Caffeine Consumption Habits, Motivations, and Experiences of New Zealand Tertiary Students

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Abstract

Background: Caffeine-related health incidents in New Zealand have escalated over the last two decades. Research suggests that in order to reduce the risk of substance-related harm, it is important to understand the consumers' motivations for its use, especially in tertiary students who are presumed to be at a higher risk due to seeking out caffeine's well-known cognitive benefits. The public health consequences of caffeine consumption can only be determined once data is available on the amount of caffeine currently being consumed by New Zealanders, and New Zealand-based studies that have examined caffeine consumption are limited.

Aim: The aim of this study was to examine the caffeine consumption habits of tertiary students in New Zealand; their motivations for use, and experiences across a broad range of caffeine products.

Method: A previously designed caffeine consumption habits questionnaire (CaffCo) was administered to 317 tertiary students via the online survey software, Qualtrics.

Results: Of the total dataset, 99.1% (n= 314), consumed at least one source of caffeine in their diet. The caffeine sources with the highest prevalence of use were chocolate (81.7% of participants), coffee (76.3%) and tea (71.6%). Motivations for consumption appear to differ between various caffeine sources. In caffeine consumers, the median estimated daily caffeine consumption was 146.73 $mg \cdot day^{-1}$ (n= 314), or 2.25 $mg \cdot kgbw^{-1} \cdot day^{-1}$ (n= 281), with coffee contributing 61.4% to the total daily caffeine consumption. An estimated 14.3% (n= 45) of caffeine consumers exceeded a suggested 'safe limit' of 400 $mg \cdot day^{-1}$, where cigarette smoking was the only participant demographic/characteristic which increased the likelihood of exceeding this level. Caffeine was co-ingested with alcohol by 38.5% (n= 122) of the participants, and those with paid employment or those who smoked cigarettes were more likely to do so. The

majority of caffeine consumers (84.7%, n= 265) reported experiencing at least one adverse symptom post caffeine consumption, 64.2% reported being dependent on at least one caffeine source, and 47.3% (n= 152) of total participants reported experiencing at least one withdrawal symptom in the past.

Conclusions: These findings provide critical information for implementing caffeine-related risk-reduction strategies for New Zealand tertiary students.

Key words: consumer, harm, energy drinks, coffee, health-risk

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List of Abbreviations

ADORA2A	Adenosine 2a receptor gene
AmED	Alcohol mixed with Energy Drinks
AMP	Adenosine monophosphate
ATP	Adenosine triphosphate
BMI	Body Mass Index
CaffCo	Caffeine consumption habits questionnaire
CHD	Coronary Heart Disease
CNS	Central Nervous System
CVD	Cardiovascular disease
CYP1A2	Cytochrome p450 1A2 enzyme gene
DSANZ	Distilled Spirits Association of New Zealand
DSM-5	Diagnostic and Statistical Manual of Mental Disorders (Fifth edition)
ECF	Extra Cellular Fluid
EEG	Electroencephalogram
EFSA	European Food Safety Authority
FDA	Food and Drug Administration
FSA	United Kingdom Food Safety Authority
FSANZ	Food Standards Australia New Zealand
GRAS	Generally Recognised as Safe
ICD-10	International Classification of Diseases (Tenth edition)
MI	Myocardial Infarction
NIP	Nutrition Information Panel
NNS	National Nutrition Survey
NPC	National Poisons Centre

NSAIDs	Nonsteriodal anti-inflammatory drugs
NZJBA	New Zealand Juice and Beverage Association
NZMPI	New Zealand Ministry for Primary Industries
RTD	Ready to drink alcoholic beverage
SES	Socioeconomic status
SNP	Single Nucleotide Polymorphism
SSB	Sugar-sweetened Beverage
UK	United Kingdom
UL	Upper Limit of intake
USA	United States of America
WADA	World Anti-Doping Agency
WHO	World Health Organisation

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Chapter 1

1.0 Introduction

1.1 Background

Caffeine is considered one of the world's most widely used mood and behaviour altering drugs (Mintz, 2001). An estimated 80% of people worldwide regularly consume caffeine in one form or another (Heckman, Weil, & de Mejia, 2010). It naturally occurs in about 60 species of plants (Nathanson, 1984) and can also be synthetically produced then added to food products or other products such as medicines (Gray, 1998; International Agency for Research on Cancer, 1991). Caffeine is well known for its positive effects such as increasing alertness and combating fatigue (Lorist & Tops, 2003; Puckeridge, Fulcher, Phillips, & Robinson, 2011), however the negative effects are not as widely recognised. Excessive caffeine consumption, can cause negative symptoms such as anxiety, nausea, palpitations, upset stomach, headaches, racing mind and sleeplessness and, in some cases, has been shown to cause respiratory problems, liver and heart damage, seizures, myocardial infarction and even death (Seifert, Schaechter, Hershorin, & Lipshultz, 2011).

It appears that adverse health incidents related to caffeine worldwide have escalated over the last decade. This is evidenced by a doubling of emergency department (ED) visits in the USA (10068 to 20783) between 2007 and 2011 (Substance Abuse and Mental Health Service Administration, 2013) and an annual increase of incidents in Australia (from 12 in 2004 to 65 in 2010) (Gunja & Brown, 2012). A concerning 11-43% of these incidents required the individual to be hospitalised. This data only covers energy drink related incidents, therefore this is likely an underestimation of the true impact of caffeine exposure on the health systems.

In New Zealand, there has not yet been an official report released in regards to caffeine-related health incidents. However, Thomson, Campbell, Cressey, Egan, and Horn (2014) report that The NZ National Poisons Centre (NPC) received 130 calls regarding incidents due consumption of caffeinated products from February 2005 through to June 2013 (information gathered via personal communication). Almost half of these incidents (63/130) were related to caffeine tablets and the consumption of energy drinks or energy shots accounted for almost a third (38/130). Twenty of the individuals calling regarding energy drink consumption required medical treatment.

There is controversy as to whether caffeine should be considered a 'friend' or 'foe'. It is likely that caffeine may be both, with the answer varying between individuals, as an individual's response to caffeine intake has been attributed to many factors including but not limited to dosage, genetics, and tolerance caused by habitual consumption (Yang, Palmer, & de Wit, 2010). This is also dependent on whether the effects of caffeine are considered beneficial or detrimental to an individual in specific circumstances (e.g. stimulatory effect causing insomnia).

The activity of the enzyme which metabolises caffeine (Cytochrome P450 1A2) differs between individuals and is dependent on numerous factors (Abernethy & Todd, 1985; Aranda, Collinge, Zinman, & Watters, 1979; Carrillo & Benitez, 1996; Fisher et al., 2009; Kalow & Tang, 1991; Krul & Hageman, 1998; Sachse, Brockmöller, Bauer, & Roots, 1999; Tsutsumi et al., 2001), therefore the dose of caffeine which causes negative effects varies greatly between individuals, with some experiencing these effects after consuming less than a cup of coffee and others not being affected after consuming 10 times as much caffeine.

Habitual consumption of caffeine can result in the development of a physiological tolerance to some of its effects in some individuals. This means that a larger amount of

caffeine may be required to achieve the same outcomes (e.g. increased alertness) (Hughes, McHugh, & Holtzman, 1998; Pelchovitz & Goldberger, 2011). When an individual who habitually consumes caffeine reduces or stops consuming caffeine abruptly, they are likely to experience symptoms of withdrawal which can range from a headache to a dysphoric mood (Ferré, 2008; Hughes et al., 1998).

Although there are no international guidelines or recommendations regarding the safe limit for daily caffeine intake, levels up to approximately 400 $mg \cdot day^{-1}$ are generally regarded as safe by multiple agencies and reviews (Cheng, Hu, Lu, Huang, & Gu, 2014; Crippa, Discacciati, Larsson, Wolk, & Orsini, 2014; Heckman et al., 2010; Nawrot et al., 2003; Taylor, 2013). This suggested upper limit does not apply to young children or pregnant women as these population groups are at a higher risk of the adverse effects of caffeine.

The caffeine content of different products can vary greatly and is influenced by many factors. Products which naturally contain caffeine, such as coffee, tea and chocolate may differ in caffeine content between batches due to differences in growing conditions, processing and brewing techniques (Bunker & McWilliams, 1979; Desbrow, Henry, & Scheelings, 2012; Matissek, 1997). While the caffeine content of coffee, tea and chocolate is not regulated, New Zealand (NZ) Food Standard requirements limit the caffeine content of kola[1]-flavoured beverages to a maximum of 145 $mg \cdot L^{-1}$ (Food Standards Australia New Zealand, 2015). Under the category 'Formulated caffeine beverages' (Energy drinks), requirements stipulate a caffeine range of 145-320 $mg \cdot L^{-1}$. Sports supplements and caffeine tablets are exempt from caffeine-related regulations as they are considered 'dietary supplements' (World Health Organisation & The New Zealand Ministry of Health, 2010).

[1] 'Kola' is used instead of 'cola' in order to differentiate from the trademark name and comprises all kola-type beverages.

NZ studies which have examined caffeine consumption habits are limited. It has been estimated that approximately 73% of New Zealanders consume caffeine in one form or another each day and that the average daily caffeine intake of New Zealanders' is 3.6 mg· $kgbw^{-1}$ (~250mg a day for a 70kg person) (Thomson & Schiess, 2011). This estimated intake is higher than the USA (2.4 mg· $kgbw^{-1}$ · day^{-1}) (Barone & Roberts, 1996; Frary, Johnson, & Wang, 2005), lower than Denmark (6.7 mg· $kgbw^{-1}$) (Barone & Roberts, 1996) and similar to that in Argentina (4.3 mg· $kgbw^{-1}$) (Olmos, Bardoni, Ridolfi, & Villaamil Lepori, 2009), the United Kingdom (UK) (4.1 mg· $kgbw^{-1}$) (Barone & Roberts, 1996) and Japan (3.7 mg· $kgbw^{-1}$) (Yamada et al., 2010).

An assessment of caffeine exposure for NZ adults (15+ years) has been undertaken by combining 24 hour diet recall data from the 2008/2009 NZ Adult Nutrition Survey with data on the caffeine concentration of the 53 caffeine-containing foods and beverages included in the survey (Thomson et al., 2014). Findings showed a quarter (26%) of all adult New Zealanders (15+ years) may be at risk of the adverse effects of caffeine based on an estimated dietary caffeine exposure level of 3mg· $kgbw^{-1}$· day^{-1}. However energy drinks were not included in this estimate and, when energy drinks were accounted for, it was demonstrated that teenagers (15-19 years), adults (20-64 years) and females (16-44 years) were at an increased risk of exceeding the adverse effect level of caffeine.

Combined energy drink sales in NZ and Australia increased from 34.5 million litres in 2001 to 155.6 million litres in 2010 (Heckman et al., 2010), therefore the prevalence of individuals who exceed this adverse effect level may now be higher than the previous estimate.

Even though the caffeine product market is increasing it has previously been assumed that consumers will substitute different types of caffeine-containing products for each other (e.g. energy drink for coffee) and therefore individuals' caffeine intake levels are

likely to remain constant (Rosenfeld, Mihalov, Carlson, & Mattia, 2014). The data to support this assumption however is minimal (Mitchell, Knight, Hockenberry, Teplansky, & Hartman, 2014) and has not been explored in the NZ context, especially among those who may be high consumers of energy drinks.

1.2 Study Justification

Research suggests that in order to reduce the risk of substance-related harm (such as caffeine intoxication) it is important to have an understanding of the consumers' motivations for its use (Boys, Marsden, & Strang, 2001; Kuntsche, Knibbe, Gmel, & Engels, 2005). It is well established that there are multiple factors related to the consumption of foods and beverages (Baranowski, Cullen, & Baranowski, 1999). Foods and beverages are not only consumed to provide energy and nourishment; there are also environmental and social aspects which influence the decision to consume certain food products. An individuals' expected outcomes (e.g. pleasure of consumption, ergogenic effect etc.) of a substance are known to contribute to whether they are likely to continue using it (Boys & Marsden, 2003; Boys et al., 1999). Hence, it is important to gain an understanding of the factors influencing and motivations behind consumption of caffeine.

The pressures of being a tertiary student have been shown to increase stress levels, especially in those also juggling paid employment (Robotham & Julian, 2006). A study by Peeling and Dawson (2007) showed that after low dose caffeine consumption, tertiary students perceived that they were significantly more alert, awake, clear-minded and more able to concentrate; all sought after qualities when it comes to academic work. Motivations for caffeine use in tertiary students most likely include an attempt to reach academic goals, but other psychological, social and environmental factors may also play

a part. Caffeine-containing products may also be included in a students' diet for lifestyle or recreational purposes.

The adverse effects associated with excess caffeine consumption combined with an ever-increasing number of available caffeine-containing products (Persad, 2011) makes an investigation of the current caffeine consumption habits of NZ tertiary students an important research area. Since the benefits and risks of caffeine consumption are dose dependent, the public health consequences of caffeine can only be determined once data is available on the amount currently being consumed by New Zealanders. Tertiary students may be at an increased risk of consuming excessive amounts of caffeine due to its well-known effect on boosting cognition, therefore it is important to investigate the caffeine habits, motivations and experiences of this specific population group.

1.3 Purpose of the Research Study

1.3.1 Aim

This study aims to examine the caffeine consumption habits of tertiary students in NZ; their motivations for use and experiences across a broad range of caffeine products.

1.3.2 Objectives

By use of an online questionnaire:

- To determine the caffeine consumption habits (source, quantity, and co-ingestion with other substances (e.g. alcohol), of tertiary students in NZ.
- To establish the strongest motivations for consumption and non-consumption of caffeine-containing products in NZ tertiary students.

- To examine NZ tertiary students' caffeine consumption habits by demographic factors and participant characteristics (i.e. gender, age, BMI, living situation, employment status, smoking status and participation in sports).
- To explore the experiences of NZ tertiary students in regards to consumption of caffeine-containing products (i.e. symptoms post consumption, dependence and withdrawal).

1.4 Structure of the Thesis

The chapter which follows (Chapter 2) will review the current relevant literature in regards to caffeine. Following this, Chapter 3 will outline the methods and materials used to recruit participants and to carry out data collection and data analysis. The results of this research will be presented in Chapter 4 and discussed in Chapter 5. Finally, a summary of the findings from this research study will be provided along with the strengths and limitations. A conclusion and recommendations for future research will also be given.

1.5 Researchers' Contributions

Table 1.1: Researchers' contributions to the thesis study

Author	Contribution
Saskia Stachyshyn	Research study proposal, ethics application, review of the literature, recruitment of participants, data collection, data entry/cleaning and analysis, formulation of results and associated discussion, preparation of thesis manuscript.
Dr Kay Rutherfurd-Markwick	Provided supervision for the study design, ethics application, conduct of the research, the write-up of all chapters and manuscript preparation for this thesis.
Dr Ajmol Ali	Provided supervision for the study design, ethics application, conduct of the research, the write-up of all chapters and manuscript preparation for this thesis.
Dr Carol Wham	Provided supervision for the study design, ethics application, conduct of the research, the write-up of all chapters and manuscript preparation for this thesis.

Chapter 2

2.0 Literature Review

2.1 Introduction

The current chapter will review the dietary sources of caffeine and how it has become one of the world's most commonly consumed psychoactive stimulants. The pharmacokinetics and pharmacodynamics (including both positive and negative effects) of caffeine and how genetics play a part in these mechanisms will then be discussed. Following this, the outcomes of habitual consumption including tolerance and dependence (symptoms of withdrawal) and also the consequences of caffeine overdose will be covered. This chapter will then outline the recommendations for caffeine consumption and NZ legislation and regulations regarding formulation of products containing caffeine. Finally, what we currently know about caffeine consumption levels and patterns worldwide and in NZ, including factors affecting consumption will be explored.

2.2 Background and History of Caffeine

Pure caffeine, which is an odourless, bitter-tasting white powder (Agyemang, 2013), was first isolated in 1819 by a German chemist named Friedlieb Runge. He termed the compound "Kaffebase", meaning "a base that exists in coffee" (Weinberg & Bealer, 2001). The first artificial synthesis of caffeine was carried out in 1895 by Hermann Fischer, another German chemist. Fischer determined the chemical structure of caffeine (1,3,7-trimethylxanthine; shown and discussed in Section 2.5.1) in 1897, and in 1902 was awarded a Nobel Prize for this work (Fredholm, 2011).

Caffeine can be found in upward of 60 species of plants worldwide (Nathanson, 1984), with the most commonly consumed being the cocoa bean (*Theobroma cacao*), coffee bean (*Coffea Arabica and Coffea Robusta*), tea leaves (*Camellia sinensis*) and the kola nut (*Cola acuminate*) (Barone & Roberts, 1996; Fredholm, 2011; Gray, 1998; International Agency for Research on Cancer, 1991). Due to advancements in technology, caffeine can also be commercially produced either by chemical extraction from these plants or by synthesis from uric acid (Gray, 1998; International Agency for Research on Cancer, 1991). This caffeine can subsequently be added to food/beverage products. Some products which naturally contain caffeine (e.g. coffee and tea) have also been manufactured to provide decaffeinated options through the same chemical extraction process.

There is evidence of humans consuming caffeine for thousands of years (Roberts & Barone, 1983), however the discovery and early history of caffeine consumption differs between sources and is considered legend rather than fact. Chinese legend states that the stimulatory effects of caffeine in tea was "accidentally" discovered by an emperor in 2737BC after noticing that when tea leaves are dropped into hot water a fragrant invigorating beverage results (Evans, 1992). The coffee bean appears to have originated several thousands of years later in Ethiopia during the 9th century. It is said that a shepherd observed that his goats appeared to have increased energy and sleeplessness after consuming wild coffee beans (Griffin, 2006). After this discovery, coffee beans were consumed by humans by chewing them whole. Soon after, they were turned into a "travel snack" by grinding them and mixing them with a fat paste. The evolution of coffee consumption as we know it (coffee bean and boiling water infusions) only began around 1000AD (Fredholm, 2011). In addition, the practice of roasting coffee beans before use only began in the 14th century, and after this, coffee use in the Arab world

spread rapidly. The exact details of the discovery of the cocoa bean is unknown, however there is evidence that the ancient Mayans consumed 'chocolate' (a liquid of crushed cocoa beans and water) back in 600BC. The history of use of the cocoa bean goes beyond its consumption as chocolate; it was even used as a form of currency throughout pre-Columbian Mesoamerica (Weinberg & Bealer, 2001). In West African culture, the kola nut was commonly chewed as a way to ease hunger and restore vigour. In the late 1800's, kola-flavoured soft drinks such as Coca-Cola and Pepsi-Cola emerged on the market (American Beverage Association, 2008). The popularity of these caffeine-containing kola drinks resulted in the appearance of energy drinks during the second half of the 20th century.

There are an ever-increasing number of caffeinated products available on the market today. This includes, but is not limited to coffee, tea, kola beverages, energy drinks, chocolate, sports supplements, caffeinated alcoholic beverages and tablets (Persad, 2011). In 2010, Thomson and Schiess (2011) identified a total of 64 individual caffeine-containing products on the market in NZ. This included 15 kola-type soft drinks, 28 energy drinks, 16 energy shots and 5 caffeinated alcoholic beverages.

