% bioavailability (Blanchard & Sawers, 1983). Peak plasma concentrations are typically reached within 45 minutes of ingestion (Smith, 2002), however can vary between 15 and 120 minutes, indicating significant interindividual variability (Fredholm et al., 1999; Marks & Kelly, 1973). Caffeine is absorbed at different rates depending on how it is consumed; for instance, caffeine may take longer to absorb when ingested with other foods or drinks than when consumed alone on an empty stomach, likely due to slowed gastric emptying (Willson, 2018). Caffeine is distributed to all tissues in the body and readily penetrates the blood-brain barrier (Nehlig et al., 1992); therefore, its effects on the central nervous system manifest quickly after consumption (Benowitz, 1990).

Caffeine is primarily metabolised in the liver by the isoenzyme P450 1A2, encoded by the gene CYP1A2, which is responsible for 95% (Cornelis et al., 2016) of the demethylation of caffeine into its metabolites (Yang et al., 2010). Caffeine clearance rate is substantially influenced by CYP1A2 activity (Nehlig, 2018; Yang et al., 2010), which also affects how long caffeine effects last. Slow caffeine metabolisers take longer to process and eliminate caffeine from their system; therefore, these individuals may experience more pronounced and persistent effects after consumption (Nehlig, 2018). Caffeine's half-life in healthy adults is typically about 4–6 hours, however can range from 2–12 hours (Benowitz, 1990). The half-life of caffeine can be influenced by many endogenous (e.g., age, gender, hormones, ethnicity and genetics) as well as exogenous factors (e.g., diet, smoking, drugs and medications), as reviewed in Nehlig (2018). Additionally, larger and repeated doses of caffeine can prolong the elimination half-life and slow down clearance (Denaro et al., 1990; Kaplan et al., 1997), meaning that caffeine remains in the body for longer.

2.11 Caffeine Pharmacodynamics

Caffeine's effects on human behaviour have been extensively studied (McLellan et al., 2016; Nehlig et al., 1992; Smith, 2002), and its psychostimulant qualities play a significant part in its appeal (Mahoney et al., 2019; Stachyshyn et al., 2021). Moderate dosages of up to about 300 mg·day^{-1} (McLellan et al., 2016) have been shown to benefit a number of cognitive and behavioural functions, including improvements in alertness (McLellan et al., 2016; Smith, 2002) and concentration (Nehlig, 2010). Additionally, caffeine has been linked to several ergogenic effects, such as increased speed and/or power output and endurance or resistance to fatigue (Graham, 2001), as well as reduced perceived muscle pain (Maridakis et al., 2007; O'Connor et al., 2004) and exertion/effort in exercise (Duncan et al., 2013). However, due to elements including individual training state, exercise duration and intensity, and employed performance measurements, the impact size of the results varies significantly between research (Graham, 2001; McLellan et al., 2016).

High doses of caffeine (≥400 mg·day^{-1}) have been shown to elicit adverse effects such as restlessness, anxiety, irritability, muscle tremor, insomnia, nausea and gastrointestinal upset (Kaplan et al., 1997; Nawrot et al., 2003). However, it is important to note that caffeine responses vary significantly between individuals (Section 2.11.1), and some people may be more susceptible to experiencing negative effects at considerably lower doses (Yang et al., 2010). It is therefore not surprising that many people alter their caffeine intake in response to their personal (subjective and objective) experiences with caffeine (Nehlig, 2018; Stern et al., 1989).

2.11.1 Factors Affecting the Caffeine Response

Many factors such as age, gender, genetics (at least seven genes (Yang et al., 2010)) and lifestyle behaviours can affect how caffeine is metabolised (see Nehlig (2018) for a review) and, therefore, how one responds to it. People who metabolise caffeine slowly may be more prone to the adverse effects of caffeine than fast caffeine metabolisers (Nehlig, 2018). Additionally, caffeine dosage and timing can have a strong influence, particularly on sleep (Hindmarch et al., 2000; Karacan et al., 1976) (discussed in Section 2.12) and ergogenic effects (McLellan et al., 2016). There is also evidence to support that an individual's expectation (i.e., whether they are aware they have consumed caffeine or not) may influence the reported effects of caffeine (Dawkins et al., 2011; Fillmore & Vogel-Sprott, 1992). One study (Kirsch & Weixel, 1988), found that people who ingested decaffeinated coffee but were informed that it contained some caffeine displayed physiological and emotional responses consistent with their expectations.

Long-term regular caffeine usage is also hypothesised to modify one's caffeine response, leading to tolerance to the stimulant's effects (Meredith et al., 2013). Hence the same dose of caffeine no longer produces the same effects or requires a higher dose to achieve the same desired outcomes (caffeine habituation). Studies in mice have demonstrated that repeated caffeine administration causes the upregulation of adenosine receptors in the brain, which is postulated to play a role in the development of caffeine tolerance and dependency (Boulenger et al., 1983; Marangos et al., 1984). Studies have indicated that humans may also develop a tolerance to the perceived effects of caffeine (Evans & Griffiths, 1992; Sigmon et al., 2009), although there have been inconsistent findings about physiological tolerance (Denaro et al., 1991; Robertson et al., 1981; Sigmon et al., 2009).

2.11.2 Caffeine Withdrawal

Caffeine has historically been considered to be a potential drug of dependence (Ogawa & Ueki, 2007; Strain et al., 1994) due to the withdrawal symptoms that regular consumers experience after abruptly ceasing use, including headache, fatigue, difficulty concentrating, irritability, depressed mood and drowsiness (Juliano & Griffiths, 2004). Symptoms typically begin 12–24 hours after abstinence, peak at 20–51 hours and last 2–9 days (Juliano & Griffiths, 2004). For this reason, there is substantial debate about whether caffeine actually improves performance or merely mitigates performance declines brought on by caffeine withdrawal/withdrawal reversal (James & Keane, 2007; James & Rogers, 2005), fatigue, or sleep restriction/deprivation (O'Callaghan et al., 2018). Given that caffeine heightens arousal, it seems logical that its effects would be more pronounced in subjects with decreased functioning than those in a normal condition, where they have a smaller potential for improvement (Fagan et al., 1988). Therefore, more research is needed to evaluate the effects of caffeine accounting for the potential confounding variable of caffeine withdrawal and withdrawal reversal.

2.12 Caffeine and Sleep

Sleep is arguably the biological function most sensitive to the effects of caffeine (Dews, 1982; Nehlig, 1999), yet anecdotal evidence suggests that consumers frequently overlook this relationship. There could be several reasons for this: firstly, people may not be aware that caffeine can impact their sleep. One study conducting participant interviews found that none thought that consuming coffee or tea before bed would impair their sleep, and several consumed their last caffeinated beverage as late as 11 p.m. or 12 a.m. (Březinová, 1974). Secondly, not everyone may realise that caffeine has an appreciable half-life and may thus underestimate its influence on sleep timing and quality. As previously mentioned (Section 2.10), caffeine’s half-life can vary substantially (between 2–12 hours) (Benowitz, 1990), and therefore effects will differ from person to person. A very fast metaboliser going to bed at 10 p.m. may be able to consume caffeine at 8 p.m. and be relatively unaffected sleep-wise, whereas a very slow metaboliser who drinks coffee as early as morning tea may still suffer substantial sleep disturbances. Thirdly, misconceptions about caffeine’s properties, such as the idea that it can replace sleep (Lee et al., 2009), may lead consumers to inappropriately use caffeine. However, other studies have revealed that people continue to use caffeine despite being aware of its effects on sleep in order to stay up later to finish work, especially when under pressure (Coveney, 2014). This suggests that modern society often prioritises meeting work and social obligations over obtaining sufficient sleep.

The role of caffeine as an adenosine receptor antagonist (Section 2.9) and its concomitant effects on sleep-wake regulation have been extensively studied (Clark & Landolt, 2017; O'Callaghan et al., 2018; Reichert et al., 2022). In a comprehensive review of epidemiological studies and randomised controlled trials (Clark & Landolt, 2017), caffeine consumption was shown to prolong sleep onset latency, reduce total sleep time and sleep efficiency, worsen perceived sleep quality and diminish slow wave (deep) sleep. It is also widely accepted that caffeine's effects on sleep are dose- and time-dependent, with adverse effects often manifesting from consumption of high doses close to bedtime (Hindmarch et al., 2000; Karacan et al., 1976). However, slow caffeine metabolisers or those more sensitive to its effects, are generally regarded to be more prone to experience sleep disruptions after caffeine ingestion than fast caffeine metabolisers or habitual users (Nehlig, 2018; Rétey et al., 2007). Furthermore, due to its reputation as a performance enhancer, caffeine is frequently used to combat sleepiness or fatigue yet interferes with subsequent sleep timing and quality which, in turn, encourages further caffeine consumption the following day (Roehrs & Roth, 2008; Snel & Lorist, 2011). Thus ensues a self-reinforcing "caffeine cycle", whereby some people may believe they 'need' caffeine to function optimally, or even adequately (O'Callaghan et al., 2018).

Studies demonstrate that changes to sleep architecture, especially deep sleep, are where caffeine's effects are most salient. Caffeine consumption reduces slow wave activity (SWA), a well-established indicator of sleep depth (Aepli et al., 2015; Landolt et al., 1995), even at low (100 mg) doses (Landolt et al., 1995). There is strong evidence suggesting that caffeine reduces the amount of slow wave (N3) sleep that is attained (Březinová, 1974; Carrier et al., 2007; Landolt et al., 1995); however, there has been conflicting data on changes to the amount of light (N1 and N2) sleep (Aepli et al., 2015; Březinová, 1974; Carrier et al., 2007). Numerous studies have also shown that caffeine consumption increases the number of night-time awakenings, thus fragmenting sleep (Březinová, 1974; Carrier et al., 2007; Karacan et al., 1976). Taken together, it has been posited that caffeine decreases the ability to enter and maintain deeper stages of sleep (N3) while increasing the capacity for arousal (Březinová, 1974). Furthermore, caffeine use has been shown to delay REM sleep until later into the night (Weibel et al., 2021), although the total amount of REM seems unaffected (Březinová, 1974; Drake et al., 2013).

Given the numerous challenges in evaluating the reciprocal link between caffeine usage and sleep, it is not surprising that contradictory results have been observed (summarised in Table 2.2). Firstly, it has been stated that people generally lack the ability to accurately assess their own sleep (Edinger et al., 2000); thus, some individuals may not realise they are experiencing caffeine-induced sleep disturbances. This further supports the notion as to why people may miss the connection between caffeine use and sleep. Secondly, it is challenging to compare the results of different studies due to the different methods used to measure intake. For example, some researchers have based caffeine content on serving sizes (Lund et al., 2010) or the number of caffeinated beverages consumed weekly (Lemma et al., 2012; Lohsoonthorn et al., 2013), while others have used food frequency questionnaires (FFQ) (Choi, 2020) to calculate average daily consumption (Watson et al., 2016). Furthermore, the amount of caffeine in a given product or source can vary significantly (Desbrow et al., 2019; McCusker et al., 2003; Reissig et al., 2009) (as mentioned in Section 2.7); therefore, estimated intakes will vary depending on the caffeine sources taken into account.

The disruptive effects of caffeine on sleep, particularly when consumed near bedtime, have been well-documented in the laboratory setting (Carrier et al., 2007; Drake et al., 2013; Drapeau et al., 2006). However, these experiments tend to administer a single, sometimes substantial caffeine dose that does not reflect typical consumption. For example, Drake et al. (2013) administered 400 mg of caffeine (equivalent to about 2 cups of double shot espresso) to participants 0, 3 and 6 hours before bedtime. There is less research on typical caffeine use, which is characterised by earlier morning consumption with tapering off in the afternoon and abstinence overnight (Hindmarch et al., 2000; James & Keane, 2007). Although research has shown that caffeine ingested even 6 hours before bedtime can disrupt both objective and subjective sleep parameters (Drake et al., 2013), more data is needed on how morning and/or afternoon consumption affects the timing, structure and quality of sleep. Evaluating the effects of various caffeine doses on sleep consumed at various times throughout the day would help to obtain a more accurate representation of how caffeine impacts sleep in the real world (Snel, 1993). This would also better account for interindividual variability caused by factors such as caffeine metabolism and habituation.

Table 2.2 Summary of studies on the association between caffeine consumption and sleep quality. Studies were included if participants were healthy young adults and adults (aged 18 years and above), and caffeine and sleep quality assessments were described. Studies involving animals, children, or adolescents, or in which sleep quality was not a primary outcome variable, were excluded. Studies are divided with a double line according to study type and are arranged alphabetically by the first author.

Reference	**Origin**	**Study design**	**Sample (*n*, cohort, age)**	**Caffeine intake or dose (units)**	**Sleep quality assessment**	**Findings**
Brick et al. (2010)	United States	Cross-sectional	*n* = 314, Medical students, 27.8 ± 4.0 y	Number of caffeinated beverages (drinks/day)	PSQI	No significant association
Choi (2020)	Korea	Cross-sectional	*n* = 381, University students, 20–26+ y	Frequency of caffeine consumption (drinks/day)	PSQI	No significant association
Kerpershoek et al. (2018)		Cross-sectional	*n* = 880, University students, 21.3 ± 3.1 y	Total weekly caffeine consumption (mg/week) (Substance-use questionnaire)	PSQI	↑ caffeine consumption was associated with poorer sleep quality for non-evening caffeine consumers (β = 0.170, p = 0.025)
Lemma et al. (2012)	Ethiopia	Cross-sectional	*n* = 2230, University students, 20.3 ± 1.3 y	Number of caffeinated beverages (drinks/week)	PSQI	Consumption of ≥ 1 caffeinated beverage/ week associated with increased odds of poor sleep quality (OR 1.29; CI 1.02–1.64)

Lohsoonthorn et al. (2013)	Thailand	Cross-sectional	*n* = 2854, University students, 20.3 ± 1.3 y	Number of caffeinated beverages (drinks/week)	PSQI	↑ caffeine consumption associated with poor sleep quality ($p < 0.001$)
Lund et al. (2010)	United States	Cross-sectional	*n* = 1125, University students, 20 ± 1.3 y	Number of caffeinated beverages (servings*/ weekday and weekend day)	PSQI	No significant association
Melone et al. (2022)	France	Cross-sectional	*n* = 339, Collegiate athletes, median 20 y	Number of caffeinated beverages (units/day)	PSQI	Caffeine consumption correlated with higher PSQI scores (OR 1.09; CI 0.18–2.01)
Ogilvie et al. (2018)	United States	Cross-sectional	*n* = 1854, Young adults, 38.9 ± 19.3 y	Frequency of caffeine consumption (drinks/week) (Project EAT-III survey)	Kandel and Davies Depressive Symptoms Questionnaire‡	↑ energy drink (PR 1.79; CI 1.24–2.34) and sports drink (PR 1.28; CI 1.00–1.55) consumption associated with poor sleep quality
Reid and Baker (2008)	South Africa	Cross-sectional	*n* = 986, University students, 21 ± 3 y	Number of caffeinated beverages (cups/day)	Self-rated sleep quality	↑ caffeine consumption associated with poor sleep quality ($p < 0.001$)
Riera-Sampol et al. (2022)		Cross-sectional	*n* = 886, University students, 20.6 ± 2.1 y	Daily caffeine consumption (mg/day)	MOS Sleep Scale	↑ caffeine consumption associated with poor sleep quality ($p < 0.001$)

Sanchez et al. (2013)	Peru	Cross-sectional	*n* = 2458, University students, 20.9 ± 2.6 y	Number of caffeinated beverages (drinks/week)	PSQI	Consumption of ≥3 caffeinated beverages/week had higher odds of poor sleep quality (OR 1.88; CI 1.42–2.50)
Watson et al. (2016)	Australia	Cross-sectional	*n* = 80, University students, 38.9 ± 19.3 y	Frequency of caffeine consumption (mg/day) (C-FFQ)	PSQI	Caffeine consumption was higher among poor sleepers than good sleepers (p = 0.008)
Young et al. (2020)	United States	Cross-sectional	*n* = 462, Young adult women, 22.9 ± 0.5 y	Frequency of caffeine consumption (drinks/day)	PSQI	Energy drink (p = 0.008) and high-calorie coffee consumption (p = 0.0002) associated with poor sleep quality
Zunhammer et al. (2014)	Germany	Longitudinal (before, during, after exams)	*n* = 142, University students, 22.2 ± 2.5 y	Number of caffeinated beverages (units[†]/week)	PSQI	No significant association
Ali et al. (2015)	New Zealand	Randomised, double-blind placebo-controlled	*n* = 10, Female athletes, 24 ± 4 y	Caffeine supplement (6 $mg \cdot kg^{-1}$) at 1800 h	LSEQ	Caffeine supplementation impaired subsequent sleep quality (p < 0.05)
Hindmarch et al. (2000)	United Kingdom	Randomised crossover	*n* = 30, Adults, 27.3 ± 0.9 y	1-2 cups of tea (≈37.5 or 75 mg caffeine) or coffee (75 or 150 mg caffeine) at 0900, 1300, 1700 and 2100 h	LSEQ	Caffeine had a negative dose-dependent effect on sleep quality (p <0.001)

Keenan (2005)	United Kingdom	Randomised, double-blind, placebo-controlled crossover	*n* = 19, Adult caffeine consumers, 32 ± 12.9 y	Caffeine (250 mg) for five consecutive nights	Actigraphy watch and subjective sleep quality (sleep diary)	Trend for ↓ sleep quality after caffeine use
Ramos-Campo et al. (2019)	Spain	Randomised, double-blind, comparative crossover	*n* = 15, Athletes, 23.7 ± 8.2 y	Caffeine supplement (≈6 $mg \cdot kg^{-1}$) 1 h before 800-m running time trial (2000 h)	Actigraphy watch and subjective sleep quality (KSD)	Caffeine impaired sleep quality variables ($p = 0.005$)
Shilo et al. (2002)	Israel	Double-blind randomised	*n* = 6, Hospital personnel, 32 ± 12 y	Decaffeinated or regular coffee (130 mg/cup)	Self-rated sleep quality	Caffeinated coffee ↓ sleep quality compared to decaffeinated coffee
Weibel et al. (2021)	Switzerland	Double-blind crossover	*n* = 20, Male caffeine consumers, 26 ± 4 y	Caffeine (3 x 150 mg) daily for 10 days, withdrawal (3 x 150 mg caffeine for 8 days then placebo), and placebo condition	LSEQ	No significant association between the 3 conditions ($p > 0.05$) however ↑ difficulty in awakening and tiredness in the caffeine compared with placebo condition ($p < 0.01$)

Abbreviations: C-FFQ = Caffeine Food Frequency Questionnaire; CI = Confidence Interval; FFQ = Food Frequency Questionnaire; KSD = Karolinska Sleep Diary; LSEQ = Leeds Sleep Evaluation Questionnaire; OR = Odds Ratio; PR = Prevalence Ratio; PSQI = Pittsburgh Sleep Quality Index
*Serving was defined as an 8 oz (237 ml) serving of coffee, espresso, tea, soft drinks, hot chocolate, or 1.5 oz (43 g) of chocolate
†Unit was defined as 200 ml of coffee or tea or 500 ml of caffeinated soft drinks (equivalent to ~50–100 mg of caffeine)
‡Sleep quality was measured from the question, "During the past 12 months, how often have you been bothered or troubled by having trouble going to sleep or staying asleep?". Possible responses to this question were 'not at all', 'sometimes', or 'very much'.

2.13 Summary of the Literature

Sleep is fundamental to human health, well-being, functioning and performance (Hamilton et al., 2007; Luyster et al., 2012; Walker, 2009), yet anecdotal data suggests that sleep is becoming less of a priority than other waking commitments (Basner et al., 2007; Batten et al., 2020). Insufficient sleep (in both quantity and quality) has significant negative consequences on an individual (e.g., increased risk of chronic diseases), at both an interpersonal and societal level. Although many biological, lifestyle and sociocultural factors (Grandner, 2019; Ohida et al., 2001) have been associated with sleep health, caffeine has received more attention recently in light of its pervasive use and our society's trend toward 24/7 living (Calamaro et al., 2009; Coveney, 2014).

Although the benefits of caffeine consumption for improving cognition and performance are frequently highlighted, little is understood or acknowledged by the general population regarding caffeine's adverse impacts, particularly on sleep. People might not be aware that in healthy adults caffeine has an average half-life of 4 to 6 hours (Benowitz, 1990; White et al., 2016), which means that its wake-promoting effects may last long after consumption and possibly past the period that it is wanted. Caffeine helps to prolong wakefulness through the blockade of adenosine (A_1 and A_{2A}) receptors in the brain (Nehlig et al., 1992; Van Galen et al., 1992) and consumption, particularly in the evening, has been shown to affect sleep timing, architecture and quality (see Clark & Landolt (2017) for a review).

Young adulthood (ages 18–25) is a crucial developmental stage during which a number of lifestyle behaviours (e.g., stimulant/drug use) are established or reinforced (Stroud et al., 2015), and may have a substantial influence on future health outcomes and quality of life (Harris, 2010). Young adults are believed to be more susceptible to restricting their sleep and accruing sleep debt (Lack, 1986; Phillips et al., 2017) as a result of biological (e.g., later circadian preference; Roenneberg et al., 2004) and environmental influences (e.g., increased academic and social demands; Wang & Bíró, 2021). In young adults, adverse repercussions linked to short and poor-quality sleep include lower academic performance (Chen & Chen, 2019), increased risk-taking behaviour (Rusnac et al., 2019) and worse mental health (Dickinson et al., 2018).

Study Aims

The objective of this study is to fill in some of the gaps left by earlier investigations examining the link between caffeine consumption and sleep quality. Firstly, there is currently no available data on the sleep quality of New Zealand young adults and international research has shown significant variability in estimates of poor sleep quality in this demographic (Table 2.1). Moreover, a broader exploration of lifestyle circumstances (e.g., studying, working, or both) is required as the majority of research to date in the young adult population has primarily concentrated on university students (Aldhawyan et al., 2020; Becker et al., 2018a; Di Benedetto et al., 2020). Secondly, although caffeine's dose- and time-dependent effects on sleep have been well documented in the laboratory setting (Carrier et al., 2007; Drake et al., 2013; Drapeau et al., 2006), the extent to which habitual intake affects sleep in naturalistic settings is less understood. Thirdly, earlier research on caffeine's effects on sleep had been mostly focused on Western male adults (Clark & Landolt, 2017), therefore, more data is needed on diverse populations. Finally, to the author's knowledge, only two other studies (Choi, 2020; Watson et al., 2016) have employed FFQs to estimate caffeine intake. In this study, the use of CaffCo will enable us to more accurately estimate caffeine intake due to its inclusion of a wide selection (product range, including volumes) of caffeinated foods and beverages in the New Zealand market as opposed to previous studies that only collected data on the number of caffeinated beverages consumed per day/week.

CHAPTER 3 RESEARCH STUDY MANUSCRIPT

The following chapter is presented as a manuscript prepared for the peer-reviewed Journal *Nutrients*. The abstract must be limited to 200 words maximum, and there are no restrictions on the length of the main text, provided it is concise and comprehensive. Supplementary information can be found in Appendices D and E and results in Appendix F.

3.1 Abstract

Background: Short and poor-quality sleep are associated with reduced cognitive functioning, increased psychological distress and increased risk of developing chronic diseases. Young adults may be more prone to irregular sleep-wake schedules and may consume caffeine to mitigate the adverse consequences of sleep loss. Although caffeine is well known for its stimulating properties, its disruptive effects on sleep are often overlooked. Sleep quality data on New Zealand young adults (aged 18–25) is required to ascertain whether there is cause for concern.

Aim: This cross-sectional study aimed to examine sleep quality in healthy young adults and the associations between sleep quality and caffeine consumption.

Method: Validated online caffeine consumption and sleep quality questionnaires were administered to 192 young adults.

Results: The majority of young adults (87.5%) slept fewer than 7 hours each night and poor sleep quality was commonplace (85.9%). Participants' average daily caffeine intake was 159.6 $mg \cdot day^{-1}$, with coffee being the primary contributor. Caffeine consumption was not associated with sleep quality. Students were more likely to experience poor sleep quality than workers.

Conclusions: Poor sleep quality is prevalent among New Zealand young adults, and further investigation is required to determine the causes.

Keywords: caffeine, caffeine consumption, sleep quality, sleep health, young adults, New Zealand.

3.2 Introduction

Sleep is essential for maintaining health, well-being and performance; but in today's modern world, it is becoming increasingly difficult to prioritise as part of our daily routines (Basner et al., 2007; Batten et al., 2020). Sleep plays a vital role in several physiological and behavioural functions, including learning and memory consolidation (Gais & Born, 2004; Walker et al., 2002), emotional regulation (Palmer & Algano, 2017; Vandekerckhove & Wang, 2017), brain metabolite clearance (Hladky & Barrand, 2017; Xie et al., 2013), immune responses (Besedovsky et al., 2012; Del Gallo et al., 2014) and hormone and energy balance (Kim et al., 2015; Spiegel et al., 2004). Total sleep deprivation can be fatal in both humans (Lugaresi et al., 1986) and animals (Rechtschaffen et al., 1989), and restricting sleep (<7 hours a night) elicits a multitude of cognitive and behavioural deficits, including reduced alertness, attention and vigilance (Banks & Dinges, 2007; Killgore, 2010), increased daytime sleepiness (Giannotti et al., 2002), and increased stress responsivity and emotional sensitivity (Minkel et al., 2012; Rosales-Lagarde et al., 2012).

Young adults may be more prone than middle-aged and older adults to experiencing and suffering from the adverse effects of sleep loss and poor-quality sleep. Researchers have suggested that this may be due to factors such as increased academic and social obligations that lead to irregular sleep-wake schedules (Taylor et al., 2013; Wang & Bíró, 2021), and the adoption of unfavourable lifestyle behaviours that may affect sleep (e.g., increased alcohol consumption) (Li et al., 2020; Lohsoonthorn et al., 2013). Short and poor-quality sleep in young adults has been linked with lower academic performance (Chen & Chen, 2019; Gomes et al., 2011), increased risk-taking and sensation-seeking behaviours (Rusnac et al., 2019; Taghvaee & Mazandarani, 2022), increased risk of psychological problems such as depression and anxiety (Dickinson et al., 2018; Regestein et al., 2010) and increased suicidal ideation and attempts (Becker et al., 2018b; Vail-Smith et al., 2009).

Although individual sleep needs may differ (Chokroverty, 2017; Watson et al., 2015), scientific experts recommend most young adults (aged 18–25 years) get between 7 to 9 hours of sleep every night (Hirshkowitz et al., 2015). A meta-analysis (Youngstedt et al., 2016) comprising 6,052 participants (aged 18–88 years) assessed sleep duration trends over the last 50 years found that young adults (aged 18–27) had a higher prevalence of short sleepers (<6 hours per night) than adults and older adults (28+ years). A recent New

Zealand study also found that more than one-third of adults (aged 18+) did not get the required amount of sleep (<7 hours) each night (Lee & Sibley, 2019). Researchers have suggested that cultural trends such as lengthy commutes, extended workdays, stimulant use and constant access to electronic devices (Luyster et al., 2012; Meredith et al., 2013; Ogilvie & Patel, 2018) are partly responsible for people limiting their sleep opportunity i.e., the amount of time they give themselves the chance to sleep.

Caffeine is a well-known stimulant that achieves its effects mainly through the antagonism of adenosine A_1 and A_{2A} receptors in the brain (Fredholm, 1995; Nehlig et al., 1992). Individuals' responses to caffeine can vary considerably depending on factors such as genetics, age, gender and caffeine habituation (Fredholm et al., 1999; Nehlig, 2018; Yang et al., 2010). It is generally accepted that low to moderate doses of caffeine, up to about 300 $mg \cdot day^{-1}$ (McLellan et al., 2016), can improve cognition (McLellan et al., 2016; Nehlig, 2010; Smith, 2002) and physical performance (Duncan et al., 2013; Graham, 2001). However, high doses (≥400 $mg \cdot day^{-1}$) may increase the risk of negative effects, such as restlessness, anxiety, irritability, muscle tremor, insomnia, nausea and gastrointestinal upset (Kaplan et al., 1997; Nawrot et al., 2003). Although sleep is arguably the biological function most sensitive to caffeine's effects (Dews, 1982; Nehlig, 1999), the impact consumption has on people's sleep quantity and quality could be the one that is most overlooked in our 24/7 culture (Basner et al., 2007; Coveney, 2014; Foster & Wulff, 2005). Strong evidence indicates that caffeine use prolongs sleep onset latency, reduces total sleep time and sleep efficiency, worsens perceived sleep quality and diminishes slow wave (deep) sleep (see Clark & Landolt (2017) for a review). Caffeine's effects on sleep are generally dose- and time-dependent, with greater dosages and evening use, particularly before bedtime, instigating sleep-disrupting effects (Hindmarch et al., 2000; Karacan et al., 1976).

It has been proposed that young adults, particularly university students, often consume more caffeine than the general public (Bertasi et al., 2021; Champlin et al., 2016). Numerous studies have reported that young adults typically use this stimulant to stay awake to study for an exam or complete a major project (Attila & Çakir, 2011; Lohsoonthorn et al., 2013; Malinauskas et al., 2007), as well as to combat sleepiness, increase energy, improve mood, alleviate stress, and boost concentration or performance (Attila & Çakir, 2011; Mahoney et al., 2019). With the surge in social media use in recent years (Villanti et al., 2017), there is also evidence to suggest that young people are consuming caffeine to stay up later in order to use their electronic devices for longer (Calamaro et al., 2009). Data on young adults' knowledge of caffeine, particularly its impact on sleep, is scarce. However, one study (Lee et al., 2009) found that some (27%) university students thought that caffeine could be used as a substitute for sleep. This is concerning because it may result in the stimulant being used improperly and causing accidental harm.

To the author's knowledge, research on sleep in young adults has mostly been conducted among university students and has not yet been examined in the New Zealand setting. Additionally, there are few studies examining how habitual caffeine consumption affects sleep compared to trials in the laboratory setting. Therefore, the present study aimed to determine the relationship between habitual caffeine consumption and sleep quality among New Zealand young adults. In particular, this research sought to (1) determine the prevalence of poor sleep quality among healthy young adults; (2) evaluate the associations between caffeine consumption and sleep quality; and (3) determine the differences in caffeine consumption between self-reported good and poor sleepers.

3.3 Materials and Methods

3.3.1 Participants

Participants were recruited via Massey University newsletters and media releases, social media, poster advertisements (Appendix A) displayed on the Massey University Albany Campus, and word of mouth. To be eligible for the study, participants had to be between 18 and 25 years, be currently residing in New Zealand, be fluent in reading and writing English, be in good general health with no history of heart, neurological and/or psychiatric illness, have no current sleep problems, and not be engaged in shift work. The study was approved by the Massey University Human Ethics Committee: Southern A (Application 21/11; see Appendix B for MUHEC approval letter).