Caffeine is currently considered the most commonly used psychoactive stimulant world-wide, even exceeding nicotine and alcohol use (Mintz, 2001), with an estimated 80% of the world's population consuming caffeine (Heckman et al., 2010).

2.3 Caffeine Content of Dietary Sources

The caffeine content varies greatly between sources and also between different varieties of the same of product (Table 2.1). The type of plant, growing conditions, processing

techniques and preparation method, all play a part in determining how much caffeine a product contains (Bunker & McWilliams, 1979; Desbrow et al., 2012; Matissek, 1997).

Table 2.1: Caffeine content of food and beverages in New Zealand

Product	Quantity of product	Caffeine content (mg)*
Coffee[1]		
- Instant coffee powder	1 teaspoon	~ 83
- Decaffeinated instant coffee powder	1 teaspoon	~ 1.9
- Plunger/ drip coffee	250 mL	~ 100
- Espresso	Single shot	~ 120
	Double shot	~ 210
Tea[1]		
- Black tea	250 mL made with 1 teabag	~ 57
- Green tea	250 mL made with 1 teabag	~ 31
- Decaffeinated black tea	250 mL made with 1 teabag	~ 4.7
Chocolate[1]		
- Milk chocolate	100 g	~ 20
- Dark chocolate	100 g	~ 60
- Cocoa powder	1 teaspoon	~ 2
Kola drinks[1]		
- Regular kola	100 mL	~ 11
- Diet kola (diet, zero, max etc.)	100 mL	~ 14
Energy drinks[2]	100 mL	~ 31.2
Energy shots[2]	60 mL	~ 162.6
Caffeinated RTDs[2,3]	100 mL	~ 14.4
Pre-workout[4]	100 g	~ 2110
Sports gel[2]	100 g	~ 77.7
Caffeine tablets[3]	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] Beer Wine and Spirits Producers (2015)
[4] Supplements.co.nz, Bodybuilding.com (average content of 20 common products available)
*Estimated caffeine content (actual content varies according to preparation and specific product)
Table adapted from Rowe (2015)

The caffeine content of dark chocolate is much higher than that of milk chocolate due to having a higher percentage of cocoa bean solids, which is the natural source of caffeine in chocolate. The brewing time of tea has been shown to affect the caffeine levels of the beverage (Bunker & McWilliams, 1979). The Robusta variety of coffee beans generally contains twice the amount of caffeine as the Arabica variety (Matissek, 1997).

Additionally, although some products may be labelled as decaffeinated, they still contain a small amount of caffeine.

The caffeine contained in energy drinks and energy shots comes from the ingredients used as well as being artificially added. Guarana is a key ingredient of energy drinks and naturally contains large amounts of caffeine (40–80 mg per gram of extract) (Bempong, Houghton, & Steadman, 1993; Gunja et al., 2012). Other than the potential for caffeine overdose, there is currently no evidence of any safety issues in regards to the consumption of Guarana (Duchan, Patel, & Feucht, 2010).

In 2013, the New Zealand Ministry for Primary Industries (NZMPI) conducted an analysis on 35 different energy drinks in order to determine the typical caffeine content for these products. The average caffeine content of energy drinks sold in NZ was 76 mg per 250 mL (Thomson & Jones, 2013).

The caffeine content of caffeinated alcoholic beverages (RTDs) is not included on their labels and these products are also not included in The Concise New Zealand Food Composition Tables. The caffeine content of these RTDs is however available in the 2013 technical report by Ministry for Primary Industries, 'Caffeine in guarana-containing foods' (Thomson & Jones, 2013) and the document 'Alcohol Beverages Containing Stimulants' (Beer Wine and Spirits Producers, 2015), reporting an average caffeine content of 17.7 mg per 100 mL (ranging 10.2-32.3 mg per 100 mL) and 11.1 mg per 100 mL (ranging 7-18.5 mg per 100 mL) respectively.

Caffeinated sports products can vary greatly in their caffeine content. The NZMPI found that depending on the product, sports supplements can contain between 1.4-1690 mg of caffeine per 100 g (Thomson & Jones, 2013), however when looking at sports gels as a distinct category, these were found to contain approximately 77.7 mg per 100 g. A more accurate and up-to-date caffeine content estimate for the category of pre

workout powders was determined by using products from two "well-known" online suppliers (Supplements.co.nz, 20l6; Bodybuilding.com, 2017). The average caffeine content of 20 common products from these suppliers was calculated to be 2110 mg· $100g^{-1}$ (ranging 750 mg· $100g^{-1}$ - 3889 mg· $100g^{-1}$). Similarly, caffeine tablets can differ greatly in their caffeine content. They can be purchased over the counter and depending on the brand can contain between 50- 200 mg of caffeine per tablet (Thomson & Jones, 2013).

Additional products which may marginally contribute to an individuals' daily caffeine intake include foods and drinks which contain cocoa/chocolate (e.g. chocolate biscuits etc.) (The New Zealand Institute for Plant and Food Research Limited & New Zealand Ministry of Health, 2015), and medications which contain caffeine for increased drug effectiveness (Gray, 1998; Hughes et al., 1998). These food and beverage products mostly contribute negligible amounts of caffeine to the diet (e.g. 2 mg of caffeine in a chocolate muffin according to the concise food composition tables) (Svakumaran, Huffman, & Sivakumaran, 2015), however medications may contain a significant amount (e.g. Panadol Extra Advance; 65 mg of caffeine per tablet) (Liu, Kotler, & Sharples, 2013). The consumption of these additional caffeine-containing products are difficult to measure due to the sheer range of products available.

2.4 Caffeine Pharmacokinetics

2.4.1 Absorption and Distribution

When caffeine is consumed orally, it stimulates gastric nerves, resulting in the induction of gastric emptying (Eteng, Eyong, Akpanyung, Agiang, & Aremu, 1997). It appears that gastric emptying profiles have larger inter-individual differences in the fed state than the fasted state, therefore intestinal feedback mechanisms, and the chemical

composition of the stomach, are likely to affect the consequent absorption rate of caffeine into the blood stream (Higaki, Choe, Löbenberg, Welage, & Amidon, 2008). Despite these differences, Higaki, et al., (2008) observed that 50% of a 100mg oral dose of caffeine was emptied within 1-2 hours and over 90% in 3-5 hours, in all subjects. Once released from the stomach, caffeine is then rapidly absorbed in the small intestine, with almost 100% bioavailability (Blanchard & Sawers, 1983a; Marks & Kelly, 1973). Caffeine reaches peak concentration in the blood at approximately 30 – 47 minutes post-ingestion (Arnaud & Welsch, 1982; Blanchard & Sawers, 1983a, 1983b; Bonati et al., 1982; Marks & Kelly, 1973; Mumford, Benowitz, Evans, Kaminski, Preston, Sannerud, & Griffiths, 1996) and the absorption rate appears to be independent of dose (Bonati et al., 1982). However, the rate of absorption of oral caffeine depends on the vehicle of administration, with caffeine from a capsule being absorbed faster than from coffee (Mumford et al., 1996), kola, or chocolate (Fredholm, Battig, Holmen, Nehlig, & Zvartau, 1999).

Absorbed caffeine is then dispersed into all the body tissues in relation to their water content (Axelrod & Reichenthal, 1953), and readily crosses the blood-brain barrier due to being both lipid- and water-soluble, therefore its effects on the Central Nervous System (CNS) are seen quickly post-ingestion (Benowitz, 1990). Although plasma and most Extra Cellular Fluid (ECF) caffeine concentrations in humans are not well correlated (Stable, Arner, & Ungerstedt, 1991), saliva caffeine concentrations are generally 80% that of plasma (Zylber-Katz, Granit, & Levy, 1984), therefore saliva sampling can also be used to determine caffeine's pharmacokinetic parameters (Carrillo, Christensen, Ramos, Alm, Dahl, Benítez, & Bertilsson, 2000; Liguori, Hughes, & Grass, 1997). The distribution of intracellular caffeine has not being studied in humans, however *in vivo* animal studies show that, although early on after administration,

caffeine concentrations vary between organs, no significant differences are seen between the plasma and intracellular concentrations 30-60 minutes after administration (Burg & Werner, 1972).

2.4.2 Metabolism and Elimination

Metabolism of caffeine is carried out in the liver via demethylation by the Cytochrome P450 oxidase enzyme system (Gu, Gonzalez, Kalow, & Tang, 1992; Lelo, Miners, Robson, & Birkett, 1986). The isoenzyme, Cytochrome P450 1A2 (coded for by the gene CYP1A2), is responsible for approximately 95% of the primary breakdown of caffeine. A small fraction is metabolised by CYP3A4, N-acetyltransferease 2 and xanthine oxidase (Berthou et al., 1991; Miners & Birkett, 1996). The primary metabolites of caffeine are paraxanthine (1, 7-dimethylxantine; 84%,), theobromine (3, 7-dimethylxanthine; 12%) and theophylline (1,3- dimethylxanthine; 4%) (Miners & Birkett, 1996). These are further metabolised via N-monodimethylation to produce monomethylxanthines and via hydroxylation reactions to produce uric acid derivatives (Tang et al., 1991).

The average half-life for caffeine elimination in adults is 4-6 hours, but can range between 2-12hours (Benowitz, 1990). This variation is partly due to differences in the caffeine dose consumed (Fredholm et al., 1999; Kaplan et al., 1997). There is evidence to suggest that at least one of the routes of caffeine metabolism may be saturated at certain caffeine doses; i.e. caffeine doses exceeding 250 mg tend to show non-linear pharmacokinetics (Kaplan et al., 1997), whereas doses below 100 mg tend to be linear (Bonati et al., 1982). This hypothesis is also supported by Sved, Hossie, and McGilveray (1976), who observed a plateau of plasma theophylline levels after a 300 mg dose of caffeine was administered to participants, and Graham and Spriet (1995),

who showed that the concentration of paraxanthine (the primary metabolite of caffeine) in the blood did not differ between caffeine doses of 6 mg· $kgbw^{-1}$ and 9 mg· $kgbw^{-1}$. The concentration of caffeine in the blood stream however still increases with higher dosage, which suggests that the variations in metabolism according to dosage are not affected by absorption.

The activity of the cytochrome p450 1A2 enzyme differs in individuals for many reasons. An estimated 70% of the variation in enzyme activity is due to genetics (explored further in Section 2.5.1), with the remaining 30% attributable to additional biological and environmental factors, such as age, gender, smoking etc. (Rasmussen, Brix, Kyvik, & Brøsen, 2002).

Babies have immature enzymes therefore metabolism of caffeine is slower than in adults, however by the age of six months there is no longer a notable difference in caffeine metabolism (Aranda et al., 1979; Fredholm et al., 1999). There is also an effect of gender on caffeine metabolism with ~ 20-30% faster clearance in females than in males (Nawrot et al., 2003); however, a 50% decrease in caffeine metabolism is seen in those who take oral contraceptives compared with those who do not (Patwardhan, Desmond, Johnson, & Schenker, 1980). Additionally, the half-life of caffeine increases in pregnancy by approximately 4 hours and 15 hours in the first and third trimesters, respectively (Aldridge, Bailey, & Neims, 1981; Brazier, Ritter, Berland, Khenfer, & Faucon, 1982; Knutti, Rothweiler, & Schlatter, 1981). Furthermore, caffeine metabolism is increased by 30-50% in those who smoke tobacco (Murphy et al., 1988), and is decreased in people with liver disease or chronic alcohol consumption (Benowitz, 1990; Fisher et al., 2009). There may also be some inter-ethnic variation in the activity of the cytochrome P450 enzyme, as seen between Caucasian and Asian groups (Grant,

Tang, & Kalow, 1983). This could however be due to differing genetic profiles among the different ethnic populations (Section 2.7.1).

The main route of excretion of caffeine is via the kidneys (Goldstein et al., 2010; Magkos & Kavouras, 2005), with approximately 70% of the metabolites from a 1000 mg dose of caffeine appearing in the urine (Cornish & Christman, 1957). Only a very small amount (1-3%) of caffeine is excreted in the urine unchanged (Axelrod & Reichenthal, 1953; Cornish & Christman, 1957; Newton et al., 1981), and this appears to be independent of dosage (Newton et al., 1981). Since the bioavailability of caffeine is close to 100% (Blanchard & Sawers, 1983a, 1983b), it has been suggested that other routes of elimination of caffeine from the body must also exist.

2.5 Caffeine Pharmacodynamics

2.5.1 Caffeine as an Adenosine Antagonist

The chemical structure of caffeine is comparable to that of a molecule found in the body called adenosine, with both containing a double ring structure (Ribeiro & Sebastiao, 2010) (shown in Figure 2.1). This structural similarity means caffeine is able to bind to adenosine receptors and therefore block the action of adenosine (Fisone, Borgkvist, & Usiello, 2004; Smith, 2002). In order to understand caffeine's mechanisms of action, it is important to have an appreciation of adenosine's role in the body and how caffeine affects this by binding to its receptors.

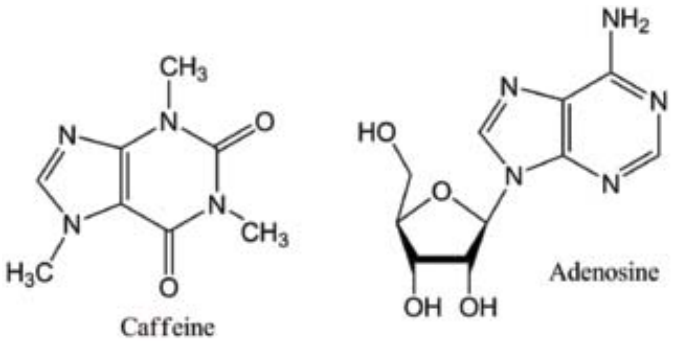

Figure 2.1: Chemical structure of caffeine and adenosine

Adenosine is an inhibitory neurotransmitter which acts to decrease activity in the brain and maintain homeostasis (Hughes et al., 1998; Ribeiro & Sebastiao, 2010). This occurs by suppressing the release of a number of other neurotransmitters, including dopamine (involved in modulation of mood, motor stimulation and regulation of some hormones), glutamate (a key excitatory neurotransmitter) and acetylcholine (involved in mood, memory and learning). It has been proposed that adenosine could also be classified as a somnogen (i.e. a sleep-promoting molecule) (Elmenhorst et al., 2007; Lorist & Tops, 2003), due to its involvement in producing fatigue and the drive to sleep.

When a person first wakes, very little adenosine can be found in the neurons of the CNS. The production of adenosine comes about via breakdown of adenine nucleotides such as adenosine monophosphate (AMP) and adenosine triphosphate (ATP) as the day progresses. This accumulation results in adenosine binding to and in turn activating the adenosine receptors (Elmenhorst et al., 2007). Antagonism of these adenosine receptors by caffeine stimulates the release of the neurotransmitters which adenosine normally inhibits (Hughes et al., 1998; Ribeiro & Sebastiao, 2010).

There are four adenosine receptor subtypes; A1, A2a, A2b and A3, of which the A1 and A2a subtypes have the greatest expression in the brain and the highest affinity for caffeine (Fisone et al., 2004; Hughes et al., 1998; MacKenzie et al., 2007; Ribeiro & Sebastiao, 2010). A1 receptors are present in most areas of the brain but a higher

density can be found in certain areas (hippocampus, specific thalamic nuclei and the cerebellar and cerebral cortex), whereas A2a receptors are only located in areas which are dopamine rich (Fredholm et al., 1999).

Animal studies have demonstrated that caffeine exhibits the same psycho-stimulant effects as "classical psychostimulants" including cocaine and amphetamine (Ferré, 2008), however, caffeine's mechanism of action appears to differ greatly. These drugs mimic the action of dopamine, whereas caffeine acts partially by facilitating the binding of dopamine to its receptors (Ferré, 2008; Fisone et al., 2004). Adenosine A2a can be found as a complex with dopamine D2 receptors and binding of caffeine to this receptor complex has been identified as the chief target for caffeine's motor-stimulatory effects (Bonaventura et al., 2015; Ferré, 2016; Ferré et al., 2015).

2.5.2 Effects of Caffeine

Although caffeine is not required for normal physiological functioning, it can have an effect on a large number of bodily functions and organs when ingested (Benowitz, 1990). The potential effects following consumption of caffeine are complex and varied, and include changes to the CNS, the cardiovascular system, diuresis, metabolism and inflammatory mechanisms. Lower doses typically yield a more positive effect whilst higher doses tend to produce negative effects (Griffiths & Woodson, 1988b), although the amount of caffeine that constitutes a "high" dose differs between individuals (Evans & Griffiths, 1991).

2.5.2.1 Mood and Cognition

Caffeine can improve overall cognition in a variety of ways, however the full extent of this is unknown (Ribeiro & Sebastiao, 2010). Caffeine's action as an adenosine

receptor antagonist causes an increase in neurotransmitter firing rate and also increases alertness (Puckeridge et al., 2011). Consumption of caffeine can increase the ability to concentrate on more than one task at a time and the capacity to adapt to different situations (Nehlig, 2010). An increase in information processing speed can also be seen almost immediately after caffeine consumption (Hindmarch, Quinlan, Moore, & Parkin, 1998; Lorist & Tops, 2003; Ribeiro & Sebastiao, 2010). Additionally, it has been found that individuals reported feeling subjectively more relaxed and alert and less irritable and nervous post caffeine consumption (Heishman & Henningfield, 1992). These effects can be seen after a relatively small amount of caffeine is consumed, such as one cup of instant coffee (Lorist & Tops, 2003). There is also some evidence to suggest that caffeine can improve short and long term memory (Levy & Zylberkatz, 1983; Lorist & Tops, 2003), however, the mechanisms by which this occurs remain unclear. Caffeine may also have a role in decreasing the rate of cognitive decline. A systematic review and meta-analysis (Santos, Costa, Santos, Vaz-Carneiro, & Lunet, 2010) found a decreased relative risk of cognitive decline/dementia in older adults with moderate long-term caffeine intake. The association is still present even when accounting for any possible confounding medical disorders or lifestyle habits (Gray, 1998). Adenosine receptor activation has a role in neurodegeneration, resulting in cognitive decline. Due to caffeine's role in antagonising adenosine, it has been suggested that this may be the mechanism by which caffeine may lower the risk of cognitive decline/dementia (Hughes et al., 1998; Ribeiro & Sebastiao, 2010).

2.5.2.2 Sleep and Fatigue

By its antagonising action on the adenosine receptors, caffeine acts to alleviate sleepiness and fatigue therefore increasing alertness (Ribeiro & Sebastiao, 2010).

Adenosine's somnogenic effect is blocked by caffeine and the body is able to function at a higher state of arousal for a prolonged period of time. By carrying out electrical activity readings in the brain (Electroencephalogram; EEG), Lorist and Tops (2003) have shown that there is an increase in neurotransmission after caffeine consumption, displaying an increase in levels of arousal. A review (Smith, 2011) concluded that caffeine's effect on energy and alertness is most prominent when the individual is already feeling fatigued (e.g. sleep-deprived).

Although the arousing action of caffeine may be beneficial for some individuals in certain circumstances (e.g. shift work, driving long distances) it has also been shown to cause sleep disturbances and extend the time required to fall asleep (Landolt et al., 2004). It has been shown that a 200 mg dose of caffeine taken 3 hours before bed acts to delay the circadian clock (sleep cycle) by approximately 40 minutes (Cornelis, El-Sohemy, Kabagambe, & Campos, 2006). Caffeine consumption can also result in a decreased number of hours of total sleep (Puckeridge et al., 2011). The extent to which caffeine causes sleep disruptions depends largely on the dosage and how close to bedtime it was consumed. Caffeine doses of less than 100 mg do not have an effect on sleep adequacy (Dorfman & Jarvik, 1970), whereas doses of about 100 mg consumed near bedtime have been shown to increase the amount of time it takes to fall asleep and also the duration of sleep (Landolt, Dijk, Gaus, & Borbély, 1995). In general, caffeine of moderate doses of caffeine are not likely to have a disruptive effect on sleep if it is taken at least 8 hours beforehand (Bonnet, Tancer, Uhde, & Yeragani, 2005), and it is evident that many caffeine consumers reduce their intake later in the day to prevent the occurrence of these effects, providing an example of self-moderation (Smith, Maben, & Brockman, 1993).

2.5.2.3 Anxiety

Caffeine use is positively associated with anxiety disorders (Lorist & Tops, 2003; Ribeiro & Sebastiao, 2010), which is not surprising given that caffeine's effects on the CNS are mediated through the adenosine receptor system, which is also involved in anxiety regulation (Alsene, Deckert, Sand, & de Wit, 2003).

Not only does caffeine consumption increase anxiety in those who already suffer from panic disorders, but excessive intake can also induce anxiety in individuals who are not pre-disposed (Huntley & Juliano, 2012; Lorist & Tops, 2003; Ribeiro & Sebastiao, 2010). Childs et al. (2008), showed that consumption of a 450 mg dose of caffeine increased subjective ratings of anxiety in light/non-caffeine consumers, whereas a 150 mg dose did not affect anxiety ratings. Despite this, even low doses of caffeine can cause an episode in those who are susceptible to anxiety or panic disorders (Ribeiro & Sebastiao, 2010).

2.5.2.4 Physical Performance

Caffeine is well acknowledged as an ergogenic aid for aerobic performance in humans (Gray, 1998; Lorist & Tops, 2003). This ergogenic effect is particularly effective for endurance exercise by extending the time to fatigue (Ganio, Klau, Casa, Armstrong, & Maresh, 2009). Consumption of caffeine has also been shown to improve long distance running and sprint cycling times (Graham & Spriet, 1991; Wiles, Coleman, Tegerdine, & Swaine, 2006), improve sprint speed (Stuart, Hopkins, Cook, & Cairns, 2005), and increase power output when cycling (Doherty, Smith, Hughes, & Davison, 2004). The caffeine dose consumed in these studies ranges from 1 $mg \cdot kg^{-1}$ – 9 $mg \cdot kg^{-1}$, therefore

the exact amount of caffeine required to achieve these effects is difficult to determine and likely to differ between activities and individuals.

The results of studies examining the potential ergogenic effect of caffeine on anaerobic performance are more variable (Davis & Green, 2009). There is a large variety of methods used in the literature which may explain the inconsistent results (e.g. different types of contraction (Warren, Park, Maresca, Mckibans, & Millard-Stafford, 2010), dosage of caffeine (3 $mg \cdot kg^{-1}$ – 6 $mg \cdot kg^{-1}$) (Astorino, Martin, Schachtsiek, & Wong, 2013; Materko & Santos 2011), and time between ingestion and exercise (45 minutes – 90 minutes) (Jacobs, Pasternak, & Bell, 2003; Williams, Cribb, Cooke, & Hayes, 2008)). It is also possible that some subjects benefit from caffeine and some do not, with evidence showing that results are more variable in non-trained than trained subjects (Magkos et al., 2005), therefore studies which report mean data may have overlooked a significant effect in some subjects. Further research is required to determine the exact ergogenic effect of caffeine on anaerobic performance, however, a recent meta-analysis (Polito, Souza, Casonatto, & Farinatti, 2016) concluded that caffeine improves isotonic muscular endurance but not maximal strength exercise. In addition, the effect of caffeine on muscular endurance appeared to be dependent on the timing of ingestion in regards to exercise (i.e. strongest effect with ingestion 60 minutes prior).

Initially, caffeine consumption was thought to improve performance by increasing circulating free fatty acid levels and sparing muscle glycogen (Costill, Dalsky, & Fink, 1977). However, more recent evidence suggests that the effects are much more likely to occur due to a decrease in perceived exertion and an increase in the firing rate of the nervous system (Graham, Helge, MacLean, Kiens, & Richter, 2000).

Due to its ergogenic effects, the World Anti-Doping Agency (WADA) placed caffeine on the list of prohibited substances in 1984 (World Anti-Doping Agency, 2003). However, it was removed from this list in 2004 due to having such a prominent place in many individuals' everyday lives and the multitude of caffeine-containing products available on the market (Del Coso, Muñoz, & Muñoz-Guerra, 2011). Now, competitors with caffeine urine concentrations of above 12μg/mL are banned from professional sporting events (Burke & Deakin, 2015).

2.5.2.5 Cardiovascular Implications

Considerable research has highlighted caffeine's potential role in the development of CVD (Coronary Heart Disease (CHD), high blood pressure and Myocardial Infarction (MI)), yet the findings are conflicting and remain equivocal (Azevedo & Barros, 2006; Cornelis et al., 2006; Hammar et al., 2003; Happonen, Voutilainen, & Salonen, 2004; Kawachi, Colditz, & Stone, 1994; Kleemola, Jousilahti, Pietinen, Vartiainen, & Tuomilehto, 2000; Lopez-Garcia et al., 2006; Myers & Basinski, 1992; Nawrot et al., 2003; Nilsson, Johansson, Lenner, Lindahl, & Van Guelpen, 2010; Panagiotakos et al., 2003; Woodward & Tunstall-Pedoe, 1999; Wu et al., 2009). Genetic variation (discussed in Section 2.7.1), is likely to account for some of the discrepancies in the literature.

Epidemiological studies which have investigated the relationship between caffeine and CVD have looked at coffee consumption as a surrogate measure for caffeine. Heavy coffee drinkers have been found to have a two to three fold increased risk of having CHD (LaCroix, Mead, Liang, Thomas, & Pearson, 1986). Other studies have found a protective effect of moderate caffeine consumption against CVD risk, therefore this

association may resemble a J-shape curve (Ding, Bhupathiraju, Satija, van Dam, & Hu, 2013; Kleemola et al., 2000; Panagiotakos et al., 2003). The possible link has been attributed to caffeine's antagonistic effect on adenosine receptors and adenosine's role as a systemic and coronary vasodilator (Hori & Kitakaze, 1991; Shryock & Belardinelli, 1997).

Intervention studies have shown an acute increase in blood pressure, catecholamine concentrations, plasma renin concentrations and an induction of cardiac arrhythmias following administration of caffeine (LaCroix et al., 1986; Willett et al., 1996). There are however, inter-individual differences in caffeine's haemodynamic effects on blood pressure. An increase in blood pressure could increase CVD risk in individuals with a history of hypertension (Robertson et al., 1978).

The relationship between coffee consumption and CVD risk may be confounded by lifestyle factors such as cigarette smoking or alcohol consumption which are typically associated with a higher coffee consumption (Ahn, Im Gwak, Yun, Choi, Nam, & Shin, 2017; Bjorngaard et al., 2017; Mineharu et al., 2010; Treur et al., 2016) and are known to increase CVD risk (Tzoulaki, Elliott, Kontis, & Ezzati, 2016). Ding et al. (2013) adjusted for these confounders and found no significant association between heavy coffee consumption and CVD risk, although the association between moderate coffee consumption and CVD risk increased in strength.

2.5.2.6 Other Effects

Caffeine has many other acute effects, uses and associations that are less well studied than the above. There is an acute increase in urine output after caffeine consumption of over 250mg (Maughan & Griffin, 2003), therefore it is considered a diuretic. This diuretic activity can be attributed to its interaction with the A1 adenosine receptor

causing an increase in renin levels and inhibiting renal reabsorption of water (Rieg et al., 2005). This can increase the risk of dehydration, however, many caffeine sources are beverages and therefore are associated with concurrent fluid intake i.e. the net amount of fluid retained in the body is greater than the amount lost due to diuresis (Grandjean, Reimers, Bannick, & Haven, 2000).

Low doses of caffeine show a weak bronchodilation effect (increasing breathing efficiency) for up to four hours in individuals with asthma (Becker, Simons, Gillespie, & Simons, 1984). It can also reduce apnoea (a pause in breathing) in preterm infants (Henderson-Smart & Steer, 2010). In addition, caffeine is an effective analgesic adjuvant, i.e. when added to nonsteroidal anti-inflammatory drugs (NSAIDs), it enhances the pain relief and reduces the amount of the drug required by approximately 40% (Zhang, 2001). As caffeine does not alter the bioavailability of the NSAIDs (Granados-Soto & Castañeda-Hernández, 1999), this action has been attributed to caffeine's role as an adenosine antagonist (Polski, Kasperek, Sobotka-Polska, & Poleszak, 2014). Although the exact mechanism is unknown, adenosine has a role in pain perception, therefore it is likely that caffeine acts to partially block the detection of pain (Sawynok, 1998).

The consumption of caffeine is associated with the occurrence of seizures (Zagnoni & Albano, 2002) both in those with epilepsy and without. Adenosine is known to be an anticonvulsant as it suppresses the rate of neurotransmission, therefore caffeine's role in antagonising adenosine may increase the risk of seizures occurring (Ribeiro & Sebastiao, 2010).

There is evidence that caffeine may have a role in weight management (Harpaz, Tamir, Weinstein, & Weinstein, 2017). The consumption of caffeine has been shown to increase basal metabolic rate (Acheson, Zahorska-Markiewicz, Pittet, Anantharaman, & Jéquier, 1980; Dulloo, Geissler, Horton, Collins, & Miller, 1989; Koot & Deurenberg, 1995), increase fat oxidation, increase resting oxygen consumption, and increase the amount of free fatty acids released into the blood for use as a fuel (Acheson et al., 1980; Dulloo et al., 1989; Greenway, 2001; Koot & Deurenberg, 1995; MacKenzie et al., 2007). Caffeine, like many other central stimulants (e.g. amphetamine), has also been shown to reduce appetite and therefore decrease caloric intake slightly. This is evidenced by a reduction in the number of meals consumed over the day rather than meal size. (Racotta, LeBlanc, & Richard, 1994; Tremblay, Masson, Leduc, Houde, & Després, 1988). This evidence however only suggests that caffeine has short term modest effects on energy expenditure and energy intake. The long term effect of caffeine in weight management is largely unknown and requires further investigation. In addition, the potential role of caffeine in weight management must also consider the calorie content of the caffeine vehicle.

In addition to caffeine's potential effect on weight management, caffeine has also been shown to decrease insulin sensitivity in individuals with and without diabetes mellitus (Keijzers, De Galan, Tack, & Smits, 2002), possibly due to the increase in free fatty acid release.

2.6 Caffeine Tolerance/ Dose Adaptation

The effects of caffeine can be influenced by whether an individual habitually consumes caffeine or not. Habitual caffeine consumption causes tolerance to its effects (Finn & Holtzman, 1987; Griffiths & Mumford, 1996; Hirsh, 1984), which means that there is a

difference in the type or extent of its effects when an individual begins to regularly consume it (Nehlig, 2004). This tolerance is shown to develop to only some of caffeine's effects but not others (Holtzman & Finn, 1988).

Chronic caffeine consumption causes an up-regulation of adenosine receptor expression (Fisone et al., 2004; Hughes et al., 1998; MacKenzie et al., 2007; Ribeiro & Sebastiao, 2010). This leads to increased binding of adenosine due to reduced competition for receptors, but can be overcome by higher doses of caffeine which the individual usually consumes (Ferré, 2008). For this reason, a marked reduction in caffeine-induced dopamine release has been seen with chronic caffeine use (Ferré, 2008, 2010), possibly due to up-regulation of A1 receptors but not A2a receptors (Ferré, 2008; Holtzman & Finn, 1988; Robertson, Wade, Workman, Woosley, & Oates, 1981) . Tolerance to caffeine's acute cardiovascular effects (i.e. increase in blood pressure and decrease in heart rate) has been shown to develop quickly and completely (Shi, Benowitz, Denaro, & Sheiner, 1993). The acute effect of caffeine on blood pressure has shown complete tolerance after three days of 250 mg caffeine doses in subjects who had abstained from caffeine for 3 weeks beforehand (Robertson et al., 1981). This is due to lower amounts of adrenaline, noradrenaline and renin being released post caffeine consumption when an individual is tolerant to caffeine's acute cardiovascular effects (Robertson et al., 1981).

Multiple studies have shown that tolerance can develop to caffeine's effects on sleep (Bonnet & Arand, 1992; Colton, Gosselin, & Smith, 1968; Curatolo & Robertson, 1983; Zwyghuizen-Doorenbos, Roehrs, Lipschutz, Timms, & Roth, 1990). One study found that in participants with habitual caffeine consumption ranging 12-160 mg· day^{-1}, sleep efficiency decreased to 80% of baseline after a caffeine dose of 400 mg· day^{-1} (Bonnet & Arand, 1992). This decrease in sleep efficiency post caffeine dosage remained true

for 5-6 days, then modestly reduced to 90% of baseline after 7 days of administration, suggesting obvious but incomplete tolerance. In addition, Pelchovitz and Goldberger (2011) found that caffeine intake causes a longer delay in time to sleep in habitually low level caffeine consumers than in high level consumers.

It should also be noted that almost complete tolerance develops towards the diuretic effect of caffeine, therefore habitual users will not experience any detrimental fluid-balance effects (Maughan et al., 2003).

Whether or not tolerance develops to caffeine's effects on cognitive performance and mood is not clear and some argue that any tolerance seen may only be due to ameliorating the symptoms of withdrawal (Koelega, 1993; Rizzo, Stamps, & Fehr, 1988). However tolerance develops to these effects even when withdrawal symptoms are ruled out (Evans & Griffiths, 1991; Judelson et al., 2005).

There are also significant differences in the level of tolerance developed between individuals, with some reports suggesting that genetics plays a part in the development of tolerance to the effects of caffeine (Kendler & Prescott, 1999). For this reason, plus multiple other contributing factors (e.g. dosage, timing, habitual intake, time period, withdrawal) it is difficult to accurately determine the full extent to which this phenomenon occurs.

2.7 The Role of Genetics

Genetics plays a role in many aspects of caffeine consumption (e.g. metabolism, risk of adverse effects and ability to form tolerance to its effects). Studies using twins (comparison between monozygotic and dizygotic) to determine the hereditability of caffeine consumption (Yang et al., 2010), found that genetics accounts for 34-58% of caffeine use and 77% of heavy caffeine consumption. Additionally, caffeine tolerance,

symptoms of withdrawal and caffeine toxicity has heritability estimates of 40%, 35% and 45%, respectively (Kendler & Prescott, 1999). The two genes most closely associated with caffeine, and the most extensively studied are CYP1A2 (Section 2.7.1) and ADORA2A (Section 2.7.2). There are increasingly more genes related to caffeine metabolism or response being discovered, however, these are less well studied (e.g. ADORA intron 1a, AHR, ADORA2A2, DRD2) (Alsene et al., 2003; Childs et al., 2008; Cornelis, 2014).

2.7.1 CYP1A2

As previously mentioned (Section 2.4.2), caffeine is metabolised by the enzyme Cytochrome p450 1A2, which is coded for by the gene CYP1A2. A Single Nucleotide Polymorphism (SNP) in this gene, rs762551A>C (also known as -164A>C or -163C>A) (SNPedia, 2014), results in an alteration of the enzyme's activity. The wild-type A allele is known as the high activity allele, where homozygotes (A/A) are considered "fast caffeine-metabolisers". The variant C allele is known as the low activity allele, however there is controversy as to whether heterozygotes (A/C), and homozygotes for the C allele (C/C) should be categorised as "intermediate caffeine-metabolisers" and "slow caffeine-metabolisers", respectively, or whether these two genotypes should be combined into one phenotype, "slow caffeine-metabolisers" (Cornelis et al., 2006; Dobrinas, Cornuz, Pedrido, & Eap, 2012; Han et al., 2001; Sachse et al., 1999). Slow metabolisers of caffeine are considered to be at a higher risk of the negative effects of caffeine due to caffeine remaining in the blood stream for a longer period of time (Yang et al., 2010). In addition, it appears that the possible relationship between caffeine consumption and CVD (Section 2.5.2.5) depends on the CYP1A2 genotype. Daily coffee consumption of ≥4 cups compared with <1 cup daily, increases non-fatal MI risk

by 2-4 fold in slow metabolisers only (combined A/C and C/C groups) (Cornelis et al., 2006). Although this enzyme is also involved in the metabolism of mutagens found in tobacco smoke, this association appears to be independent of smoking status (Cornelis et al., 2006).

According to current research, the genotype frequencies likely fall within the following ranges; A/A 40.3-54%, C/A 37.6-53.2%, C/C 6.5-16.4% (Castorena-Torres et al., 2005; Chida et al., 1999; Cornelis et al., 2006; Djordjevic, Ghotbi, Jankovic, & Aklillu, 2010; Dobrinas et al., 2012; Goodman, Tung, McDuffie, Wilkens, & Donlon, 2003; Hamdy et al., 2003; Nakajima et al., 1999; Tiwari et al., 2005). Genotype ratios do not differ between Chinese (Han et al., 2001), Asian (Nakajima et al., 1999) and Caucasian populations (Sachse et al., 1999). The differences in prevalence according to some populations could be due to an insufficient sample size in some cases, for example, in a sample of 46 Mexicans, only the C/A and A/A genotypes were detected in the population (Castorena-Torres et al., 2005).

2.7.2 ADORA2A

A SNP, Rs5751876 (also known as 1976T>C), on the adenosine 2a receptor gene (ADORA2A) has been associated with anxiety and sleep disturbances post caffeine-consumption (Alsene et al., 2003; Retey et al., 2005). This has been attributed to an increased A2a AR expression in these individuals (Retey et al., 2007; Yang et al., 2010). Caffeine's other known effects on stimulation, heart rate and psychomotor tasks, do not appear to be affected by AR genotype (Alsene et al., 2003). The current evidence suggests that the prevalence of the ADORA2A rs5751876 TT genotype falls somewhere between 17- 29% (Alsene et al., 2003; Childs et al., 2008; Rogers et al., 2010).