3.3.2 Procedures

An information sheet (Appendix C) outlining the study's objectives was sent to those who expressed interest, along with a disclaimer that implied consent would be obtained through completing and submitting the questionnaires. An online survey software was used to administer the questionnaires (Qualtrics, 2021), and data were collected between May and August 2021. Participants could gain access on their own devices via the survey link or QR code and complete the questionnaires at a time/location suitable for them. It was estimated that the questionnaires would take approximately 30 to 40 minutes to complete. Participants were provided with the option to enter a draw for a gift voucher upon completion of their questionnaires.

3.3.3 Measures

Pittsburgh Sleep Quality Index (PSQI) – The PSQI is a self-rated questionnaire that retrospectively evaluates sleep quality and disturbances over a one-month period (Buysse et al., 1988). It contains 19 items (note: question 10 relating to having a bed partner or roommate was removed from our version) which generate seven "component" scores, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication and daytime dysfunction. Each component is graded on a 4-point scale from '0' to '3', where '3' indicates the greatest dysfunction. The sum of these scores produces a "global score", ranging from 0 (no difficulties) to 21 (severe difficulties), distinguishing individuals as “good” (score < 5) or “poor” (score ≥ 5) sleepers. The PSQI is a robust and reliable instrument (Backhaus et al., 2002; Buysse et al., 1988; Carpenter & Andrykowski, 1998) for assessing sleep quality that has been extensively used in studies on young adult populations (Ahrberg et al., 2012; Becker et al., 2018a; Carpi et al., 2022; Mah et al., 2018). See Appendix D.1 for the complete list of questionnaire items and Appendix D.2 for the scoring protocol.

***Caffeine Consumption Habits (CaffCo) Questionnaire* –** The CaffCo is a self-report questionnaire containing 49 sections that assess the caffeine intake patterns, influences on consumption and experiences of adults across eight caffeine sources (tea, coffee, chocolate, energy drinks, kola drinks, caffeinated ready-to-drink (RTD) alcoholic beverages, sports supplements and caffeine tablets) (Rowe et al., 2020). Demographic information, including age, gender, ethnicity, self-reported weight (kg) and height (cm), employment status, living situation and smoking status, were also collected. See Appendix E.1 for the complete list of questionnaire items. Participants’ daily caffeine intake was determined by matching product caffeine content information (Appendix E.2) with consumption frequency data retrieved from the questionnaire. A numerical factor was assigned to the consumption frequencies (“never” to “6+ times per day”) to measure daily caffeine intake. For instance, if a product was consumed once per week, the factor was 1/7 = 0.143. The median value of the frequency range was utilised wherever one was provided (e.g., for products consumed 4–5 times per day, the factor would be 4.5). Each product in each source category was added to estimate the total amount of caffeine consumed. Similarly, to determine the estimated total daily caffeine intake, the sum of each caffeine source was added together (i.e., the total intake for coffee, tea, energy drinks, etc.). CaffCo is a validated and reliable tool to evaluate caffeine consumption patterns (Rowe et al., 2020) and effectively captures the variety of caffeinated products available in the present New Zealand market.

3.3.4 Data Analysis

Classifications by groups – Participants were categorised into caffeine consumer groups, classified as low (<80 mg·day^{-1}), moderate (80 – 400 mg·day^{-1}), and high (>400 mg·day^{-1}), based on Food Standards Australia NZ classifications for intake (Australia New Zealand Food Authority Expert Working Group on Caffeine, 2000) and by sleep quality group, i.e., good sleeper (PSQI global score <5) or poor sleeper (PSQI global score ≥5) (Buysse et al., 1988).

Body mass index (BMI) – For participants (n = 166) who provided self-reported weight (kg) and height (cm), a BMI (kg/m^2) value was calculated. Using the World Health Organization (WHO) BMI cut-offs, individuals were categorised as being underweight (<18.5 kg·m^2), normal weight (18.5 – 24.9 kg·m^2), overweight (25.0 – 29.9 kg·m^2), or obese (>30.0 kg·m^2) (World Health Organization, 2018).

Covariates – Demographic factors including gender, ethnicity, living situation and BMI, did not impact sleep quality other than employment status; as a result, they were not included as covariates. Smoking status was included as a covariate in our binary logistic models, even though there were no significant differences between groups in our sample, as several studies have indicated that smokers are more likely than non-smokers to have poor-quality sleep and sleep disturbances (Fatima et al., 2016; Gómez-Chiappe et al., 2020; Liao et al., 2019; Mamun et al., 2020).

3.3.5 Statistical Analysis

Questionnaire data was exported from Qualtrics into Microsoft Excel (2018) and screened for any missing or invalid information, and then imported into SPSS statistical software (Version 27, SPPS Inc., Chicago, IL) to perform statistical analysis. Outliers for the caffeine variables (>1.5 SD above the mean) were clarified with the participant and considered accurate and viable. All data were checked for normality using Shapiro–Wilk and Kolmogorov–Smirnov tests. Not normally distributed data that could not be log transformed were analysed using non-parametric tests. Participant characteristics were summarised using frequency and percentage for categorical variables and mean ± standard deviation (SD) for normally distributed data (e.g., age) and median [25^{th}, 75^{th} percentiles] (e.g., total caffeine intake, caffeine intake from beverages and sources, and sleep variables).

Chi-square tests were used to assess differences in sleep quality by demographic variables. Spearman's rank correlation was utilised to determine the relationship between total daily caffeine consumption and PSQI global score. Differences in PSQI global score and sleep subscales by caffeine consumer groups were analysed using Mann–Whitney *U* tests. For further analysis, binary logistic regression modelling was used to calculate odds ratios (OR) and 95% confidence intervals (95% CI) for predictors of poor sleep quality. In all tests, significance was determined if $p < 0.05$.

3.4 Results

3.4.1 Participants

Of the 771 people who expressed interest in the study, 489 met the inclusion criteria, and 315 completed both the CaffCo and PSQI questionnaires. Post-hoc data cleaning identified five questionnaires with missing data, which were removed from the dataset. Due to a technical error in the survey, sleep efficiency could not be accurately calculated for 118 participants, and data from these participants were also excluded from analyses. The total study population analysed comprised 192 participants. The participant recruitment process is summarised in Figure 3.1.

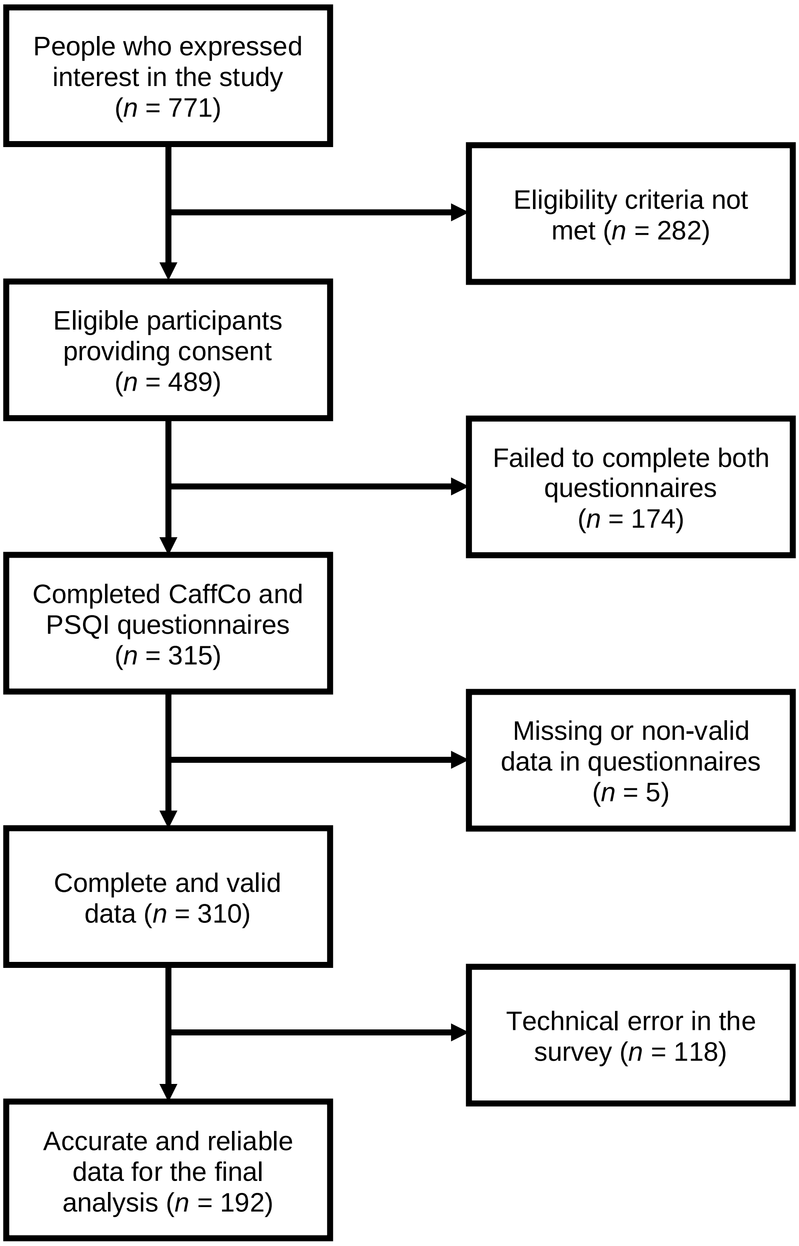


Figure 3.1 Flow diagram of participant recruitment and the inclusion/exclusion process of the study.

3.4.2 Participant Characteristics

Participant characteristics are summarised in Table 3.1. The study population was predominantly female (85.4%; mean reported age of 22 ± 2.2 years), European (79.2%), students (68.8%), non-smokers (85.9%), and flatting (48.4%) or living in a family home (41.1%) and had a BMI within the normal range (56.8%). Additional detail about participant age and ethnicity can be found in Appendix F (Table F.1 and Figure F.1, respectively).

Table 3.1 Participant socio-demographic characteristics (*n* = 192).

Variable	*n* (%)
Age, years, mean ± SD	22 ± 2.2 years
Gender	
Female	164 (85.4)
Male	24 (12.5)
Non-binary/Other	4 (2.1)
Ethnicity†	
NZ European/European	152 (79.2)
Māori	15 (7.8)
Asian§	51 (26.6)
Pacific peoples¶	1 (0.5)
Other#	2 (1.0)
Living situation	
Flatting with others	93 (48.4)
Living in a family home with others	79 (41.1)
Living with partner	12 (6.3)
Living alone	5 (2.6)
Halls of residence	3 (1.6)
Employment Status	
Full-time employment	50 (26.0)
Part-time employment	6 (3.1)
Student	81 (42.2)
Student with employment	51 (26.6)
Unemployed	4 (2.1)
Body mass index (BMI) ♠, ‡	
Underweight (<18.5 kg·m^{-2})	8 (4.2)
Normal weight (18.5-24.9 kg·m^{-2})	109 (56.8)
Overweight (25.0-29.9 kg·m^{-2})	34 (17.7)
Obese (≥30.0 kg·m^{-2})	15 (7.8)
Smoking status	
Non-smoker	165 (85.9)
Smoker	27 (14.1)

†Participants were able to select multiple ethnicities; hence total is greater than 100%.
§Includes Southeast Asian, Filipino, Chinese, Korean, Japanese, Indian, Taiwanese, Vietnamese
¶Includes Tongan.
#Includes Middle Eastern, African.
♠Participants who provided height and weight (*n* = 166).
‡BMI cut-offs according to WHO categorisation (World Health Organization, 2018).

3.4.3 Total Caffeine Consumption and Sources Contributing to Intake

Total Daily Caffeine Consumption by Source

Estimated total daily caffeine consumption by source (mg·day^{-1}) is shown in Figure 3.2. Participants' median daily caffeine intake was 159.6 [Interquartile range (IQR) 78.5 – 217.7] mg·day^{-1}, and ranged from 0 to 848.2 mg·day^{-1}. Coffee contributed the greatest amount to total daily caffeine intake, with a median reported intake of 84.0 [8.5 – 167.6] mg·day^{-1}. There was a wide variation of intakes reported for coffee (0 to 395.5 mg·day^{-1}) and energy drinks/shots (0 to 344.4 mg·day^{-1}).

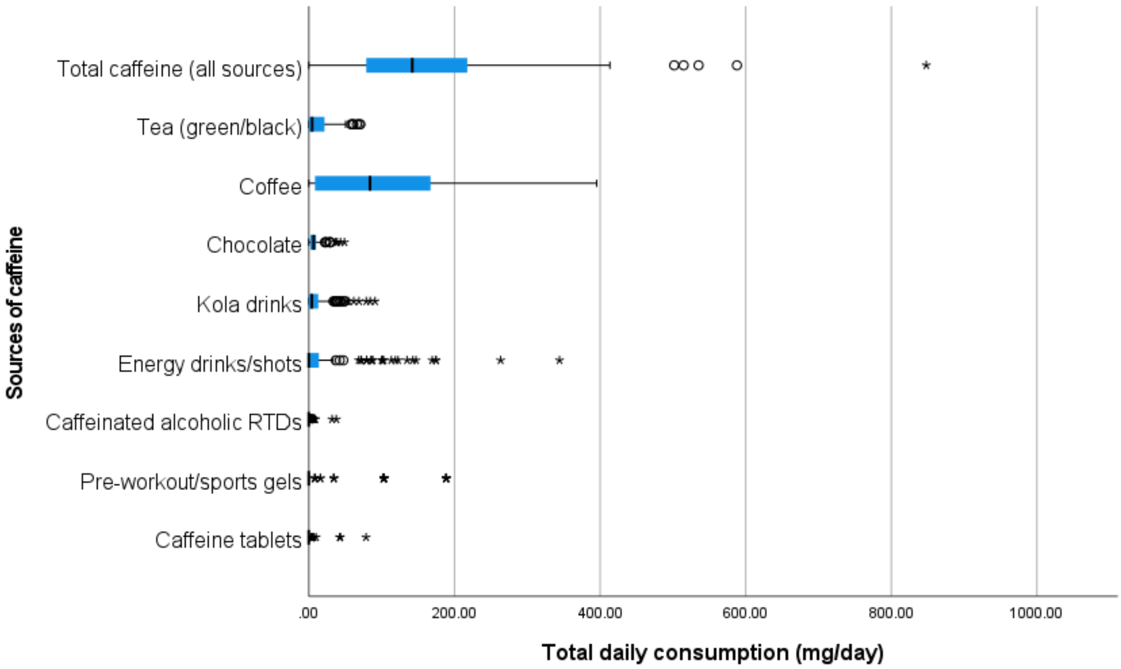


Figure 3.2 Distribution of total daily caffeine intake by source (*n* = 192).

Values more than 1.5 IQR from the end of the box are labelled as outliers (o).
Values more than 3 IQR are labelled as extreme outliers, denoted by asterisks (*).

Caffeine Consumption Groups

The majority of participants (70.8%) were moderate caffeine consumers (80 to 400 mg·day^{-1}), with 25.5% being low (<80 mg·day^{-1}) consumers, and the remaining 3.6% classified as high caffeine consumers (>400 mg·day^{-1}). Figure 3.3 shows a comparison of the intake ranges for the three caffeine intake groups (low, moderate, high). In order to conduct sleep analysis by caffeine consumption level, the high caffeine consumer group (*n* = 7) and the moderate caffeine consumer group (*n* = 136) were combined to form one group due to insufficient numbers in each group. In light of this, this group will hereafter be referred to as "moderate-to-high caffeine consumers" (*n* = 143).

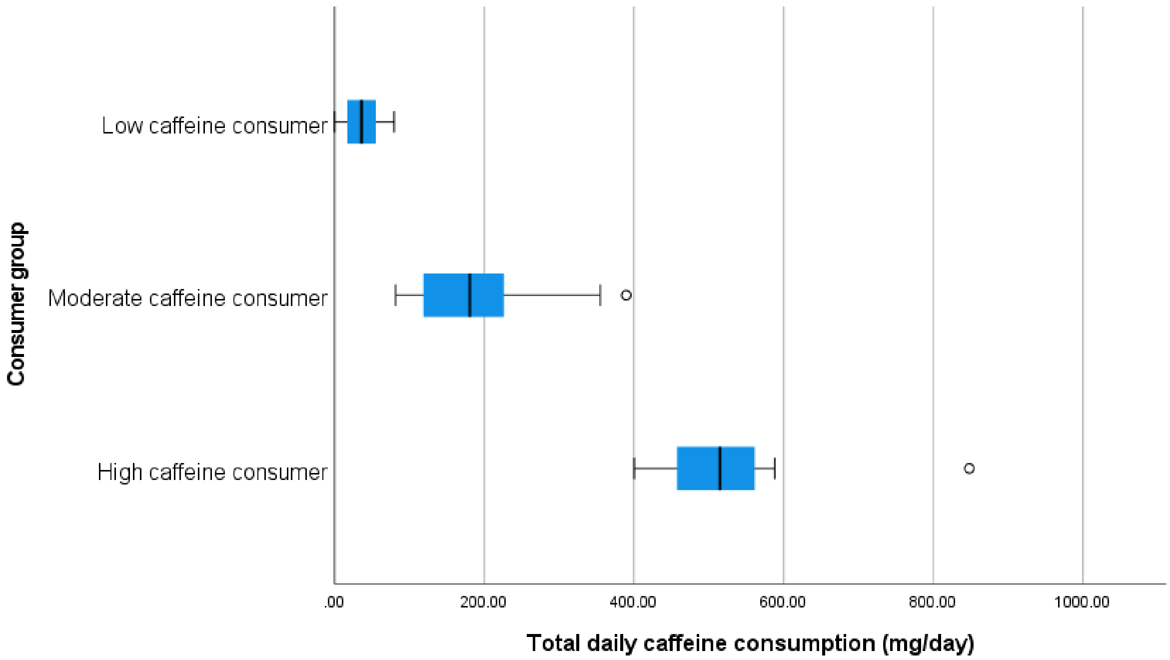


Figure 3.3 Distribution of total daily caffeine intake by consumer group (*n* = 192).
Values more than 1.5 IQR from the end of the box are labelled as outliers (o).

Frequency of Consumption of Common Caffeine Sources

Figure 3.1 shows the percentage of participants that consumed popular caffeine sources. The most frequently consumed sources of caffeine in the diet were chocolate (82.3%), coffee (78.6%), tea (57.3%) and kola drinks (55.7%). Almost half of the cohort (44.3%) indicated consuming energy drinks, and a small proportion indicated consuming pre-workout/sports gels and caffeine tablets (12.5% and 8.3%, respectively). Only 1.6% of participants (*n* = 3) did not consume caffeine.

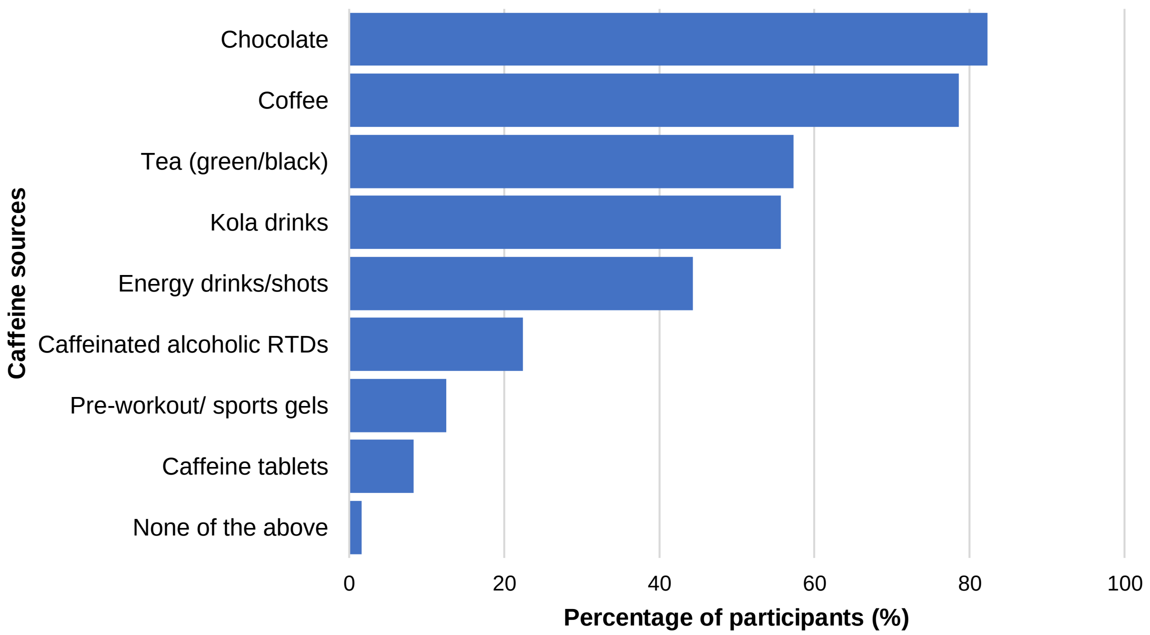


Figure 3.4 Percentage of participants consuming common caffeine sources (*n* = 192).

3.4.4 Sleep Characteristics

The results of the PSQI were analysed according to component scores and overall global score (Table 3.2). The majority (85.9%) of participants reported having poor sleep quality (global score ≥5), and 14.1% having good sleep quality (global score <5). The mean global PSQI score of the total sample was 7.79 ± 3.08 (distribution of PSQI global scores can be found in Figure G3). Nearly two-thirds (64.6%) of participants described their subjective sleep quality to be “fairly/very good”, and 43.2% indicated trouble falling asleep at night (>30 minutes). Only 12.5% of participants reported getting 7 or more hours of sleep per night, but most (69.3%) obtained 6–7 hours of sleep per night. On average, participants reported getting into bed at 10:10 p.m. and waking up at 7:30 a.m. Only about one-third of participants (30.2%) indicated having good sleep efficiency (≥85%). Most of the cohort had not used any sleep medication in the past month (90.6%) and reported no/low levels of sleep disturbances (77.6%) and no/low levels of daytime dysfunction (57.9%).

Table 3.2 Sleep quality in young adults based on the components of the PSQI (*n* = 192).

PSQI Sleep Quality Components	*n* (%)
Global PSQI score and overall rating	
Good (global score < 5)	27 (14.1)
Poor (global score ≥ 5)	165 (85.9)
Subjective sleep quality	
Very good	14 (7.3)
Fairly good	110 (57.3)
Fairly bad	60 (31.3)
Very bad	8 (4.2)
Sleep latency	
<15 minutes	31 (16.1)
16-30 minutes	78 (40.6)
31-60 minutes	49 (25.5)
>60 minutes	34 (17.7)
Sleep duration	
>7 hours	24 (12.5)
6-7 hours	133 (69.3)
5-6 hours	32 (16.7)
<5 hours	3 (1.6)
Habitual sleep efficiency	
≥85%	58 (30.2)
75-84%	60 (31.3)
65-74%	52 (27.1)
≤65%	22 (11.5)
Sleep disturbances	
No sleep disturbance	7 (3.6)
Low sleep disturbance	142 (74.0)
Medium sleep disturbance	39 (20.3)
High sleep disturbance	4 (2.1)
Use of sleep medication	
Not during the past month	174 (90.6)
Less than once a week	12 (6.3)
Once or twice a week	3 (1.6)
Three or more times a week	3 (1.6)
Daytime dysfunction	
No effect on daily work	17 (8.9)
Low effect on daily work	94 (49.0)
Medium effect on daily work	68 (35.4)
High effect on daily work	13 (6.8)

3.4.5 Association Between Caffeine Consumption and Sleep Quality

Differences in Total Daily Caffeine Consumption Between Good and Poor Sleepers

Total daily caffeine consumption was non-significantly higher for poor sleepers than good sleepers, 143.1 [81.6 – 217.7] vs. 118.9 [65.1 – 205.3] mg·day^{-1}, respectively (p = 0.452; Figure 3.4). For the various caffeine sources, there were no differences in intake according to sleep quality (p >0.05; refer to Appendix F, Table F.2).

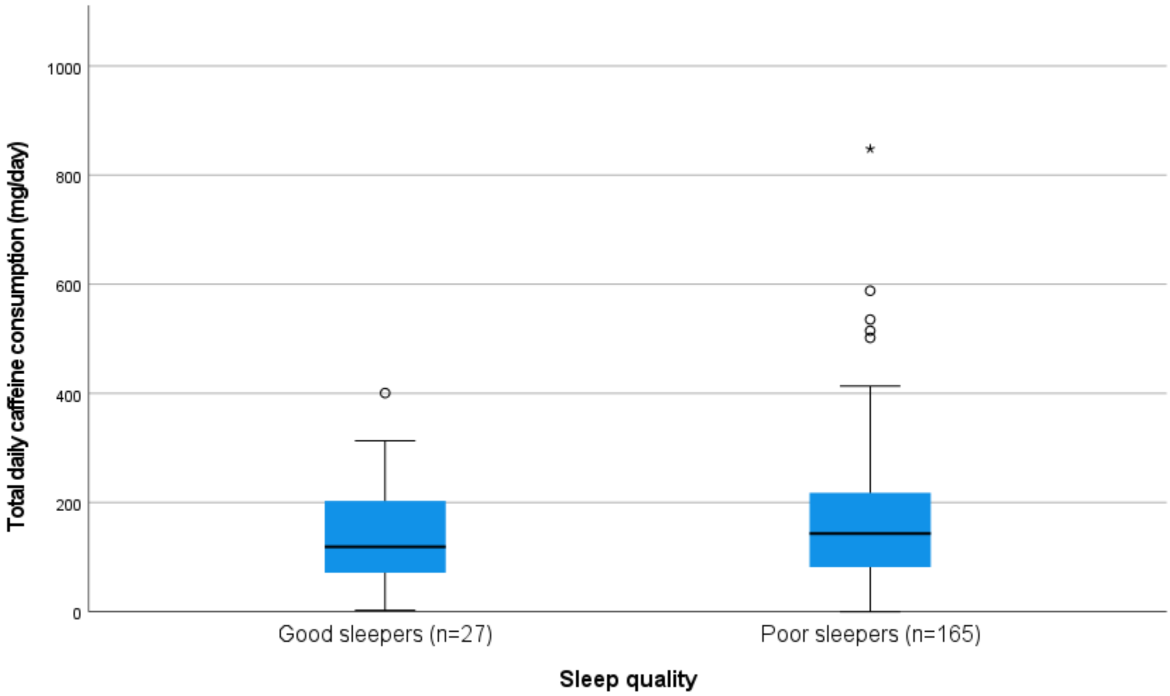


Figure 3.5 Total caffeine intake according to sleep quality (n = 192).

Values more than 1.5 IQR from the end of the box are labelled as outliers (o).
Values more than 3 IQR are labelled as extreme outliers, denoted by asterisks (*).

Relationship Between Total Daily Caffeine Consumption and PSQI Global Score

There was no significant correlation between total daily caffeine consumption and PSQI global score (*r* = 0.037*, p* = 0.614; Figure 3.5) or any of the PSQI sleep components (sleep latency, duration, efficiency, disturbances, use of sleep medication, daytime dysfunction, or perceived sleep quality; *p* >0.05). Participants' experiences with sleep disturbances are outlined in Appendix F, Figure F.4.

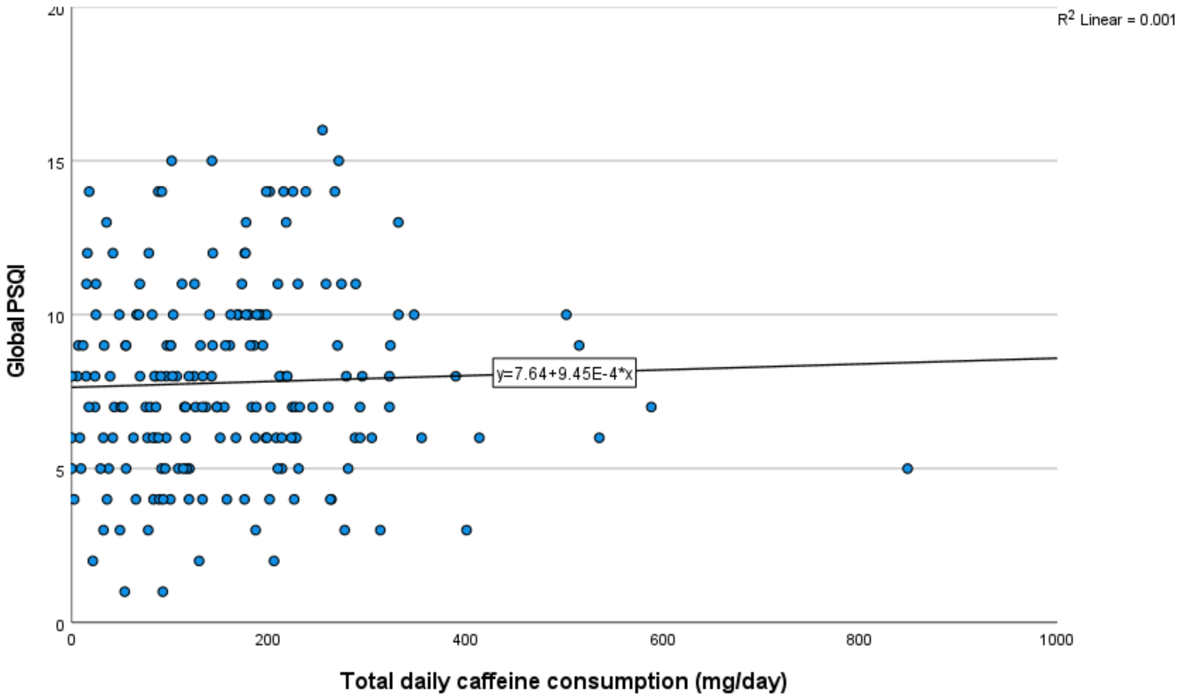


Figure 3.6 Scatterplot showing the relationship between total daily caffeine consumption (mg·day^{-1}) and PSQI global score (*n* = 192).

Each blue circle represents a study participant aligning with their respective total daily caffeine intake (X-axis) and PSQI global score (Y-axis).

PSQI component scores were compared between caffeine consumer groups. There were no statistically significant differences in total and PSQI component scores between low and moderate-to-high caffeine consumers, with the exception of the usage of sleep medication. Compared to low caffeine consumers (0.00 ± 0.00), those who consumed moderate to high amounts of caffeine (0.19 ± 0.57) reported using sleep medication more frequently in the previous month (*p* = 0.009).