Individuals homozygous for the T allele (T/T) appear to experience higher subjective levels of anxiety after consumption of moderate levels of caffeine (150 mg) (Alsene et al., 2003). A dose of 50 mg did not increase anxiety levels in any of the genotype groups, whereas a dose of 450 mg increased anxiety levels in most of the participants and did not differ between groups. This finding is supported by work by Childs et al. (2008) who also discovered that another SNP, rs35320474 (2592T/−), is almost completely linked with the Rs5751876 SNP. Ratings of anxiety before caffeine administration or after placebo did not differ according to genotype; therefore the anxiogenic effect post administration can be attributed to the caffeine. As both these studies were carried out in occasional caffeine users (<300 mg weekly self-reported use), another study aimed to determine the effect of tolerance (Section 2.6) on this association (Rogers et al., 2010). It appears those individuals who habitually consume minimal or no caffeine (0-40 mg daily) experience anxiety after caffeine consumption (100 mg), with the effect being significantly higher in those with the ADORA2A rs5751876 T/T genotype. Individuals who habitually consume medium to high amounts of caffeine (>40 mg daily) do not appear to experience caffeine's anxiogenic effect, even those who are considered genetically susceptible (T/T genotype). Panic disorder, a condition which is characterised by recurring episodes of extreme anxiety and panic attacks, has also found to be associated with the A2a polymorphism 1976T>C in general (i.e. not in relation to caffeine consumption) (Deckert et al., 1998).

There is less research available on the genotypic differences in caffeine-induced sleep disturbances, however individuals with the T/T genotype were more likely to be "caffeine sensitive" (self-reported) and also showed reduced EEG beta activity during sleep (similar to that of insomniacs) post caffeine consumption (200 mg) compared to those with the C/C genotype (Retey et al., 2007).

2.8 Recommendations for Caffeine Intake

There is no standard reference range of safe caffeine consumption; for example an Upper Limit of intake (UL) (The National Health and Medical Research Council, 2006). In New Zealand an advisory statement for the general population does not currently exist, however, the Ministry of Health (MOH) has provided advice for children/young people and pregnant/breastfeeding women (New Zealand Ministry of Health, 2010b, 2012). The recommendations are delivered to the public as a food-based recommendation (i.e. which food products to avoid/limit) rather than a specific caffeine limit (Table 2.2).

Table 2.2: Recommendations for daily caffeine intake from around the world

Authority/ Country	Recommendation	Reference
New Zealand Ministry of Health	- Children, young people (2-18 years old), pregnant and breast feeding should not consume energy drinks/energy shots. They should also limit their caffeine intake altogether. - Pregnant women should limit their daily caffeine consumption to a maximum of three cups of single-shot espresso coffee, or six cups of instant coffee or tea.	(New Zealand Ministry of Health, 2010b, 2012)
European Food Safety Authority	- General population: up to 400 mg · day^{-1} (corresponding to about 5.7 mg · kgbw · day^{-1} body for a 70 kg adult), single doses up to 200 mg - Breastfeeding and pregnant women: up to 200 mg · day^{-1}	(Tetens, 2015)
United States Food and Drug Administration	- General adult population: up to 400 mg · day^{-1}	(US Food and Drug Administration, 2013)
Health Canada	- General adult population: up to 400 mg · day^{-1} - Children and adolescents: no more than 2.5 mg · kgbw · day^{-1} - Females of childbearing age: do not exceed 300 mg · day^{-1}	(Nawrot et al., 2003)
European Commission Scientific Committee on Food	- Pregnant women: ”moderation of caffeine intake”	(Scientific Committee on Food, 2003)
United Kingdom Food Standards Agency	- Pregnant women: maximum of 200 mg · day^{-1}	(CARE Study Group, 2009; Food Standards Agency, 2008)
Belgium Superior Health Council	- Adults: up to 400 mg · day^{-1} (5.7 mg · kgbw^{-1} for a 70 kg adult) - Children and adolescents: maximum of 2.5 mg · kgbw^{-1} - Women of childbearing age: up to 300 mg · day^{-1} or even 200 mg · day^{-1}	(Superior Health Council, 2012)

The general consensus of the most recent safety assessments of caffeine conclude that up to 400 mg of caffeine a day (corresponding to 5.7 mg· kgbw^{-1}· day^{-1} for a 70 kg adult) is safe for the general healthy adult population (Nawrot et al., 2003; Superior Health Council, 2012; Tetens, 2015; US Food and Drug Administration, 2013). This limit is based on reviews of prospective cohort studies and the risk of general toxicity, cardiovascular effects, changes in adult behaviour, increased incidence of cancer, effects on male fertility, or bone status/calcium balance (if an adequate amount is consumed). Increased anxiety levels can be seen in adults after receiving 3 mg· kgbw^{-1} (210 mg for a 70 kg male) of caffeine intravenously (Nickell & Uhde, 1994), however this was not considered a health risk in this population subgroup (Smith, 2002; Superior Health Council, 2012).

The recommended caffeine limits for children are mainly based on its effects on the CNS (i.e. altered behaviour, anxiety) due to incomplete brain maturation in this population subgroup (Nawrot et al., 2003; Superior Health Council, 2012). Consumption of more than 2.5 mg· kgbw^{-1}· day^{-1} (~95 mg) in children has been reported to increase anxiety levels (Bernstein et al., 1994). The FDA has not set a recommended caffeine limit for children due to limited research available (US Food and Drug Administration, 2013); however the American Academy of Paediatrics discourages the consumption of caffeine in children (Seifert et al., 2011). Again due to limited information in this area, the EFSA reports that a recommendation cannot be made, however, the value below which there are no concerns for adults (3 mg· kgbw^{-1}· day^{-1}) may be a good starting point in developing an appropriate recommendation (Tetens, 2015).

In 2003, the European Commission Scientific Committee on Food recommended ‘moderation of caffeine intake” for pregnant women, after concluding that consumption

of up to 300 mg·day^{-1} appeared to be safe (Scientific Committee on Food, 2003). The same recommendation by Health Canada was based on observational studies looking into the following outcomes; spontaneous abortion, pre-term delivery, foetal growth, congenital malformations and post-natal development (Nawrot et al., 2003). In addition, Health Canada also provided a conservative recommendation for women of child-bearing age corresponding to their recommendations during pregnancy. In 2008, the UK Food Standards Agency (Food Standards Agency, 2008) delivered the advice that the previously recommended limit of 300 mg of caffeine in pregnancy should be reduced to a maximum of 200 mg·day^{-1} after emerging evidence showed negative outcomes at daily intakes at and above this value. Intakes of more than 200 mg in pregnant women was associated with an increased risk of foetal growth restriction and risk of miscarriage, whereas other outcome measurements (i.e. pre-term birth and congenital malformation) were inconclusive (CARE Study Group, Olsen, & Bech, 2008; Nawrot et al., 2003).

2.9 Regulations and Legislations

Although caffeine intakes of up to 400 mg· day^{-1} are generally considered safe for the average person (Section 2.8), it is important for consumers to understand that there are possible risks of over consumption and that some individuals may be at a higher risk of these even at lower levels. It is also important that there are regulations on certain caffeine-containing products put in place in order to reduce the risk of caffeine overdose/intoxication in the public. Regulations on caffeine-containing products vary between countries due to the fact that there are no internationally-recognised caffeine guidelines.

In New Zealand, manufacturers of products which naturally contain caffeine (coffee, tea, chocolate) are not regulated in regards to caffeine content and are not required to declare the levels of caffeine they contain on their nutrition information panels (NIPs) (Food Standards Australia New Zealand, 2015). There are however, regulatory standards stating the maximum amount permitted to be added to certain foods/beverages (Table 2.3).

Table 2.3: Regulations surrounding caffeine content in New Zealand products

Product	Regulation/legislation	Regulatory authority/ reference	Caffeine limit
Kola-drinks	Australia New Zealand Food Standards Code; standard 1.3.1 'Food additives'	(Food Standards Australia New Zealand, 2015)	≤145 mg· L^{-1}
Energy drinks	Australia New Zealand Food Standards Code; standard 2.6.2, 'Formulated caffeinated beverages'	(Food Standards Australia New Zealand, 2015)	145-320 mg· L^{-1}
Energy shots	Voluntary Industry code- Manufacturing and Marketing of Energy Shots	(New Zealand Juice and Beverage Association, 2012)	<160mg per unit
Caffeinated RTDs	Voluntary Industry Code for RTDs	(Distilled Spirits Association of New Zealand, 2013)	≤145 mg· L^{-1}
Sports supplements	Australia New Zealand Food Standards Code; standard 2.9.4 'Formulated supplementary sports foods' & Dietary Supplements Regulations of 1985	(Food Standards Australia New Zealand, 2015; New Zealand Ministry of Health, 2010a)	NA
Caffeine tablets	Dietary Supplements Regulations of 1985	(New Zealand Ministry of Health, 2010a)	NA

RTD- Ready to drink alcoholic beverage
NA- Not Applicable

Energy drinks are defined as “a non-alcoholic water-based flavoured beverage which contains caffeine and may contain carbohydrates, amino acids, vitamins and other substances, including other foods, for the purpose of enhancing mental performance” (Food Standards Australia New Zealand, 2015). It has been suggested that energy drinks are allowed a higher caffeine limit than kola-drinks due to containing added vitamins (Reissig, Strain, & Griffiths, 2009). However, it can be argued that this is not a legitimate reason for being exempt from the same caffeine-related regulations as this does not alter the action of the caffeine contained in the drinks.

Energy drinks, however, are subject to labelling requirements regulated by the Australia New Zealand Food Standards Code, Standard 1.2.4 (Food Standards Australia New Zealand, 2015). Labels on energy drinks must include the amount of caffeine, an advisory statement declaring the product is not recommended for certain population groups such as pregnant/ breastfeeding women, children and caffeine-sensitive individuals, and a statement of the recommended consumption limit per day. The effectiveness of these labelling measures is arguably low in comparison to a caffeine content restriction (Kole & Barnhill, 2013).

Energy shots, sports supplements and caffeine tablets contain caffeine levels above the limits prescribed in the Food Standards Code: Standard 2.6.4. Hence they are marketed as dietary supplements/supplemented foods and therefore fall under either the Dietary Supplements Regulations 1985 or Australia New Zealand Food Standards Code: Standard 2.9.4, “Formulated Supplementary Sports Foods” (Food Standards Australia New Zealand, 2015; New Zealand Ministry of Health, 2010a). Neither of these regulations specifically mentions caffeine content restrictions. In addition, the labels are only required to include a warning of the dangers of overdosing on the product and include the method of preparation if applicable. However, energy shot manufacturers who are part of the New Zealand Juice and Beverage

Association (NZJBA) follow a voluntary code that states that products must not exceed 160 mg of caffeine per energy shot unit (New Zealand Juice and Beverage Association, 2012). This voluntary code also includes an agreement to specify recommended maximum daily intake and include the same advisory statements required for energy drinks as mentioned above. These members have also agreed to market these products to adults only, although the specific age this relates to is not mentioned in the code. Since the NZJBA represents a large proportion (95%) of the non-alcoholic beverage industry in New Zealand, most beverages of this type are covered by this code. However, the caffeine content of sports supplements and caffeine tablets which are available over the counter, are dependent on the manufacturer.

There is no legislation which regulates the caffeine content of Ready to Drink (RTD) products, however, in 2013 the Distilled Spirits Association of New Zealand (DSANZ) generated the "Voluntary Industry Code for RTDs". Under this code, members of the DSANZ agreed to not produce RTDs containing more than 145 $mg \cdot L^{-1}$ (corresponding to regulations for kola-drinks) (Distilled Spirits Association of New Zealand, 2013; Food Standards Australia New Zealand, 2015). The proportion of RTD manufacturers who belong to this association is unknown.

Although there are regulations in place regarding the concentration of caffeine contained in some beverages, no regulations exist which control the volume of the beverage units (size of the package), which means the caffeine dose per retail unit is essentially unrestricted. Many energy drinks are sold in large cans which, regardless of how many servings are listed on the label, are frequently consumed in one sitting due to the container being non-resealable (Pomeranz, Munsell, & Harris, 2013).

In addition, major caffeine sources for the general population (e.g. coffee, tea) (Camargo, 1999; Lachenmeier et al., 2013) are exempt from any caffeine content or advisory statement

labelling regulations, therefore consumers may be ingesting a large amount of caffeine without knowing. Doing so may be a useful public health intervention, however it can be argued that this will only target a certain 'consumer type' (i.e. health-conscious shoppers who already read the nutrition labels) (Cowburn & Stockley, 2005).

2.10 Caffeine Dependency, Withdrawal and Intoxication

As caffeine is a psychoactive substance, it is not surprising that there are multiple mental and behavioural disorders related to caffeine use (Table 2.4).

Table 2.4: Clinical diagnoses related to caffeine use

Diagnostic manual	Diagnosis	Diagnostic criteria	Reference
ICD-10	Caffeine dependency	Three or more of the following symptoms at the same time over the past year: o Evidence of tolerance o A physiological withdrawal state o A strong desire or sense of compulsion to take the substance o Difficulties controlling substance-taking behaviour o Progressive neglect of alternative pleasures or interests o Persisting with substance use despite clear evidence of overtly harmful consequences	(World Health Organisation, 2015)
DSM-5	Caffeine withdrawal	Three or more of the following withdrawal symptoms occurring within 24 hours after the termination of prolonged daily caffeine consumption or a reduction in the amount of caffeine regularly consumed: o Marked fatigue/ drowsiness o Dysphoric/depression mood or irritability o Difficulty concentration and flu- like symptoms (e.g. nausea, vomiting, and muscle-pain/stiffness). o Headaches	(American Psychiatric Association, 2013)
ICD-10	Caffeine withdrawal	The presence of physiological symptoms including anxiety, sleep difficulties and depression upon disuse and an alleviation of these symptoms once the drug is re-administered.	(World Health Organisation, 2015)
WHO	Caffeine overuse	An intake of 500 mg or more in a day.	(Meredith, Juliano, Hughes, & Griffiths, 2013)
DSM-5	Caffeine intoxication	A "high" dose well in excess of 250 mg and five or more of the following symptoms: o restlessness o nervousness o excitement o insomnia o diuresis o gastrointestinal disturbance o muscle twitching o rambling flow of thought and speech o tachycardia or cardiac arrhythmia o periods of inexhaustibility o psychomotor agitation o flushed face	(American Psychiatric Association, 2013)

There is debate on whether there is enough evidence to support a diagnosis of caffeine addiction. Some research supports the belief that caffeine has an effect on the reward system (Temple, 2009), whereas others believe this is not supported by sufficient evidence (Malenka, Nestler, & Hyman, 2009; P. M. Miller, 2013; Nehlig, 2010; Nestler, 2013). The ICD-10 manual (International Classification of Diseases) includes a diagnosis of caffeine dependence under the section "mental and behavioural disorders due to psychoactive substance abuse" (World Health Organisation, 2015). The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) however states that the clinical significance of including caffeine dependence as a disorder is unclear and, consequently lists "caffeine use disorder" in the manual as an emerging model which requires further research (American Psychiatric Association, 2013). Daily doses of caffeine as low as 100 mg (approximately 1 cup of espresso) can be sufficient to result in the development of a "dependence" on caffeine and cause symptoms of withdrawal if caffeine is discontinued (Ferré, 2008; Kendler, Myers, & Gardner, 2006). The theory behind caffeine dependence and hence withdrawal symptoms is that habitual consumption leads to adenosine receptor up-regulation within the brain (Ahlijanian & Takemori, 1986; Boulenger, Patel, Post, Parma, & Marangos, 1983; Chou, Khan, Forde, & Hirsh, 1985; Marangos, Boulenger, & Patel, 1984). As caffeine usually acts to oppose the action of adenosine, withdrawal from caffeine causes the body's sensitivity to adenosine to increase as the receptors shift to a state of high affinity (Green & Stiles, 1986). In those who have developed a dependence on caffeine, withdrawal symptoms peak at approximately 24 hours post their last dose of caffeine and in general will discontinue after 1-5 days, which corresponds to the amount of time it takes for adenosine receptor numbers to return back to baseline levels (Griffiths & Woodson, 1988a). There is however evidence of withdrawal symptoms lasting up to

several months (Ahlijanian & Takemori, 1986). A gradual reduction in caffeine intake over a number of days rather than stopping 'cold-turkey' has been advised, in order to avoid withdrawal symptoms (Gray, 1998).

It has been suggested that the behavioural and cognitive benefits seen with caffeine consumption are simply due to eliminating the negative effects seen with caffeine withdrawal (James & Rogers, 2005). This theory however, is not likely as there is evidence to show that these behavioural and cognitive benefits are still seen with consumption after a seven-day washout period (which has been shown to be long enough for withdrawal symptoms to have diminished) (Smith, Christopher, & Sutherland, 2013), and can also be seen when an individual is not deprived of caffeine (caffeine has been consumed prior) (Smith, Sutherland, & Christopher, 2005).

The WHO diagnosis of caffeine overuse is very broad in comparison to the DSM-5's diagnosis criteria for caffeine intoxication (American Psychiatric Association, 2013; Meredith et al., 2013). The DSM-5 definition of caffeine intoxication appears more appropriate due to the large inter-individual differences in the response to caffeine at different doses.

2.11 Consequences of Caffeine Overdose

The FDA classifies caffeine as "generally recognized as safe" (GRAS) (Miles, 1983), however, consumption of too much caffeine results in over-stimulation of the CNS (Seifert et al., 2011). The symptoms that occur with overdose of caffeine are comparable to those that are seen with overdose of other stimulants (e.g. cocaine or amphetamines) (Stolerman, 2010).

There are multiple case reports of caffeine overdose in the scientific literature (Campana, Griffin, & Simon, 2014; Jabbar & Hanly, 2013; Kerrigan & Lindsey, 2005; Poussel et al., 2013; Rudolph & Knudsen, 2010). These cases are generally the result of individual caffeine doses exceeding 5 g and in some cases, have resulted in death. The oral lethal dose of caffeine in humans is estimated to be 150-200 $mg \cdot kgbw^{-1}$, however the time period of consumption is not specified (corresponding to 75-100 cups of coffee for an adult who weighs 70 kg) (Peters, 1967). There is however evidence of individuals surviving caffeine doses of up to 50 g (Bioh, Gallagher, & Prasad, 2013). Those with pre-existing heart conditions are at higher risk of fatality after caffeine overdose (Cannon, Cooke, & McCarthy, 2001). Co-ingestion of caffeine with other substances such as recreational drugs or alcohol (Section 2.11.1) (Gunja et al., 2012) and consumption after exercise (Kapner, 2008) also contribute to the risk of caffeine-induced fatality.

According to the New Zealand National Poisons Centre the main caffeine products involved in caffeine overdoses were energy drinks/shots and caffeine tablets, where over half of the individuals who called regarding energy drink/shot consumption required medical treatment. The minimum confirmed level of caffeine consumed by a caller (13-year-old) was 200 mg (4 $mg \cdot kgbw^{-1}$) from a single energy shot. The maximum confirmed level of caffeine consumed by a caller was 11.5 $mg \cdot kgbw^{-1}$ in the form of energy drinks. An estimated 1622 mg (35.54 $mg \cdot kgbw^{-1}$) was consumed by a 14-year-old in the form of caffeine tablets plus energy drinks (Thomson & Schiess, 2011).