3.4.6 Predictors of Sleep Quality

Predictors of sleep quality were assessed using a binary logistic regression model and summarised in Table 3.6. No association was found between caffeine consumption level (low versus moderate-to-high caffeine consumption) and sleep quality (p = 0.598). The only significant predictor of sleep quality in the model was employment status. Compared to working young adults, the odds of experiencing poor sleep quality were increased for both students with employment [90 vs 75%, OR = 3.07 (1.02 – 9.25)] and without employment [91 vs. 75%, OR = 3.52, 95% CI (1.32 – 9.42)]. Smoking status was not a significant predictor of sleep quality in this cohort (p >0.05).

Table 3.3 Predictors of sleep quality (*n* = 188¶).

	Good sleep quality n (%)	Poor sleep quality n (%)	Univariate OR (95% CI)	Multivariate adjusted† OR (95% CI)
Caffeine consumption level				
Low	8 (16.3)	41 (83.7)	Reference	Reference
Moderate to high	18 (12.9)	121 (87.1)	1.31 (0.53 – 3.24)	1.66 (0.63 – 4.34)
Employment status				
Employed (full- or part-time)	14 (25.0)	42 (75.0)	Reference	Reference
Students without employment	7 (8.6)	74 (91.4)	3.52 (1.32 – 9.42)	3.94 (1.42 – 10.94)
Students with employment	5 (9.8)	46 (90.2)	3.07 (1.02 – 9.25)	3.11 (1.02 – 9.52)
Smoking status				
Non-smoker	24 (14.8)	138 (85.2)	Reference	Reference
Smoker	2 (7.7)	24 (92.3)	2.09 (0.46 – 9.41)	1.83 (0.39 – 8.55)

Abbreviations: OR = odds ratio, CI = confidence interval.
OR >1 indicates an increased likelihood of poor sleep quality and OR <1 indicates decreased likelihood of poor sleep quality. The base value against which variable groups are compared is noted where the word “Reference” is used.
†Caffeine consumption, employment status, and smoking status were included in the model.
¶Total *n* = 188 (*n* = 4 participants identified as unemployed and were removed from the analysis).

3.5 Discussion

This cross-sectional study examined caffeine consumption habits and sleep quality of New Zealand young adults (aged 18–25 years). We sought to determine the degree to which poor sleep quality affected this otherwise healthy population and whether there were any correlations between caffeine use and poor sleep quality.

The majority (98.6%) of the study cohort reported consuming caffeine from one or more sources, with chocolate, coffee, tea and kola drinks being the most popular choices. Participants' median daily caffeine consumption was 159.6 $mg \cdot day^{-1}$, which is similar to the average daily intake (169 $mg \cdot day^{-1}$) among the 19 to 30-year-old age group reported in the New Zealand 2008/9 Adult Nutrition Survey (University of Otago and Ministry of Health, 2011). Our findings indicate that young adults' caffeine consumption has not changed significantly over the past decade and that New Zealanders (aged 18–25) have relatively moderate caffeine intakes when compared to estimates (155 to 850 $mg \cdot day^{-1}$) for the young adult population abroad (McIlvain et al., 2011; Riera-Sampol et al., 2022). Consistent with national data (University of Otago and Ministry of Health, 2011), coffee contributed the most to total daily caffeine consumption (median daily intake of 84.0 $mg \cdot day^{-1}$) compared to other popular sources such as chocolate, tea and kola drinks. This is not surprising given that these different sources contain significantly less caffeine than coffee (refer to Appendix E.2). A small proportion (4%) of individuals exceeded the recommended safe upper limit for daily consumption (≥400 $mg \cdot day^{-1}$), with the highest recorded intake being 848.2 $mg \cdot day^{-1}$. Education on the importance of sleep and the possible detrimental effects of caffeine consumption on sleep may be needed, specifically among university students with high caffeine intakes.

This study found that 86% of participants experienced poor sleep quality, which is a major concern given that this problem had not previously been recognised in this demographic. Our results highlight that the prevalence of poor sleep quality among New Zealand young adults is at the higher end of the range (estimated to be between 38–87%) found in overseas research (see Table 2.1). Future research should examine the elements particular to the New Zealand setting further because it is well known that sociodemographic and cultural factors substantially impact people's sleep health (Knutson, 2013). It should be noted that the skewed gender composition (85% females) in the current sample may have played a role in the high incidence of poor sleep quality found. Previous studies have shown that females are more likely than males to experience sleep problems (Lindberg et al., 1997; Oginska & Pokorski, 2006), such as difficulty maintaining sleep, as well as reporting poorer sleep quality, increased daytime sleepiness and waking feeling exhausted and unrested (Fatima et al., 2016; Madrid-Valero et al., 2017; Tang et al., 2017).

This study was carried out during the COVID-19 pandemic, and research has demonstrated COVID's adverse effects on sleep globally (see Neculicioui et al., (2022) for a review). One Canadian study (Ramos Socarras et al., 2021) found that young adults (aged 18–25) reported increased sleep problems following lockdown restrictions, including greater difficulty falling asleep, increased nocturnal and early morning awakenings, and nightmares. Similarly, a New Zealand study (Gibson et al., 2022) found that 45% of adults (aged 20–85) claimed their sleep quality had worsened following the country's first lockdown in 2020. Less social interaction, physical inactivity and limited sunlight exposure (Gibson et al., 2022) were key contributing factors consistent with the body of research, emphasising the significance of social and environmental factors for sleep health (Hale et al., 2015). Thus, our study's findings may have been impacted, at least partly, by the pandemic's disruptions to personal and social routines.

Irrespective of employment status, students were considerably more likely than workers to have poor sleep quality. These findings are consistent with the plethora of studies showing the high prevalence of poor sleep quality among university populations (Aldhawyan et al., 2020; Becker et al., 2018a; Di Benedetto et al., 2020). However, the current study is unique in that it is one of the first to examine sleep quality among young adults in various contexts beyond the academic setting (e.g. students with employment, students without employment and workers). University timetables can have variable start and finish times around which students must fit in social, study and other commitments, in contrast to people who work professions that usually have regular hours (i.e., a 9 to 5 schedule). Variable timetables may be one of the key reasons behind students' irregular sleep-wake schedules, especially during periods of high demand, such as examinations or when assignment deadlines are approaching (Ahrberg et al., 2012; Zunhammer et al., 2014).

The majority of study participants (88%) reported getting less than the minimum 7 hours of sleep per night that is advised for young adults (aged 18–25) to achieve optimal health and well-being (Hirshkowitz et al., 2015; Watson et al., 2015). A study (Peltzer & Pengpid, 2016) examining sleep duration in 19,417 university students (aged 16–30) from 26 countries reported that more than half the population (61%) obtained an adequate amount of sleep (>7 hours). Despite the somewhat broader age range in the study by Peltzer and Pengpid (2016), it is alarming that a significantly higher percentage of young adults in New Zealand are not meeting sleep recommendations. Although ethnic differences were not analysed in the current investigation, previous national research has highlighted that Māori (Paine & Gander, 2016) and Pacific peoples (Lee & Sibley, 2019) are at higher risk of short sleep. Therefore, future studies should investigate if such patterns also exist in the young adult population.

Around 43% of the cohort in the current study reported having trouble falling asleep (>30 minutes), and 22% said they had moderate to severe sleep disturbances. It is important to note that when individuals were questioned further about the causes of this, stress and anxiety were frequently mentioned. This is in line with research that demonstrates psychological distress (e.g., depression, stress and anxiety symptoms) is a significant predictor of poor sleep quality in young adults (Almojali et al., 2017; Carpi et al., 2022; Lund et al., 2010). The current data suggests that future initiatives to improve sleep in this demographic should concentrate on techniques to manage stress and anxiety.

Research on the relationship between habitual caffeine consumption and sleep quality has been inconclusive (Table 2.2), and the results from this study corresponded with the findings of many others that found no correlation. However, similar to results from one Australian study (Watson et al., 2016), this study found that poor sleepers were more likely to have higher caffeine intakes on average than good sleepers. Researchers postulate that most people adjust their caffeine consumption based on their subjective (positive or negative) experiences with the stimulant (Nehlig, 2018; Stern et al., 1989). Therefore, our findings may more closely reflect consumer choice rather than provide evidence of caffeine's impact on sleep. The current sample likely includes individuals who are aware of how caffeine affects their sleep and therefore choose to limit or control their intake, as well as those who are impacted but still choose to consume caffeine anyway. Further research is still required to determine how habitual caffeine use affects sleep quality in non-laboratory environments.

In this study, moderate-to-high caffeine consumers reported being unable to sleep more often than low caffeine consumers (Appendix F, "Side Effects of Caffeine Consumption"). People may not recognise the connection between caffeine use and sleep if they can still fall and stay asleep at night. However, if a person's sleep pressure exceeds their circadian drive to remain awake, they will always be able to fall asleep (Borbély et al., 2016). It is also feasible that caffeine use in this cohort had indirect effects on sleep that may have been overlooked. For example, three of the most commonly reported sleep disturbances among study participants were waking up in the middle of the night or early morning (51.5%), being unable to fall asleep within 30 minutes (44.8%) and having to get up to use the bathroom (36.4%) (Appendix F, Figure F.4). It is widely known that caffeine delays sleep onset and increases the number of night-time awakenings (Březinová, 1974; Karacan et al., 1976) and has a mild diuretic effect (Maughan & Griffin, 2003). Thus, more studies are required to fully comprehend how habitual caffeine consumption may impact directly and/or indirectly on sleep quality.

Participants' PSQI global scores showed a large spread (ranging from 1 to 16) even though the majority of respondents (71%) were classified as moderate caffeine consumers (consuming 80–400 mg·day^{-1}). This illustrates the significant heterogeneity in sleep quality in our sample (Figure 3.5) and highlights the fact that sleep can be influenced by a variety of factors, from biological (chronotype, age, gender), to social (environment, income level, marital status), to lifestyle behaviours (diet and physical activity) (Knutson, 2013; Ohida et al., 2001). Further research is necessary to determine what other factors are affecting young adults' sleep quality because the findings of this study suggest that caffeine use was not a significant driver of sleep quality.

The findings from this study should be interpreted in the context of the study's design and limitations. Firstly, using a convenience sample may have introduced volunteer bias. People who were more attentive to the researched domains (i.e., poor sleep quality) may have been more likely to participate, which could have impacted the outcomes. Secondly, the nature of the subjective data may be influenced by method, memory recall and social desirability biases. Thirdly, a technical error with the PSQI questionnaire prevented us from reliably estimating sleep efficiency for a large number of respondents (n = 118), and the smaller dataset as a consequence decreased the strength of the results. The findings may also not be generalisable to the broader population due to unbalanced gender and ethnic distributions and the selection of healthy individuals. However, the study also had several advantages. Firstly, anonymous and validated (CaffCo and PSQI) questionnaires helped mitigate concerns about the self-reported data. Secondly, CaffCo improved accuracy by including various caffeine sources and being more precise about serving sizes than other methods of calculating caffeine consumption. Finally, the inclusion of workers and university students enhances the representation of the various life circumstances of this demographic. Future studies would benefit from implementing a multi-method (e.g., daily sleep diaries, wrist-actigraphy) and longitudinal design to determine the directional routes of the relationship between caffeine consumption and sleep using a larger and more representative sample.

3.6 Conclusion

Poor sleep quality is widespread (86%) among young adults in New Zealand, which prior to this study, was a previously unreported problem. Most participants consumed caffeine from one or more sources (98.6%), with coffee being the main contributor to total daily caffeine consumption. Participants' median daily caffeine intake was 159.6 $mg \cdot day^{-1}$, which is equivalent to about two cups of instant coffee per day. No significant association was found between caffeine consumption and sleep quality. Students, independent of employment status, had a three-fold increased risk of poor sleep quality compared to working young adults. More research is required to elucidate the causes of poor sleep quality in young New Zealand adults.

CHAPTER 4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary of Results/Main Findings

To the author's knowledge, this is the first population study to examine the relationship between habitual caffeine consumption and sleep quality in New Zealand young adults.

The study's first objective was to determine the prevalence of poor sleep quality among young New Zealand adults. We found that the majority (85.9%) of young adults suffered from poor sleep quality (PSQI global score <5), and only 1 in 8 (12.5%) obtained the recommended seven or more hours of sleep every night. These results have identified a previously unreported problem: young adults in New Zealand are not achieving sufficient sleep; either in quantity or quality. Furthermore, the study showed that students, independent of employment status, were more likely to have poor sleep quality than workers. Young adulthood is a crucial period when established, or altered behaviour can significantly affect later life (Stroud et al., 2015); therefore, it is important to identify concerns early on before they manifest into serious problems. Further research on young adults' sleep health is required, particularly on gender and ethnic differences and the potential causes of poor sleep quality. Identifying what contributes to poor sleep quality and who is most affected can help develop targeted interventions (e.g., education programmes).

The second objective was to explore the association between caffeine consumption habits and subjective sleep quality. Caffeine consumption among young adults ranged from 0 to 848 mg·day^{-1}, with an average intake of 160 mg·day^{-1}. A small proportion of participants (4%) consumed more caffeine than was considered safe (>400 mg·day^{-1}; Nawrot et al., 2003), indicating that further education may be needed to encourage better consumer decisions. There was no significant correlation between total daily caffeine consumption and sleep quality. The distribution of PSQI global scores ranged from 1 to 16 and showed a wide spectrum of sleep quality from very good to extremely poor. Given most participants (71%) were classified as moderate caffeine consumers (80–400 mg·day^{-1}), this range of scores suggests that caffeine consumption was not a significant factor in determining sleep quality in the current study. Therefore, investigating other biological (e.g.

chronotype, gender, genes), lifestyle (e.g., diet, physical activity, stress) or social factors (e.g., social support, income level, environment) known to influence sleep quality (Knutson, 2013; Ohida et al., 2001) may be worthwhile.

The final objective was to investigate whether there were any differences in caffeine intake between individuals with good sleep quality and those with poor sleep quality. Although the results were not statistically significant, the study found that poor sleepers tended to have higher caffeine intakes on average than good sleepers. Additionally, moderate-to-high caffeine consumers were more likely than their counterparts to report having problems falling asleep after consuming the stimulant. It is important to note that this study did not consider the timing of caffeine ingestion relative to initiating sleep; it merely measured the amount consumed. Therefore, our results may more closely reflect consumer choices as opposed to the actual effects of caffeine, which have been well documented in the laboratory setting (Carrier et al., 2007; Drake et al., 2013; Drapeau et al., 2006). It's possible that the young adults in our study are already aware of how caffeine affects their sleep and therefore manage their intake accordingly or that they habitually consume caffeine in a manner that has little to no noticeable impact on their sleep (i.e. early in the day). A larger study considering caffeine timing and dosage is needed to show caffeine's actual effects on sleep timing and quality.

4.2 Strengths

Three essential aspects of the current study set it apart from related earlier studies. Firstly, this study provides the first data on sleep quality among New Zealand young adults. Research conducted previously in this demographic showed that the estimated prevalence of poor sleep quality differs substantially between countries (refer to Table 2.1). It was crucial to determine the extent of the issue in our small but ethnically diverse nation, given that the New Zealand population may be subject to different sociodemographic and cultural influences. Prior sleep quality research in New Zealand has focused on particular aspects of sleep quality, e.g., nocturnal awakenings (Paine et al., 2005; Paine et al., 2019), feeling refreshed upon waking (Paine et al., 2005) and sleep satisfaction (Wilsmore et al., 2013). However, using the Pittsburgh Sleep Quality Index (PSQI) to measure sleep quality allowed us to compare our results to other international studies that had also employed the same tool. The PSQI was used in one other New Zealand study (Gibson et al., 2022), although this investigation included a considerably larger age range of participants (20–85 years) and was conducted to assess the effects of the COVID pandemic on sleep.

Secondly, previous research on young adults' sleep quality has primarily focused on university students (Becker et al., 2018a; Li et al., 2020; Lohsoonthorn et al., 2013), whereas this study included participants from a variety of life contexts (e.g., students with and without jobs, as well as those who were employed). The fact that university populations might frequently comprise individuals ranging from late teens to older adults is an important consideration. It is well recognised that sleep parameters change over the course of a person's life (Ohayon et al., 2004), and so too would lifestyle variables impacting sleep, such as sharing a bed with a partner or having a baby in the room. By defining young adulthood in our study as being between 18 and 25, we were able to mitigate these effects to some extent. Moreover, including workers and students in our sample may have helped to balance confounding factors distinctive to student lifestyles, such as varied class schedules.

Finally, utilising the previously validated CaffCo questionnaire ensured that the variety of caffeine sources reflective of the current New Zealand market were evaluated. A caffeine food frequency questionnaire has only been used in a small number of studies (Choi, 2020; Watson et al., 2016) examining the relationship between habitual caffeine use and sleep quality, even though it is well known that caffeine content can vary significantly between sources and products (Desbrow et al., 2019; McCusker et al., 2003; Reissig et al., 2009). Additionally, the use of CaffCo enhanced the accuracy in estimating participants' caffeine intakes by incorporating visual aids and serving size options in comparison to some earlier studies, which merely asked participants how many caffeinated beverages they consumed each day or week (Brick et al., 2010; Lemma et al., 2012; Lohsoonthorn et al., 2013).

4.3 Limitations

It is important to acknowledge the limitations of the current research. Firstly, using a convenience sample likely led to self-selection bias, with caffeine users and those more concerned with their sleep quality more inclined to participate. Additionally, method, memory recall and social desirability biases could have been introduced due to the self-report and retrospective design of the CaffCo and PSQI questionnaires. Given that some studies have found discrepancies between subjective (e.g., questionnaires and sleep diaries) and objective measurements (e.g., polysomnography and actigraphy) of sleep parameters (Hughes et al., 2018; Lauderdale et al., 2008; Trajanovic et al., 2007), our results, which were based on subjective ratings of sleep quality, should be interpreted with care. Self-report techniques are susceptible to both extremes of sleep misperception (Trajanovic et al., 2007), with larger discrepancies often exhibited among individuals who complain of insomnia (Edinger et al., 2000) or a sleep disturbance (Hughes et al., 2018). Research has shown that people are more likely to overreport sleep duration (Lauderdale et al., 2008), underestimate sleep efficiency (Hughes et al., 2018) and miscalculate sleep onset in either direction (Lockley et al., 1999). However, there is no clear agreement on the differences between subjective and objective data in the literature. Therefore, researchers and practitioners are advised to use objective and subjective assessments to reduce tool limitations and inconsistencies (Zhang & Zhao, 2008), particularly when identifying people who may need sleep treatment (Hughes et al., 2018).

The fact that a substantial proportion of participants (64% response rate) did not complete one or both questionnaires raises the possibility that some were discouraged by the survey's length (30–40 minutes). Additionally, due to a technical error with the PSQI questionnaire, we could not accurately estimate sleep efficiency for a large number of respondents (n = 118). This resulted in a smaller dataset and reduced the power of the study's findings. Moreover, variables known to impact sleep quality were not taken into account in this study, including psychological distress, alcohol consumption, physical activity and electronic device use before bed (see Wang & Bíró (2021) for a review), which may have confounded the results.

It is also important to note that this study was conducted during the COVID pandemic, which significantly elevated stress and anxiety for many people. Although data collection (May–August 2021) did not occur during a lockdown, covid-related stress may have adversely impacted people's sleep timing or quality. However, we could not explore the possible influence of COVID in our analyses because we did not record personal or context-specific COVID experiences (such as exposure to infection or feelings of isolation and loneliness). We also did not consider any additional stress factors that may have temporarily impacted the participants' sleep quality and/or caffeine intake, e.g., life events, student placements or project deadlines. However, efforts were made to avoid the final exam season, considering that prior research has shown sleep quality can change drastically during exam periods (Ahrberg et al., 2012; Zunhammer et al., 2014).

Finally, the generalisability of the study's findings to the broader population may be limited. We could not conduct gender analyses because of our sample's strong bias towards females (85% of participants). Furthermore, there was an insufficient representation of Māori and Pacific peoples in our dataset, though earlier research has shown that these groups are more likely than people of other ethnicities to experience short and poor-quality sleep (Paine & Gander, 2016; Paine et al., 2005). Shift workers and people with sleep problems were also not included in the sample; thus, results will not apply to these groups.

4.4 Use of Findings

This study presents previously unreported, novel insights about young adults' sleep quality in New Zealand. Because sleep is vital for health (Luyster et al., 2012), cognitive function (Walker, 2009), performance (Venter, 2012) and productivity (Swanson et al., 2011); our study's finding that young adults frequently experience insufficient (quantity and quality) sleep has significant implications for educational institutions and workplaces. Individuals may be putting themselves and others at risk without even realising it, simply by not recognising the importance of sleep and the consequences that result when they don't get enough. Young adults require more comprehensive sleep education, especially since some may not recognise the extent of the impairment in their functioning caused by a lack of sleep.

This study also provides the most recent data on caffeine intake levels and patterns among young adults in New Zealand, as opposed to earlier national data from the 2008/9 Adult Nutrition Survey, which is more than a decade old. Despite previous concerns that young adults are at increased risk of overconsuming (Bertasi et al., 2021; Reid et al., 2016) or even misusing caffeine (Ferré, 2013), the current study findings show that the majority of participants consumed moderate doses (80–400 mg day^{-1}), with only a small minority exceeding the safe upper limit (>400 mg day^{-1}). However, it would still be beneficial to promote increased caffeine education, particularly in sharing knowledge about the dose of caffeine in products and the extent to which this might vary, to help young adults make better-informed decisions about their intake.

In this study, moderate-to-high caffeine consumers were more likely to report greater difficulties falling asleep and experiencing poor sleep quality than low caffeine consumers. While caffeine is well known for its ability to improve cognition and performance, the general public needs to be made aware of its possible adverse effects, particularly on sleep. For example, prior research found that some young adults believed that caffeine could be used as a substitute for sleep (Lee et al., 2009). This highlights the need to promote high-quality education on sleep hygiene (or good sleep habit) practices, including elements that may affect sleep (e.g., cigarette smoking).

Young adulthood is a pivotal developmental stage, and actions taken at this time can have significant long-term effects later in adulthood (Stroud et al., 2015). Given the prevalence of short and poor-quality sleep in this cohort, more education is needed for young adults in order to raise public awareness of the issue and, perhaps more importantly, to prevent it from worsening and becoming a more serious concern in later life, e.g., sleep disorders. The results of this study indicate that students may need to be targeted since they are substantially more likely than workers to have poor sleep quality. Furthermore, it may be advantageous to begin educating young people earlier about healthy sleep hygiene practices (such as in primary and secondary school), so that students can enter university or their place of employment in an educated and informed position.

4.5 Future Directions/Recommendations

More research with larger sample sizes is required to corroborate our findings of the high prevalence of poor sleep quality found among young adults in this study. It would also be beneficial to conduct further study on the various sleep health dimensions (e.g., sleep timing, sleep efficiency), to provide a more complete understanding of what characterises and impacts young adults' sleep. This will also help give a clearer indication of where interventions are most needed. For instance, analysing the disparities between weekday and weekend sleep may identify cases of social jetlag; as a result, the focus would be on fostering appropriate sleep hygiene habits such as sleep regularity.

The relationship between habitual caffeine consumption and sleep quality was not significantly correlated. However, it still merits further investigation in light of trends that moderate-to-high caffeine consumers were more likely to experience poorer quality sleep and greater difficulty falling asleep than low caffeine consumers. Future studies may enhance our understanding of the relationship between caffeine and sleep and research could be improved by:

- Employing objective measurements such as polysomnography or actigraphy, alongside self-report questionnaires, as part of a multi-method approach to evaluate sleep. The availability of objective data may aid in minimising biases and enhance the accuracy of findings.
- Collecting information on the timing of caffeine use (e.g., using a prospective sleep diary), to enable further analysis of caffeine's effects on sleep as opposed to participant choices. For instance, comparing the effects on sleep when consumed in the morning or afternoon vs. evening.
- Exploring the role of chronotype concerning caffeine consumption, sleep timing and quality.
- Gathering more specific data on participant characteristics to reduce the possibility of confounding effects, such as sociodemographic factors (e.g., income, marital status), health and well-being (e.g., social support, mental health) and sleep-related lifestyle behaviours (e.g., alcohol consumption, physical activity).

- Larger and more representative samples with an equal gender distribution and sufficient numbers of Māori/Pacifica participants to conduct further analyses on gender and ethnic differences.
- Further investigation into participants' knowledge of caffeine and its effects on sleep, such as the safe upper limit for caffeine intake. This might help determine what participants know and don't know, thus indicating where education should be concentrated.

Finally, further investigation is still needed to determine the causes of insufficient (quantity and quality) sleep among young adults in this country. Why, in particular, are there significant discrepancies between students and people with jobs? The numerous life circumstances we addressed in this study (e.g., students with and without jobs, part- or full-time employment) should be replicated in future research. This is the first study to provide information on sleep quality among young adults in New Zealand, underscoring the need for greater research focus on this subject.

REFERENCES

Abel, T., Havekes, R., Saletin, J. M., & Walker, M. P. (2013). Sleep, plasticity and memory from molecules to whole-brain networks. *Current Biology*, *23*(17), R774–R788. https://doi.org/10.1016/j.cub.2013.07.025

Adan, A. (1994). Chronotype and personality factors in the daily consumption of alcohol and psychostimulants. *Addiction*, *89*(4), 455-462. https://doi.org/10.1111/j.1360-0443.1994.tb00926.x

Adan, A., Archer, S. N., Hidalgo, M. P., Di Milia, L., Natale, V., & Randler, C. (2012). Circadian typology: A comprehensive review. *Chronobiology International*, *29*(9), 1153–1175. https://doi.org/10.3109/07420528.2012.719971

Aepli, A., Kurth, S., Tesler, N., Jenni, O. G., & Huber, R. (2015). Caffeine consuming children and adolescents show altered sleep behavior and deep sleep. *Brain Sciences*, *5*(4), 441-455. https://doi.org/10.3390/brainsci5040441

Ahmed, S., Khan, S., Hsan, K., Sen, L. C., Yunus, F. M., & Griffiths, M. D. (2020). Factors affecting sleep quality among the university students in Bangladesh: A cross-sectional structured interview study. *Sleep Vigilance*, *4*(177-184). https://doi.org/10.1007/s41782-020-00106-4

Ahrberg, K., Dresler, M., Niedermaier, S., Steiger, A., & Genzel, L. (2012). The interaction between sleep quality and academic performance. *Journal of Psychiatric Research*, *46*(12), 1618-1622. https://doi.org/10.1016/j.jpsychires.2012.09.008

Al-Kandari, S., Alsalem, A., Al-Mutairi, S., Al-Lumai, D., Dawoud, A., & Moussa, M. (2017). Association between sleep hygiene awareness and practice with sleep quality among Kuwait University students. *Sleep Health*, *3*(5), 342-347. https://doi.org/10.1016/j.sleh.2017.06.004

Alapin, I., Fichten, C. S., Libman, E., Creti, L., Bailes, S., & Wright, J. (2000). How is good and poor sleep in older adults and college students related to daytime sleepiness, fatigue, and ability to concentrate? *Journal of Psychosomatic Research*, *49*(5), 381-390. https://doi.org/10.1016/s0022-3999(00)00194-x

Aldhawyan, A. F., Alfaraj, A. A., Elyahia, S. A., Alshehri, S. Z., & Alghamdi, A. A. (2020). Determinants of subjective poor sleep quality in social media users among freshman college students. *Nature and Science of Sleep*, *12*, 279-288. https://doi.org/10.2147/NSS.S243411

Ali, A., O'Donnell, J. M., Starck, C., & Rutherfurd-Markwick, K. J. (2015). The effect of caffeine ingestion during evening exercise on subsequent sleep quality in females. *International Journal of Sports Medicine*, *36*(6), 433-439. https://doi.org/10.1055/s-0034-1398580

Alkhatatbeh, M. J., Abdul-Razzak, K. K., & Khwaileh, H. N. (2020). Poor sleep quality among young adults: The role of anxiety, depression, musculoskeletal pain, and low dietary calcium intake. *Perspectives in Psychiatric Care*, *57*(1). https://doi.org/10.1111/ppc.12533

Almojali, A. I., Almalki, S. A., Alothman, A. S., Masuadi, E. M., & Alaqeel, M. K. (2017). The prevalence and association of stress with sleep quality among medical students. *Journal of Epidemiology and Global Health*, *7*(3), 169-174. https://doi.org/10.1016/j.jegh.2017.04.005.

Almoosawi, S., Vingeliene, S., Gachon, F., Voortman, T., Palla, L., Johnston, J. D., . . . Karagounis, L. G. (2019). Chronotype: Implications for epidemiologic studies on chrono-nutrition and cardiometabolic health. . *Advances in Nutrition*, *10*(1), 30-42. https://doi.org/10.1093/advances/nmy070.

Altun, I., Cınar, N., & Dede, C. (2012). The contributing factors to poor sleep experiences in according to the university students: A cross-sectional study. *Journal of Research in Medical Sciences*, *17*(6), 557-561.

Amici, R., Bastianini, S., Berteotti, C., Cerri, M., Del Vecchio, F., Lo Martire, V., . . . Zoccoli, G. (2014). Sleep and bodily functions: The physiological interplay between body homeostasis and sleep homeostasis. *Archives Italiennes de Biologie*, *152*(2-3), 66-78. https://doi.org/10.12871/000298292014232.

Anderson, C., & Horne, J. A. (2006). Sleepiness enhances distraction during a monotonous task. *Sleep*, *29*(4), 573–576. https://doi.org/10.1093/sleep/29.4.573

Andreatta, G., & Allen, C. N. (2021). Circadian rhythm: How neurons adjust to diurnality. *eLife*, *10*, e74704. https://doi.org/10.7554/eLife.74704

Archer, S. N., Robilliard, D. L., Skene, D. J., Smits, M., Williams, A., Arendt, J., & von Schantz, M. (2003). A length polymorphism in the circadian clock gene Per3 is linked to delayed sleep phase syndrome and extreme diurnal preference. *Sleep*, *26*(4), 413-415. https://doi.org/10.1093/sleep/26.4.413

Assefa, S. Z., Diaz-Abad, M., Wickwire E.M., & Scharf, S. M. (2015). The functions of sleep. *AIMS Neuroscience*, *2*(3), 155-171. https://doi.org/10.3934/Neuroscience.2015.3.155

Attila, S., & Çakir, B. (2011). Energy-drink consumption in college students and associated factors. *Nutrition*, *27*(3), 316-322. https://doi.org/10.1016/j.nut.2010.02.008

Australia New Zealand Food Authority Expert Working Group on Caffeine. (2000). *The Safety Aspects of Dietary Caffeine*. Food Standards Australia New Zealand.

Ayas, N. T., White, D. P., Manson, J. E., Stampfer, M. J., Speizer, F. E., Malhotra, A., & Hu, F. B. (2003). A prospective study of sleep duration and coronary heart disease in women. *Archives of Internal Medicine.*, *163*(2), 205-209. https://doi.org/10.1001/archinte.163.2.205.