2.11.1 Caffeine and Alcohol Co-ingestion

There is growing international concern in regards to the concomitant consumption of caffeine and alcohol. A pilot study (Pennay & Lubman, 2012) exploring alcohol mixed with energy drinks (AmED) consumption provided an insight into the motivations behind this practice in young people (19-31 years). Increased energy and wakefulness were reported to be the primary reasons for consuming AmED rather than alcohol alone. More enjoyable taste, increased or reduced intoxication and sociability were also reported benefits.

Multiple countries, including New Zealand, have released warning statements about the health risks of co-ingesting alcohol and energy drinks (O'Brien, McCoy, Rhodes, Wagoner, & Wolfson, 2008; US Food and Drug Administration, 2010). There are several reasons for public health concern when it comes to the co-ingestion of these two drugs. Firstly, evidence shows that consumers of AmED consume larger quantities of alcohol than those who consume alcohol alone (Marczinski, Fillmore, Henges, Ramsey, & Young, 2013; K. E. Miller, 2008; Oteri, Salvo, Caputi, & Calapai, 2007). Additionally, the consumption of energy drinks with alcohol results in a larger amount of energy drinks being consumed regularly (Reissig et al., 2009). When alcohol is consumed on its own, it acts as a depressant, causing sleepiness (Valenzuela, 1997), however when combined with caffeine, the depressant effects are decreased (Ferreira, De Mello, Pompéia, Souza-Formigoni, & Oliveira, 2006), reducing the appearance and sensation of drunkenness. This means that the consumer (or server) is likely to underestimate their level of alcohol intoxication and consume more alcohol overall because the drinking session is prolonged. This has been termed "wide-awake drunkenness" (Cleary, Levine, & Hoffman, 2012).

Secondly, AmED consumption is associated with a higher risk of negative alcohol-related consequences (e.g. driving whilst intoxicated, riding with an intoxicated driver, taking advantage of or being taken advantage of sexually, physical injury, illegal substance use) (O'Brien et al., 2008; Snipes & Benotsch, 2013; Weldy, 2010). This association is still significant after adjusting for the amount of alcohol consumed (O'Brien et al., 2008). The link between AmED consumption, binge drinking, and negative alcohol-related behaviours may be attributed to a certain personality type which draws individuals towards carrying out these behaviours (O'Brien et al., 2008). Exploration of this theory, showed that level of sensation-seeking does not fully explain the higher-risk drinking behaviours or negative outcomes, but does increase the risk of alcohol-related injury that requires medical input (O'Brien et al., 2013). Although experimental findings on the antagonistic effects of caffeine on psychomotor and cognitive impairment due to alcohol are varied and conflicting, it is apparent that caffeine decreases the level of subjective symptoms of alcohol intoxication (e.g. increased reaction time and impaired motor coordination) but does not alter the actual blood alcohol level at which intoxication occurs (Ferreira et al., 2006; Marczinski & Fillmore, 2006). The effects of caffeine and alcohol co-ingestion may also depend on the amount of alcohol consumed; i.e. may decrease cognitive and psychomotor impairments at low alcohol levels but not at higher blood alcohol levels (Liguori & Robinson, 2001; Moskowitz & Burns, 1981).

There are some weaknesses in the current evidence; the majority of the current research which details the association between alcohol and caffeine co-ingestion and high risk drinking behaviours is based on self-reported retrospective data which is prone to reporting error, therefore, the ability to determine a causal relationship is limited. New Zealand is known to have a high prevalence of binge-drinking behaviour, especially in

tertiary students where intakes commonly exceed the national safe drinking guidelines level (Kypri, Langley, McGee, Saunders, & Williams, 2002). It would be unethical to conduct experiments which are likely to cause harm to the participants, therefore experimental studies have set their upper limits much lower than what is likely to be consumed in the 'real world'. Methods of studies vary greatly with some experimental studies exploring within subject differences (Attwood, Rogers, Ataya, Adams, & Munafò, 2012; Liguori & Robinson, 2001; Peacock, Bruno, Martin, & Carr, 2013), whereas others have explored between-subject differences (Alford, Hamilton-Morris, & Verster, 2012; Fillmore, Roach, & Rice, 2002; Marczinski, Fillmore, Henges, Ramsey, & Young, 2012). As many of the studies have very small sample sizes ($n \leq 20$) (Alford et al., 2012; Liguori & Robinson, 2001; Marczinski et al., 2012) the impact of inter-individual responses to caffeine are likely to affect the results. It should also be mentioned that some studies which suggest caffeine and alcohol co-ingestion is not a health risk have ties with the energy drink industry (e.g. provided funding for research or provided a placebo product) (McKetin, Coen, & Kaye, 2015; Verster, Aufricht, & Alford, 2012).

Before energy drinks appeared on the market, combined caffeine and alcohol consumption was already prevalent through the consumption of RTDs and caffeine-containing soda mixers (kola drinks) (Thombs et al., 2010). However, as energy drinks contain notably more caffeine than other caffeine sources, when the practice of consuming AmED emerged, concern arose. Hence, most research on the effects of combining alcohol and caffeine is carried out specifically on energy drinks, whereas in reality mixing alcohol with caffeinated sodas (kola drinks) and consuming pre-mixed alcohol varieties (RTDs) may also be a cause for concern. Since the consumption pattern of alcohol does not differ between the various combinations of caffeine and

alcohol it has been suggested they should be treated the same (Cobb, Nasim, Jentink, & Blank, 2015).

There is currently limited research available currently to determine the prevalence of combining alcohol and caffeine in New Zealand tertiary students, however, overseas research suggests that this practice is widespread and increasing. This practice is particularly evident in the tertiary student populations in the USA, where up to 28% report carrying out this behaviour at least once within the past month (Malinauskas, Aeby, Overton, Carpenter-Aeby, & Barber-Heidal, 2007; K. E. Miller, 2008; O'Brien et al., 2008).

2.12 Caffeine Consumption Levels and Patterns

Over 80% of the population regularly consumes caffeinated products (Ogawa & Ueki, 2007), making it the world's most popular psychoactive drug world-wide, even exceeding alcohol and nicotine use (Mintz, 2001). The average amount of caffeine consumed per person daily in the world has been estimated at 70-76 mg (Fredholm et al., 1999). However, the amount of caffeine consumed daily differs greatly between populations. Kenya and South Africa have the lowest average caffeine intake (approximately 0.7 mg· $kgbw^{-1}$), whilst Denmark and Finland have the highest average caffeine intake (approximately 6.7 mg· $kgbw^{-1}$) (Heckman et al., 2010).

In 2014, Thomson and Schiess (2011), using data from the ANS 2008/09, estimated that 73% of New Zealanders consume caffeine, with an estimated average consumption of 196 mg for adults (20-64 years). This estimate is similar to that of the UK, higher than that of the USA, and less than that of South American and European countries (Barone & Roberts, 1996; Frary et al., 2005; Olmos et al., 2009; Rojo Camargo, Toledo, & Farah, 1999). This estimate for New Zealand did not take into account energy

drinks/shots, RTDs or caffeine tablets and is therefore unreliable. In an attempt to determine the impact of energy drinks on total caffeine consumption, Thomson et al. (2014), found that only 3.1% of New Zealanders reported consuming these in the ANS 2008/09 and therefore did not have a significant effect on total caffeine exposure. The number of caffeine-containing products on the market is rapidly increasing, therefore any existing information on caffeine consumption is unlikely to be representative of what the consumption levels and patterns look like currently. Limited research in the US suggests that although the range of caffeinated products on the market is continuously increasing, the total consumption of caffeine stays reasonably stable (Fulgoni, 2014). It is unclear whether this is the case in New Zealand also.

The main world-wide dietary sources of caffeine are products derived from the coffee bean and the tea leaf (Barone & Roberts, 1996). However, this varies between geographic regions, cultures and age groups (Fredholm et al., 1999). In the UK and countries within the Asian continent, tea is the most common source of caffeine. European countries and North America, however, mainly consume coffee as their primary caffeine source (Barone & Roberts, 1996; Nawrot et al., 2003). Adults commonly obtain their caffeine through intake of coffee and tea, whereas teenagers/children consume caffeine mainly through kola-flavoured drinks and energy drinks (Reissig et al., 2009; Temple, 2009). Energy drinks are particularly targeted at the 18-35 age group and world-wide consumption of these doubled between 2006 and 2012 (Reissig et al., 2009), with New Zealand being in the top five countries for energy drink consumption per capita (Pomeranz et al., 2013). This may be because New Zealand does not currently have a sugar tax on these products, therefore making them more accessible to consumers (Mhurchu et al., 2015).

Tertiary students have been targeted as an 'at risk' group of consuming large amounts of caffeine due to their presumed cognitive enhancement motivations (Malinauskas et al., 2007), however a lot of the current research on caffeine and tertiary students is based only on energy drink consumption. In the USA, the percentage of undergraduates who had consumed an energy drink in the past ranged between 39-80% (Hoyte, Albert, & Heard, 2013; Malinauskas et al., 2007; Marczinski, Fillmore, Bardgett, & Howard, 2011; K. E. Miller, 2008; Oteri et al., 2007). Only one study has looked into total caffeine consumption in a tertiary student population, however, this is only relevant to a USA context and is limited to only a few caffeine sources (McIlvain, Noland, & Bickel, 2011). In order to determine whether there should be emphasis placed on a certain caffeine product, it is important to explore caffeine consumption from all sources.

2.13 Factors Influencing Caffeine Consumption

It is well established that there are multiple reasons for the consumption of foods and beverages (Baranowski et al., 1999) other than just providing energy and nourishment. There are many factors which may influence the consumption of caffeine including the expected outcomes (i.e. the functional qualities) (Ajzen, 1991), environmental influences (Malinauskas et al., 2007), and sociocultural influences (Hattersley, Irwin, King, & Allman-Farinelli, 2009). These reasons may differ according to different caffeine sources and different population groups.

2.13.1 Functional Expectations and Intrinsic Factors

The 'Theory of Planned Behaviour' (Ajzen, 1991) provides an explanation of why consumers' motivations and expected outcomes are likely to predict and explain specific caffeine consumption behaviours.

The proclaimed benefits of caffeine, including increased alertness, better concentration, and its use as an ergogenic aid are well known (Sections 2.5.2.1, 2.5.2.2 and 2.5.2.4). These desirable effects are likely to reinforce caffeine consumption, whereas negative effects, such as anxiety, nervousness and sleep disturbances are likely to discourage additional/continued consumption (Benowitz, 1990; Fredholm et al., 1999; Garrett & Griffiths, 1997; Lorist & Tops, 2003; Nehlig, 1999; Smith, 2005). Self-moderation of caffeine (i.e. an individual reducing/limiting their caffeine consumption according to their expected negative/positive symptoms), is a plausible idea often discussed in the literature (Doepker et al., 2016; Lachenmeier et al., 2013; Rees, Allen, & Lader, 1999). Since genetics affect whether an individual responds to caffeine in a positive or negative way (Section 2.7), there will also be a genetic influence on the amount of caffeine consumed by an individual. The 1976T>C polymorphism has been associated with habitual consumption of caffeine where subjects consuming more than 200 mg· day^{-1} were significantly less likely to have this polymorphism compared to those consuming less than 100 mg· day^{-1} (Cornelis, El-Sohemy, & Campos, 2007).

Caffeine consumption has been shown to result in more positive effects and less negative effects in regular coffee drinkers (those who drink at least 5 cups per day) (Goldstein & Kaizer, 1969; Griffiths, Bigelow, & Liebson, 1986). These subjective ratings of effects are present under double-blind placebo controlled study designs and demonstrate how the individualised responses to caffeine can act to reinforce or discourage caffeine consumption habits. It is difficult however, to distinguish whether

these differences in symptoms are due to tolerance or whether there is a pre-existing difference in caffeine sensitivity for these individuals. It is also likely that habitual caffeine consumers continue to consume caffeine at the same or even higher levels in order to prevent withdrawal symptoms (Section 2.10) from occurring (Garrett & Griffiths, 1998; Griffiths et al., 1986; Hughes, Oliveto, Bickel, Higgins, & Badger, 1993; Schuh & Griffiths, 1997).

According to Fredholm et al. (1999) those who seek professional help to control their caffeine intake usually do not wish to be dependent on it or have been told by a health professional to reduce their intake. It seems individuals with higher levels of habitual caffeine consumption are less likely to want to completely cease consumption than those with lower habitual consumption levels (Gurley, Steelman, & Thomas, 2015).

The majority of caffeine's sources are commonly consumed according to their hedonic properties such as taste and temperature (Lorist & Tops, 2003). In a New Zealand based study by Bunting, Baggett, and Grigor (2013), the main contributing factor for energy drink consumption was taste.

The weight of an individual can also affect the symptoms experienced after a specific caffeine dose due to the relative concentration in the body (Kaplan et al., 1997). In addition, some studies have suggested that the rate of caffeine elimination in the body may differ between individuals according to their proportion of fat mass and lean mass (Bracco, Ferrarra, Arnaud, Jequier, & Schutz, 1995; Kamimori, Somani, Knowlton, & Perkins, 1987), here alas, the effect of the same absolute dose of caffeine in overweight/ obese vs lean individuals may differ for this reason. This theory however is based on the results of studies with small sample sizes (n= 6 - 20), which are not supported by more recent research (Magkos et al., 2005).

The desired effects of caffeine, and therefore motivations for consumption, differ between user-type. For example, athletes may use caffeine as an ergogenic aid to increase their performance during training or competition (Graham & Spriet, 1995), whereas students and shift workers are likely to consume caffeine to stay awake or combat fatigue due to sleep loss (Griffiths & Woodson, 1988b; Malinauskas et al., 2007; Schweitzer, Randazzo, Stone, Erman, & Walsh, 2006). In addition, the likely need to carry out paid employment whilst studying may increase the consumption of caffeine in this population group. One Canadian study found that tertiary students who consumed energy drinks worked on average twice as much as non-consumers (Dufour, 2015). A study carried out on university students in the USA found that the reasons for caffeine consumption were, in decreasing order, to feel awake (77%), for the taste (66%), social reasons (38%), for an increase in concentration (30%), for physical energy (26%), to improve mood (18%), and to decrease stress (9%) (Lieberman et al., 2015).

2.13.2 Sociocultural and Environmental Factors

Although caffeine has been shown to model qualities similar to that of illicit drugs (e.g. build-up of tolerance) (Franke, Lieb, & Hildt, 2012), society has accepted caffeine-use as a normalised behaviour and the consumption of caffeine-containing beverages is socially acceptable in many settings. Certain demographic, environmental factors and social factors are known to influence habitual caffeine consumption.

The Western world can be considered to be embedded in a ‘café culture’, where the act of going out for tea or coffee is considered a social activity. In an environment where others are consuming caffeinated products, an individual may be more likely to consume it in order to feel accepted (Hattersley et al., 2009).

Certain caffeine-containing products are marketed towards specific populations. Energy drinks are often marketed at 18-35 year olds, by associating these products with activities that appeal to this population group, such as extreme sports (Malinauskas et al., 2007; Schneider & Benjamin, 2011). Similarly, soft drinks and RTDs are marketed towards young adults and adolescents (Malinauskas et al., 2007). Whether this marketing actually influences consumption of these products has not yet been determined.

Lifestyle factors such as smoking cigarettes and drinking alcohol have also been associated with a high intake of caffeine (Gray, 1998). Possible explanations behind this includes that smokers often drink coffee and smoke simultaneously and this has become a habit for some (de Castro & Taylor, 2008; Wesensten, 2014). Co-ingestion of alcohol and caffeine is also common (Peacock, Bruno, & Martin, 2012), which has been suggested to be based on an expectation of the stimulatory effect of caffeine negating the depressive effects of alcohol.

Consumption of energy drinks and soft drinks have been linked to lower socioeconomic status (SES) (Arria et al., 2011; Vereecken, Inchley, Subramanian, Hublet, & Maes, 2005). Factors which may influence this are working conditions (e.g. shift work), low cost, convenience and availability (e.g. more fast food outlets in low SES areas) (Griffiths & Woodson, 1988b; Hattersley et al., 2009).

Level of nutritional knowledge may also affect caffeine intake. An increased awareness of the negative effects of consuming energy drinks is associated with a decreased consumption (Gallimberti et al., 2013). This however appears to be dependent on consumer type with evidence that even if an advisory health statement is processed, existing beliefs, experiences and information from peers alter how consumers interpret the message (Argo & Main, 2004; Lovatt et al., 2015; Mason & Scammon, 2011). It

also appears that the importance placed on the health message can differ according to gender, with males often making poorer food/beverage choices compared to females (Wardle et al., 2004).

Some people have cultural/religious reasons why they may or may not consume caffeine (Weinberg & Bealer, 2001). For example, Jehovah's witnesses, Hindus and Mormons abstain from caffeine due to its psycho-stimulating properties (Ribeiro & Sebastiao, 2010).

2.14 Summary of the Literature

There is an exceptional amount of literature based on many aspects of caffeine (e.g. metabolism, effects, consumption etc.), however, it is difficult to determine the exact effect that caffeine will have on an individual. This is due to a magnitude of influencing factors such as; dose, timing, genetics, tolerance, habitual intake, gender, medications, lifestyle factors etc. What we do know is that there are definite risks of overconsumption and it appears that these generally occur at doses over 400 mg· day^{-1}. There are currently some regulations in place to reduce caffeine-related health-risk in consumers (e.g. caffeine limits on energy drinks), however without an understanding of consumption levels and motivations in tertiary students we cannot determine whether further public health interventions must be put in place.

Chapter 3

3.0 Methods

3.1 Introduction

This thesis is part of a larger study which aims to explore caffeine consumption nationwide, whilst also determining how specific caffeine-related genes may influence consumption habits. This study involved two main data collection aspects: an online questionnaire (CaffCo) and the collection and genetic testing of saliva samples. As the genetic results will not be included in this thesis due to time restrictions, the genetic testing methods will not be detailed. The purpose of this chapter is to outline the study design, ethical approval and considerations, participant recruitment and selection, data collection method and materials, data processing and statistical analysis.

3.2 Ethical Approval

Ethical approval was gained from the Massey University Human Ethics Committee: Southern A (Application 15/76; see Appendix A for MUHEC approval letter), before the commencement of data collection.

3.2.1 Informed Voluntary Consent

Participants who volunteered for this study were provided with an Information Sheet (Appendix B). Written informed consent was gained from all participants when completing the questionnaire (incorporated into the beginning of the questionnaire). This study aimed to include participants aged 15 years and over. Participants under the

age of 16 were required to obtain parental/guardian consent in order to take part in the study.

3.2.2 Participant Confidentiality

Due to the manner of the data collection (in-person), participants were not able to remain anonymous to the researchers. The data however, was completely anonymized. A coding system was used where each participant was given a unique identifier. This code was used to link together each participants' questionnaire, saliva sample, and contact information. The unique identifier was a six-digit numerical figure. The first two digits were derived manually according to the number of participants recruited i.e. for the first 100 participants the first two digits were 01, the second 100 participants had the first two digits 02. For the final four digits of the unique identifier, an online random number generator was used (StatTrek.com, 2017) to generate 100 random four digit numbers at once with no duplicate entries allowed. This technique was used to ensure no duplicate numbers occurred when generating codes for additional participants.

3.3 Participants

3.3.1 Recruitment

Although the target sample population for this thesis was tertiary students, other willing participants were still accepted for participation and will be included in future analysis. A media release for this study was sent out to generate interest for involvement in this research project by the Massey University Communications Advisor. Furthermore, The New Zealand Herald and North Shore Times printed an article in their newspapers detailing the aims of this study and inviting interested participants to contact the researcher. An online article and video was also posted on The New Zealand Herald

website. Additionally, advertisement posters (Appendix C) were distributed on the Massey University Albany (East Precinct) campus.

All recruitment procedures detailed above invited interested individuals to contact the researchers via the study email (caffeinestudy@outlook.co.nz) and were then provided with additional information regarding data collection (i.e. dates, locations and times). Researchers' personal contacts were also recruited via word of mouth.

In addition to the recruitment procedures detailed above, participants were also directly recruited in person at the time of data collection (Section 3.4).

Participants who completed the online questionnaire and provided a saliva sample were invited to be placed into a random prize draw where they had the chance to win an iPad worth approximately $700. The website, https://www.random.org/lists/, was used to randomly choose the winning participant.

The participants' involvement in the study from recruitment to completion is summarised in Figure 3.1.

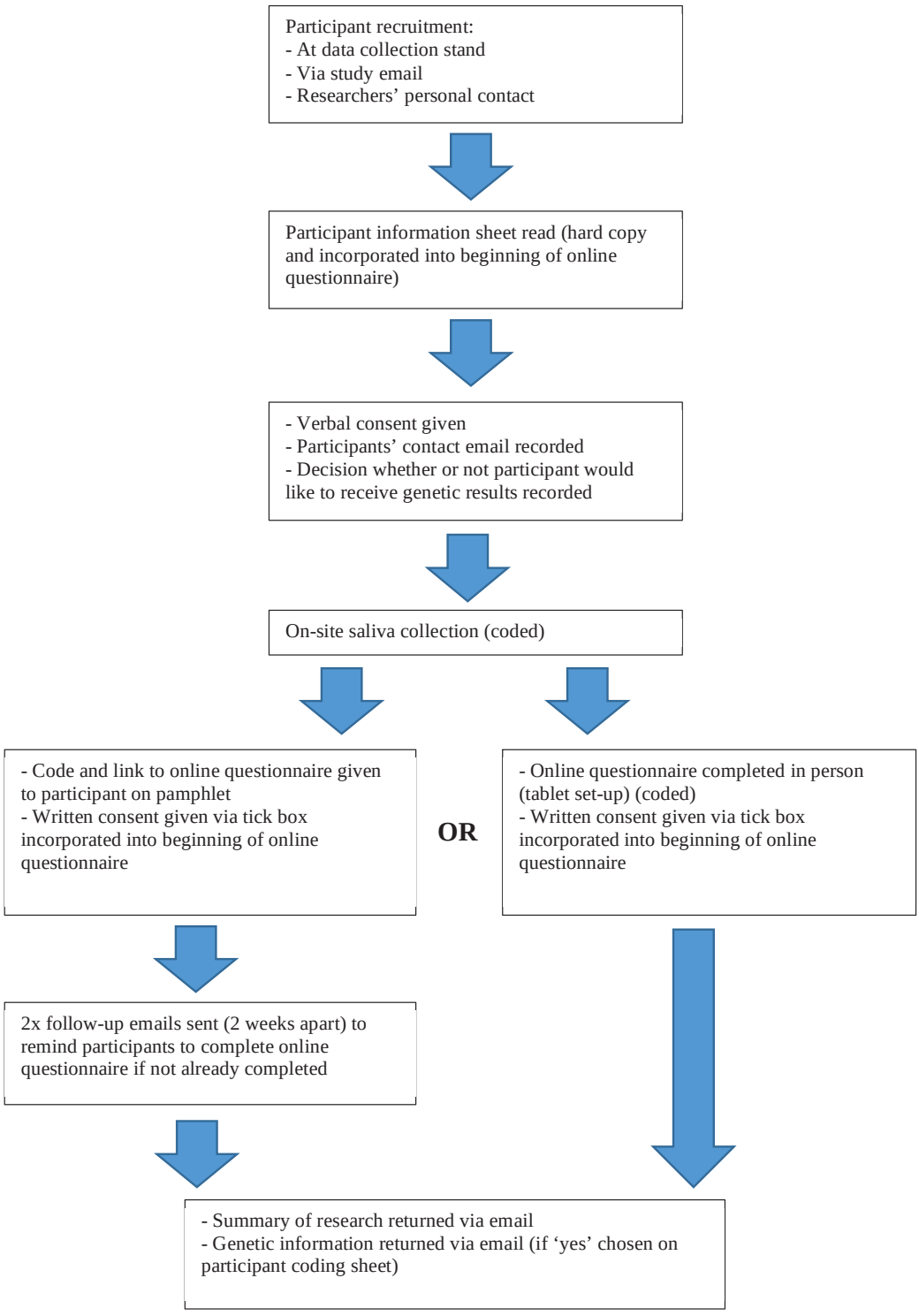

Figure 3.1: Participants' study involvement summary

3.3.2 Sample Size

A priori sample size estimation for investigating genetic aspects relating to caffeine intake in tertiary students determined at least 382 ± 19 participants were required for adequate statistical power (Fox, Hunn, & Mathers, 1998).

The calculation for this determination is shown below:

$N= P (100-P)/ (SE)^2$

SE = the standard error. This was calculated by dividing the confidence interval by the level of significance (z-score). The confidence interval accepted for this study was ± 5% and the level of significance accepted was $p<0.05$ which translates to a z-score of 1.96.

SE = 5/1.96 = 2.55

P = the proportion expected (obtained from previous research). The proportion of the population which were fast metabolisers from a previous study (Sachse et al., 1999) was 46%.

P = 46

$N= 46 (100-46)/ (2.55)^2$

N= 382 (±5%)

As this thesis does not include the genetic aspect which the above sample size was based on, it did not require this number of participants. Other published research exploring caffeine consumption in college (tertiary) students in the USA has included a sample size of 300 participants and established significant results (McIlvain et al., 2011).

3.3.3 Selection Criteria

After reading the participant information sheet, individuals who showed interest in volunteering for this study were directed to screening questions incorporated into the online questionnaire to determine whether they met the inclusion criteria:

- 15 years of age or older
- Competent in reading English
- Willing to provide a saliva sample
- Willing to complete a questionnaire

The consumption of caffeinated products was not necessary for inclusion in the study. Those under the age of 15 years old were excluded to allow the results obtained from this research to be aligned with the data from the 2008/2009 New Zealand Adult Nutrition Survey University of Otago and Ministry of Health (2011). If the option '14 years or under' was selected in the screening question, participants were notified with a message that they were not eligible to take part in the study. As parental consent was required for participants under 16 years, participants who selected the option '15 years old' in the screening questionnaire were redirected to a page where they could provide their contact email and receive a copy of the parental consent form. This was required to be signed and returned to the researcher before taking part in the study.

When analysing the data for this thesis, the inclusion criteria also included:

- Provided saliva sample AND completed questionnaire
- Tertiary student (i.e. currently enrolled in either part-time or full-time study at a higher education facility)

3.4 Data Collection

3.4.1 Study Locations

Data collection was undertaken at three different university campuses on a total of 7 separate occasions over June and August 2016:

1. Massey University Albany
2. Massey University Palmerston North and
3. Auckland University City campus.

A data collection stand was set up for approximately 6 hours each day (~9:30am - ~3:30pm) and was located in areas where a large amount of human traffic was expected (e.g. outside the library and outside on-campus food outlets).

The data collection stand consisted of two trestle tables with four tablets (iPad, Apple Inc, Cupertino, California) set up on stands. To set up and man the data collection stand efficiently and effectively, this required at least one researcher and one research assistant.

The researchers also collected data from their personal contacts in private locations.

3.4.2 Questionnaire

A questionnaire specifically designed to meet the broader study aim (CaffCo) had been previously developed and pilot-tested in 2015 (Rowe, 2015) (Appendix D).

The platform used to administer the questionnaire was Qualtrics online survey software (Qualtrics, 2015). Participants were given the option of whether to complete their questionnaire on the tablets provided at the data collection stand or at a separate location (e.g. their home or work). If they chose the latter, a card was provided with the link to

the questionnaire (study's Facebook page) and a unique identifier code. It was not necessary to be a Facebook member to access this page.

The screening questions, participant information sheet and informed voluntary consent statement (with yes/no tick box options) were incorporated into the beginning of the questionnaire. The participant was required to enter their unique identifier code before continuing onto the main block of questions. It was expected that the questionnaire would take approximately 15-20 minutes for the participants to complete.

Participants who chose to complete the questionnaire at home were sent two reminder emails at two-weekly intervals if they had not already completed the questionnaire.

3.5 Data Storage

During analysis and write-up of the results, the hard copy of the participant contact information (coding) forms were filed and stored in a locked cabinet on campus at Massey University, Oteha Rohe Campus (Building 60). Soft copies of data were kept in password-protected files on password-protected computers. The passwords/keys were only available to the researchers. Three months after the completion of genetic analysis, the genetic results and questionnaire results were completely anonymised (unique identifier code removed). The completely anonymised raw results data will be kept for 5 years after which the data will be disposed by Dr Ajmol Ali or another member of staff at Massey University (Albany).

3.6 Data Handling and Statistical Analysis

Questionnaire data was exported from Qualtrics into Microsoft Excel (2013) and screened for any missing information. The estimated daily caffeine consumption was calculated for every caffeine-consuming participant. In order to do this, the caffeine

concentration data for the various caffeine-containing products (see Chapter 2, Table 2.1) was combined with the consumption frequency data from the CaffCo questionnaire using Microsoft Excel software. The different consumption frequencies were assigned a factor according to their relationship to daily consumption (e.g. if the consumption frequency was once a week, the factor would be 1/7= 0.143). If the consumption frequency included a range, the middle value would be used (e.g. 2-3 times a day would be a factor of 2.5). All data was then entered into IBM SPSS statistics package version 22.0 (IBM corporation, New York, USA, 2013) in order to carry out statistical analysis. Scale variables were tested for normality by carrying out Kolmogorov-Smirnov and Shapiro-Wilk tests and also by observing normality plots and histograms. All scale data was non-parametric and therefore reported as median (interquartile range). Categorical data was reported as frequency and percentage. The contribution of each caffeine source to the total daily caffeine consumption was calculated by summing the caffeine consumption of all participants from that source and expressing this as a percentage of the total caffeine consumed from all participants.

Contingency tables were used to compare percentage consumption of the caffeine sources according to different demographic and participant characteristic groups. Since all scale data was non-parametric, Mann-Whitney U-tests, Kruskal-Wallis tests, and Kendall's Tau correlations were used. A p value of <0.05 was indicative of statistical significance for all tests.

For 2x2 contingency tables, if all expected counts were 10 or greater, the Pearson's chi-squared test for independence was used. If any of the expected counts were less than 10 but greater than or equal to 5, the Yate's continuity correction was applied. If any of the expected counts were less than 5, the Fisher exact test was used (Cochran, 1954). For contingency tables larger than 2x2, the Pearson's chi-square test of independence was

used on the condition that “No more than 20% of the expected counts are less than 5 and all individual expected counts are 1 or greater” (Yates, 1999). If these conditions were not met, the Fisher’s exact test was used. If contingency tables larger than 2x2 reached significance, post hoc testing was carried using multiple 2x2 contingency tables and the stepwise Holm-Bonferroni method. For contingency tables which showed significance, the odds ratio was also calculated to show the practicality of the significance.

If Kruskal-Wallis tests showed significance, post hoc testing using multiple Mann-Whitney U-tests and the stepwise Holm-Bonferroni method was carried out. If significance was reached for any Mann-Whitney U-test, the effect size (r) was calculated in order to show practical significance, using the formula; $r=z/\sqrt{N}$ (Fritz, Morris, & Richler, 2012). A value of |0.1| signifies a 'small' effect size, |0.3| signifies a 'medium' effect size and |0.5| signifies a 'large' effect size (Field, 2013).

For Kendall’s Tau correlations, Cohen’s standard was used to determine the strength of the relationship. Correlations between 0.10 and 0.29 signified a small association; correlations between 0.30 and 0.49 signified a medium association; and correlations of 0.50 and higher signified a large association (Cohen, Cohen, West, & Aiken, 2013).

Chapter 4

4.0 Results

4.1 Participants

Whilst a total of 424 participants were recruited for this study, some did not fit the inclusion criteria, and were therefore not included in the data set. The final number of participants who took part in the study and the reasons for exclusion are shown in Figure 4.1 below.

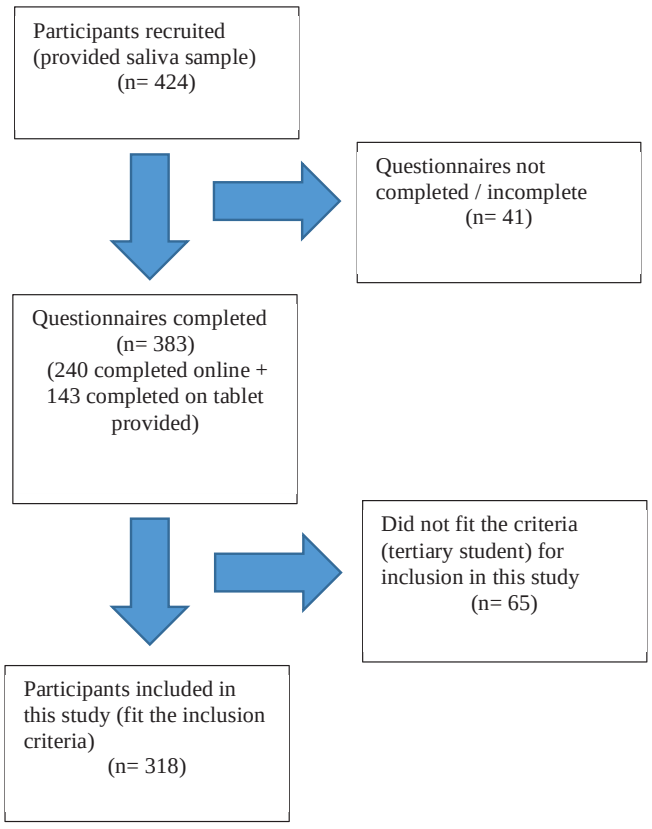

Figure 4.1: Flow diagram of participant recruitment and inclusion/exclusion in the study

Participant demographics

While 318 participants satisfied the inclusion criteria for this study, some post data-collection screening was required. One participant identified gender as 'other', and as this category was unlikely to carry sufficient statistical power for analysis, the participant was removed from the dataset. The final dataset therefore consisted of 317 participants. Female and male participants accounted for 46.7% (n= 148) and 53.3% (n= 169) of the dataset, respectively. The 19-30-year-old age group was highly represented, constituting 74.4% of the dataset. The full breakdown of age group and gender is shown in Table 4.1. For statistical purposes, the single participant in the 71+ age group was combined with the 51-70 age group, creating a new age group of 51+ years.

Table 4.1: Age group and gender of the participants

Age group	**Men**	**(%)**	**Women**	**(%)**	**Total**	**(%)**
16-18 years	22	(6.9)	29	(9.1)	51	(16)
19-30 years	112	(35.3)	124	(39.1)	236	(74.4)
31-50 years	12	(3.8)	13	(4.1)	25	(7.9)
51-70 years	2	(0.6)	2	(0.6)	4	(1.3)
71+ years	0	(0.0)	1	(0.3)	1	(0.3)
Total n	148	(46.7)	169	(53.3)	317	(100)

The major ethnic groups contained in the dataset were; 47.5% New Zealand European (n= 150), 16.5% European (n= 52), 15.8% Chinese (n= 50), 10.1% South East Asian (n= 32), 7.3% Indian (n= 23), 5.4% Maori (n= 17), and 5.1% Korean (n= 16) (N.B. participants were able to choose multiple groups, therefore the total exceeds 100%). The full ethnic spread of the participants is shown in Figure 4.2.

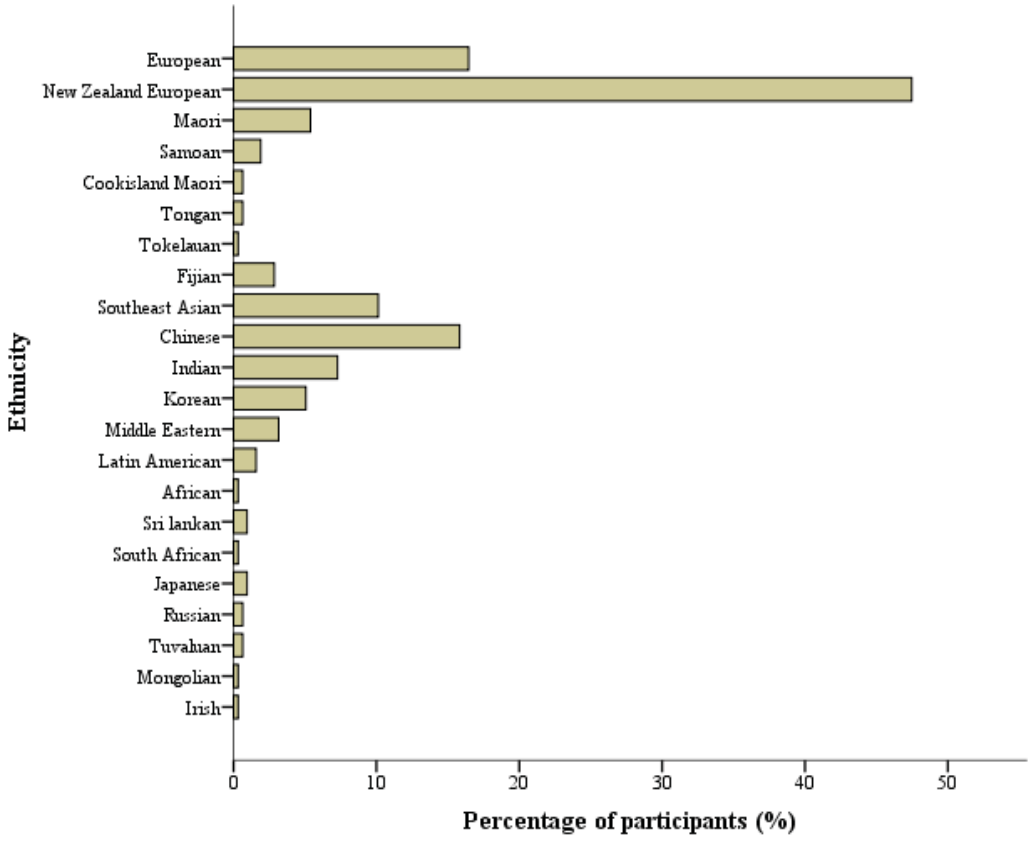

Figure 4.2: Ethnicity of the participants (n=317)

Participants' Body Mass Index

Participants were given the option of whether or not to disclose their body weight and height. The majority of participants (83%, n= 263) provided this information and Body Mass Index (BMI) was calculated. The median BMI of the participants was 22.9 kg· m^{-2} (IQR= 20.8-25.1). The BMI of the male participants (*M*= 23.4 kg· m^{-2}) was significantly higher than that of the females (*M*= 22.3 kg· m^{-2}), (U= 7137, p= 0.014, r= -0.15) (Table 4.2). There was no significant difference in BMI between the different age groups (X^2 (3) = 7.327, p= 0.062).