Backhaus, J., Junghanns, K., Broocks, A., Riemann, D., & Hohagen, F. (2002). Test-retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. *Journal of Psychosomatic Research*, *53*(3), 737-740. https://doi.org/10.1016/s0022-3999(02)00330-6

Baglioni, C., Nanovska, S., Regen, W., Spiegelhalder, K., Feige, B., Nissen, C., . . . Riemann, D. (2016). Sleep and mental disorders: A meta-analysis of polysomnographic research. *Psychological Bulletin*, *142*(9), 969-990. https://doi.org/10.1037/bul0000053.

Banks, S., & Dinges, D. F. (2007). Behavioural and physiological consequences of sleep restriction. *Journal of Clinical Sleep Medicine*, *3*(5), 519-528.

Barone, J. J., & Roberts, H. R. (1996). Caffeine consumption. *Food and Chemical Toxicology*, *34*(1), 119-129. https://doi.org/10.1016/0278-6915(95)00093-3

Basheer, R., Strecker, R. E., Thakkar, M. M., & McCarley, R. W. (2004). Adenosine and sleep-wake regulation. *Progress in neurobiology*, *73*(6), 379–396. https://doi.org/10.1016/j.pneurobio.2004.06.004

Basner, M., & Dinges, D. F. (2018). Sleep duration in the United States 2003-2016: First signs of success in the fight against sleep deficiency? *Sleep*, *41*(4). https://doi.org/10.1093/sleep/zsy012

Basner, M., Fomberstein, K. M., Razavi, F. M., Banks, S., William, J. H., Rosa, R. R., & Dinges, D. F. (2007). American time use survey: Sleep time and its relationship to waking activities. . *30*(9), 1085-1095. https://doi.org/10.1093/sleep/30.9.1085

Batten, R., Liddiard, K., Raynor, A. J., Brown, C. A., & Stanley, M. (2020). Cross-sectional survey of sleep practices of Australian university students. *Nature and Science of Sleep*, *12*, 39-48. https://doi.org/10.2147/NSS.S221472

Becker, S. P., Dvorsky, M. R., Holdaway, A. S., & Luebbe, A. M. (2018b). Sleep problems and suicidal behaviors in college students. *Journal of Psychiatric Research*, *99*, 122-128. https://doi.org/10.1016/j.jpsychires.2018.01.009

Becker, S. P., Jarrett, M. A., Luebbe, A. M., Garner, A. A., Burns, G. L., & Kofler, M. J. (2018a). Sleep in a large, multi-university sample of college students: Sleep problem prevalence, sex differences, and mental health correlates. *Sleep Health*, *4*(2), 174-181. https://doi.org/10.1016/j.sleh.2018.01.001

Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond,, D. P., R., M. B.,, & Balkin, T. J. (2003). Patterns of performance deradation and resortation during sleep restriction and subsequent recovery: A sleep dose-response study. *Journal of sleep research*, *12*(1), 1-12. https://doi.org/10.1046/j.1365-2869.2003.00337.x

Benowitz, N. L. (1990). Clinical pharmacology of caffeine. *Annual review of medicine*, *41*, 277-288. https://doi.org/10.1146/annurev.me.41.020190.001425

Bertasi, R., Humeda, Y., Bertasi, T., Zins, Z., Kimsey, J., & Pujalte, G. (2021). Caffeine Intake and Mental Health in College Students. *Cureus*, *13*(4), e14313. https://doi.org/10.7759/cureus.14313

Besedovsky, L., Lange, T., & Born, J. (2012). Sleep and immune function. *European Journal of Physiology*, *463*(1), 121-137. https://doi.org/10.1007/s00424-011-1044-0

Bin, Y. S. (2016). Is sleep quality more important than sleep duration for public health? *Sleep*, *39*(9), 1629-1630. https://doi.org/10.5665/sleep.6078

Bin, Y. S., Marshall, N. S., & Glozier, N. (2013). Sleeping at the limits: The changing prevalence of short and long sleep durations in 10 countries. *American Journal of Epidemiology*, *177*(8), 826-833. https://doi.org/10.1093/aje/kws308

Bjorness, T. E., & Greene, R. W. (2009). Adenosine and sleep. *Current Neuropharmacology*, *7*(3), 238-245. https://doi.org/10.2174/157015909789152182

Blackwell, T., Redline, S., Ancoli-Israel, S., Schneider, J. L., Surovec, S., Johnson, N. L., . . . Study of Osteoporotic Fractures Research Group. (2008). Comparison of sleep parameters from actigraphy and polysomnography in older women: the SOF study. *Sleep*, *31*(2), 283-291. https://doi.org/10.1093/sleep/31.2.283

Blanchard, J., & Sawers, S. J. (1983). The absolute bioavailability of caffeine in man. *European Journal of Cinical Pharmacology*, *24*(1), 93-98. https://doi.org/10.1007/BF00613933

Bodur, M., Baspinar, B., & Özçelik, A. Ö. (2021). Do sleep quality and caffeine consumption mediate the relationship between late chronotype and body mass index?. *Food and Function*, *12*(13), 5959-5966. https://doi.org/10.1039/d0fo03435e

Borbély, A. A. (1982). A two process model of sleep regulation. *Human Neurobiology*, *1*(3), 195-204.

Borbély, A. A., Baumann, F., Brandeis, D., Strauch, I., & Lehmann, D. (1981). Sleep deprivation: Effect on sleep stages and EEG power density in man. . *Electroencephalography and Clinical Neurophysiology*, *51*(5), 483–495. https://doi.org/10.1016/0013-4694(81)90225-x

Borbély, A. A., Daan, S., Wirz-Justice, A., & Deboer, T. (2016). The two-process model of sleep regulation: A reappraisal. *Journal of sleep research*, *25*(2), 131-143. https://doi.org/10.1111/jsr.12371

Boulenger, J. P., Patel, J., Post, R. M., Parma, A. M., & Marangos, P. J. (1983). Chronic caffeine consumption increases the number of brain adenosine receptors. *Life Sciences*, *32*(10), 1135-1142. https://doi.org/10.1016/0024-3205(83)90119-4

Březinová, V. (1974). Effect of caffeine on sleep: EEG study in late middle age people. *British Journal of Clinical Pharmacology*, *1*(3), 203-208. https://doi.org/10.1111/j.1365-2125.1974.tb00237.x
Brick, C. A., Seely, D. L., & Palermo, T. M. (2010). Association between sleep hygiene and sleep quality in medical students. *Behavioral Sleep Medicine*, *8*(2), 113-121. https://doi.org/10.1080/15402001003622925
Budney, A. J., & Edmond, J. A. (2014). Caffeine addiction? Caffeine for youth? Time to act! *Addiction*, *109*(11), 1771-1772. https://doi.org/10.1111/add.12594
Bunker, M. L., & McWilliams, M. (1979). Caffeine content of common beverages. *Journal of the American Dietetic Association*, *74*(1), 28-32.
Buysse, D. J. (2014). Sleep health: Can we define it? Does it matter? *Sleep*, *37*(1), 9-17. https://doi.org/10.5665/sleep.3298
Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1988). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193-213. https://doi.org/10.1016/0165-1781(89)90047-4
Calamaro, C. J., Mason, T. B., & Ratcliffe, S. J. (2009). Adolescents living the 24/7 lifestyle: Effects of caffeine and technology on sleep duration and daytime functioning. *Pediatrics*, *123*(6), e1005-e1010. https://doi.org/10.1542/peds.2008-3641.
Cappuccio, F. P., D'Elia, L., Strazzullo, P., & Miller, M. A. (2010). Sleep duration and all-cause mortality: A systematic review and meta-analysis of prospective studies. *Sleep*, *33*(5), 585-592. https://doi.org/10.1093/sleep/33.5.585
Cappuccio, F. P., D'Elia, L., Strazzullo, P., & Miller, M. A. (2010). Quantity and quality of sleep and incidence of type 2 diabetes: A systematic review and meta-analysis. *Diabetes Care*, *33*(2), 414-420. https://doi.org/10.2337/dc09-1124
Cappuccio, F. P., Taggart, F. M., Kandala, N. B., Currie, A., Peile, E., Stranges, S., & Miller, M. A. (2008). Meta-analysis of short sleep duration and obesity in children and adults. *Sleep*, *31*(5), 619-626. https://doi.org/10.1093/sleep/31.5.619
Carpenter, J. S., & Andrykowski, M. A. (1998). Psychometric evaluation of the Pittsburgh Sleep Quality Index. *Journal of Psychosomatic Research*, *45*(1), 5-13. https://doi.org/10.1016/s0022-3999(97)00298-5
Carpi, M., Cianfarani, C., & Vestri, A. (2022). Sleep quality and its associations with physical and mental health-related quality of life among university students: A cross-sectional study. . *International Journal of Environmental Research and Public Health*, *19*(5), 2874. https://doi.org/10.3390/ijerph19052874
Carrier, J., Fernandez-Bolanos, M., Robillard, R., Dumont, M., Paquet, J., Selmaoui, B., & Filipini, D. (2007). Effects of caffeine are more marked on daytime recovery sleep than on nocturnal sleep. *Neuropsychopharmacology*, *32*(4), 964-972. https://doi.org/10.1038/sj.npp.1301198
Carskadon, M. A. (2011). Sleep in adolescents: The perfect storm. *Pediatric Clinics of North America*, *58*(3), 637-647. https://doi.org/10.1016/j.pcl.2011.03.003
Carskadon, M. A., & Dement, W. (2005). Normal Human Sleep: An Overview. In Kryger M.H., Roth T., & Dement W.C. (Eds.), *Principles and Practices of Sleep Medicine. 4th ed.* (pp. 12-23). Elsevier Saunders.
Carskadon, M. A., & Dement, W. C. (2011). Monitoring and staging human sleep. In M. H. Kryger, T. Roth, & W. C. Dement (Eds.), *Principles and Practice of Sleep Medicine, 5th edition.* (pp. 16-26). St Louis: Elsevier Saunders.
Carskadon, M. A., Vieira, C., & Acebo, C. (1993). Association between puberty and delayed phase preference. *Sleep*, *16*(3), 258-262. https://doi.org/10.1093/sleep/16.3.258

Champlin, S. E., Pasch, K. E., & Perry, C. L. (2016). Is the consumption of energy drinks associated with academic achievement among college students? *The Journal of Primary Prevention*, *37*(4), 345-359. https://doi.org/10.1007/s10935-016-0437-4

Chandola, T., Ferrie, J. E., Perski, A., Akbaraly, T., & Marmot, M. G. (2010). The effect of short sleep duration on coronary heart disease risk is greatest among those with sleep disturbance: a prospective study. *Sleep*, *33*(6), 739-744. https://doi.org/10.1093/sleep/33.6.739

Chen, W.-L., & Chen, J.-H. (2019). Consequences of inadequate sleep during the college years: Sleep deprivation, grade point average, and college graduation. *Preventive Medicine*, *124*, 23-28. https://doi.org/10.1016/j.ypmed.2019.04.017

Childs, E., Hohoff, C., Deckert, J., Xu, K., Badner, J., & de Wit, H. (2008). Association between ADORA2A and DRD2 polymorphisms and caffeine-induced anxiety. *Neuropsychopharmacology*, *33*(12), 2791-2800. https://doi.org/10.1038/npp.2008.17

Chin, J. M., Merves, M. L., Goldberger, B. A., Sampson-Cone, A., & Cone, E. J. (2008). Caffeine content of brewed teas. *Journal of Analytical Toxicology*, *32*(8), 702-704. https://doi.org/10.1093/jat/32.8.702

Choi, J. (2020). Motivations influencing caffeine consumption behaviors among college students in Korea: Associations with sleep quality. *Nutrients*, *12*(4), 953. https://doi.org/10.3390/nu12040953

Chokroverty, S. (2017). Overview of Normal Sleep. In S. Chokroverty (Ed.), *Sleep Disorders Medicine, Fourth Edition.* (pp. 5-27). Springer. https://doi.org/10.1007/978-1-4939-6578-6_2

Choudhary, A. K., Kishanrao, S. S., Dadarao Dhanvijay, A. K., & Alam, T. (2016). Sleep restriction may lead to disruption in physiological attention and reaction time. *Sleep Science*, *9*(3), 207-211. https://doi.org/10.1016/j.slsci.2016.09.001

Clark, I., & Landolt, H. P. (2017). Coffee, caffeine, and sleep: A systematic review of epidemiological studies and randomized controlled trials. *Sleep medicine reviews*, *31*(70-78). https://doi.org/10.1016/j.smrv.2016.01.006

Clement-Carbonell, V., Portilla-Tamarit, I., Rubio-Aparicio, M., & Madrid-Valero, J. J. (2021). Sleep quality, mental and physical health: A differential relationship. . *International Journal of Environmental Research and Public Health,*, *18*(2), 460. https://doi.org/10.3390/ijerph18020460

Cloughley, J. B. (1982). Factors influencing the caffeine content of black tea: Part 1 — the effect of field variables. *Food Chemistry*, *9*(4), 269-276. https://doi.org/10.1016/0308-8146(82)90077-2

Cohen, S., Doyle, W. J., Alper, C. M., Janicki-Deverts, D., & Turner, R. B. (2009). Sleep habits and susceptibility to the common cold. *Archives of Internal Medicine.*, *169*(1), 62-67. https://doi.org/10.1001/archinternmed.2008.505

Connor, J., Norton, R., Ameratunga, S., Robinson, E., Civil, I., Dunn, R., . . . Jackson, R. (2002). Driver sleepiness and risk of serious injury to car occupants: Population based case control study. *BMJ (Clinical Research ed.)*, *324*(7346), 1125. https://doi.org/10.1136/bmj.324.7346.1125

Cormier, B., Reid, J. L., & Hammond, D. (2018). At-a-glance - Perceptions of caffeinated drinks among youth and young adults in Canada. *Health Promotion and Chronic Disease Prevention in Canada: Research, Policy and Practice*, *38*(5), 214-218. https://doi.org/10.24095/hpcdp.38.5.04

Cornelis, M. C., El-Sohemy, A., & Campos, H. (2007). Genetic polymorphism of the adenosine A2A receptor is associated with habitual caffeine consumption. . *The American Journal of Clinical Nutrition*, *86*(1), 240-244. https://doi.org/10.1093/ajcn/86.1.240

Cornelis, M. C., Kacprowski, T., Menni, C., Gustafsson, S., Pivin, E., Adamski, J., . . . Ingelsson, E. (2016). Genome-wide association study of caffeine metabolites provides new insights to caffeine metabolism and dietary caffeine-consumption behavior. *Human Molecular Genetics*, *25*(24), 5472-5482. https://doi.org/10.1093/hmg/ddw334

Coveney, C. M. (2014). Managing sleep and wakefulness in a 24-hour world. *Sociology of Health & Illness*, *36*(1), 123-136. https://doi.org/10.1111/1467-9566.12046

Crowley, S. J., Acebo, C., & Carskadon, M. A. (2007). Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Medicine*, *8*(6), 602-612. https://doi.org/10.1016/j.sleep.2006.12.002

Crowley, S. J., Wolfson, A. R., Tarokh, L., & Carskadon, M. A. (2018). An update on adolescent sleep: New evidence informing the perfect storm model. *Journal of Adolescence*, *67*, 55-65. https://doi.org/10.1016/j.adolescence.2018.06.001

Cunningham, J. E. A., Jones, S. A. H., Eskes, G. A., & Rusak, B. (2018). Acute sleep restriction has differential effects on components of attention. *Frontiers in Psychiatry*, *9*, 499. https://doi.org/10.3389/fpsyt.2018.00499

Davis, J. M., Zhao, Z., Stock, H. S., Mehl, K. A., Buggy, J., & Hand, G. A. (2003). Central nervous system effects of caffeine and adenosine on fatigue. *American Journal of Physiology*, *284*(2), R399-R404. https://doi.org/10.1152/ajpregu.00386.2002

Dawkins, L., Shahzad, F. Z., Ahmed, S. S., & Edmonds, C. J. (2011). Expectation of having consumed caffeine can improve performance and mood. *Appetite*, *57*(3), 597-600. https://doi.org/10.1016/j.appet.2011.07.011

Deatherage, J. R., Roden, R. D., & Zouhary, K. (2009). Normal sleep architecture. *Seminars in Orthodontics*, *15*(2), 86-87. https://doi.org/10.1053/j.sodo.2009.01.002

Deboer, T. (2018). Sleep homeostasis and the circadian clock: Do the circadian pacemaker and the sleep homeostat influence each other's functioning?. *Neurobiology of Sleep and Circadian Rhythms*, *5*, 68-77. https://doi.org/10.1016/j.nbscr.2018.02.003

Del Gallo, F., Opp, M. R., & Imeri, L. (2014). The reciprocal link between sleep and immune responses. *Archives Italiennes de Biologie*, *152*(2-3), 93-102. https://doi.org/10.12871/000298292014234

Denaro, C. P., Brown, C. R., Jacob, P., 3rd,, & Benowitz, N. L. (1991). Effects of caffeine with repeated dosing. *European Journal of Cinical Pharmacology*, *40*(3), 273-278. https://doi.org/10.1007/BF00315208

Denaro, C. P., Brown, C. R., Wilson, M., Jacob, P., 3rd,, & Benowitz, N. L. (1990). Dose-dependency of caffeine metabolism with repeated dosing. *Clinical pharmacology and therapeutics*, *48*(3), 277-285. https://doi.org/10.1038/clpt.1990.150

Desbrow, B., Hall, S., & Irwin, C. (2019). Caffeine content of Nespresso® pod coffee. *Nutrition and Heaalth*, *25*(1), 3-7. https://doi.org/10.1177/0260106018810941

Dews, P. B. (1982). Caffeine. *Annual review of nutrition*, *2*, 323-341. https://doi.org/10.1146/annurev.nu.02.070182.001543

Di Benedetto, M., Towt, C. J., & Jackson, M. L. (2020). A cluster analysis of sleep quality, self-care behaviours, and mental health risk in Australian university students. *Behavioural Sleep Medicine*, *18*(3), 309-320. https://doi.org/10.1080/15402002.2019.1580194.

Dickinson, D. L., Wolkow, A. P., Rajaratnam, S., & Drummond, S. (2018). Personal sleep debt and daytime sleepiness mediate the relationship between sleep and mental health outcomes in young adults. *Depression and Anxiety*, *35*(8), 775-783. https://doi.org/10.1002/da.22769

Dillon, P., Kelpin, S., Kendler, K., Thacker, L., Dick, D., & Svikis, D. (2019). Gender differences in any-source caffeine and energy drink use and associated adverse health behaviors. *Journal of caffeine and adenosine research*, *9*(1), 12-19. https://doi.org/10.1089/caff.2018.0008

Dinges, D. F. (1995). An overview of sleepiness and accidents. *Journal of sleep research*, *4*(S2), 4-14. https://doi.org/10.1111/j.1365-2869.1995.tb00220.x
Doepker, C., Franke, K., Myers, E., Goldberger, J. J., Lieberman, H. R., O'Brien, C., . . . Wikoff, D. (2018). Key findings and implications of a recent systematic review of the potential adverse effects of caffeine consumption in healthy adults, pregnant women, adolescents, and children. *Nutrients*, *10*(10), 1536. https://doi.org/10.3390/nu10101536
Drake, C., Roehrs, T., Shambroom, J., & Roth, T. (2013). Caffeine effects on sleep taken 0, 3, or 6 hours before going to bed. *Journal of Clinical Sleep Medicine*, *9*(11), 1195-1200. https://doi.org/10.5664/jcsm.3170
Drapeau, C., Hamel-Hébert, I., Robillard, R., Selmaoui, B., Filipini, D., & Carrier, J. (2006). Challenging sleep in aging: the effects of 200 mg of caffeine during the evening in young and middle-aged moderate caffeine consumers. *Journal of sleep research*, *15*(2), 133-141. https://doi.org/10.1111/j.1365-2869.2006.00518.x
Drewnowski, A., & Rehm, C. D. (2016). Sources of caffeine in diets of US children and adults: Trends by beverage type and purchase location. *Nutrients*, *8*(3), 154. https://doi.org/10.3390/nu8030154
Duncan, M. J., Stanley, M., Parkhouse, N., Cook, K., & Smith, M. (2013). Acute caffeine ingestion enhances strength performance and reduces perceived exertion and muscle pain perception during resistance exercise. *European Journal of Sport Science*, *13*(4), 392-399. https://doi.org/10.1080/17461391.2011.635811
Edéll-Gustafsson, U. M., Kritz, E. I., & Bogren, I. K. (2002). Self-reported sleep quality, strain and health in relation to perceived working conditions in females. *Scandinavian Journal of Caring Sciences*, *16*(2), 179-187. https://doi.org/10.1046/j.1471-6712.2002.00078.x.
Edinger, J. D., Fins, A. I., Glenn, D. M., Sullivan, R. J., Jr,, Bastian, L. A., Marsh, G. R., . . . Vasilas, D. (2000). Insomnia and the eye of the beholder: Are there clinical markers of objective sleep disturbances among adults with and without insomnia complaints? *Journal of Consulting and Clinical Psychology*, *68*(4), 586-693.
Enright, T., & Refinetti, R. (2017). Chronotype, class times, and academic achievement of university students. *Chronobiology International*, *34*(4), 445-450. https://doi.org/10.1080/07420528.2017.1281287
Escourrou, P., Luriau, S., Rehel, M., Nédelcoux, H., & Lanoë, J. L. (2000). Needs and costs of sleep monitoring. *Studies in Health Technology and Informatics*, *78*, 69-85.
ESFA Panel on Dietetic Products Nutrition and Allergies (NDA). (2015). Scientific opinion on the safety of caffeine. *ESFA Journal*, *13*(5), 4102. https://doi.org/10.2903/j.efsa.2015.4102
Evans, S. M., & Griffiths, R. R. (1992). Caffeine tolerance and choice in humans. *Psychopharmacology*, *108*(1-2), 51-59. https://doi.org/10.1007/BF02245285
Everson, C. A., Bergmann, B. M., & Rechtschaffen, A. (1989). Sleep deprivation in the rat: III. Total sleep deprivation. *Sleep*, *12*(1), 13-21. https://doi.org/10.1093/sleep/12.1.13
Ezenwanne, E. (2011). Current concepts in the neurophysiologic basis of sleep; a review. . *Annals of Medical and Health Sciences Research*, *1*(2), 173-179.
Fabbian, F., Zucchi, B., De Giorgi, A., Tiseo, R., Boari, B., Salmi, R., . . . Manfredini, R. (2016). Chronotype, gender and general health. *Chronobiology International*, *33*(7), 863-882. https://doi.org/10.1080/07420528.2016.1176927
Fabbri, M., Beracci, A., Martoni, M., Meneo, D., Tonetti, L., & Natale, V. (2021). Measuring subjective sleep quality: A review. *International Journal of Environmental Research and Public Health*, *18*(3), 1082. https://doi.org/10.3390/ijerph18031082

Fagan, D., Swift, C. G., & Tiplady, B. (1988). Effects of caffeine on vigilance and other performance tests in normal subjects. *Journal of Psychopharmacology*, *2*(1), 19-25. https://doi.org/10.1177/026988118800200104

Fatima, Y., Doi, S. A., Najman, J. M., & Mamun, A. A. (2016). Exploring gender difference in sleep quality of young adults: Findings from a large population study. *Clinical Medicine and Resaerch*, *14*(3-4), 138-144. https://doi.org/10.3121/cmr.2016.1338

Ferré, S. (2013). Caffeine and substance use disorders. *Journal of Caffeine Research*, *3*(2), 57-58. https://doi.org/10.1089/jcr.2013.0015

Fiani, B., Zhu, L., Musch, B. L., Briceno, S., Andel, R., Sadeq, N., & Ansari, A. Z. (2021). The neurophysiology of caffeine as a central nervous system stimulant and the resultant effects on cognitive function. *Cureus*, *13*(5). https://doi.org/10.7759/cureus.15032

Figueiro, M. G. (2017). Disruption of circadian rhythms by light during day and night. *Current Sleep Medicine Reports*, *3*(2), 76-84. https://doi.org/10.1007/s40675-017-0069-0

Fillmore, M., & Vogel-Sprott, M. (1992). Expected effect of caffeine on motor performance predicts the type of response to placebo. *Psychopharmacology*, *106*(2), 209-214. https://doi.org/10.1007/BF02801974

Fiorino, A. S. (1996). Sleep, genes and death: Fatal familial insomnia. *Brain Research. Brain Research Reviews*, *22*(3), 258–264. https://doi.org/10.1016/s0165-0173(96)00010-0

Fischer, D., Lombardi, D. A., Marucci-Wellman, H., & Roenneberg, T. (2017). Chronotypes in the US - Influence of age and sex. *PLOS ONE*, *12*(6), e0178782. https://doi.org/10.1371/journal.pone.0178782

Fisk, A. S., Tam, S. K., Brown, L. A., Vyazovskiy, V. V., Bannerman, D. M., & Peirson, S. N. (2018). Light and cognition: Roles for circadian rhythms, sleep, and arousal. *Frontiers in Neurology*, *9*, 56. https://doi.org/10.3389/fneur.2018.00056

Ford, E. S., Cunningham, T. J., & Croft, J. B. (2015). Trends in self-reported sleep duration among US adults from 1985 to 2012. *Sleep*, *38*(5), 829-832. https://doi.org/10.5665/sleep.4684

Foster, R. G., & Wulff, K. (2005). The rhythm of rest and excess. *Nature Reviews. Neuroscience*, *6*(5), 407-414. https://doi.org/10.1038/nrn1670

Frary, C. D., Johnson, R. K., & Wang, M. Q. (2005). Food sources and intakes of caffeine in the diets of persons in the United States. *Journal of the American Dietetic Association*, *105*(1), 110-113. https://doi.org/https://doi.org/10.1016/j.jada.2004.10.027

Fredholm, B. B. (1995). Adenosine, adenosine receptors and the actions of caffeine. *Pharmacology & Toxicology*, *76*(2), 93-101. https://doi.org/10.1111/j.1600-0773.1995.tb00111.x

Fredholm, B. B., Bättig, K., Holmén, J., Nehlig, A., & Zvartau, E. E. (1999). Actions of caffeine in the brain with special reference to factors that contribute to Its widespread use. *Pharmacological Reviews*, *51*(1), 83. http://pharmrev.aspetjournals.org/content/51/1/83.abstract

Fredholm, B. B., Chen, J. F., Cunha, R. A., Svenningsson, P., & Vaugeois, J. M. (2005). Adenosine and brain function. *International Review of Neurobiology*, *63*, 191-270. https://doi.org/10.1016/S0074-7742(05)63007-3

Gais, S., & Born, J. (2004). Declarative memory consolidation: Mechanisms acting during human sleep. *Learning and Memory*, *11*(6), 679-685. https://doi.org/10.1101/lm.80504

Gangwar, A., Tiwari, S., Rawat, A., Verma, A., Singh, K., Kant, S., . . . Singh, P. K. (2018). Circadian Preference, Sleep Quality, and Health-impairing Lifestyles Among Undergraduates of Medical University. *Cureus*, *10*(6), e2856. https://doi.org/10.7759/cureus.2856

Gangwisch, J. E., Feskanich, D., Malaspina, D., Shen, S., & Forman, J. P. (2013). Sleep duration and risk for hypertension in women: Results from the nurses' health study. *American Journal of Hypertension*, *26*(7), 903-911. https://doi.org/10.1093/ajh/hpt044

Gangwisch, J. E., Heymsfield, S. B., Boden-Albala, B., Buijs, R. M., Kreier, F., Pickering, T. G., . . . Malaspina, D. (2006). Short sleep duration as a risk factor for hypertension: Analyses of the first National Health and Nutrition Examination Survey. . *Hypertension*, *47*(5), 833-839. https://doi.org/10.1161/01.HYP.0000217362.34748.e0.

Gangwisch, J. E., Heymsfield, S. B., Boden-Albala, B., Buijs, R. M., Kreier, F., Pickering, T. G., . . . Malaspina, D. (2007). Sleep duration as a risk factor for diabetes incidence in a large U.S. sample. *Sleep*, *30*(12), 1667-1673. https://doi.org/10.1093/sleep/30.12.1667

Gao, C., Guo, J., Gong, T. T., Lv, J. L., Li, X. Y., Liu, F. H., . . . Wu, Q. J. (2022). Sleep duration/quality with health outcomes: An umbrella review of meta-analyses of prospective studies. *Frontiers in Medicine*, *8*, 813943. https://doi.org/10.3389/fmed.2021.813943

Gaultney, J. F. (2010). The prevalence of sleep disorders in college students: Impact on academic performance. *Journal of American College Health*, *59*(2), 91-97. https://doi.org/10.1080/07448481.2010.483708

Giannotti, F., Cortesi, F., Sebastiani, T., & Ottaviano, S. (2002). Circadian preference, sleep and daytime behaviour in adolescence. *Journal of sleep research*, *11*(3), 191-199. https://doi.org/10.1046/j.1365-2869.2002.00302.x

Gibson, R., Shetty, H., Carter, M., & Münch, M. (2022). Sleeping in a bubble: Factors affecting sleep during New Zealand's COVID-19 lockdown. *Sleep Advances*, *3*(1), zpac017. https://doi.org/10.1093/sleepadvances/zpac017

Gilbert, R. M., Marshman, J. A., Schwieder, M., & Berg, R. (1976). Caffeine content of beverages as consumed. *Canadian Medical Association Journal*, *114*(3), 205-208.