Table 4.2: Body Mass Index of participants by gender and age group categories (n= 263).

	25th percentile BMI (kg· m-2)	Median BMI (kg· m-2)	75th percentile BMI (kg· m-2)
Gender			
- **Male**	21.0	23.4	26.1
- **Female**	20.3	22.3	24.2
Age Range			
- **16-18 years**	20.1	21.6	24.0
- **19-30 years**	20.8	23.0	25.6
- **31-50 years**	22.5	23.7	26.1
- **51+ years**	22.5	24.8	27.6

Based on the BMI results participants were categorised into one of four categories; underweight (< 18.5 kg· m^{-2}), healthy weight (18.5 – 24.9 k· gm^{-2}), overweight (25 – 29.9 kg· m^{-2}) or obese (≥ 30 kg· m^{-2}). There was a significant association between gender and BMI category (X^2 (3) = 11.808, p = 0.008) (Table 4.3). Post hoc testing showed that the male participants were 2.51 times more likely than female participants to be overweight than normal weight (X^2 (1) = 11.734, p= 0.001). There was no association between age group and BMI category (p> 0.05).

Table 4.3: Body Mass Index categories according to gender and age group (n= 263)

	Number of underweight (<18.5 kg· m^{-2}) participants (%)		Number of healthy weight (18.5 – 24.9 kg· m^{-2}) participants (%)		Number of overweight (25 – 29.9 kg· m^{-2}) participants (%)		Number of obese (≥30 kg· m^{-2}) participants (%)	
Total	11	(3.5)	239	(75.4)	51	(16.1)	16	(5.0)
Male	5	(3.4)	101	(68.2)	35	(23.6)	7	(4.7)
Female	6	(3.6)	138	(81.7)	16	(9.5)	9	(5.3)
16-18 years	3	(5.9)	41	(80.4)	6	(11.8)	1	(2)
19-30 years	8	(3.4)	175	(74.2)	41	(17.4)	12	(5.1)
31-50 years	0	(0)	20	(80)	2	(8)	3	(12)
51+ years	0	(0)	3	(60)	2	(40)	0	(0)

Additional participant characteristics: living situation, employment status, smoking status and participation in sport

Additional participant characteristics, including living situation, employment status, smoking status and participation in sport are summarised in Table 4.4.

The majority of participants lived with family members (54.9%) or co-habited ('flatted') with others (34.1%). Only a minor proportion of participants lived with their partner (1.6%) or in halls of residence (2.2%).

The majority (66.6%) of participants were not employed at the time of the study; with just under one third (32.2%) of participants indicating they undertook part-time paid employment and a small number were in full-time paid employment (1.3%). Employment status was condensed into two groups for analysis: i.e. 'paid employment' and 'no paid employment'. Of those who had paid employment, 50% were shift

workers, 27.4% were involved in manual labour, and 16% were required to drive long distances.

A total of 14.8% of the participants were current smokers (this includes occasional tobacco smoking). Participants were not asked to disclose their smoking frequency. Over half of the participants in the dataset (59.6%) reported that they were involved in some sort of sporting activity. Of those who were involved in sport, 38.6% were involved in resistance/weight training, 34.9% were involved in a recreational team sport, 14.3% were involved in a competitive team sport, 12.3% were involved in a recreational individual sport, 12.2% were involved in a competitive individual sport, and 9.0% were involved in an endurance sport (N.B. participants were able to choose multiple options, therefore the total exceeds 100%).

Table 4.4: Participant characteristics (n=317).

	Number of participants	(%)
Living situation		
- **Living alone**	23	(7.4)
- **Living with family**	174	(54.9)
- **Flatting with others**	108	(34.1)
- **Halls of residence**	7	(2.2)
- **Living with partner**	5	(1.6)
Employment status		
- **No paid employment**	211	(66.6)
- **Part-time employment**	102	(32.2)
- **Full-time employment**	4	(1.3)
Smoking status		
- **Smokes**	47	(14.8)
- **Does not smoke**	268	(84.5)
- **Did not disclose smoking status**	2	(0.6)
Participation in sport		
- **Plays sport**	189	(59.6)
- **Does not play sport**	128	(40.4)

4.2 Sources of Caffeine in the Diet

Figure 4.3 shows the percentage of participants who commonly consume the different caffeine sources in their diet. The caffeine sources which were most likely to be consumed were chocolate, coffee, and tea, whereas the least likely consumed caffeine source was caffeine tablets; and only 0.9% (n= 3) of participants reported consuming no caffeine.

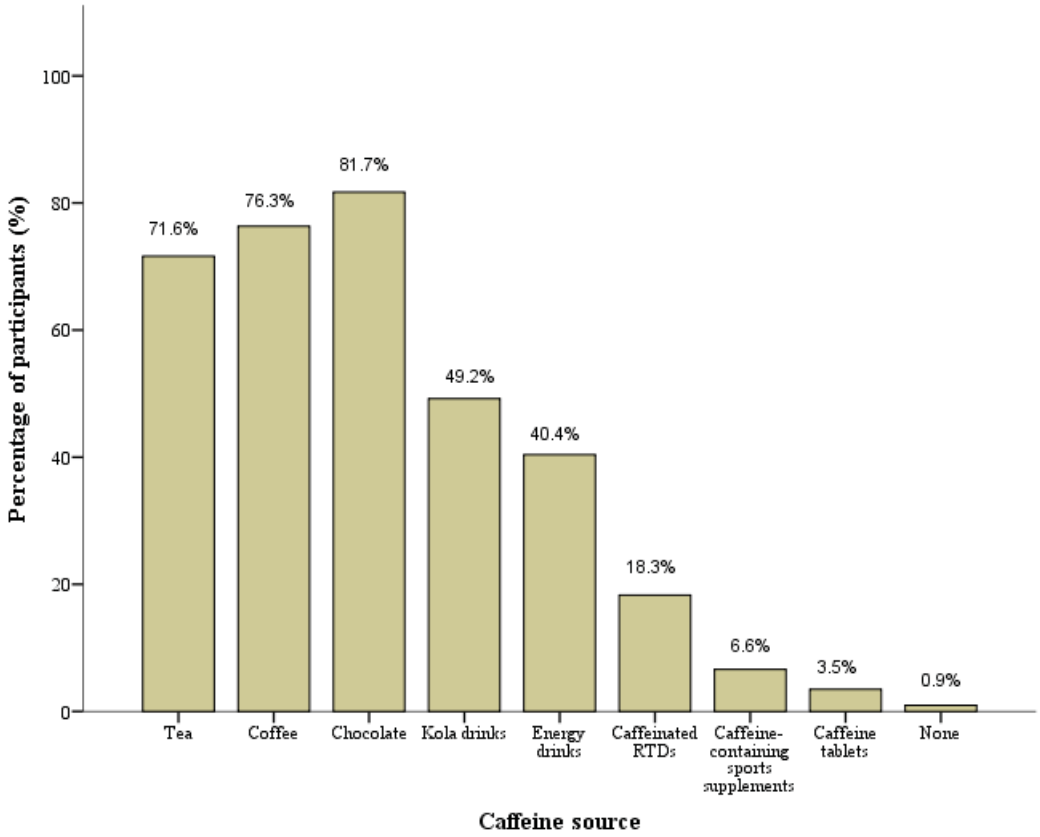

Figure 4.3: Percentage of participants who consume each caffeine source (n= 317)
RTD- Ready to drink alcoholic beverage

Frequency of caffeine consumption

Table 4.5 provides information regarding frequency of consumption patterns of the various caffeine-containing products. The caffeine-containing product consumed most frequently (highest median of consumption frequency) was black tea, which was consumed on average 2-4 times a week, followed by instant coffee, single shot espresso coffee, double shot espresso coffee and pre-workout sports supplements, which were all consumed on average once per week. The least frequently consumed caffeine-containing products were iced tea, iced coffee, large block of dark chocolate, 600 mL bottle of regular kola drink, all diet/zero/max varieties of kola drink products and sports gels, which were all consumed on average less than once per month. The product with the highest number of participants consuming once or more a day was instant coffee

(21.3%), followed by pre-workout sports supplements (19%), black tea (18.7%) and double shot espresso coffee (18.4%). As 200 mg caffeine tablets were only reported to be consumed by one participant, the frequency of consumption information for this product is not reliable. In addition, the 50 mg caffeine tablets were not consumed by any of the participants. More extensive frequency of consumption information is provided in Appendix E.

Table 4.5: Frequency of consumption of caffeine-containing products.

Product	**Most common consumption frequency (% of those consuming product)**	**Median (corresponding frequency of consumption)**	**% of participants consuming 1+ per day**
Green tea - 1 cup (n= 199)	1-3 x a month (27.6)	1-3 x a month	11
Black tea - 1 cup (n= 197)	2-4 x a week (25.9)	2-4 x a week	18.7
Iced tea - 1 glass (n= 153)	< 1 x a month (64.7)	< 1 x a month	1.4
Decaffeinated tea - 1 cup (n= 54)	< 1 x a month (33.3)	1-3 x a month	5.6
Instant coffee -1 tsp coffee powder (n= 182)	< 1 x a month (29.1)	1 x a week	21.3
Plunger/drip coffee - 250 mL (n= 156)	< 1 x a month (32.7)	1-3 x a month	17.3
Small espresso coffee - single shot (n= 169)	< 1 x a month (23.7)	1 x a week	12.4
Large espresso coffee - double shot (n= 174)	< 1 x a month (24.1)	1 x a week	18.4
Decaffeinated coffee - 1 cup (n= 58)	< 1 x a month (50)	<1 x a month – 1-3 x a month	5.1
Iced coffee - 1 glass (n= 154)	< 1 x a month (63.6)	< 1 x a month	0
Milk chocolate bar - 50 g (n= 225)	1-3 x a month (33.8)	1-3 x a month	1.7
Milk chocolate block - 200 – 250 g (n= 207)	< 1 x a month (47.8)	1-3 x a month	0.5
Dark chocolate bar - 50 g (n= 205)	< 1 x a month (38.5)	1-3 x a month	2.5
Dark chocolate block - 200 – 250 g (n= 176)	< 1 x a month (58.5)	< 1 x a month	2.3
Hot chocolate - 1 cup (n= 231)	< 1 x a month (39)	1-3 x a month	4.7

Glass of regular kola drink - 250 mL (n= 138)	1-3 x a month (36.2)	1-3 x a month	2.2
Can of regular kola drink - 355 mL (n= 131)	< 1 x a month (42)	1-3 x a month	1.6
Bottle of regular kola drink - 600 mL (n= 123)	< 1 x a month (54.5)	< 1 x a month	0
Glass of of DIET / ZERO / MAX kola drink - 250 mL (n= 87)	< 1 x a month (51.7)	< 1 x a month	1.1
Can of DIET / ZERO / MAX kola drink - 355 mL (n= 78)	< 1 x a month (56.4)	< 1 x a month	1.3
Bottle of DIET / ZERO / MAX kola drink - 600 mL (n= 69)	< 1 x a month (56.5)	< 1 x a month	0
Energy shot (n= 37)	< 1 x a month (48.6)	1-3 x a month	0
Can of energy drink - 250 mL (n= 115)	< 1 x a month (41.7)	1-3 x a month	0.9
Bottle of energy drink - 350 mL (n= 99)	< 1 x a month (41.4)	1-3 x a month	0
Can / bottle of energy drink - 500 mL (n= 81)	< 1 x a month (42)	1-3 x a month	1.2
Can of caffeinated RTD - 250 – 330 mL (n= 53)	1-3 x a month (37.7)	1-3 x a month	0
Bottle of caffeinated RTD - 330 – 350 mL (n= 52)	< 1 x a month (44.2)	1-3 x a month	0
Pre-workout sports supplement - 1 serve (n= 21)	1-3 x a month (28.6)	1 x a week	19
Sports gel - 1 serve (n= 7)	< 1 x a month (57.1)	< 1 x a month	0
Caffeine tablet - 50 mg (n= 0)	-	-	-
Caffeine tablet - 100 mg (n= 10)	< 1 x a month (40)	1-3 x a month	0
Caffeine tablet - 200 mg (n= 1)	1 x a day (100)	-	100

RTD- Ready to drink alcoholic beverage

Consumption of caffeine sources according to participant demographics and characteristics

Females were 2.4 times more likely than males to consume tea (79.9% vs 62.2%, p< 0.001), 1.75 times more likely to consume coffee (81.1% vs. 76.3%, p= 0.034), and 2.35 times more likely to consume chocolate (87.6% vs. 75.0%, p= 0.004) (Table 4.6). There was no difference in the consumption of any other caffeine-containing products between males and females (p> 0.05). However, the relationships between both energy drinks (p= 0.097) and caffeine-containing sports supplements (p= 0.094) and gender, are worthy of further research in a higher powered study.

Table 4.6: Comparison of consumption of caffeine sources by gender

Caffeine source	**Male (%) (n= 148)**	**Female (%) (n= 169)**	**Pearson Chi-square value (χ^2)**	**p value**
Tea	62.2	79.9	12.185	< 0.001
Coffee	76.3	81.1	4.473	0.034
Chocolate	75.0	87.6	8.345	0.004
Kola drinks	52.7	46.2	1.354	0.245
Energy drinks	45.3	36.1	2.759	0.097
Caffeinated RTDs	19.6	17.2	0.313	0.576
Caffeine-containing sports supplements	9.5	4.1	2.798[a]	0.094[a]
Caffeine tablets	2.7	4.1	0.153[a]	0.696[a]
None	1.4	0.6	-	0.6[b]

RTD- Ready to drink alcoholic beverage
[a]Yates continuity correction (Minimum expected count <10)
[b]Fisher's exact test (Minimum expected count <5)

As shown in Table 4.7, no association was seen between age group and consumption of any of the caffeine sources (p> 0.05). However, the relationship between consumption of energy drinks and age group (p= 0.066) is worthy of further research in a higher powered study.

Table 4.7: Comparison of consumption of caffeine sources by age group

Caffeine source	16-18 years (%) (n= 51)	19-30 years (%) (n= 236)	31-50 years (%) (n= 25)	51+ years (%) (n= 5)	Pearson Chi-square value (χ^2)	p value
Tea	66.7	71.6	80	80	-	0.699[b]
Coffee	68.6	77.1	84	80	-	0.440[b]
Chocolate	86.3	80.5	84	80	-	0.788[b]
Kola drinks	45.1	51.3	44	20	-	0.469[b]
Energy drinks	35.3	44.1	20	20	-	0.066[b]
Caffeinated RTDs	21.6	19.1	8	0	-	0.409[b]
Caffeine-containing sports supplements	0	8.5	4	0	-	0.118[b]
Caffeine tablets	0	4.7	0	0	-	0.356[b]
None	2.0	0.8	0	0	-	0.589[b]

RTD- Ready to drink alcoholic beverage
[b]Fisher's exact test (More than 20% of expected counts <5)

There was no association between the consumption of any of the caffeine sources according to BMI ($p > 0.05$) (Table 4.8). There was however an association between consuming no caffeine and BMI category ($p = 0.047$), however, post-hoc testing did not reveal any significant pairwise comparisons.

Table 4.8: Comparison of consumption of caffeine sources by BMI category

Caffeine source	Underweight (<18.5 kg· m^{-2}) (%) (n= 11)	Healthy weight (18.5 – 24.9 kg· m^{-2}) (%) (n= 239)	Overweight (25 – 29.9 kg· m^{-2}) (%) (n= 51)	Obese (≥30 kg· m^{-2}) (%) (n= 16)	Pearson Chi-square value (χ^2)	p value
Tea	63.6	75.1	58.8	75.0	5.630[b]	0.128
Coffee	54.5	76.8	74.5	81.3	2.992[b]	0.394
Chocolate	90.9	80.5	72.5	81.3	2.262[b]	0.527
Kola drinks	45.5	49.7	56.9	68.8	2.852	0.433
Energy drinks	27.3	37.8	52.9	56.3	6.125	0.105
Caffeinated RTDs	27.3	18.4	21.6	18.8	1.065[b]	0.782
Caffeine-containing sports supplements	0	8.6	7.8	6.3	0.423[b]	0.966
Caffeine tablets	0	4.3	2	6.3	1.130[b]	0.671
None	9.1	0.5	0.0	6.3	8.236[b]	0.047

RTD- Ready to drink alcoholic beverage
[b]Fisher's exact test (More than 20% of expected counts <5)

Fisher's exact test showed that there was an association between coffee consumption and living situation ($p= 0.047$; Table 4.9). However, once post-hoc tests using the Holm-Bonferroni method were carried out, the significant association was no longer seen. There was no difference in the consumption of any other caffeine-containing products according to living situation ($p> 0.05$).

Table 4.9: Comparison of consumption of caffeine sources by living situation

Caffeine source	Living alone (%) (n= 23)	Living with family (%) (n= 174)	Flatting (%) (n= 108)	Hall of residence (%) (n= 7)	Living with partner (%) (n= 5)	Pearson Chi-square value (χ^2)	p value
Tea	65.2	69.0	77.8	85.7	40	-	0.172[b]
Coffee	65.2	74.7	83.3	42.9	80	-	0.047[b]
Chocolate	82.6	81.6	80.6	100	80	-	0.874[b]
Kola drinks	39.1	51.1	47.2	57.1	60	-	0.788[b]
Energy drinks	26.1	43.1	39.8	14.3	60	-	0.271[b]
Caffeinated RTDs	17.4	14.9	23.1	28.6	20	-	0.339[b]
Caffeine-containing sports supplements	13.0	4.0	10.2	0	0	-	0.150[b]
Caffeine tablets	0	4.0	3.7	0	0	-	1.000[b]
None	0	1.1	0.9	0	0	-	1.000[b]

RTD- Ready to drink alcoholic beverage
[b]Fisher's exact test (More than 20% of expected counts <5)

Those who were unemployed were 1.71 times more likely to consume tea than those who were employed either fulltime or part time (75.4% vs 64.2%, p= 0.037) (Table 4.10), whereas those who were employed were 1.81 times more likely to consume energy drinks (50% vs 35.5%, p= 0.013), and 9.69 times more likely to consume caffeine tablets (8.5% vs 0.5%, p= 0.001) than those who were not employed. There was no difference in the consumption of any other caffeine-containing products between participants who were employed and those who were not employed (p> 0.05).