Goel, N., Basner, M., Rao, H., & Dinges, D. F. (2013). Circadian rhythms, sleep deprivation, and human performance. *Progress in Molecular Biology and Translational Science*, *119*, 155-190. https://doi.org/10.1016/B978-0-12-396971-2.00007-5

Goel, N., Rao, H., Durmer, J. S., & Dinges, D. F. (2009). Neurocognitive consequences of sleep deprivation. *Seminars in Neurology*, *29*(4), 320-339. https://doi.org/10.1055/s-0029-1237117

Gomes, A. A., Tavares, J., & de Azevedo, M. H. (2011). Sleep and academic performance in undergraduates: A multi-measure, multi-predictor approach. *Chronobiology International*, *28*(9), 786-801. https://doi.org/10.3109/07420528.2011.606518

Gómez-Chiappe, N., Lara-Monsalve, P. A., Gómez, A. M., Gómez, D. C., González, J. C., González, L., . . . Castillo, J. S. (2020). Poor sleep quality and associated factors in university students in Bogotá D.C., Colombia. *Sleep Science*, *13*(2), 125-130. https://doi.org/10.5935/1984-0063.20190141

Gordon, A. M., & Chen, S. (2014). The role of sleep in interpersonal conflict: Do sleepless nights mean worst fights? *Social Psychological and Personality Science*, *5*(2), 168-175. https://doi.org/10.1177/1948550613488952

Gottlieb, D. J., Redline, S., Nieto, F. J., Baldwin, C. M., Newman, A. B., Resnick, H. E., & Punjabi, N. M. (2006). Association of usual sleep duration with hypertension: The Sleep Heart Health Study. *Sleep*, *29*(8), 1009-1014. https://doi.org/10.1093/sleep/29.8.1009

Graham, T. E. (2001). Caffeine and exercise: Metabolism, endurance and performance. *Sports Medicine*, *31*(11), 785-807. https://doi.org/10.2165/00007256-200131110-00002

Grandner, M. A. (2019). Social-ecological model of sleep health. *Sleep and Health*, 45-53. https://doi.org/10.1016/B978-0-12-815373-4.00005-8

Guion, K., & Avis, K. T. (2011). Sleep Architecture. In Goldstein S. & Naglieri J. A. (Eds.), *Encyclopedia of Child Behaviour and Development*. Springer. https://doi.org/10.1007/978-0-387-79061-9

Hafner, M., Stepanek, M., Taylor, J., Troxel, W. M., & van Stolk, C. (2016). *Why Sleep Matters—The Economic Costs of Insufficient Sleep: A Cross-Country Comparative Analysis*. RAND Corporation.

Hale, L., Emanuele, E., & James, S. (2015). Recent updates in the social and environmental determinants of sleep health. *Current Sleep Medicine Reports*, *1*(4), 212-217. https://doi.org/10.1007/s40675-015-0023-y

Hamilton, N. A., Nelson, C. A., Stevens, N., & Kitzman, H. (2007). Sleep and psychological well-being. *Social Indicators Research*, *82*, 147-163. https://doi.org/10.1007/s11205-006-9030-1

Harris, K. M. (2010). An integrative approach to health. *Demography*, *47*(1), 1-22. https://doi.org/10.1353/dem.0.0091

Heckman, M. A., Weil, J., & Gonzalez de Mejia, E. (2010). Caffeine (1, 3, 7-trimethylxanthine) in foods: A comprehensive review on consumption, functionality, safety, and regulatory matters. *Journal of Food Science*, *75*(3), R77-R87. https://doi.org/10.1111/j.1750-3841.2010.01561.x

Hershner, S., & O'Brien, L. M. (2018). The impact of a randomised sleep education intervention for college students. *Journal of Clinical Sleep Medicine*, *14*(3), 337-347. https://doi.org/10.5664/jcsm.6974

Hershner, S. D., & Chervin, R. D. (2014). Causes and consequences of sleepiness among college students. *Nature and Science of Sleep*, *6*, 73-84. https://doi.org/10.2147/NSS.S62907

Hillman, D., Mitchell, S., Streatfeild, J., Burns, C., Bruck, D., & Pezzullo, L. (2018). The economic cost of inadequate sleep. *Sleep*, *41*(8), zsy083. https://doi.org/10.1093/sleep/zsy083.

Hindmarch, I., Rigney, U., Stanley, N., Quinlan, P., Rycroft, J., & Lane, J. (2000). A naturalistic investigation of the effects of day-long consumption of tea, coffee and water on alertness, sleep onset and sleep quality. *Psychopharmacology*, *149*(3), 203-216. https://doi.org/10.1007/s002130000383

Hirshkowitz, M. (2004). Normal human sleep: An overview. *The Medical Clinics of North America*, *88*(3), 551-vii. https://doi.org/10.1016/j.mcna.2004.01.001

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., . . . Adams Hillard, P. J. (2015). National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health*, *1*(1), 40-43. https://doi.org/10.1016/j.sleh.2014.12.010

Hladky, S. B., & Barrand, M. A. (2017). Metabolite Clearance During Wakefulness and Sleep. In H. P. Landolt & D. J. Dijk (Eds.), *Sleep-Wake Neurobiology and Pharmacology. Handbook of Experimental Pharmacology.* (Vol. 253). Springer, Cham. https://doi.org/10.1007/164_2017_37

Horne, J. A., & Reyner, L. A. (1995). Sleep related vehicle accidents. *BMJ (Clinical Research ed.)*, *310*(6979), 565-567. https://doi.org/10.1136/bmj.310.6979.565

Huang, Z. L., Urade, Y., & Hayaishi, O. (2011). The role of adenosine in the regulation of sleep. *Current Topics in Medicinal Chemistry*, *11*(8), 1047–1057. https://doi.org/10.2174/156802611795347654

Hughes, J. M., Song, Y., Fung, C. H., Dzierzewski, J. M., Mitchell, M. N., Jouldjian, S., . . . Martin, J. L. (2018). Measuring sleep in vulnerable older adults: A comparison of subjective and objective sleep measures. *Clinical Gerontologist*, *41*(2), 145-157. https://doi.org/10.1080/07317115.2017.1408734

Hutchison, I. C., & Rathore, S. (2015). The role of REM sleep theta activity in emotional memory. *Frontiers in Psychology*, *6*, 1439. https://doi.org/10.3389/fpsyg.2015.01439

Irish, L. A., Kline, C. E., Gunn, H. E., Buysse, D. J., & Hall, M. H. (2015). The role of sleep hygiene in promoting public health: A review of empirical evidence. *Sleep medicine reviews*, *22*(23-36). https://doi.org/10.1016/j.smrv.2014.10.001.

James, J. E., & Keane, M. A. (2007). Caffeine, sleep and wakefulness: Implications of new understanding about withdrawal reversal. *Human Psychopharmacology*, *22*(8), 549-558. https://doi.org/10.1002/hup.881

James, J. E., & Rogers, P. J. (2005). Effects of caffeine on performance and mood: Withdrawal reversal is the most plausible explanation. *Psychopharmacology*, *182*(1), 1-8. https://doi.org/10.1007/s00213-005-0084-6

Jenni, O. G., Achermann, P., & Carskadon, M. A. (2005). Homeostatic sleep regulation in adolescents. *Sleep*, *28*(11), 1446–1454. https://doi.org/10.1093/sleep/28.11.1446

Joshi, S. C., Woodward, J., & Woltering, S. (2022). Nighttime cell phone use and sleep quality in young adults. *Sleep and Biological Rhythms*, *20*, 97-106. https://doi.org/10.1007/s41105-021-00345-6

Juliano, L. M., & Griffiths, R. R. (2004). A critical review of caffeine withdrawal: Empirical validation of symptoms and signs, incidence, severity, and associated features. *Psychopharmacology*, *176*(1), 1-29. https://doi.org/10.1007/s00213-004-2000-x

Kaplan, G. B., Greenblatt, D. J., Ehrenberg, B. L., Goddard, J. E., Cotreau, M. M., Harmatz, J. S., & Shader, R. I. (1997). Dose-dependent pharmacokinetics and psychomotor effects of caffeine in humans. *Journal of Clinical Pharmacology*, *37*(8), 693-703. https://doi.org/10.1002/j.1552-4604.1997.tb04356.x

Karacan, I., Thornby, J. I., Anch, M., Booth, G. H., Williams, R. L., & Salis, P. J. (1976). Dose-related sleep disturbances induced by coffee and caffeine. *Clinical pharmacology and therapeutics*, *20*(6), 682-689. https://doi.org/10.1002/cpt1976206682

Katzenberg, D., Young, T., Finn, L., Lin, L., King, D. P., Takahashi, J. S., & Mignot, E. (1998). A CLOCK polymorphism associated with human diurnal preference. *Sleep*, *21*(6), 569-576. https://doi.org/10.1093/sleep/21.6.569

Keenan, S. A. (2005). Chapter 3 An Overview of Polysomnography. In C. Guilleminault (Ed.), *Handbook of Clinical Neurophysiology* (Vol. 6, pp. 33-50). Elsevier.

Kerpershoek, M. L., Antypa, N., & Van den Berg, J. F. (2018). Evening use of caffeine moderates the relationship between caffeine consumption and subjective sleep quality in students. *Journal of sleep research*, *27*(5), e12670. https://doi.org/10.1111/jsr.12670

Killgore, W. D. (2010). Effects of sleep deprivation on cognition. *Progress in Brain Research*, *185*, 105-129. https://doi.org/10.1016/B978-0-444-53702-7.00007-5

Kim, T. W., Jeong, J. H., & Hong, S. C. (2015). The impact of sleep and circadian disturbance on hormones and metabolism. *International Journal of Endocrinology*, 591729. https://doi.org/10.1155/2015/591729

Kirsch, I., & Weixel, L. J. (1988). Double-blind versus deceptive administration of a placebo. *Behavioural Neuroscience*, *102*(2), 319-323. https://doi.org/10.1037//0735-7044.102.2.319

Knutson, K. L. (2013). Sociodemographic and cultural determinants of sleep deficiency: Implications for cardiometabolic disease risk. *Social Science & Medicine*, *79*, 7-15. https://doi.org/10.1016/j.socscimed.2012.05.002

Knutson, K. L., & von Schantz, M. (2018). Associations between chronotype, morbidity and mortality in the UK Biobank cohort. *Chronobiology International*, *35*(8), 1045-1053. https://doi.org/10.1080/07420528.2018.1454458

Kohyama, J. (2021). Which is more important for health: Sleep quantity or sleep quality? *Children*, *8*(7), 542. https://doi.org/10.3390/children8070542

Krystal, A. D., & Edinger, J. D. (2008). Measuring sleep quality. *Sleep Medicine*, *9*(Suppl 1), S10-S17. https://doi.org/10.1016/S1389-9457(08)70011-X

Lack, L. C. (1986). Delayed sleep and sleep loss in university students. *Journal of American College Health*, *35*(3), 105-110. https://doi.org/10.1080/07448481.1986.9938970

Lamond, N., & Dawson, D. (1999). Quantifying the performance impairment associated with fatigue. *Journal of sleep research*, *8*(4), 255-262. https://doi.org/10.1046/j.1365-2869.1999.00167.x

Landolt, H. P. (2008). Sleep homeostasis: A role for adenosine in humans? *Biochemical Pharmacology*, *75*(11), 2070-2079. https://doi.org/10.1016/j.bcp.2008.02.024

Landolt, H. P., Dijk, D. J., Gaus, S. E., & Borbély, A. A. (1995). Caffeine reduces low-frequency delta activity in the human sleep EEG. *Neuropsychopharmacology*, *12*(3), 229-238. https://doi.org/10.1016/0893-133X(94)00079-F

Lara, B., Ruiz-Moreno, C., Salinero, J. J., & Del Coso, J. (2019). Time course of tolerance to the performance benefits of caffeine. *PLOS ONE*, *14*(1), e0210275. https://doi.org/10.1371/journal.pone.0210275

Lauderdale, D. S., Knutson, K. L., Yan, L. L., Liu, K., & Rathouz, P. J. (2008). Self-reported and measured sleep duration: How similar are they?. *Epidemiology*, *19*(6), 838-845. https://doi.org/10.1097/EDE.0b013e318187a7b0

Lee, C. H., & Sibley, C. G. (2019). Sleep duration and psychological well-being among New Zealanders. *Sleep Health*, *5*(6), 606-614. https://doi.org/10.1016/j.sleh.2019.06.008

Lee, K.-H., Human, G. P., Fourie, J. J., Louw, W. A. N., Larson, C. O., & Joubert, G. (2009). Medical students' use of caffeine for 'academic purposes' and their knowledge of its benefits, side-effects and withdrawal symptoms. *South African Family Practice*, *51*(4). https://doi.org/10.1080/20786204.2009.10873872

Lemma, S., Patel, S. V., Tarekegn, Y. A., Tadesse, M. G., Berhane, Y., Gelaye, B., & Williams, M. A. (2012). The epidemiology of sleep quality, sleep patterns, consumption of caffeinated beverages, and khat use among Ethiopian college students. *Sleep Disorders*, 583510. https://doi.org/10.1155/2012/583510

Li, Y., Bai, W., Zhu, B., Duan, R., Yu, X., Xu, W., . . . Kou, C. (2020). Prevalence and correlates of poor sleep quality among college students: A cross-sectional survey. *Health and Quality of Life Outcomes*, *18*(1), 210. https://doi.org/10.1186/s12955-020-01465-2

Liao, Y., Xie, L., Chen, X., Kelly, B. C., Qi, C., Pan, C., . . . Tang, J. (2019). Sleep quality in cigarette smokers and nonsmokers: Findings from the general population in central China. *BMC Public Health*, *19*(1), 808. https://doi.org/10.1186/s12889-019-6929-4

Lim, J., & Dinges, D. F. (2010). A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychological Bulletin*, *136*(3), 375-389. https://doi.org/10.1037/a0018883

Lindberg, E., Janson, C., Gislason, T., Björnsson, E., Hetta, J., & Boman, G. (1997). Sleep disturbances in a young adult population: Can gender differences be explained by differences in psychological status?. *Sleep*, *20*(6), 381-387. https://doi.org/10.1093/sleep/20.6.381

Liu, D. J., Kotler, M., & Sharples, S. (2011). Pharmacokinetic and bioequivalence study evaluating a new paracetamol/caffeine formulation in healthy human volunteers. *Journal of Bioequivalence and Bioavailability*, *3*(11), 251-257. https://doi.org/10.4172/jbb.1000095

Liu, J., Zhu, L., & Liu, C. (2020). Sleep quality and self-control: The mediating roles of positive and negative affects. *Frontiers in Psychology*, *11*, 607548. https://doi.org/10.3389/fpsyg.2020.607548

Liu, Y., Wheaton, A. G., Chapman, D. P., Cunningham, T. J., Lu, H., & Croft, J. B. (2016). Prevalence of healthy sleep duration among adults—United States, 2014. *MMWR. Morbidity and mortality weekly report*, *65*(6), 137-141. https://doi.org/10.15585/mmwr.mm6506a1

Lockley, S. W., Skene, D. J., & Arendt, J. (1999). Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. *Journal of sleep research*, *8*(3), 175-183. https://doi.org/10.1046/j.1365-2869.1999.00155.x.

Lohsoonthorn, V., Khidir, H., Casillas, G., Lertmaharit, S., Tadesse, M. G., Pensuksan, W. C., . . . Williams, M. A. (2013). Sleep quality and sleep patterns in relation to consumption of energy drinks, caffeinated beverages, and other stimulants among Thai college students. *Sleep and Breathing*, *17*(3), 1017-1028. https://doi.org/10.1007/s11325-012-0792-1

Ludden, A. B., & Wolfson, A. R. (2010). Understanding adolescent caffeine use: Connecting use patterns with expectancies, reasons, and sleep. *Health Education and Behaviour*, *37*(3), 330-342. https://doi.org/10.1177/1090198109341783

Lugaresi, E., Medori, R., Montagna, P., Baruzzi, A., Cortelli, P., Lugaresi, A., . . . Gambetti, P. (1986). Fatal familial insomnia and dysautonomia with selective degeneration of thalamic nuclei. *The New England Journal of Medicine*, *315*(16), 997-1003. https://doi.org/10.1056/NEJM198610163151605

Lund, H. G., Reider, B. D., Whiting, A. B., & Prichard, J. R. (2010). Sleep patterns and predictors of disturbed sleep in a large population of college students. *The Journal of Adolescent Health*, *46*(2), 124-132. https://doi.org/10.1016/j.jadohealth.2009.06.016

Luyster, F. S., Strollo, P. J., Jr.,, Zee, P. C., Walsh, J. K., & Boards of Directors of the American Academy of Sleep Medicine and the Sleep Research Society. (2012). Sleep: A health imperative. *Sleep*, *35*(6), 727-734. https://doi.org/10.5665/sleep.1846.

Machado, E. R. S., Varella, V. B. R., & Andrade, M. M. M. (1998). The influence of study schedules and work on the sleep-wake cycle of college students. *Biological Rhythm Research*, *29*(5), 578-584. https://doi.org/10.1076/brhm.29.5.578.4827

Machado, R. B., & Suchecki, D. (2016). Neuroendocrine and peptidergic regulation of stress-induced REM sleep rebound. *Frontiers in Endocrinology*, *7*, 163. https://doi.org/10.3389/fendo.2016.00163

Madrid-Valero, J. J., Martínez-Selva, J. M., Ribeiro do Couto, B., Sánchez-Romera, J. F., & Ordoñana, J. R. (2017). Age and gender effects on the prevalence of poor sleep quality in the adult population. *Gaceta Sanitaria*, *31*(1), 18-22. https://doi.org/10.1016/j.gaceta.2016.05.013

Mah, C. D., Kezirian, E. J., Marcello, B. M., & Dement, W. C. (2018). Poor sleep quality and insufficient sleep of a collegiate student-athlete population. *Sleep Health*, *4*(3), 251-257. https://doi.org/10.1016/j.sleh.2018.02.005.

Mahoney, C. R., Giles, G. E., Marriott, B. P., Judelson, D. A., Glickman, E. L., Geiselman, P. J., & Lieberman, H. R. (2019). Intake of caffeine from all sources and reasons for use by college students. *Clinical Nutrition*, *38*(2), 668–675. https://doi.org/10.1016/j.clnu.2018.04.004

Malinauskas, B. M., Aeby, V. G., Overton, R. F., Carpenter-Aeby, T., & Barber-Heidal, K. (2007). A survey of energy drink consumption patterns among college students. *Nutrition Journal*, *6*(35). https://doi.org/10.1186/1475-2891-6-35

Mamun, M. A., Hossain, S., Kamruzzaman., Khalil, I., Sikder, T., Manzar, D., & Griffiths, M. D. (2020). Prevalence of poor sleep quality and its determinants among Bangladeshi students:

A pilot study. *Sleep and Vigilance*, *4*, 185-193. https://doi.org/10.1007/s41782-020-00109-1
Mandel, H. G. (2002). Update on caffeine consumption, disposition and action. *Food and Chemical Toxicology*, *40*(9), 1231-1234. https://doi.org/10.1016/S0278-6915(02)00093-5
Marangos, P. J., Boulenger, J. P., & Patel, J. (1984). Effects of chronic caffeine on brain adenosine receptors: Regional and ontogenetic studies. *Life Sciences*, *34*(9), 899-907. https://doi.org/10.1016/0024-3205(84)90207-8
Maridakis, V., O'Connor, P. J., Dudley, G. A., & McCully, K. K. (2007). Caffeine attenuates delayed-onset muscle pain and force loss following eccentric exercise. *The Journal of Pain*, *8*(3), 237-243. https://doi.org/10.1016/j.jpain.2006.08.006
Markov, D., & Goldman, M. (2006). Normal sleep and circadian rhythms: Neurobiologic mechanisms underlying sleep and wakefulness. *Psychiatric Clinics of North America*, *29*(4), 841-853. https://doi.org/10.1016/j.psc.2006.09.008
Marks, V., & Kelly, J. F. (1973). Absorption of caffeine from tea, coffee, and coca cola. *Lancet*, *1*(7807), 827. https://doi.org/10.1016/s0140-6736(73)90625-9
Martin, J. L., & Hakim, A. D. (2011). Wrist actigraphy. *Chest*, *139*(6), 1514-1527. https://doi.org/10.1378/chest.10-1872
Matissek, R. (1997). Evaluation of xanthine derivatives in chocolate – nutritional and chemical aspects. *Zeitschrift für Lebensmitteluntersuchung und Forschung*, *205*, 175-184. https://doi.org/10.1007/s002170050148
Maughan, R. J., & Griffin, J. (2003). Caffeine ingestion and fluid balance: A review. *Journal of Human Nutrition and Dietetics*, *16*(6), 411-420. https://doi.org/10.1046/j.1365-277x.2003.00477.x
McArdle, N., Ward, S. V., Bucks, R. S., Maddison, K., Smith, A., Huang, R.-C., . . . Eastwood, P. R. (2020). The prevalence of common sleep disorders in young adults: a descriptive population-based study. *Sleep*, *43*(10), zsaa072. https://doi.org/10.1093/sleep/zsaa072
McCusker, R. R., Fuehrlein, B., Goldberger, B. A., Gold, M. S., & Cone, E. J. (2006). Caffeine content of decaffeinated coffee. *Journal of Analytical Toxicology*, *30*(8), 611-613. https://doi.org/doi.org/10.1093/jat/30.8.611
McCusker, R. R., Goldberger, B. A., & Cone, E. J. (2003). Caffeine content of specialty coffees. *Journal of Analytical Toxicology*, *27*(7), 520-522. https://doi.org/10.1093/jat/27.7.520
McLellan, T. M., Caldwell, J. A., & Lieberman, H. R. (2016). A review of caffeine's effects on cognitive, physical and occupational performance. *Neuroscience and Biobehavioral Reviews*, *71*, 294-312. https://doi.org/10.1016/j.neubiorev.2016.09.001
McIlvain, G. E., Noland, M. P., & Bickel, R. (2011). Caffeine consumption patterns and beliefs of college freshmen. *American Journal of Health Education*, *42*(4), 235-244. https://doi.org/10.1080/19325037.2011.10599193
Melone, M. A., Tourny, C., Gehlbach, B. K., Schmidt, E. L., Lalevée, M., & L'Hermette, M. (2022). Prevalence and risk factors of poor sleep quality in collegiate athletes during COVID-19 pandemic: A cross-sectional study. . *International Journal of Environmental Research and Public Health*, *19*(5), 3098. https://doi.org/10.3390/ijerph19053098
Memar, P., & Faradji, F. (2018). A novel multi-class EEG-based sleep stage classification system. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *26*(1), 84-95. https://doi.org/10.1109/TNSRE.2017.2776149
Meredith, S. E., Juliano, L. M., Hughes, J. R., & Griffiths, R. R. (2013). Caffeine use disorder: A comprehensive review and research agenda. . *Journal of Caffeine Research*, *3*(3), 114-130. https://doi.org/10.1089/jcr.2013.0016

Ministry of Health. (2003). *NZ Food NZ Children: Key results of the 2002 National Children's Nutrition Survey*. Ministry of Health: Wellington New Zealand.

Minkel, J. D., Banks, S., Htaik, O., Moreta, M. C., Jones, C. W., McGlinchey, E. L., . . . Dinges, D. F. (2012). Sleep deprivation and stressors: Evidence for elevated negative affect in response to mild stressors when sleep deprived. *Emotion*, *12*(5), 1015-1020. https://doi.org/10.1037/a0026871

Mishra, J., Panigrahi, A., Samanta, P., Dash, K., Mahapatra, P., & Behera, M. R. (2022). Sleep quality and associated factors among undergraduate medical students during Covid-19 confinement. *Clinical Epidemiology and Global Health*, *15*, 101004. https://doi.org/10.1016/j.cegh.2022.101004

Mitchell, D. C., Knight, C. A., Hockenberry, J., Teplansky, R., & Hartman, T. J. (2014). Beverage caffeine intakes in the U.S. *Food and Chemical Toxicology*, *63*, 136-142. https://doi.org/10.1016/j.fct.2013.10.042

Mohamed, R. A., Alotaibi, M. G., & Almutairi, N. A. (2020). The prevalence of sleep disturbance among medical college students of Jouf University and its effect on academic achievement. *International Journal of Medicine in Developing Countries*, *4*(12), 2182-2186. https://doi.org/10.24911/IJMDC.51-1602942617

Mukherjee, S., Patel, S. R., Kales, S. N., Ayas, N. T., Strohl, K. P., Gozal, D., . . . American Thoracic Society ad hoc Committee on Healthy Sleep. (2015). An official American Thoracic Society statement: The importance of healthy sleep. Recommendations and future priorities. *American Journal of Respiratory and Critical Care Medicine*, *191*(12), 1450–1458. https://doi.org/10.1164/rccm.201504-0767ST

Nagai, M., Hoshide, S., & Kario, K. (2010). . (2010). Sleep duration as a risk factor for cardiovascular disease- a review of the recent literature. *Current Cardiology Reviews*, *6*(1), 54-61. https://doi.org/10.2174/157340310790231635

Natsky, A. N., Vakulin, A., Coetzer, C. L. C., McEvoy, R. D., Adams, R. J., & Kaambwa, B. (2021). Economic evaluation of diagnostic sleep studies for obstructive sleep apnoea: a systematic review protocol. *Systematic Reviews*, *10*, 104. https://doi.org/10.1186/s13643-021-01651-3

Nawrot, P., Jordan, S., Eastwood, J., Rotstein, J., Hugenholtz, A., & Feeley, M. (2003). Effects of caffeine on human health. *Food Additives and Contaminants*, *20*(1), 1-30. https://doi.org/10.1080/0265203021000007840

Neculicioiu, V. S., Colosi, I. A., Costache, C., Sevastre-Berghian, A., & Clichici, S. (2022). Time to sleep?—A review of the impact of the COVID-19 pandemic on sleep and mental health. *International Journal of Environmental Research and Public Health*, *19*(6), 3497. https://doi.org/10.3390/ijerph19063497

Nehlig, A. (1999). Are we dependent upon coffee and caffeine? A review on human and animal data. *Neuroscience and Biobehavioral Reviews*, *23*(4), 563-576. https://doi.org/10.1016/s0149-7634(98)00050-5.

Nehlig, A. (2010). Is caffeine a cognitive enhancer? *Journal of Alzheimer's Disease*, *20*(Suppl 1), S85-94. https://doi.org/10.3233/JAD-2010-091315

Nehlig, A. (2018). Interindividual differences in caffeine metabolism and factors driving caffeine consumption. *Pharmacological Reviews*, *70*(2), 384–411. https://doi.org/10.1124/pr.117.014407

Nehlig, A., Daval, J. L., & Debry, G. (1992). Caffeine and the central nervous system: Mechanisms of action, biochemical, metabolic and psychostimulant effects. *Brain Research Reviews*, *17*(2), 139-170. https://doi.org/10.1016/0165-0173(92)90012-b

Nelson, K. L., Davis, J. E., & Corbett, C. F. (2022). Sleep quality: An evolutionary concept analysis. *Nursing Forum*, *57*(1), 144-151. https://doi.org/10.1111/nuf.12659

Ness, T. E. B., & Saksvik-Lehouillier, I. (2018). The relationships between life satisfaction and sleep quality, sleep duration and variability of sleep in university students. *Journal of European Psychology Students*, *9*(1), 28-39. https://doi.org/10.5334/jeps.434

O'Callaghan, F., Muurlink, O., & Reid, N. (2018). Effects of caffeine on sleep quality and daytime functioning. *Risk management and healthcare policy*, *11*, 263-271. https://doi.org/10.2147/RMHP.S156404

O'Connor, P. J., Motl, R. W., Broglio, S. P., & Ely, M. R. (2004). Dose-dependent effect of caffeine on reducing leg muscle pain during cycling exercise is unrelated to systolic blood pressure. *The Journal of the International Association for the Study of Pain*, *109*(3), 291-298. https://doi.org/10.1016/j.pain.2004.01.017

O'Donnell, D., Silva, E. J., Münch, M., Ronda, J. M., Wang, W., & Duffy, J. F. (2009). Comparison of subjective and objective assessments of sleep in healthy older subjects without sleep complaints. *Journal of sleep research*, *18*(2), 254-263. https://doi.org/10.1111/j.1365-2869.2008.00719.x

Ogawa, N., & Ueki, H. (2007). Clinical importance of caffeine dependence and abuse. *Psychiatry and Clinical Neurosciences*, *61*(3), 263-268. https://doi.org/10.1111/j.1440-1819.2007.01652.x

Ogilvie, R. P., Lutsey, P. L., Widome, R., Laska, M. N., Larson, N., & Neumark-Sztainer, D. (2018). Sleep indices and eating behaviours in young adults: Findings from Project EAT. *Public Health Nutrition*, *21*(4), 689-701. https://doi.org/10.1017/S1368980017003536

Ogilvie, R. P., & Patel, S. R. (2018). Changing national trends in sleep duration: Did we make America sleep again? *Sleep*, *41*(4), zsy055. https://doi.org/10.1093/sleep/zsy055

Oginska, H., & Pokorski, J. (2006). Fatigue and mood correlates of sleep length in three age-social groups: School children, students, and employees. *Chronobiology International*, *23*(6), 1317-1328. https://doi.org/10.1080/07420520601089349

Ohayon, M., Wickwire, E. M., Hirshkowitz, M., Albert, S. M., Avidan, A., Daly, F. J., . . . Vitiello, M. V. (2017). National Sleep Foundation's sleep quality recommendations: first report. *Sleep Health*, *3*(1), 6-19. https://doi.org/https://doi.org/10.1016/j.sleh.2016.11.006

Ohayon, M. M., Carskadon, M. A., Guilleminault, C., & Vitiello, M. V. (2004). Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan. *Sleep*, *27*(7), 1255–1273. https://doi.org/10.1093/sleep/27.7.1255

Ohida, T., Kamal, A. M., Uchiyama, M., Kim, K., Takemura, S., Sone, T., & Ishii, T. (2001). The influence of lifestyle and health status factors on sleep loss among the Japanese general population. *Sleep*, *24*(3), 333-338. https://doi.org/10.1093/sleep/24.3.333

Okano, K., Kaczmarzyk, J. R., Dave, N., Gabrieli, J. D. E., & Grossman, J. C. (2019). Sleep quality, duration, and consistency are associated with better academic performance in college students. *NPJ Science of Learning*, *4*, 16. https://doi.org/10.1038/s41539-019-0055-z

Olechno, E., Puścion-Jakubik, A., Zujko, M. E., & Socha, K. (2021). Influence of various factors on caffeine content in coffee brews. *Foods*, *10*(6), 1208. https://doi.org/10.3390/foods10061208

Paine, S. J., & Gander, P. H. (2016). Explaining ethnic inequities in sleep duration: A cross-sectional survey of Māori and non-Māori adults in New Zealand. . *Sleep Health*, *2*(2), 109-115. https://doi.org/10.1016/j.sleh.2016.01.005

Paine, S. J., Gander, P. H., Harris, R. B., & Reid, P. (2005). Prevalence and consequences of insomnia in New Zealand: disparities between Maori and non-Maori. *Australian and New Zealand Journal of Public Health*, *29*(1), 22-28. https://doi.org/10.1111/j.1467-842x.2005.tb00743.x

Paine, S. J., Harris, R., Cormack, D., & Stanley, J. (2019). Self-reported sleep complaints are associated with adverse health outcomes: cross-sectional analysis of the 2002/03 New Zealand Health Survey. *Ethnicity & Health*, *24*(1), 44-56. https://doi.org/10.1080/13557858.2017.1315368

Palmer, C. A., & Algano, C. A. (2017). Sleep and emotion regulation: An organizing, integrative review. *Sleep medicine reviews*, *31*, 6-16. https://doi.org/10.1016/j.smrv.2015.12.006

Parrott, A. C., & Hindmarch, I. (1980). The Leeds Sleep Evaluation Questionnaire in psychopharmacological investigations - A review. *Psychopharmacology*, *71*(2), 173-179. https://doi.org/10.1007/BF00434408

Patel, S. R., Malhotra, A., Gao, X., Hu, F. B., Neuman, M. I., & Fawzi, W. W. (2012). A prospective study of sleep duration and pneumonia risk in women. *Sleep*, *35*(1), 97-101. https://doi.org/10.5665/sleep.1594

Patrick, M. E., Griffin, J., Huntley, E. D., & Maggs, J. L. (2018). Energy drinks and binge drinking predict college students' sleep quantity, quality, and tiredness. *Behavioural Sleep Medicine*, *16*(1), 92-105. https://doi.org/10.1080/15402002.2016.1173554

Paudel, K., Adhikari, T. B., Khanal, P., Bhatta, R., Paudel, R., Bhusal, S., & Basel, P. (2022). Sleep quality and its correlates among undergraduate medical students in Nepal: A cross-sectional study. *PLOS Global Public Health*, *2*(2), e0000012. https://doi.org/10.1371/journal.pgph.0000012

Peltzer, K., & Pengpid, S. (2016). Sleep duration and health correlates among university students in 26 countries. *Psychology, Health and Medicine*, *21*(2), 208-220. https://doi.org/10.1080/13548506.2014.998687.

Phillips, A. J., Clerx, W. M., O'Brien, C. S., Sano, A., Barger, L., K.,, Picard, R. W., . . . Czeisler, C. A. (2017). Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Scientific Reports*, *7*, 3216.

Pilcher, J. J., Ginter, D. R., & Sadowsky, B. (1997). Sleep quality versus sleep quantity: Relationships between sleep and measures of health, well-being and sleepiness in college students. *Journal of Psychosomatic Research*, *42*(6), 583-596. https://doi.org/10.1016/s0022-3999(97)00004-4

Pilcher, J. J., & Huffcutt, A. I. (1996). Effects of sleep deprivation on performance: A meta-analysis. *Sleep*, *19*(4), 318-326. https://doi.org/10.1093/sleep/19.4.318

Porcheret, K., Wald, L., Fritschi, L., Gerkema, M., Gordijn, M., Merrrow, M., . . . Foster, R. G. (2018). Chronotype and environmental light exposure in a student population. *Chronobiology International*, *35*(10), 1365-1374. https://doi.org/10.1080/07420528.2018.1482556.

Porkka-Heiskanen, T., Alanko, L., Kalinchuk, A., & Stenberg, D. (2002). Adenosine and sleep. *Sleep medicine reviews*, *6*(4), 321-332. https://doi.org/10.1053/smrv.2001.0201

Poudel, G. R., Innes, C. R., Bones, P. J., Watts, R., & Jones, R. D. (2014). Losing the struggle to stay awake: Divergent thalamic and cortical activity during microsleeps. *Human Brain Mapping*, *35*(1), 257-269. https://doi.org/10.1002/hbm.22178

Purves, D., Augustine, G. J., Fitzpatrick, D., Katz, L. C., LaMantia, A. D., McNamara, J. O., & Williams, S. M. (2001). Physiological Changes in Sleep States. In *Neuroscience. 2nd edn.* Sinauer Associates.

Quadra, G. R., Paranaíba, J. R., Vilas-Boas, J., Roland, F., Amado, A. M., Barros, N., . . . Cardoso, S. J. (2020). A global trend of caffeine consumption over time and related-environmental impacts. *Environmental Pollution*, *256*, 113343. https://doi.org/10.1016/j.envpol.2019.113343

Ramar, K., Malhotra, R. K., Carden, K. A., Martin, J. L., Abbasi-Feinberg, F., Aurora, R. N., . . . Trotti, L. M. (2021). Sleep is essential to health: An American Academy of Sleep Medicine position statement. *Journal of Clinical Sleep Medicine*, *17*(10), 2115-2119. https://doi.org/10.5664/jcsm.9476

Ramos Socarras, L., Potvin, J., & Forest, G. (2021). COVID-19 and sleep patterns in adolescents and young adults. *Sleep Medicine*, *83*, 26-33. https://doi.org/10.1016/j.sleep.2021.04.010

Ramos-Campo, D. J., Pérez, A., Ávila-Gandía, V., Pérez-Piñero, S., & Rubio-Arias, J. Á. (2019). Impact of caffeine intake on 800-m running performance and sleep quality in trained runners. *Nutrients*, *11*(9), 2040. https://doi.org/10.3390/nu11092040

Randler, C., & Engelke, J. (2019). Gender differences in chronotype diminish with age: A meta-analysis based on morningness/chronotype questionnaires. *Chronobiology International*, *36*(7), 888-905. https://doi.org/10.1080/07420528.2019.1585867

Randler, C., Faßl, C., & Kalb, N. (2017). From Lark to Owl: Developmental changes in morningness-eveningness from new-borns to early adulthood. *Scientific Reports*, *7*, 45874. https://doi.org/10.1038/srep45874

Rechtschaffen, A. (1998). Current perspectives on the function of sleep. *Perspectives in Biology and Medicine*, *41*(3), 359-390. https://doi.org/10.1353/pbm.1998.0051

Rechtschaffen, A., Bergmann, B. M., Everson, C. A., Kushida, C. A., & Gilliland, M. A. (1989). Sleep deprivation in the rat: X. Integration and discussion of the findings. *Sleep*, *12*(1), 68-87.

Regestein, Q., Natarajan, V., Pavlova, M., Kawasaki, S., Gleason, R., & Koff, E. (2010). Sleep debt and depression in female college students. *Psychiatry Research*, *176*(1), 34-39. https://doi.org/10.1016/j.psychres.2008.11.006

Reichert, C. F., Deboer, T., & Landolt, H. P. (2022). Adenosine, caffeine, and sleep-wake regulation: State of the science and perspectives. *Journal of sleep research*, *Online ahead of print.*, 1-21. https://doi.org/10.1111/jsr.13597

Reichert, C. F., Veitz, S., Bühler, M., Gruber, G., Deuring, G., Rehm, S. S., . . . Weibel, J. (2021). Wide awake at bedtime? Effects of caffeine on sleep and circadian timing in male adolescents - A randomized crossover trial. *Biochemical Pharmacology*, *191*, 114283. https://doi.org/10.1016/j.bcp.2020.114283

Reid, A., & Baker, F. C. (2008). Perceived sleep quality and sleepiness in South African University Students. *South African Journal of Psychology*, *38*(2), 287-303. https://doi.org/10.1177/008124630803800203

Reid, J. L., McCrory, C., White, C. M., Martineau, C., Vanderkooy, P., Fenton, N., & Hammond, D. (2016). Consumption of caffeinated energy drinks among youth and young adults in Canada. *Preventive Medicine Reports*, *5*, 65-70. https://doi.org/10.1016/j.pmedr.2016.11.012

Reissig, C. J., Strain, E. C., & Griffiths, R. R. (2009). Caffeinated energy drinks—A growing problem. *Drug and Alcohol Dependence*, *99*(1-3), 1-10. https://doi.org/10.1016/j.drugalcdep.2008.08.001

Rétey, J. V., Adam, M., Khatami, R., Luhmann, U. F., Jung, H. H., Berger, W., & Landolt, H. P. (2007). A genetic variation in the adenosine A2A receptor gene (ADORA2A) contributes to individual sensitivity to caffeine effects on sleep. *Clinical pharmacology and therapeutics*, *81*(5), 692-698. https://doi.org/10.1038/sj.clpt.6100102

Reyes, C. M., & Cornelis, M. C. (2018). Caffeine in the diet: Country-level consumption and guidelines. *Nutrients*, *10*(11), 1772. https://doi.org/10.3390/nu10111772

Richards, J., & Gumz, M. L. (2012). Advances in understanding the peripheral circadian clocks. *FASEB Journal: official publication of the Federation of American Societies for Experimental Biology*, *26*(9), 3602-3613. https://doi.org/10.1096/fj.12-203554

Riera-Sampol, A., Rodas, L., Martínez, S., Moir, H. J., & Tauler, P. (2022). Caffeine intake among undergraduate students: Sex differences, sources, motivations, and associations with smoking status and self-reported sleep quality. *Nutrients*, *14*(8), 1661. https://doi.org/10.3390/nu14081661

Robbins, R., Affouf, M., Seixas, A., Beaugris, L., Avirappattu, G., & Jean-Louis, G. (2020). Four-year rrends in sleep duration and quality: A longitudinal study using data from a commercially available sleep tracker. *Journal of Medical Internet Research*, *22*(2), e14735. https://doi.org/10.2196/14735

Robertson, D., Wade, D., Workman, R., Woosley, R. L., & Oates, J. A. (1981). Tolerance to the humoral and hemodynamic effects of caffeine in man. *The Journal of Clinical Investigation*, *67*(4), 1111-1117. https://doi.org/10.1172/jci110124

Rodak, K., Kokot, I., & Kratz, E. M. (2021). Caffeine as a factor influencing the functioning of the human body—friend or foe? *Nutrients*, *13*(9), 3088. https://doi.org/10.3390/nu13093088

Roehrs, T., & Roth, T. (2008). Caffeine: Sleep and daytime sleepiness. *Sleep medicine reviews*, *12*(2), 153-162. https://doi.org/10.1016/j.smrv.2007.07.004

Roenneberg, T., Kuehnle, T., Pramstaller, P. P., Ricken, J., Havel, M., Guth, A., & Merrow, M. (2004). A marker for the end of adolescence. *Current Biology*, *14*(24), R1038–R1039. https://doi.org/10.1016/j.cub.2004.11.039

Roenneberg, T., Wirz-Justice, A., & Merrow, M. (2003). Life between clocks: Daily temporal patterns of human chronotypes. *Journal of Biological Rhythms*, *18*(1), 80-90. https://doi.org/10.1177/0748730402239679

Rosales-Lagarde, A., Armony, J. L., Del Río-Portilla, Y., Trejo-Martínez, D., Conde, R., & Corsi-Cabrera, M. (2012). Enhanced emotional reactivity after selective REM sleep deprivation in humans: An fMRI study. *Frontiers in Behavioural Neuroscience*, *6*, 25. https://doi.org/10.3389/fnbeh.2012.00025

Rosekind, M. R., Gregory, K. B., Mallis, M. M., Brandt, S. L., Seal, B., & Lerner, D. (2010). The cost of poor sleep: Workplace productivity loss and associated costs. . *Journal of Occupational and Environmental Medicine*, *51*(1), 91-98. https://doi.org/10.1097/JOM.0b013e3181c78c30

Rowe, K., Wham, C., Rutherfurd-Markwick, K., & Ali, A. (2020). CaffCo: A valid and reliable tool to assess caffeine consumption habits, caffeine expectancies, and caffeine withdrawal effects in adults. *Journal of caffeine and adenosine research*, *10*(4), 154-160. https://doi.org/10.1089/caff.2020.0015

Rusnac, N., Spitzenstetter, F., & Tassi, P. (2019). Chronic sleep loss and risk-taking behavior: Does the origin of sleep loss matter? *Behavioural Sleep Medicine*, *17*(6), 729-739. https://doi.org/10.1080/15402002.2018.1483368

Safhi, M. A., Alafif, R. A., Alamoudi, N. M., Alamoudi, M. M., Alghamdi, W. A., Albishri, S. F., & Rizk, H. (2020). The association of stress with sleep quality among medical students at King Abdulaziz University. *Journal of Family Medicine and Primary Care*, *9*(3), 1662-1667. https://doi.org/10.4103/jfmpc.jfmpc_745_19

Samoggia, A., & Rezzaghi, T. (2021). The consumption of caffeine-containing products to enhance sports performance: An application of an extended model of the theory of planned behavior. *Nutrients*, *13*(2), 344. https://doi.org/10.3390/nu13020344

Sanchez, S. E., Martinez, C., Oriol, R. A., Yanez, D., Castañeda, B., Sanchez, E., . . . Williams, M. A. (2013). Sleep quality, sleep patterns and consumption of energy drinks and other caffeinated beverages among Peruvian college students. *Health (Irvine Calif)*, *5*(8B), 26-35. https://doi.org/10.4236/health.2013.58A2005

Saper, C. B., Fuller, P. M., Pedersen, N. P., Lu, J., & Scammell, T. E. (2010). Sleep state switching. *Neuron*, *68*(6), 1023-1042. https://doi.org/10.1016/j.neuron.2010.11.032

Schibler, U. (2008). The Mammalian Circadian Timekeeping System. In D. Lloyd, & Rossi, E. L. (Ed.), *Ultradian Rhythms from Molecules to Mind*. Springer: Dordrecht. https://doi.org/10.1007/978-1-4020-8352-5_12

Schuld, A., Haack, M., Hinze-Selch, D., Mullington, J., & Pollmächer, T. (2005). Experimental studies on the interaction between sleep and the immune system in humans. *Psychotherapie, Psychosomatik, Medizinische Psychologie*, *55*(1), 29-35. https://doi.org/10.1055/s-2004-834561

Scott, A. J., Webb, T. L., Martyn-St James, M., Rowse, G., & Weich, S. (2021). Improving sleep quality leads to better mental health: A meta-analysis of randomised controlled trials. *Sleep medicine reviews*, *60*, 101556. https://doi.org/10.1016/j.smrv.2021.101556

Shan, Z., Ma, H., Xie, M., Yan, P., Guo, Y., Bao, W., . . . Liu, L. (2015). Sleep duration and risk of type 2 diabetes: A meta-analysis of prospective studies. *Diabetes Care*, *38*(3), 529-537. https://doi.org/10.2337/dc14-2073

Sharma, S., & Kavuru, M. (2010). Sleep and metabolism: An overview. *International Journal of Endocrinology*, *2010*, 270832. https://doi.org/10.1155/2010/270832

Shi, L., Chen, S. J., Ma, M. Y., Bao, Y. P., Han, Y., Wang, Y. M., . . . Lu, L. (2018). Sleep disturbances increase the risk of dementia: A systematic review and meta-analysis. *Sleep medicine reviews*, *40*, 4-16. https://doi.org/10.1016/j.smrv.2017.06.010

Shilo, L., Sabbah, H., Hadari, R., Kovatz, S., Weinberg, U., Dolev, S., . . . Shenkman, L. (2002). The effects of coffee consumption on sleep and melatonin secretion. *Sleep Medicine*, *3*(3), 271-273. https://doi.org/10.1016/s1389-9457(02)00015-1

Shin, J. E., & Kim, J. K. (2018). How a good sleep predicts life satisfaction: The role of zero-sum beliefs about happiness. *Frontiers in Psychology*, *9*, 1589. https://doi.org/10.3389/fpsyg.2018.01589

Shochat, T. (2012). Impact of lifestyle and technology developments on sleep. *Nature and Science of Sleep*, *4*, 19-31. https://doi.org/10.2147/NSS.S18891

Shrestha, D., Adhikari, S. P., Rawal, N., Budhathoki, P., Pokharel, S., Adhikari, Y., . . . Raut, U. (2021). Sleep quality among undergraduate students of a medical college in Nepal during COVID-19 pandemic: An online survey. *F1000Research*, *10*(505). https://doi.org/10.12688/f1000research.53904.2

Siegel, J. M. (2005). Clues to the functions of mammalian sleep. *Nature*, *437*(7063), 1264-1271. https://doi.org/10.1038/nature04285.

Sigmon, S. C., Herning, R. I., Better, W., Cadet, J. L., & Griffiths, R. R. (2009). Caffeine withdrawal, acute effects, tolerance, and absence of net beneficial effects of chronic administration: Cerebral blood flow velocity, quantitative EEG, and subjective effects. *Psychopharmacology*, *204*(4), 573-585. https://doi.org/10.1007/s00213-009-1489-4

Sivertsen, B., Vedaa, Ø., Harvey, A. G., Glozier, N., Pallesen, S., Aarø, L. E., . . . Hysing, M. (2019). Sleep patterns and insomnia in young adults: A national survey of Norwegian university students. *Journal of sleep research*, *28*(2), e12790. https://doi.org/10.1111/jsr.12790

Smith, A. (2002). Effects of caffeine on human behavior. *Food and Chemical Toxicology*, *40*(9), 1243-1255. https://doi.org/10.1016/s0278-6915(02)00096-0

Snel, J. (1993). Coffee and Caffeine: Sleep and Wakefulness. In Garattini S. (Ed.), *Caffeine, Coffee and Health* (pp. 244-290). Raven Press, New York.

Snel, J., & Lorist, M. M. (2011). Effects of caffeine on sleep and cognition. *Progress in Brain Research*, *190*, 105-117. https://doi.org/10.1016/B978-0-444-53817-8.00006-2

Spiegel, K., Leproult, R., L'hermite-Balériaux, M., Copinschi, G., Penev, P. D., & Van Cauter, E. (2004). Leptin levels are dependent on sleep duration: Relationships with sympathovagal balance, carbohydrate regulation, cortisol, and thyrotropin. *The Journal of Clinical Endocrinology and Metabolism*, *89*(11), 5762-5771. https://doi.org/10.1210/jc.2004-1003

Spoormaker, V. I., Verbeek, I., van den Bout, J., & Klip, E. C. (2005). Initial validation of the SLEEP-50 questionnaire. *Behavioural Sleep Medicine*, *3*(4), 227-246. https://doi.org/10.1207/s15402010bsm0304_4

Stachyshyn, S., Wham, C., Ali, A., Knightbridge-Eager, T., & Rutherfurd-Markwick, K. (2021). Motivations for caffeine consumption in New Zealand tertiary students. *Nutrients*, *13*(12), 4236. https://doi.org/10.3390/nu13124236

Statistics New Zealand. (2018a). *2018 Census Ethnic Group Summaries*. https://www.stats.govt.nz/tools/2018-census-ethnic-group-summaries/

Statistics New Zealand. (2018b). *2018 Cencus Place Summaries - Auckland Region*. https://www.stats.govt.nz/tools/2018-census-place-summaries/auckland-region#ethnicity-culture-and-identity

Stern, K. N., Chait, L. D., & Johanson, C. E. (1989). Reinforcing and subjective effects of caffeine in normal human volunteers. *Psychopharmacology*, *98*(1), 81-88. https://doi.org/10.1007/BF00442010

Strain, E. C., Mumford, G. K., Silverman, K., & Griffiths, R. R. (1994). Caffeine dependence syndrome. Evidence from case histories and experimental evaluations. . *Jama*, *272*(13), 1043-1048.

Stroud, C., Walker, L. R., Davis, M., & Irwin, C. E., Jr (2015). Investing in the health and well-being of young adults. *The Journal of Adolescent Health*, *56*(2), 127-129.

Suen, L. K., Tam, W. W., & Hon, K. L. (2010). Association of sleep hygiene-related factors and sleep quality among university students in Hong Kong. *Hong Kong Medical Journal*, *16*(3), 180-185.

Swanson, L. M., Arnedt, J. T., Rosekind, M. R., Belenky, G., Balkin, T. J., & Drake, C. (2011). Sleep disorders and work performance: Findings from the 2008 National Sleep Foundation Sleep in America poll. *Journal of sleep research*, *20*(3), 487-494. https://doi.org/10.1111/j.1365-2869.2010.00890.x

Swift, C. G., & Tiplady, B. (1988). The effects of age on the response to caffeine. *Psychopharmacology*, *94*(1), 29-31. https://doi.org/https://doi.org/10.1007/BF00735876

Taghvaee, L., & Mazandarani, A. A. (2022). Poor sleep is associated with sensation-seeking and risk behavior in college students. *Sleep Science*, *15*(Spec 1), 249-256. https://doi.org/10.5935/1984-0063.20220024

Taillard, J., Philip, P., Coste, O., Sagaspe, P., & Bioulac, B. (2003). The circadian and homeostatic modulation of sleep pressure during wakefulness differs between morning and evening chronotypes. *Journal of sleep research*, *12*, 275-282. https://doi.org/10.1046/j.0962-1105.2003.00369.x

Tang, J., Liao, Y., Kelly, B. C., Xie, L., Xiang, Y. T., Qi, C., . . . Chen, X. (2017). Gender and regional differences in sleep quality and insomnia: A general population-based study in Hunan Province of China. *Scientific Reports*, *7*, 43690. https://doi.org/10.1038/srep43690

Taylor, D. J., Bramoweth, A. D., Grieser, E. A., Tatum, J. I., & Roane, B. M. (2013). Epidemiology of insomnia in college students: Relationship with mental health, quality of life, and substance use difficulties. *Behavior Therapy*, *44*(3), 339-348. https://doi.org/10.1016/j.beth.2012.12.001.

Taylor, D. J., Jenni, O. G., Acebo, C., & Carskadon, M. A. (2005). Sleep tendency during extended wakefulness: Insights into adolescent sleep regulation and behavior. *Journal of sleep research*, *14*(3), 239-244. https://doi.org/10.1111/j.1365-2869.2005.00467.x

Tefft, B. C. (2018). Acute sleep deprivation and culpable motor vehicle crash involvement. *Sleep*, *41*(10), zsy144. https://doi.org/10.1093/sleep/zsy144

Temple, J. L., Bernard, C., Lipshultz, S. E., Czachor, J. D., Westphal, J. A., & Mestre, M. A. (2017). The safety of ingested caffeine: A comprehensive review. *Frontiers in Psychiatry*, *8*, 80-80. https://doi.org/10.3389/fpsyt.2017.00080

Temple, J. L., & Ziegler, A. M. (2011). Gender differences in subjective and physiological responses to caffeine and the role of steroid hormones. *Journal of Caffeine Research*, *1*(1), 41-48. https://doi.org/10.1089/jcr.2011.0005

Thomson, B. M., Campbell, D. M., Cressey, P., Egan, U., & Horn, B. (2014). Energy drink consumption and impact on caffeine risk. *Food Additives and Contaminants. Part A, Chemistry, Analysis, Control, Exposure and Risk Assessment*, *31*(9), 1476-1488. https://doi.org/10.1080/19440049.2014.940608

Tonetti, L., Fabbri, M., & Natale, V. (2008). Sex difference in sleep-time preference and sleep need: A cross-sectional survey among Italian pre-adolescents, adolescents, and adults. *Chronobiology International*, *25*(5), 745–759. https://doi.org/10.1080/07420520802394191

Trajanovic, N. N., Radivojevic, V., Kaushansky, Y., & Shapiro, C. M. (2007). Positive sleep state misperception - a new concept of sleep misperception. *Sleep Medicine*, *8*(2), 111-118. https://doi.org/10.1016/j.sleep.2006.08.013

Tran, N. L., Barraj, L. M., Bi, X., & Jack, M. M. (2016). Trends and patterns of caffeine consumption among US teenagers and young adults, NHANES 2003-2012. *Food and Chemical Toxicology*, *94*, 227-242. https://doi.org/10.1016/j.fct.2016.06.007

Turnbull, D., Rodricks, J. V., & Mariano, G. F. (2016). Neurobehavioral hazard identification and characterization for caffeine. Regulatory toxicology and pharmacology. *Regulatory Toxicology and Pharmacology*, *74*, 81-92. https://doi.org/10.1016/j.yrtph.2015.12.002

University of Otago and Ministry of Health. (2011). *A Focus on Nutrition: Key Findings of the 2008/9 New Zealand Adult Nutrition Survey*. Ministry of Health: Wellington New Zealand.

Vail-Smith, K., Felts, W. M., & Becker, C. (2009). Relationship between sleep quality and health risk behaviours in undergraduate college students. *College Student Journal*, *43*(3), 924-930.

Van de Water, A. T., Holmes, A., & Hurley, D. A. (2011). Objective measurements of sleep for non-laboratory settings as alternatives to polysomnography—A systematic review. *Journal of sleep research*, *20*(1 Pt 2), 183-200. https://doi.org/10.1111/j.1365-2869.2009.00814.x

Van Dongen, H. P., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, *26*(2), 117-126. https://doi.org/10.1093/sleep/26.2.117

Van Galen, P. J., Stiles, G. L., Michaels, G., & Jacobson, K. A. (1992). Adenosine A1 and A2 receptors: Structure--function relationships. *Medicinal Research Reviews*, *12*(5), 423-471. https://doi.org/10.1002/med.2610120502

Vandekerckhove, M., & Wang, Y. L. (2017). Emotion, emotion regulation and sleep: An intimate relationship. *AIMS Neuroscience*, *5*(1), 1-17. https://doi.org/10.3934/Neuroscience.2018.1.1
Vegro, C. L. R., & de Almeida, L. R. (2020). Chapter 1—Global coffee market: Socio-economic and cultural dynamics. In *Coffee Consumption and Industry Strategies in Brazil* (pp. 3-19). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-814721-4.00001-9
Venter, R. E. (2012). Role of sleep in performance and recovery of athletes: A review article. *South African Journal for Research in Sport, Physical Education and Recreation*, *34*(1), 167-184.
Verster, J. C., & Koenig, J. (2018). Caffeine intake and its sources: A review of national representative studies. *Critical Reviews in Food Science And Nutrition*, *58*(8), 1250–1259. https://doi.org/10.1080/10408398.2016.1247252
Vikram, R., Comondore, Wenner, J. B., & Ayas, N. T. (2008). The impact of sleep deprivation in resident physicians on physician and patient safety: Is it time for a wake-up call? *BC Medical Journal*, *50*(10), 560-564.
Villanti, A. C., Johnson, A. L., Ilakkuvan, V., Jacobs, M. A., Graham, A. L., & Rath, J. M. (2017). Social media use and access to digital technology in US young adults in 2016. *Journal of Medical Internet Research*, *19*(6), e196. https://doi.org/10.2196/jmir.7303
Walker, M. P. (2009). The role of sleep in cognition and emotion. *Annals of the New York Academy of Sciences*, *1156*, 168-197. https://doi.org/10.1111/j.1749-6632.2009.04416.x
Walker, M. P., Brakefield, T., Morgan, A., Hobson, J. A., & Stickgold, R. (2002). Practice with sleep makes perfect: Sleep-dependent motor skill learning. *Neuron*, *35*(1), 205-211. https://doi.org/10.1016/s0896-6273(02)00746-8
Wang, F., & Bíró, É. (2021). Determinants of sleep quality in college students: A literature review. . *Explore*, *17*(2), 170-177. https://doi.org/10.1016/j.explore.2020.11.003
Wang, J., Wu, N., & Zhang, L. (2022). The causal relationship between sleep and obesity: Novel insights and therapeutic target. *The Journal of Clinical Endocrinology and Metabolism*, *107*(10), e4265-e4266. https://doi.org/10.1210/clinem/dgac372
Wang, Y. H., Wang, J., Chen, S. H., Li, J. Q., Lu, Q. D., Vitiello, M. V., . . . Bao, Y. P. (2020). Association of longitudinal patterns of habitual sleep duration with risk of cardiovascular events and all-cause mortality. *JAMA Network Open*, *3*(5), e205246. https://doi.org/10.1001/jamanetworkopen.2020.5246
Watson, E. J., Coates, A. M., Kohler, M., & Banks, S. (2016). Caffeine consumption and sleep quality in Australian adults. *Nutrients*, *8*(8), 479. https://doi.org/10.3390/nu8080479
Watson, N. F., Badr, M. S., Belenky, G., Bliwise, D. L., Buxton, O. M., Buysse, D., . . . Tasali, E. (2015). Joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society on the recommended amount of sleep for a healthy adult: Methodology and discussion. *Sleep*, *38*(8), 1161-1183. https://doi.org/10.5665/sleep.4886
Weibel, J., Lin, Y. S., Landolt, H. P., Berthomier, C., Brandewinder, M., Kistler, J., . . . Reichert, C. F. (2021). Regular caffeine intake delays REM sleep promotion and attenuates sleep quality in healthy men. *Journal of Biological Rhythms*, *36*(4), 384-394. https://doi.org/10.1177/07487304211013995
White, J. R., Jr,, Padowski, J. M., Zhong, Y., Chen, G., Luo, S., Lazarus, P., . . . McPherson, S. (2016). Pharmacokinetic analysis and comparison of caffeine administered rapidly or slowly in coffee chilled or hot versus chilled energy drink in healthy young adults. *Clinical Toxicology*, *54*(4), 308-312. https://doi.org/10.3109/15563650.2016.1146740
Wikoff, D., Welsh, B. T., Henderson, R., Brorby, G. P., Britt, J., Myers, E., . . . Doepker, C. (2017). Systematic review of the potential adverse effects of caffeine consumption in healthy

adults, pregnant women, adolescents, and children. *Food and Chemical Toxicology*, *109*(Pt 1), 585-648. https://doi.org/10.1016/j.fct.2017.04.002
Williamson, A. M., & Feyer, A. M. (2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occupational and Environmental Medicine*, *57*(10), 649-655. https://doi.org/10.1136/oem.57.10.649
Willson, C. (2018). The clinical toxicology of caffeine: A review and case study. *Toxicology Reports*, *5*, 1140-1152. https://doi.org/10.1016/j.toxrep.2018.11.002
Wilsmore, B. R., Grunstein, R. R., Fransen, M., Woodward, M., Norton, R., & Ameratunga, S. (2013). Sleep habits, insomnia, and daytime sleepiness in a large and healthy community-based sample of New Zealanders. *Journal of Clinical Sleep Medicine*, *9*(6), 559-566. https://doi.org/10.5664/jcsm.2750
Wittmann, M., Dinich, J., Merrow, M., & Roenneberg, T. (2006). Social jetlag: Misalignment of biological and social time. *Chronobiology International*, *23*(1-2), 497-509. https://doi.org/10.1080/07420520500545979
Wondie, T., Molla, A., Mulat, H., Damene, W., Bekele, M., Madoro, D., & Yohannes, K. (2021). Magnitude and correlates of sleep quality among undergraduate medical students in Ethiopia: cross-sectional study. *Sleep Science and Practice*, *5*, 7. https://doi.org/10.1186/s41606-021-00058-2
World Health Organization. (2018). *Cut-off for BMI according to WHO standards*. https://gateway.euro.who.int/en/indicators/mn_survey_19-cut-off-for-bmi-according-to-who-standards/
Wu, Y., Zhai, L., & Zhang, D. (2014). Sleep duration and obesity among adults: A meta-analysis of prospective studies. *Sleep Medicine*, *15*(12), 1456-1462. https://doi.org/10.1016/j.sleep.2014.07.018
Xie, L., Kang, H., Xu, Q., Chen, M. J., Liao, Y., Thiyagarajan, M., . . . Nedergaard, M. (2013). Sleep drives metabolite clearance from the adult brain. *Science*, *342*(6156), 373-377. https://doi.org/10.1126/science.1241224
Yang, A., Palmer, A. A., & de Wit, H. (2010). Genetics of caffeine consumption and responses to caffeine. *Psychopharmacology*, *211*(3), 245-257. https://doi.org/10.1007/s00213-010-1900-1
Yazdi, Z., Loukzadeh, Z., Moghaddam, P., & Jalilolghadr, S. (2016). Sleep hygiene practices and their relation to sleep quality in medical students of Qazvin University of Medical Sciences. *Journal of Caring Sciences*, *5*(2), 153-160. https://doi.org/10.15171/jcs.2016.016
Yin, J., Jin, X., Shan, Z., Li, S., Huang, H., Li, P., . . . Liu, L. (2017). Relationship of sleep duration with all-cause mortality and cardiovascular events: A systematic review and dose-response meta-analysis of prospective cohort studies. *Journal of the American Heart Association*, *6*(9), e005947. https://doi.org/10.1161/JAHA.117.005947
Young, D. R., Sidell, M. A., Grandner, M. A., Koebnick, C., & Troxel, W. (2020). Dietary behaviors and poor sleep quality among young adult women: watch that sugary caffeine! *Sleep Health*, *6*(2), 214-219. https://doi.org/10.1016/j.sleh.2019.12.006
Youngstedt, S. D., Goff, E. E., Reynolds, A. M., Kripke, D. F., Irwin, M. R., Bootzin, R. R., . . . Jean-Louis, G. (2016). Has adult sleep duration declined over the last 50+ years?. *Sleep medicine reviews*, *28*(69-85). https://doi.org/10.1016/j.smrv.2015.08.004
Zee, P. C., & Turek, F. W. (2006). Sleep and health: Everywhere and in both directions. *Archives of Internal Medicine.*, *166*(16), 1686-1688. https://doi.org/10.1001/archinte.166.16.1686

Zele, A. J., Feigl, B., Smith, S. S., & Markwell, E. L. (2011). The circadian response of intrinsically photosensitive retinal ganglion cells. *PLOS ONE*, *6*(3), e17860. https://doi.org/10.1371/journal.pone.0017860

Zhang, L., & Zhao, Z.-X. (2008). Objective and subjective measures for sleep disorders. *Neuroscience Bulletin*, *22*(236-240).

Zhou, Q., Zhang, M., & Hu, D. (2019). Dose-response association between sleep duration and obesity risk: A systematic review and meta-analysis of prospective cohort studies. *Sleep Breath*, *23*, 1035-1045. https://doi.org/10.1007/s11325-019-01824-4

Zitting, K. M., Münch, M. Y., Cain, S. W., Wang, W., Wong, A., Ronda, J. M., . . . Duffy, J. F. (2018). Young adults are more vulnerable to chronic sleep deficiency and recurrent circadian disruption than older adults. *Scientific Reports*, *8*(1), 11052. https://doi.org/10.1038/s41598-018-29358-x

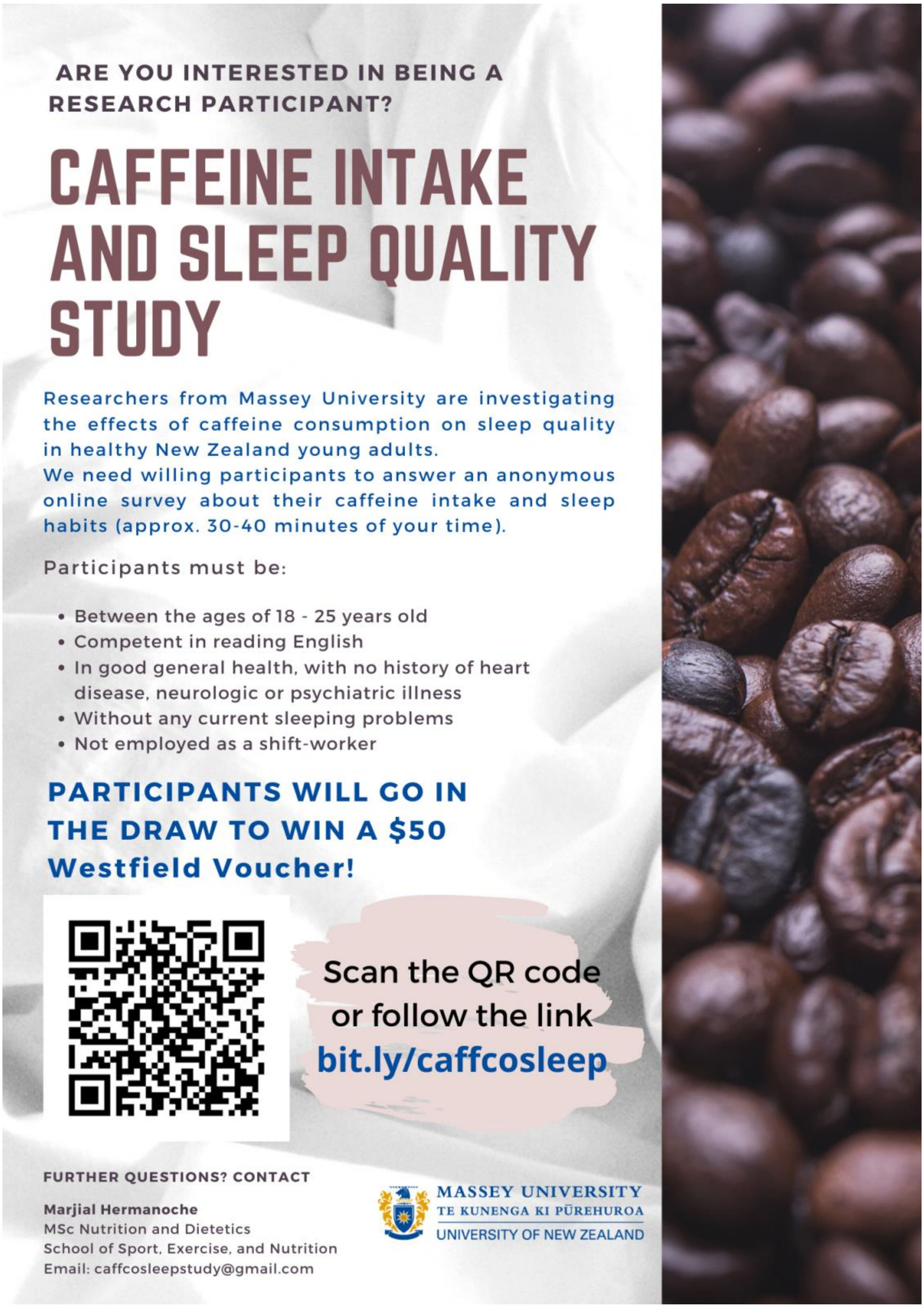
Zomers, M. L., Hulsegge, G., van Oostrom, S. H., Proper, K. I., Verschuren, W., & Picavet, H. (2017). Characterizing adult sleep behaviour over 20 years - The Population-Based Doetinchem Cohort Study. *Sleep*, *40*(7), zsx085. https://doi.org/10.1093/sleep/zsx085

Zoomer, J., Peder, R., Rubin, A. H., & Lavie, P. (1985). Mini Sleep Questionnaire for screening large populations for EDS complaints. In W. P. Koella, E. Ruther, & H. Schulz (Eds.), *Sleep '84* (pp. 467-470). Gustav Fischer: Stuttgart, Germany.

Zunhammer, M., Eichhammer, P., & Busch, V. (2014). Sleep quality during exam stress: the role of alcohol, caffeine and nicotine. *PLOS ONE*, *9*(10), e109490. https://doi.org/10.1371/journal.pone.0109490

APPENDICES

Appendix A: Study Advertisement Poster



Appendix B: Massey University Human Ethics Committee (MUHEC) Letter of Approval

Date: 27 April 2021

Dear Marjial Hermanoche

Re: Ethics Notification - **SOA 21/11** - **The Effects of Caffeine Consumption on Sleep Quality in Healthy New Zealand Young Adults (aged 18-25 years old).**

Thank you for the above application that was considered by the Massey University Human Ethics Committee: **Human Ethics Southern A Committee** at their meeting held on **Tuesday, 27 April, 2021**.

Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)

Research Ethics Office, Research and Enterprise
Massey University, Private Bag 11 222, Palmerston North, 4442, New Zealand **T** 06 350 5573; 06 350 5575 **F** 06 355 7973
E humanethics@massey.ac.nz **W** http://humanethics.massey.ac.nz

Appendix C: Participant Information Sheet

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

The Effects of Caffeine Consumption on Sleep Quality in New Zealand Young Adults

Information sheet (Part 1)

We invite you to complete an **anonymous** online survey to learn more about the impact of your caffeine consumption on sleep quality. This study is being conducted by researchers at the School of Sport, Exercise and Nutrition, and the School of Health Sciences at Massey University.

What is the study about?

Caffeine, particularly in the form of coffee, is the most widely consumed psychostimulant drug in the world. It is commonly used to fight fatigue and is believed to improve both concentration and performance. However, caffeine is also known to have poor effects on sleep including prolonging the time it takes to fall asleep, causing more disturbances, reducing total sleep time and increasing daytime sleepiness. With an increasing supply of caffeinated products on the market and a rise in chronic sleep problems in the population, this is highlighted as being an important area of research. There is currently very little information on the caffeine habits and prevalence of poor sleep quality among young adults in New Zealand. This study aims to fill this gap in our research knowledge.

Who will participate?

To participate, you need to be:

- Currently living in New Zealand
- Between the ages of 18-25 years old
- Fluent in reading and writing in English
- Willing to complete two questionnaires
- Be in good general health with no current sleep problems or history of heart, neurological or psychiatric illness
- Not working as a shift-worker

What will you need to do?

You will need to complete two online questionnaires that ask you about your caffeine intake, influences and experiences as well as your usual sleep habits. The questionnaires are anonymous, and your responses will be kept confidential. We expect the questionnaires to take approximately 30-40 minutes to complete, depending on what parts are applicable to you.

To thank you for your time, you will have the opportunity to enter your details in a prize draw to win a $50 Westfield voucher. Email addresses **will not** be kept with survey data and will be destroyed after the prize draw has been made.

Te Kunenga ki Pūrehuroa

School of Sport & Exercise
Private Bag 102904, North Shore City 0745, New Zealand T +64 9 443 9770 **www.massey.ac.nz**

How will your data be looked after?

Your data will only be used for research purposes and will be stored securely on password-protected computers in password-protected files, only viewable to the research team. In order to maintain confidentiality, a coding system will be used where each participant is given a unique identifier. This means that although you will not be anonymous to the research team, all data will be anonymised.

If you feel concerned about your caffeine or other food and beverage consumption, please consult with your GP. Otherwise, Samaritans NZ is an organisation available for non-judgemental, confidential support to anyone in distress (04 473 9739). Alcohol Drug Helpline (0800 787 797) is a free, anonymous service available if you have concerns about your alcohol consumption.

What are my rights?

Completion and return of the questionnaires imply your consent. You have the right to decline to answer any particular question and/or may exit the survey at any time (up until submission).

How can I be more involved in this study?

At the end of the survey, more details will be provided on how you can be involved in Part 2 of the study. The research team are looking to collect and analyse sleep measures using sleep/wake activity watches (similar to a Fitbit).

Project Contacts

If you have any questions regarding this project, please contact the student researcher and/or one of the supervisors.

Student Researcher
Marjial Hermanoche (School of Sport, Exercise, and Nutrition)
Email: caffcosleepstudy@gmail.com
Mob: [redacted]

Supervisors
A/Prof Kay Rutherfurd-Markwick (School of Health Sciences)
Email: K.J.Rutherfurd@massey.ac.nz
Phone: +64 (09) 213 6646

Prof Ajmol Ali (School of Sport, Exercise and Nutrition)
Email: A.Ali@massey.ac.nz
Phone: +64 (09) 213 6414

Prof Carol Wham (School of Sport, Exercise and Nutrition)
Email: C.A.Wham@massey.ac.nz
Phone: +64 (09) 213 6644

Dr Karyn O'Keeffe (School of Health Sciences)
Email: K.M.OKeeffe@massey.ac.nz
Phone: +64 (04) 979 3260

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 21/11. If you have any concerns about the conduct of this research, please contact Dr Negar Partow, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 x 63363, email humanethicsoutha@massey.ac.nz.

Appendix D: Pittsburgh Sleep Quality Index (PSQI) Questionnaire

Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. **Please answer all questions.**

1. During the past month, what time have you usually gone to bed at night?
   [:] AM/PM

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?
   - □15 minutes
   - 16-30 minutes
   - 31-60 minutes
   - >60 minutes

3. During the past month, what time have you usually gotten up in the morning?
   [:] AM/PM

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)
   - >7 hours
   - 6-7 hours
   - 5-6 hours
   - <5 hours

5. During the past month, how often have you had trouble [illegible]	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				

h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe				

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
6. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				

	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
8. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?				

	Very good	Fairly good	Fairly bad	Very bad
9. During the past month, how would you rate your sleep quality overall?				

Appendix D.2: PSQI Scoring

Scoring Instructions for the Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) contains 19 self-rated questions and 5 questions rated by the bed partner or roommate (if one is available). Only self-rated questions are included in the scoring. The 19 self-rated items are combined to form seven "component" scores, each of which has a range of 0-3 points. In all cases, a score of "0" indicates no difficulty, while a score of "3" indicates severe difficulty. The seven component scores are then added to yield one "global" score, with a range of 0-21 points, "0" indicating no difficulty and "21" indicating severe difficulties in all areas.

Scoring proceeds as follows:

Component 1: Subjective sleep quality

Examine question #6, and assign scores as follows:

Response	Component 1 score
"Very good"	0
"Fairly good"	1
"Fairly bad"	2
"Very bad"	3

Component 1 score: ______

Component 2: Sleep latency

1. Examine question #2, and assign scores as follows:

Response	Score
≤ 15 minutes	0
16-30 minutes	1
31-60 minutes	2
> 60 minutes	3

Question #2 score: ______

2. Examine question #5a, and assign scores as follows:

Response	Score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Question #5a score: ______

3. Add #2 score and #5a score

Sum of #2 and #5a: ______

4. Assign component 2 score as follows:

Sum of #2 and #5a	Component 2 score
0	0
1-2	1
3-4	2
5-6	3

Component 2 score: ______

Component 3: Sleep duration

Examine question #4, and assign scores as follows:

Response	Component 3 score
> 7 hours	0
6-7 hours	1
5-6 hours	2
< 5 hours	3

Component 3 score: ______

Component 4: Habitual sleep efficiency

(1) Write the number of hours slept (question # 4) here: ______

(2) Calculate the number of hours spent in bed:

Getting up time (question # 3): ______

− Bedtime (question # 1): ______

Number of hours spent in bed: ______

(3) Calculate habitual sleep efficiency as follows:

(Number of hours slept/Number of hours spent in bed) × 100 = Habitual sleep efficiency (%)

(______/______) × 100 = ______%

(4) Assign component 4 score as follows:

Habitual sleep efficiency %	Component 4 score
> 85%	0
75-84%	1
65-74%	2
< 65%	3

Component 4 score: ______

Component 5: Sleep disturbances

(1) Examine questions # 5b-5j, and assign scores for *each* question as follows:

Response	Score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

#5b score ______
c score ______
d score ______
e score ______
f score ______
g score ______
h score ______
i score ______
j score ______

(2) Add the scores for questions # 5b-5j:

Sum of # 5b-5j: ______

(3) Assign component 5 score as follows:

Sum of # 5b-5j	Component 5 score
0	0
1-9	1
10-18	2
19-27	3

Component 5 score: ______

Component 6: Use of sleeping medication

Examine question # 7 and assign scores as follows:

Response	Component 6 score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Component 6 score: ______

Component 7: Daytime dysfunction

(1) Examine question # 8, and assign scores as follows:

Response	Score
Never	0
Once or twice	1
Once or twice each week	2
Three or more times each week	3

Question # 8 score: ______

(2) Examine question # 9, and assign scores as follows:

Response	Score
No problem at all	0
Only a very slight problem	1
Somewhat of a problem	2
A very big problem	3

Question # 9 score: ______

(3) Add the scores for question # 8 and # 9:

Sum of #8 and #9: ______

(4) Assign component 7 score as follows:

Sum of # 8 and #9	Component 7 score
0	0
1-2	1
3-4	2
5-6	3

Component 7 score: ______

Global PSQI Score

Add the seven component scores together:

Global PSQI Score: ______

Appendix E: Caffeine Consumption Habits (CaffCo) Questionnaire

<u>CaffCo Questionnaire</u>

Q1. Which of these items do you drink / eat? Include those that you only consume occasionally.

- ❑ Tea (black / green)
- ❑ Coffee
- ❑ Chocolate
- ❑ Cola flavoured drinks (e.g. Coke cola, Pepsi etc)
- ❑ Energy drinks / energy shots
- ❑ Premixed alcoholic RTDs with a cola drink base (e.g. rum and cola) or with added caffeine / guarana
- ❑ Pre-workout sports supplements and sports gels
- ❑ Caffeine Tablets (e.g. No Doz)
- ❑ None one of the above

Q2. How often do you drink the following types of tea (on average)? If you do not drink tea please skip to Question 6.

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
Green tea (1 cup)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Black tea with or without milk (1 cup)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Iced tea (1 glass)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Decaffeinated tea (1 cup)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q3. Think about your own reasons for drinking tea. Read the following statements about the different reasons for tea consumption and consider whether you agree, strongly agree, disagree or strongly disagree.
I drink tea…

	Strongly Agree	Agree	Disagree	Strongly Disagree
Because it is cheaper than other hot drinks	❍	❍	❍	❍
Because it is what I drink with food	❍	❍	❍	❍
To comfort and relax myself	❍	❍	❍	❍
For the warmth	❍	❍	❍	❍
For the taste	❍	❍	❍	❍
With friends	❍	❍	❍	❍
Whenever it is offered to me	❍	❍	❍	❍
For mental energy	❍	❍	❍	❍
With family	❍	❍	❍	❍
Out of boredom	❍	❍	❍	❍
Because I feel I am influenced by peer pressure	❍	❍	❍	❍
Out of habit	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
Because it is easily available	❍	❍	❍	❍
To wake up	❍	❍	❍	❍
Because others are drinking it	❍	❍	❍	❍
As my culture influences me to drink it	❍	❍	❍	❍
For energy	❍	❍	❍	❍
When I have had enough coffee for the day	❍	❍	❍	❍
To replace food or meals	❍	❍	❍	❍
Because I think coffee has too much caffeine in it	❍	❍	❍	❍

Q4. What time of day do you drink tea? Choose all options that apply to you.

❑ Before breakfast
❑ At breakfast time
❑ Between breakfast and lunch
❑ At lunch time
❑ Between lunchtime and dinner
❑ At dinner time
❑ After dinner
❑ All day
❑ At no particular time

Q5. In which environments do you drink tea? Select all that apply.

❑ A home environment (your own or others)
❑ A work environment
❑ A cafe or other socialising environment
❑ A study environment
❑ Other (please specify) ____________________

Q6. How often do you drink the following types of coffee (on average)? If you consume other variants of coffee e.g. flat white etc., please answer according to how many shots they contain. If you do not drink coffee, please skip to Question 10.

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
Instant coffee (made with 1 teaspoon coffee powder)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Plunger / drip coffee (1 medium cup - 250ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Small espresso coffee (single shot)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Large espresso coffee (double shot)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Decaffeinated coffee (1 cup)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Iced coffee (1 glass)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q7. Think about your own reasons for drinking coffee. Read the following statements about the different reasons for coffee consumption and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'.
I drink coffee...

	Strongly Agree	Agree	Disagree	Strongly Disagree
Because it is easily available	❍	❍	❍	❍
Out of boredom	❍	❍	❍	❍
As a treat or luxury drink	❍	❍	❍	❍
Because it is what I drink with food	❍	❍	❍	❍
To comfort and relax myself	❍	❍	❍	❍
For the warmth	❍	❍	❍	❍
For the taste	❍	❍	❍	❍
With friends	❍	❍	❍	❍
Whenever it is offered to me	❍	❍	❍	❍
Because others are drinking it	❍	❍	❍	❍
With family	❍	❍	❍	❍
While driving long distances	❍	❍	❍	❍
For physical energy	❍	❍	❍	❍
For mental energy	❍	❍	❍	❍
For energy	❍	❍	❍	❍
Because I feel I am influenced by peer pressure	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
Out of habit	❍	❍	❍	❍
As my culture influences me to drink it	❍	❍	❍	❍
To stay awake	❍	❍	❍	❍
To wake up	❍	❍	❍	❍
To replace food or meals	❍	❍	❍	❍
When I am smoking	❍	❍	❍	❍

Q8. What time of day do you drink coffee? Choose all options that apply to you.

❑ Before breakfast
❑ At breakfast time
❑ Between breakfast and lunch
❑ At lunch time
❑ Between lunchtime and dinner
❑ At dinner time
❑ After dinner
❑ All day
❑ At no particular time

Q9. In which environments do you drink coffee? Select all that apply.

- ❑ A home environment (your own or others)
- ❑ A cafe or other socialising environment
- ❑ A work environment
- ❑ A study environment
- ❑ A physical exercise environment (before or during)
- ❑ A physical exercise environment (after)
- ❑ Other (please specify) ____________________

Q10 Think about your own reasons for drinking decaffeinated coffee / tea instead of regular coffee / tea. Read the following statements about the different reasons for consumption and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'. If you do not drink decaffeinated coffee / tea, please skip to question 11.

I drink decaffeinated coffee / tea...

	Strongly agree	Agree	Disagree	Strongly Disagree
When I feel that I have had enough regular coffee / tea for the day	❍	❍	❍	❍
Because I do not want the caffeine in regular coffee / tea	❍	❍	❍	❍
Because it is offered to me	❍	❍	❍	❍
Because I can't tolerate the caffeine in regular coffee / tea	❍	❍	❍	❍
For medical reasons	❍	❍	❍	❍
Because I prefer the taste of decaffeinated coffee / tea compared to regular	❍	❍	❍	❍
Other (please specify)	❍	❍	❍	❍

Q11. How often do you eat the following types of chocolate (on average)? **Please choose the closest portion size to what you would usually consume. If you do not eat chocolate, please skip to question 16.**

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
Milk Chocolate small bar (50g)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Milk Chocolate large block (200-250g)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Dark Chocolate small bar (50g)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Dark Chocolate large block (200-250g)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Hot chocolate (1 medium cup)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q12. Think about your own reasons for eating chocolate. Read the following statements about the different reasons for chocolate consumption and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'.
I eat chocolate...

	Strongly Agree	Agree	Disagree	Strongly Disagree
To comfort and relax myself	❍	❍	❍	❍
For the taste	❍	❍	❍	❍
More when I am on my period	❍	❍	❍	❍
As a treat or luxury food	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
With friends	❍	❍	❍	❍
With family	❍	❍	❍	❍
Because it is already in many of the foods that I eat	❍	❍	❍	❍
For the warmth (drinking chocolate)	❍	❍	❍	❍
Because I feel I am influenced by peer pressure	❍	❍	❍	❍
To replace other food or meals	❍	❍	❍	❍
Whenever it is offered to me	❍	❍	❍	❍
Out of boredom	❍	❍	❍	❍
Because others are eating it	❍	❍	❍	❍
Out of habit	❍	❍	❍	❍
Because it is easily available	❍	❍	❍	❍

Q13. What time of day do you eat chocolate? Choose all options that apply to you.
❑ Before breakfast
❑ At breakfast time
❑ Between breakfast and lunch
❑ At lunch time
❑ Between lunchtime and dinner
❑ At dinner time
❑ After dinner
❑ All day
❑ At no particular time

Q14. Which pattern of eating chocolate best describes your own?
❑ I regularly eat a large amount of chocolate at one time
❑ I regularly eat small amounts of chocolate
❑ I occasionally eat small amounts of chocolate
❑ I occasionally eat a large amount of chocolate all at one time
❑ Other (please specify) ____________________

Q15. In which environments do you eat chocolate? Select all that apply.

❑ A home environment (your own or others)
❑ A cafe or other socialising environment
❑ A work environment
❑ A study environment
❑ Other (please specify) ____________________

Q16. How often do you drink the following types of cola-flavoured drinks (on average)? This includes brands such as Coca-Cola, Pepsi and other brands of cola-flavoured drinks. 'Diet', 'Zero', 'Max' varieties are included in their own category below ('diet'), rather than with 'regular' cola drinks. If you do not drink cola-flavoured drinks, please skip to question 20.

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
1 glass of regular cola drink (250ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 can of regular cola drink (355ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 small bottle of regular cola drink (600ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 glass of DIET / ZERO / MAX cola drink (250ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 can of DIET / ZERO / MAX cola drink (355ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 small bottle of DIET / ZERO / MAX cola drink (600ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q17. Think about your own reasons for drinking cola drinks (both regular and diet). Read the following statements about the different reasons for coffee consumption and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'. I drink cola drinks (both regular and diet)...

	Strongly Agree	Agree	Disagree	Strongly Disagree
Because they are cheaper than other drinks	❍	❍	❍	❍
Because is the drink I have with meals	❍	❍	❍	❍
Because it is cold and refreshing	❍	❍	❍	❍
For the taste	❍	❍	❍	❍
With friends	❍	❍	❍	❍
Out of habit	❍	❍	❍	❍
To replace food or meals	❍	❍	❍	❍
For the bubbles / how it feels in my mouth	❍	❍	❍	❍
Whenever it is offered to me	❍	❍	❍	❍
For energy	❍	❍	❍	❍
Because they are easily available	❍	❍	❍	❍
Out of boredom	❍	❍	❍	❍
Instead of coffee when the weather is hot	❍	❍	❍	❍
Instead of alcohol	❍	❍	❍	❍
Because others are drinking it	❍	❍	❍	❍
With family	❍	❍	❍	❍
As a treat drink	❍	❍	❍	❍
As a mixer for alcohol	❍	❍	❍	❍
With takeaway food	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
Because I feel I am influenced by peer pressure	❍	❍	❍	❍

Q18. What time of day do you drink cola drinks (both regular and diet)? Choose all options that apply to you.

❑ Before breakfast
❑ At breakfast time
❑ Between breakfast and lunch
❑ At lunch time
❑ Between lunchtime and dinner
❑ At dinner time
❑ After dinner
❑ All day
❑ At no particular time

Q19. In which environments do you drink cola drinks (both regular and diet)? Select all that apply.

❑ A home environment (your own or others)

- ❑ A cafe or other socialising environment
- ❑ A work environment
- ❑ A party environment
- ❑ A study environment
- ❑ A physical exercise environment (before or during)
- ❑ A bar environment
- ❑ Other (please specify) ____________________

Q20. How often do you drink the following types of energy drinks? Energy drinks include brands such as Red Bull, V, Mother, Monster Energy and others. If you do not drink energy drinks, please skip to question 24.

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
1 energy shot	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 small can of energy drink (250ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 small bottle of energy drink (350ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 large can / bottle of energy drink (500ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q21. Think about your own reasons for drinking energy drinks. Read the following statements about the different reasons for energy drink consumption and consider whether you; agree, strongly agree, disagree or strongly disagree.
I drink energy drinks...

	Strongly Agree	Agree	Disagree	Strongly Disagree
Because they are cold and refreshing	❍	❍	❍	❍
For the taste	❍	❍	❍	❍
Because I feel I am influenced by peer pressure	❍	❍	❍	❍
Out of habit	❍	❍	❍	❍
For physical energy	❍	❍	❍	❍
While driving long distances	❍	❍	❍	❍
With family	❍	❍	❍	❍
For energy	❍	❍	❍	❍
Whenever one is offered to me	❍	❍	❍	❍
Out of boredom	❍	❍	❍	❍
With takeaway food	❍	❍	❍	❍
To improve physical performance	❍	❍	❍	❍
For mental energy	❍	❍	❍	❍
Instead of alcohol	❍	❍	❍	❍
As a mixer for alcohol	❍	❍	❍	❍
Because others are drinking it	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
To replace food or meals	❍	❍	❍	❍

Q22. What time of day do you drink energy drinks? Choose all options that apply to you.

❑ Before breakfast
❑ At breakfast time
❑ Between breakfast and lunch
❑ At lunch time
❑ Between lunchtime and dinner
❑ At dinner time
❑ After dinner
❑ All day
❑ At no particular time

Q23. In which environments do you drink energy drinks?

❑ A home environment
❑ A cafe or other socialising environment
❑ A work environment
❑ A party environment
❑ A physical exercise environment
❑ A study environment
❑ A bar environment
❑ Other (please specify) ____________________

Q24. How often do you drink caffeinated RTDs? Caffeinated RTDs are premixed alcoholic drinks with either a cola base (e.g. Jack Daniels, Jim Beam, Woodstock, Coruba and cola etc) or with added caffeine or guarana (e.g. some Smirnoff Ice, Purple Goanna). If you do not drink caffeinated RTDs please skip to question 28.

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
1 RTD can (250-330ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 RTD bottle (330 -350ml)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q25. Think about your own reasons for drinking Caffeinated RTDs. Read the following statements about the different reasons for coffee consumption and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'.
I drink RTDs ...

	Strongly Agree	Agree	Disagree	Strongly Disagree
Because they are cold and refreshing	❍	❍	❍	❍
For the taste	❍	❍	❍	❍
For the alcohol content	❍	❍	❍	❍
Because I feel I am influenced by peer pressure	❍	❍	❍	❍
Out of habit	❍	❍	❍	❍
Because I know how much alcohol is in them	❍	❍	❍	❍
Whenever one is offered to me	❍	❍	❍	❍
Out of boredom	❍	❍	❍	❍
To replace food or meals	❍	❍	❍	❍
To stay awake	❍	❍	❍	❍
For energy	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
Because others are drinking them	❍	❍	❍	❍
Because they are easy to transport	❍	❍	❍	❍
While socialising with friends	❍	❍	❍	❍
With family	❍	❍	❍	❍
For physical energy	❍	❍	❍	❍
Because they are cheaper than other alcoholic drinks	❍	❍	❍	❍
Instead of spirits	❍	❍	❍	❍
To comfort and relax me	❍	❍	❍	❍

Q26. What time of day do you drink RTDs? Choose all options that apply to you.

❑ Before breakfast
❑ At breakfast time
❑ Between breakfast and lunch
❑ At lunch time
❑ Between lunchtime and dinner
❑ At dinner time
❑ After dinner
❑ All day
❑ At no particular time

Q27. In which environments do you drink caffeinated RTDs?

- ❑ A home environment
- ❑ A party environment
- ❑ A bar environment
- ❑ Other (please specify) ____________________

Q28. How often do you take caffeinated pre-workout sports supplements or sports gels? If you do not take caffeinated pre-workout supplements or gels please skip to question 32.

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
Pre-workout sports supplements	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Sports gels	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q29. Think about your own reasons for using sports supplements. Read the following statements about the different reasons for coffee consumption and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'.
I take sports supplements ...

	Strongly Agree	Agree	Disagree	Strongly Disagree
For physical energy	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
Because of peer pressure	❍	❍	❍	❍
Because of pressure from coaches / trainers	❍	❍	❍	❍
To improve physical performance	❍	❍	❍	❍
As they are convenient to take	❍	❍	❍	❍
As a substitute for illegal drugs	❍	❍	❍	❍
For energy	❍	❍	❍	❍
To replace food or meals	❍	❍	❍	❍
Because they are easy to transport	❍	❍	❍	❍
Because others are using them	❍	❍	❍	❍
Out of habit	❍	❍	❍	❍
While socialising with friends	❍	❍	❍	❍

Q30. The following is a list of different types of physical activities. Indicate if you take pre workout supplements or sports gels in any of the following environments (select as many or as little as you like)

	Pre workout supplements	Sports gels	I am involved in this type of activity but do not use these	I am not involved in this type of activity
Resistance training (e.g. weight training at the gym, body weight exercises)	❑	❑	❑	❑
Endurance training (e.g. for triathlons, marathons)	❑	❑	❑	❑
Competitive team sports (e.g. for competitions, events)	❑	❑	❑	❑
Competitive individual sports (e.g. for competitions, events)	❑	❑	❑	❑
Recreational team sports (e.g. social netball, rugby, soccer)	❑	❑	❑	❑
Recreational individual sports (e.g. running, biking, hiking, swimming)	❑	❑	❑	❑
Other (please specify)	❑	❑	❑	❑

Q31. In which environments do take caffeinated pre-workout sports supplements or sports gels?

❑ A party environment
❑ A physical exercise environment
❑ Other (please specify) ____________________

Q32. How often do you take caffeine tablets? Caffeine tablets in include No Doz, Thermo, AllMax, Caffeine Pro, Inner Amour and others. If you do not take caffeine tablets please skip to question 35.

	Never	Less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4-5 times a day	6+ times a day
1 caffeine tablet containing 50mg of caffeine (e.g. Pro Plus)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 caffeine tablet containing 100mg of caffeine (e.g. No Doz)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 caffeine tablet containing 200mg caffeine (e.g. Thermo, AllMax, Myprotein Caffeine Pro, Inner Armor etc)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Other (please specify)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q33. Think about your own reasons for using caffeine tablets. Read the following statements about the different reasons for coffee consumption and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'.
I take caffeine tablets...

	Strongly Agree	Agree	Disagree	Strongly Disagree
For physical energy	❍	❍	❍	❍
Because I feel I am influenced by peer pressure	❍	❍	❍	❍
Because of pressure from coaches / trainers	❍	❍	❍	❍
As they are convenient to take	❍	❍	❍	❍
To replace food or meals	❍	❍	❍	❍
To wake up	❍	❍	❍	❍
To improve physical performance	❍	❍	❍	❍
For energy	❍	❍	❍	❍
As a substitute for illegal drugs	❍	❍	❍	❍
Because others are using them	❍	❍	❍	❍
For mental energy	❍	❍	❍	❍
While driving long distances	❍	❍	❍	❍
Because I feel that I am influenced by advertising	❍	❍	❍	❍
To stay awake	❍	❍	❍	❍
While socialising with friends	❍	❍	❍	❍

Q34. In which environments do you drink take caffeine tablets?

❑ A work environment
❑ A party environment
❑ A physical exercise environment
❑ A study environment
❑ Other (please specify) ____________________

Q35. Read the following statements and select consider whether you 'agree', 'strongly agree', 'disagree', 'strongly disagree'. When I use these products to replace food or meals, I do it because... If this does not apply to you please skip to question 36.

	Tea	Coffee	Drinking chocolate	Eating chocolate	Cola drinks (regular and diet)	Energy drinks	Caffeinated RTDs	Pre-workout supplements / sports gels	Caffeine tablets
I want to lose weight	❑	❑	❑	❑	❑	❑	❑	❑	❑
It is cheaper than food	❑	❑	❑	❑	❑	❑	❑	❑	❑
I did not prepare / organise food	❑	❑	❑	❑	❑	❑	❑	❑	❑
It is more easily accessible than food	❑	❑	❑	❑	❑	❑	❑	❑	❑
I am not hungry or do not feel like eating	❑	❑	❑	❑	❑	❑	❑	❑	❑
Other (please specify)	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q36. Have you ever felt dependent on any of the following products? For example - that you needed them to 'feel normal' or to 'get through the day'? Choose as many products that apply to you.

❑ Tea
❑ Coffee
❑ Chocolate
❑ Cola-flavoured drinks (both regular and diet)
❑ Energy drinks / energy shots
❑ Caffeinated pre workout sports supplements / sports gels
❑ Caffeine tablets
❑ No, I have never felt dependent on any of these products

Q37. Think about your consumption of the caffeinated products that have been explored. Have you ever experienced any of the following symptoms within one day of stopping their normal use? Please tick all options that apply to you.

- ❑ Headaches
- ❑ Mood changes (e.g. depressed mood, easily annoyed)
- ❑ Marked tiredness or drowsiness
- ❑ Difficulty concentrating
- ❑ 'Flu like' feelings (e.g. nausea, vomiting, muscle pain, stiffness)
- ❑ Other (please specify) ____________________
- ❑ No, I have never experienced any of these

Q38. With which products did these symptoms occur? Please skip to question 40 if this does not apply to you.

	Headaches	Mood changes	Marked tiredness / drowsiness	Difficulty concentrating	'Flu-like' feelings	Other
Tea	❑	❑	❑	❑	❑	❑
Coffee	❑	❑	❑	❑	❑	❑
Chocolate	❑	❑	❑	❑	❑	❑
Cola-flavoured drinks	❑	❑	❑	❑	❑	❑
Energy drinks / shots	❑	❑	❑	❑	❑	❑
Caffeinated sports supplements / sports gels	❑	❑	❑	❑	❑	❑
Caffeine tablets	❑	❑	❑	❑	❑	❑

Q39. Did these negative effects impact on your social life, work life or cause you any kind of distress?

- ❍ Yes
- ❍ No

Q40. Again, think of your experiences with the caffeinated products that have been explored. Shortly after consuming them, have you ever felt any of these effects? Please tick all options that apply to you.

- ❑ Restless
- ❑ Nervous
- ❑ Excited
- ❑ Unable to sleep
- ❑ A hot or red face
- ❑ Needing to pee a lot
- ❑ An upset stomach
- ❑ Twitches
- ❑ Unable to concentrate
- ❑ A fast or uneven heartbeat

❑ Feelings of unlimited energy
❑ Agitated movements / jittery
❑ Other (please specify) ____________________
❑ No, I have never felt any of these effects shortly after consuming caffeinated products.

Q41. With which products did these symptoms occur? Please skip to Question 45 if this does not apply to you.

	Restless	Nervous	Excited	Unable to sleep	A hot or red face	Needing to pee a lot	An upset stomach	Twitches	Unable to concentrate	A fast or uneven heartbeat	Feelings of unlimited energy	Agitated movements	Other
Tea	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Coffee	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Chocolate	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Cola-flavoured drinks	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Energy drinks / shots	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Caffeinated sports supplements / sports gels	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Caffeine tablets	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q42. Did these effects impact negatively on your social life, work life or cause you any kind of distress?
❍ Yes
❍ No

Q43. Have these effects mentioned above ever led to any of the following? Select as many options as are relevant.

	Restless	Nervous	Excited	Unable to sleep	A hot or red face	Needing to pee a lot	An upset stomach	Twitches	Unable to concentrate	A fast or uneven heart beat	Feelings of unlimited energy	Agitated movements	Other
I have never had concern about these effects	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Worry or concern	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Hospitalisation	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
First aid being applied	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Talking to someone about these effects	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Seeking help to stop these effects	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q44. When seeking help to try and stop these effects, who did you contact? Select as many options as apply. (Leave blank if not applicable).

❑ Friends
❑ Family
❑ Poisons Hot-line
❑ Medical professional
❑ Other (please specify) ____________________

Q45. Has anyone ever talked to you specifically about your caffeine intake?

❍ Yes
❍ No

Q46. For the following products, please select the main reasons why you don't consume them. This includes products that you never consume but also ones that you may consume but not all of the time. Select the options that apply to you. **Skip to question 48 if this does not apply to you.**

	I have never considered taking it	I don't like the flavour	There is too much sugar in it	I don't want to be dependent on it	I react badly to it	It isn't 'good' for me	It has too much caffeine in it	It's too expensive	I don't consume caffeine due to medical reasons
Tea	❑	❑	❑	❑	❑	❑	❑	❑	❑
Coffee	❑	❑	❑	❑	❑	❑	❑	❑	❑
Chocolate	❑	❑	❑	❑	❑	❑	❑	❑	❑
Cola-flavoured drinks	❑	❑	❑	❑	❑	❑	❑	❑	❑
Energy drinks / energy shots	❑	❑	❑	❑	❑	❑	❑	❑	❑
Caffeinated alcoholic RTDs	❑	❑	❑	❑	❑	❑	❑	❑	❑
Caffeinated sports supplements / sports gels	❑	❑	❑	❑	❑	❑	❑	❑	❑
Caffeine tablets	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q47. Is there any other reason why you don't consume these products? (Please specify product and reason if applicable)

❍ No
❍ Yes ____________________

Q48. The following are statements on attitudes and behaviors around caffeinated products. Read the following statements and consider whether you 'agree', 'strongly agree', 'disagree' or 'strongly disagree'.

	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
When someone comes to my house, I should offer them a hot drink	❍	❍	❍	❍	❍
I give chocolate as a gift	❍	❍	❍	❍	❍
Sometimes I 'go out for a coffee' but will drink something else that is not coffee	❍	❍	❍	❍	❍
It is normal to always have cola-flavoured drinks in the fridge at home	❍	❍	❍	❍	❍
Cola-flavoured drinks are mainly for special occasions	❍	❍	❍	❍	❍
Caffeinated RTDs are more socially acceptable way to drink alcohol than spirits	❍	❍	❍	❍	❍
It is socially acceptable to drink cola drinks and energy drinks in the morning	❍	❍	❍	❍	❍

Q49. Thinking about the following items, is there an age group that you think of as being the main consumers for each product? Select as many options as apply.

	14 and under	15-18	19-30	31-50	51-70	70 and over	All age groups	Unsure
Tea	❑	❑	❑	❑	❑	❑	❑	❑
Coffee	❑	❑	❑	❑	❑	❑	❑	❑
Chocolate	❑	❑	❑	❑	❑	❑	❑	❑
Cola drinks	❑	❑	❑	❑	❑	❑	❑	❑
Energy drinks / energy shots	❑	❑	❑	❑	❑	❑	❑	❑
Caffeinated RTDs	❑	❑	❑	❑	❑	❑	❑	❑
Caffeinated pre-workout sports supplements / sports gels	❑	❑	❑	❑	❑	❑	❑	❑
Caffeine tablets	❑	❑	❑	❑	❑	❑	❑	❑

Q50. Thinking about the following items, is there a gender that you think of as being the main consumers for each product? Select as many options as apply.

	Male	Female	Both	Unsure
Tea	❑	❑	❑	❑
Coffee	❑	❑	❑	❑
Chocolate	❑	❑	❑	❑
Cola drinks	❑	❑	❑	❑
Energy drinks / energy shots	❑	❑	❑	❑
Caffeinated RTDs	❑	❑	❑	❑
Caffeinated pre-workout sports supplements / sports gels	❑	❑	❑	❑
Caffeine tablets	❑	❑	❑	❑

Q51. What is your gender?
- ❍ Male
- ❍ Female
- ❍ Other

Q52. What is your ethnicity?
- ❑ European
- ❑ NZ European
- ❑ Maori
- ❑ Samoan
- ❑ Cook Islands Maori
- ❑ Tongan
- ❑ Niuean
- ❑ Tokelauan
- ❑ Fijian
- ❑ Southeast Asian
- ❑ Chinese
- ❑ Indian
- ❑ Middle Eastern
- ❑ Latin American
- ❑ African
- ❑ Other (please specify) ____________________

Q53. Employment status (choose more than one option if applicable):
- ❑ Student
- ❑ Unemployed
- ❑ Part time worker
- ❑ Full time worker

Q54. Does your job involve any of the following? (Leave blank if unemployed).

	Yes	No
Manual labour	❍	❍
Driving long distances	❍	❍
Shift work	❍	❍
Mainly sitting e.g. office work	❍	❍
Mainly standing e.g. retail/ hospitality	❍	❍

Q55. What is your highest level of education?
- ❍ Primary school education
- ❍ Completed year 11 / 5th form
- ❍ Completed year 12 / 6th form
- ❍ Completed high school
- ❍ Diploma / Certificate
- ❍ Bachelor's Degree
- ❍ Postgraduate degree

Q56. What is your living situation?
- ❍ Living alone
- ❍ Living in a family home with others
- ❍ Flatting with others
- ❍ Other (please specify) ____________________

Q57. Do you smoke?
- ❍ Yes
- ❍ No
- ❍ Occasionally
- ❍ Prefer not to answer

Q58. (For female participants) Are you currently on any type of oral contraceptive?
- ❍ Yes
- ❍ No
- ❍ Prefer not to answer

Q59. How much do you weigh (kg)?
- ❍ Kg - ____________________
- ❍ Don't know / prefer not to answer

Q60. How tall are you (cm)?
- ❍ Cm - ____________________
- ❍ Don't know / prefer not to answer

Appendix E.2: Caffeine Content Reference Values

Table E Average caffeine content of food and beverages in New Zealand.

Product	**Quantity of product**	***Estimated caffeine content (mg)**
Coffee		
- Decaffeinated, instant, dry powder[1]	1 teaspoon	1.9
- Regular, instant, dry powder[1]	1 teaspoon	83
- Plunger/ drip coffee[1]	1 cup (250 mL)	100
- Espresso, café variety[1]	Single shot (30 mL)	120
	Double shot (55m L)	210
- Iced coffee[5]	1 serve (250 mL)	89.2
Tea		
- Decaffeinated black tea[1]	250 mL made with 1 teabag	4.7
- Green tea[1]	250 mL made with 1 teabag	31
- Black tea[1]	250 mL made with 1 teabag	57
- Iced tea[5]	1 glass (250 mL)	49.6
Chocolate		
- Cocoa powder[1]	1 teaspoon (5g)	1.9
	1 serve made with 15g	5.7
- Milk chocolate[1]	100g	19
- Dark chocolate[1]	100g	59
Kola drinks		
- Regular †kola[1]	100 mL	11
- Diet †kola (diet, zero, max, etc)[1]	100 mL	14
Other caffeinated beverages		
- Caffeinated ready-to-drink (RTDs)[1,2]	100 mL	14
- Energy drinks[2]	100 mL	31.2
- Energy shots[2]	60 mL	271
Sports supplements		
- Sports gel[2]	41 g	31.9
- Pre-workout[3]	1 serve made with 1-2 level scoops powder (6 - 25g)	240
Caffeine tablets[4]	1 tablet	50-200

[1]The New Zealand Institute for Plant and Food Research Limited and New Zealand Ministry of Health (2015).
[2]Thomson and Jones (2013).
[3]Supplements.co.nz (average content of 20 common products available).
[4]NZmuscle.co.nz, newworld.co.nz (average content of 10 products available).
[5]Caffeineinformer.com (average content in a 250ml serve).
*Actual content for each specific product varies according to preparation techniques and brand.
†'Kola' is used instead of 'cola' in order to differentiate from the popular brand and encompasses all kola-type beverages.
Table adapted from Stachyshyn (2017).

Appendix F: Supplementary Results

Additional Participant Characteristics

Table F.1 Age distribution* of participants (*n* = 192).

Age (years)	*N* (%)
18	14 (7.3)
19	19 (9.9)
20	27 (14.1)
21	27 (14.1)
22	31 (16.1)
23	21 (10.9)
24	25 (13.0)
25	28 (14.6)
Total	192 (100)

*Age differences in caffeine consumption and/or sleep quality were not analysed due to the narrow range comprised in the study population (18–25 years).

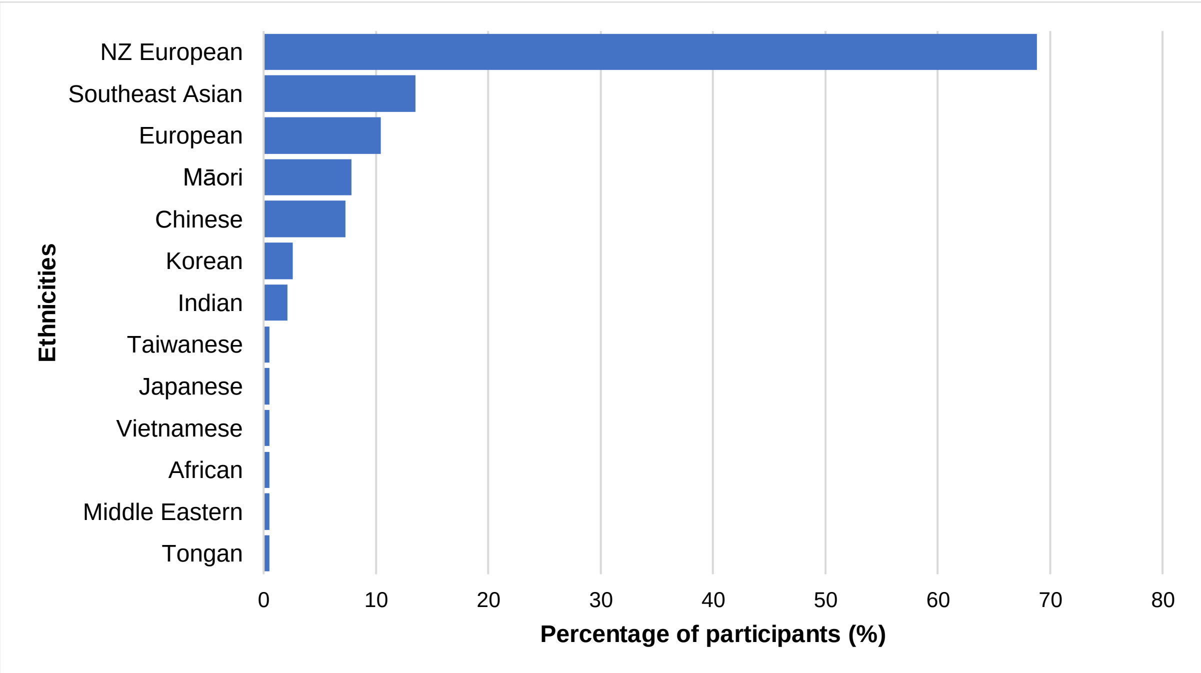


Figure F.1 Study participants' ethnicities (*n* = 192).

N.B. Study participants were able to select multiple ethnicities; hence the total is greater than 100%.

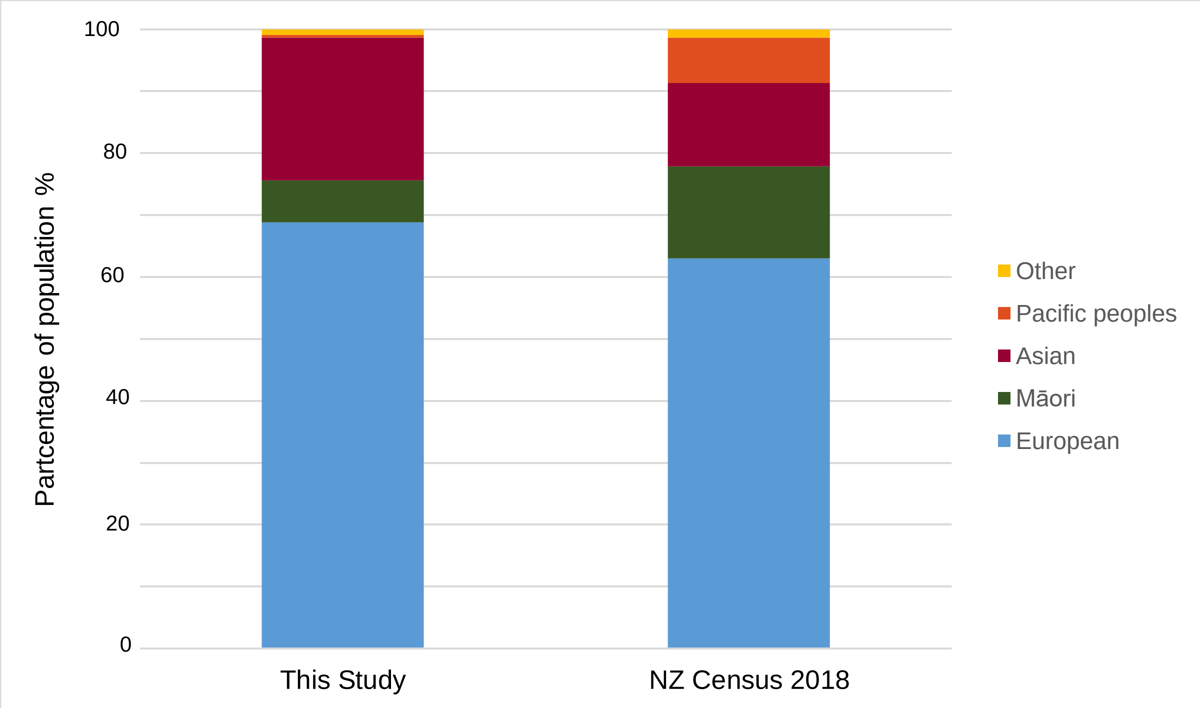


Figure F.2 Ethnicities of study participants (*n* = 192) compared to the New Zealand (NZ) population (2018) (Statistics New Zealand, 2018a).

N.B. When completing the census, people could select more than one ethnicity hence the total percentage is greater than 100%. The graph has been adjusted to compare results between the two populations.

According to the most recent NZ Census (2018), 70.2% of the NZ population are European, 16.5% Māori, 15.1% Asian, 8.1% Pacific peoples and the remaining 1.5% constitute other ethnicities (Middle Eastern/ Latin American/ African). Whilst our study cohort was also predominantly NZ European (79.2%), it lacked notable representation from Māori, Pacific and 'Other' ethnic groups.

Considering that most study participants were from Auckland, ethnic distributions were also compared to the Auckland Region 2018 census data, which reported 53.5% European, 11.5% Māori, 15.5% Pacific peoples, 28.2% Asian and 3.4% Other (MELAA) (Statistics New Zealand, 2018b). While the percentage of participants with Asian ancestry was more comparable (26.6% in our study), the ethnic distribution was still not representative of the broader New Zealand population. It was deemed unethical to conduct an ethnic analysis due to insufficient case numbers for each group.

PSQI Global Score Distribution

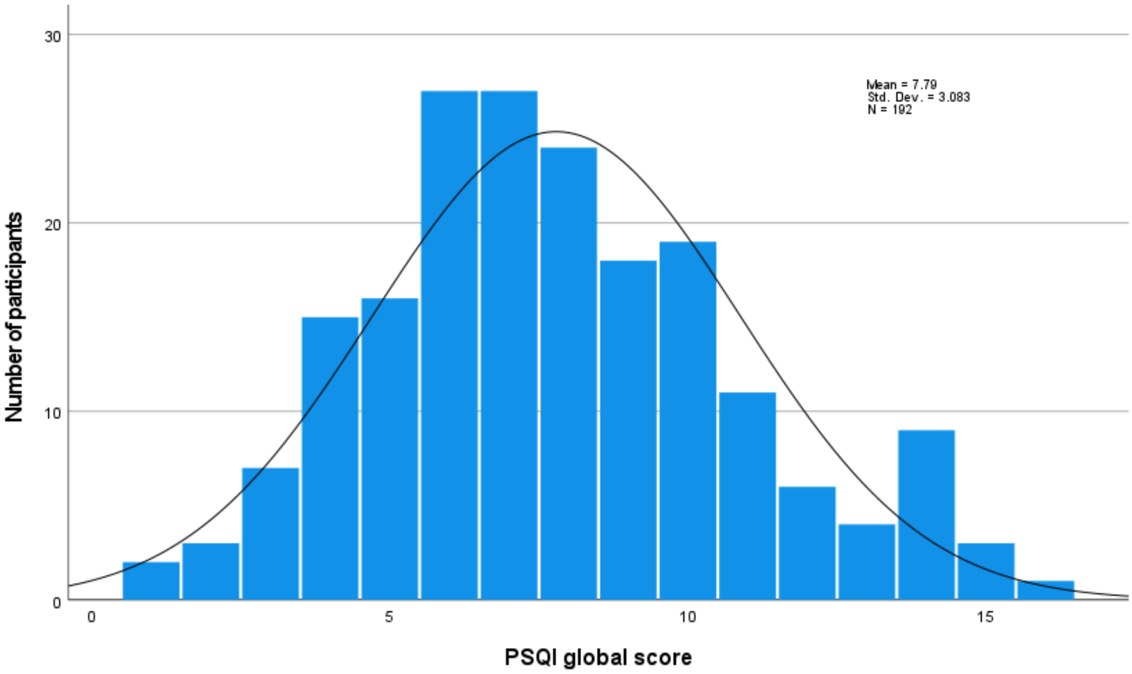


Figure F.3 Distribution of PSQI global score in young adults (*n* = 192).

The global PSQI score has a possible range 0–21. The distribution was slightly left-skewed (skewness = 0.384) and platykurtic (kurtosis = -0.168).

Daily Caffeine Intake of Caffeine Sources by Sleep Quality

Table F.2 Median daily caffeine intake ($mg \cdot day^{-1}$) from various sources by sleep quality (*n* = 192).

Caffeine source ($mg \cdot day^{-1}$)	All participants (*n* = 192) ($mg \cdot day^{-1}$)	Good sleepers (*n* = 27) ($mg \cdot day^{-1}$)	Poor sleepers (*n* = 165) ($mg \cdot day^{-1}$)
Total caffeine intake	142.1 [78.5, 217.7]	118.9 [65.1, 205.3]	143.1 [81.6, 217.7]
Tea (green/black)	4.7 [0, 21.5]	7.0 [0, 15.9]	4.3 [0, 21.5]
Coffee	84.0 [8.5, 167.6]	48.1 [9.7, 168.0]	86.1 [8.4, 166.6]
Chocolate	6.6 [1.9, 10.1]	3.8 [2.1, 8.7]	6.8 [1.9, 10.3]
Kola drinks	4.2 [0, 13.0]	2.2 [0, 17.7]	4.4 [0, 12.7]
Energy drinks/shots	0 [0. 13.9]	0 [0, 20.3]	0 [0, 12.4]
Caffeinated alcoholic RTDs	0 [0, 0]	0 [0, 0]	0 [0, 0]
Pre workout/ sports gels	0 [0, 0]	0 [0, 0]	0 [0, 0]
Caffeine tablets	0 [0, 0]	0 [0, 0]	0 [0, 0]

Values are medians [25^{th}, 75^{th} percentile].

There were no statistically significant differences in consumption by caffeine source between good sleepers and poor sleepers ($p > 0.05$). Coffee contributed the most to total daily caffeine intake for both good and poor sleepers, with median intakes of 48.1 $mg \cdot day^{-1}$ and 86.1 $mg \cdot day^{-1}$, respectively. Energy drinks/shots, alcoholic RTDs, pre workout/ sports gels and caffeine tablets were the least consumed, with median daily intakes of 0 $mg \cdot day^{-1}$ each.

Sleep Disturbances

The main causes of reported sleep disturbances (based on the percentage of positive, experienced weekly responses) were waking up in the middle of the night or early morning (51.5%), being unable to fall asleep within 30 minutes (44.8%), having to get up to use the bathroom (36.4%) and feeling too cold (34.9%). 'Other' reasons cited by participants included stress/anxiety, overthinking, and noise (e.g., partner snoring).

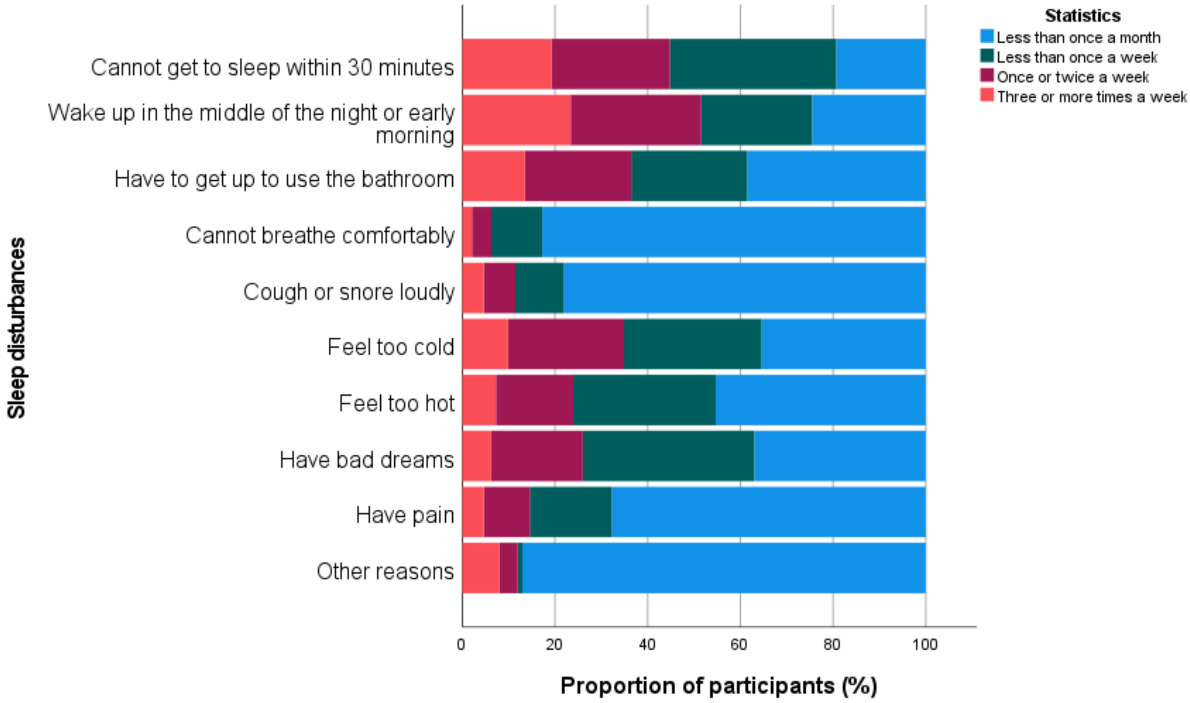


Figure F.4 Participants' experiences with sleep disturbances (*n* = 192).

Side Effects of Caffeine Consumption

When asked about the negative effects experienced after consuming caffeinated products (CaffCo Questionnaire Q40), over one-third (38%) of participants reported being unable to sleep. There was a trend ($p = 0.057$) where those who consumed moderate to high amounts of caffeine daily were more likely to report this side effect than those who consumed little to no caffeine daily [42 vs. 27%; OR = 2.00, 95% CI (0.98, 4.10)].