Table 4.10: Comparison of consumption of caffeine sources by employment status

Caffeine source	No paid employment (%) (n= 211)	Paid employment (%) (n= 106)	Pearson Chi-square value (χ^2)	p value
Tea	75.4	64.2	4.357	0.037
Coffee	73.9	81.1	2.024	0.155
Chocolate	81.5	82.1	0.015	0.903
Kola drinks	50.7	46.2	0.568	0.451
Energy drinks	35.5	50.0	6.124	0.013
Caffeinated RTDs	16.1	22.6	2.011	0.156
Caffeine-containing sports supplements	6.6	6.6	0.000[a]	1.000[a]
Caffeine tablets	0.9	8.5	-	0.001[b]
None	0.5	1.9	0.373[a]	0.541[a]

RTD- Ready to drink alcoholic beverage
[a]Yates continuity correction (Minimum expected count <10)
[b]Fisher's exact test (Minimum expected count <5)

Those who smoked were 3.73 times more likely to consume coffee (91.5% vs 74.3%, p= 0.010), 2.29 times more likely to consume kola drinks (66% vs 36.9%, p= 0.011), 2.75 times more likely to consume energy drinks (61.7% vs 36.9%, p= 0.001), and 5.21

times more likely to consume caffeinated RTDs (44.7% vs 13.4%, p< 0.001) than non-smokers (Table 4.11). There was no difference in the consumption of any other caffeine-containing products between those who smoked and those who did not (p> 0.05).

Table 4.11. Comparison of consumption of caffeine sources by smoking status

Caffeine source	Smokes (%) (n= 47)	Does not smoke (%) (n= 268)	Pearson Chi-square value (χ^2)	p value
Tea	61.7	73.5	2.749	0.097
Coffee	91.5	74.3	6.672	0.010
Chocolate	74.5	83.2	1.514[a]	0.219[a]
Kola drinks	66.0	45.9	6.441	0.011
Energy drinks	61.7	36.9	10.164	0.001
Caffeinated RTDs	44.7	13.4	24.279	< 0.001
Caffeine-containing sports supplements	8.5	6.3	-	0.532[b]
Caffeine tablets	6.4	3.0	-	0.216[b]
None	0	1.1	-	1.000[b]

RTD- Ready to drink alcoholic beverage
[a]Yates continuity correction (Minimum expected count <10)
[b]Fisher's exact test (Minimum expected count <5)

Individuals who took part in some sort of sporting activity were 14.94 times more likely to consume caffeine-containing sports supplements than those who did not (10.6% vs 0.78%, p= 0.001; Table 4.12). There was no difference in the consumption of any other caffeine-containing products between participants who were involved in sports versus those who did not (p> 0.05).

Table 4.12: Comparison of consumption of caffeine sources by participation in sports

Caffeine source	Plays sport (%) (n= 189)	Does not play sport (%) (n= 128)	Pearson Chi-square value (χ^2)	p value
Tea	71.4	71.9	0.007	0.931
Coffee	76.7	75.8	0.037	0.847
Chocolate	80.4	83.6	0.513	0.474
Kola drinks	47.6	51.6	0.475	0.491
Energy drinks	41.3	39.1	0.154	0.694
Caffeinated RTDs	18.0	18.8	0.030	0.864
Caffeine-containing sports supplements	10.6	0.78	10.319[a]	0.001[a]
Caffeine tablets	2.1	5.5	-	0.127[b]
None	0.5	1.6	-	0.568[b]

RTD- Ready to drink alcoholic beverage
[a]Yates continuity correction (Minimum expected count <10)
[b]Fisher's exact test (Minimum expected count <5)

Relationships between consumption of different caffeine sources in the diet

Table 4.13 shows the relationships between caffeine sources in the diet i.e. whether there is an association between the likelihood of consuming one caffeine source if another is also consumed. The largest positive association was between energy drinks and caffeine tablets, where students who consumed energy drinks were 4.19 times more likely to consume caffeine tablets than those who did not and vice versa (p= 0.032). Additionally, students who consumed kola drinks were 3.34 times more likely to consume caffeinated RTDs that those who did not and vice versa (p< 0.001). Students who consumed kola drinks were also 3.28 times more likely to consume energy drinks than those who did not and vice versa (p< 0.001). The largest negative association was between caffeine-containing sports supplements and chocolate where those who consumed caffeine-containing sports supplements were 3.03 times less likely to

consume chocolate and vice versa (p= 0.015). Other, weaker, relationships are shown in Table 4.13.

Table 4.13: Significant relationships between consumption of different caffeine sources

	Tea						
Coffee	χ^2= 13.871 p< 0.001 Odds ratio= 2.75	**Coffee**					
Chocolate	χ^2= 9.433 p= 0.002 Odds ratio= 2.48	NS	**Chocolate**				
Kola drinks	NS	NS	χ^2= 4.803 p= 0.028 Odds ratio= 1.92	**Kola drinks**			
Energy drinks	χ^2= 8.762 p= 0.003 Odds ratio= -2.08	NS	NS	χ^2= 25.387 p< 0.001 Odds ratio= 3.28	**Energy drinks**		
Caffeinated RTDs	NS	NS	NS	χ^2= 15.291 p< 0.001 Odds ratio= 3.34	χ^2= 8.04 p= 0.005 Odds ratio= 2.28	**Caffeinated RTDs**	
Caffeine-containing sports supplements	NS	NS	χ^2= 5.897 p= 0.015 Odds ratio= -3.03	NS	NS	NS	**Caffeine-containing sports supplements**
Caffeine tablets	NS	NS	NS	NS	P= 0.032[b] Odds ratio= 4.19	NS	NS

NS- Not a significant relationship (p>0.05)
RTD- Ready to drink alcoholic beverage
[b]Fisher's exact test (Minimum expected count <5)

Table 4.14 shows the relationships between the amounts of the different caffeine sources consumed in those who reportedly consumed more than one source. In those who consumed both energy drinks and caffeine tablets, the amount of energy drinks consumed was largely, inversely related to the amount of caffeine tablets consumed (τ = -0.645, p= 0.036). There was a medium strength, positive relationship between the amount of kola drinks and caffeine-containing sports supplements consumed in those who consumed both sources (τ = 0.457, p= 0.044). A medium strength, positive association was also seen between the amount of kola drinks and energy drinks consumed, in those who consumed both sources (τ = 0.306, p= 0.000). All other relationships between the amounts of the caffeine sources consumed were either not significant or only weakly associated.

Table 4.14: Significant relationships between the amounts of the different caffeine sources consumed

	Tea						
Coffee	τ = 0.129 p= 0.009 n= 186	**Coffee**					
Chocolate	τ = 0.082 p= 0.038 n= 195	NS N= 201	**Chocolate**				
Kola drinks	τ = -0.090 p= 0.033 N= 105	τ = 0.139 p= 0.030 N= 113	NS N= 135	**Kola drinks**			
Energy drinks	τ = -0.110 p= 0.011 N= 80	τ = 0.181 p= 0.009 N= 97	NS N= 105	τ = 0.306 p< 0.001 N= 85	**Energy drinks**		
Caffeinated RTDs	NS N= 41	τ = 0.119 p= 0.009 N= 48	NS N= 49	τ = 0.202 p< 0.001 N= 42	τ = 0.159 p= 0.001 N= 33	**Caffeinated RTDs**	
Caffeine-containing sports supplements	NS N= 14	NS N= 16	NS N= 13	τ = 0.457 p= 0.044 N= 12	NS N= 12	NS N= 6	**Caffeine-containing sports supplements**
Caffeine tablets	NS N= 8	τ = 0.119 p= 0.011 n= 11	NS N= 9	NS N= 9	τ = -0.645 p= 0.036 N= 9	NS N= 2	NS N= 2

NS- Not a significant relationship (p>0.05)
RTD- Ready to drink alcoholic beverage

4.3 Reasons for the Consumption of Caffeine-Containing Products

Reasons for tea consumption

The main reasons given for tea consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.4) were; “for the warmth” (92.6%), “for the taste” (89.5%), “to comfort and relax myself” (86.9%), “because it is easily available” (80.8%), “whenever one is offered to me” (79.9%), “with family” (73.8%), and “with friends” (61.6%). The reasons for consumption of tea which had the least influence were “because I feel that I am influenced by advertising” (10.1%), “because I feel I am influenced by peer pressure” (12.3%), and “to replace food or meals” (19.7%).

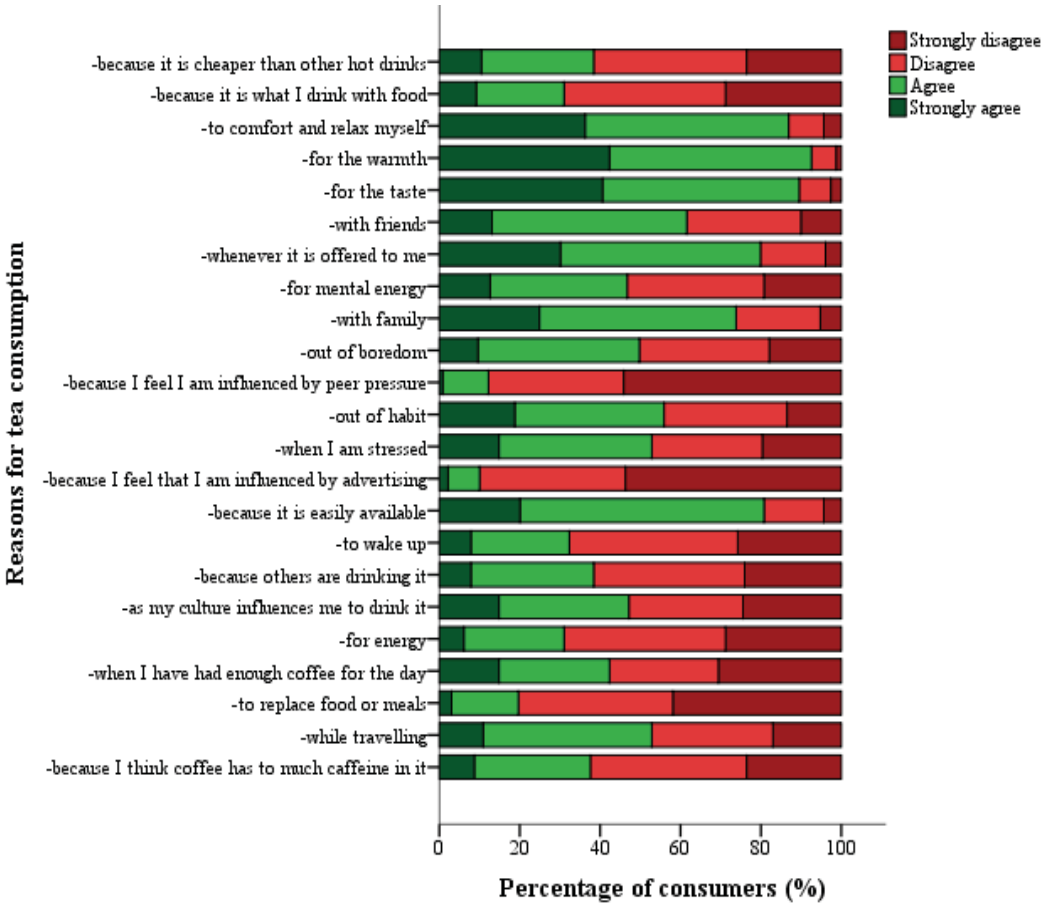

Figure 4.4: Stacked bar graph showing 4 point Likert scale responses to reasons for tea consumption (n= 227)

Reasons for coffee consumption

The main reasons given for coffee consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.5) were; “to stay awake” (86.8%), “for the warmth” (86.3%), “to wake up” (85.9%), “for mental energy” (85.5%), “for the taste” (85.1%), “for energy” (84.3%), and “with friends” (83%). The reasons for consumption of coffee which had the least influence were “when I am smoking” (10.3%), “because I feel I am influenced by peer pressure “(14.9%), “because I feel that I am influenced by advertising” (14.8%). When looking at just smokers, 48.8% of those who consume coffee, report that they do so when they are smoking.

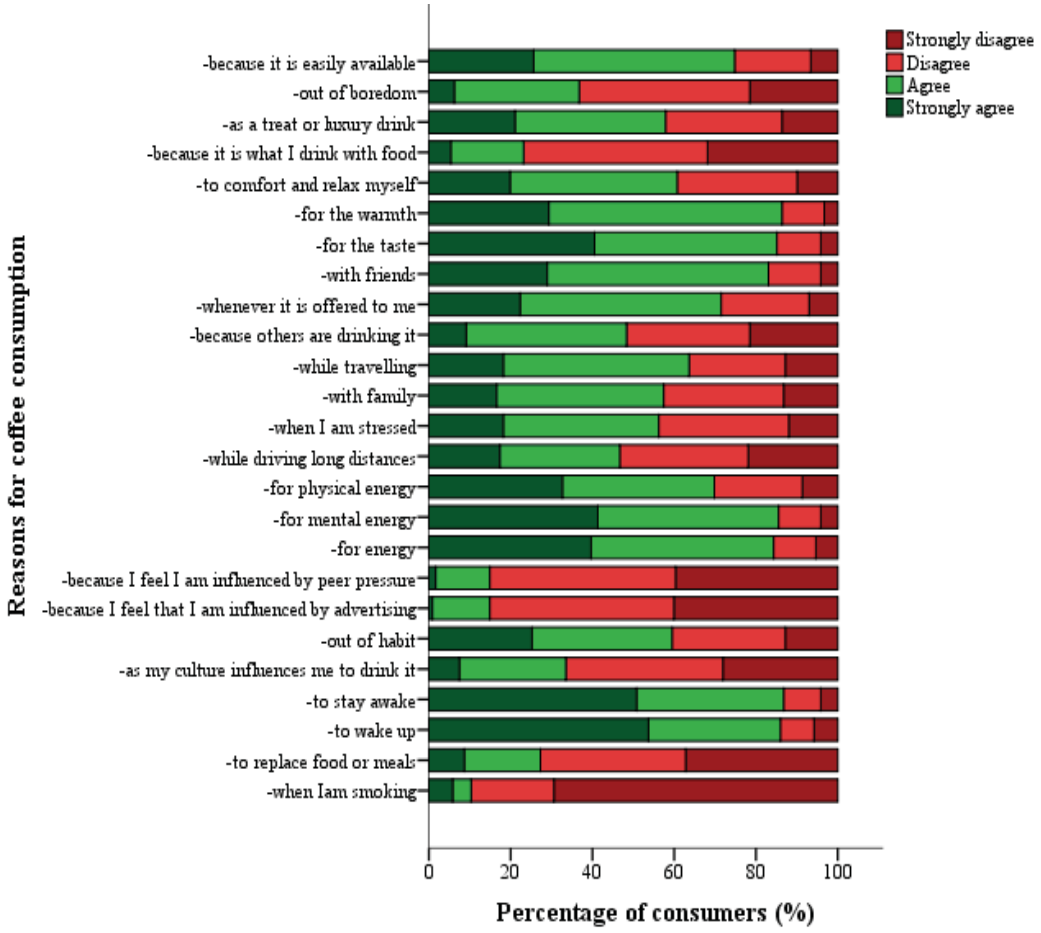

Figure 4.5: Stacked bar graph showing 4 point Likert scale responses to reasons for coffee consumption (n= 242)

Reasons for chocolate consumption

The main reasons given for chocolate consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.6) were; “for the taste” (95.4%), “as a treat or luxury food” (88.8%), “to comfort and relax myself “(79.6%), “with friends” (77.6%), “whenever it is offered” (77.2%), “with family” (72.9%), and “for the warmth (drinking chocolate)” (71%). The reasons for consumption of chocolate which had the least influence were “because I feel I am influenced by peer pressure” (12.4%), “to replace food or meals” (25.8%), and “because I feel that I am influenced by advertising” (29.3%).

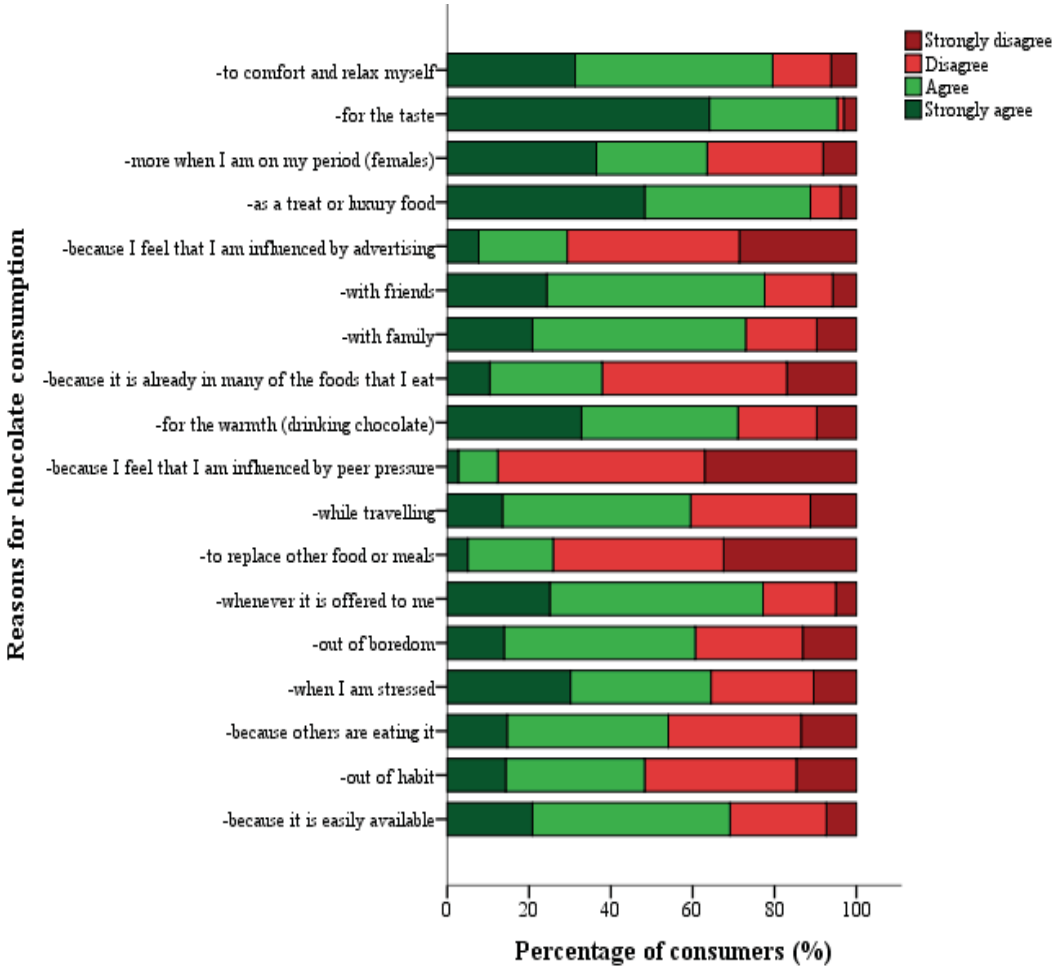

Figure 4.6: Stacked bar graph showing 4 point Likert scale responses to reasons for chocolate consumption (n= 259)

Reasons for kola drink consumption

The main reasons for kola drink consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.7) were; “because they are cold and refreshing” (90.6%), “for the taste” (89.3%), “with takeaway food” (85.5%), “with friends” (78%), “as a treat drink” (75.4%), “because it is easily available” (67.3%), and “while travelling” (67.3%). The reasons for consumption of kola drinks which had the least influence were “to replace food or meals” (5.7%), “because I feel I am influenced by peer pressure” (10.1%), and “when I am stressed” (26.4%).

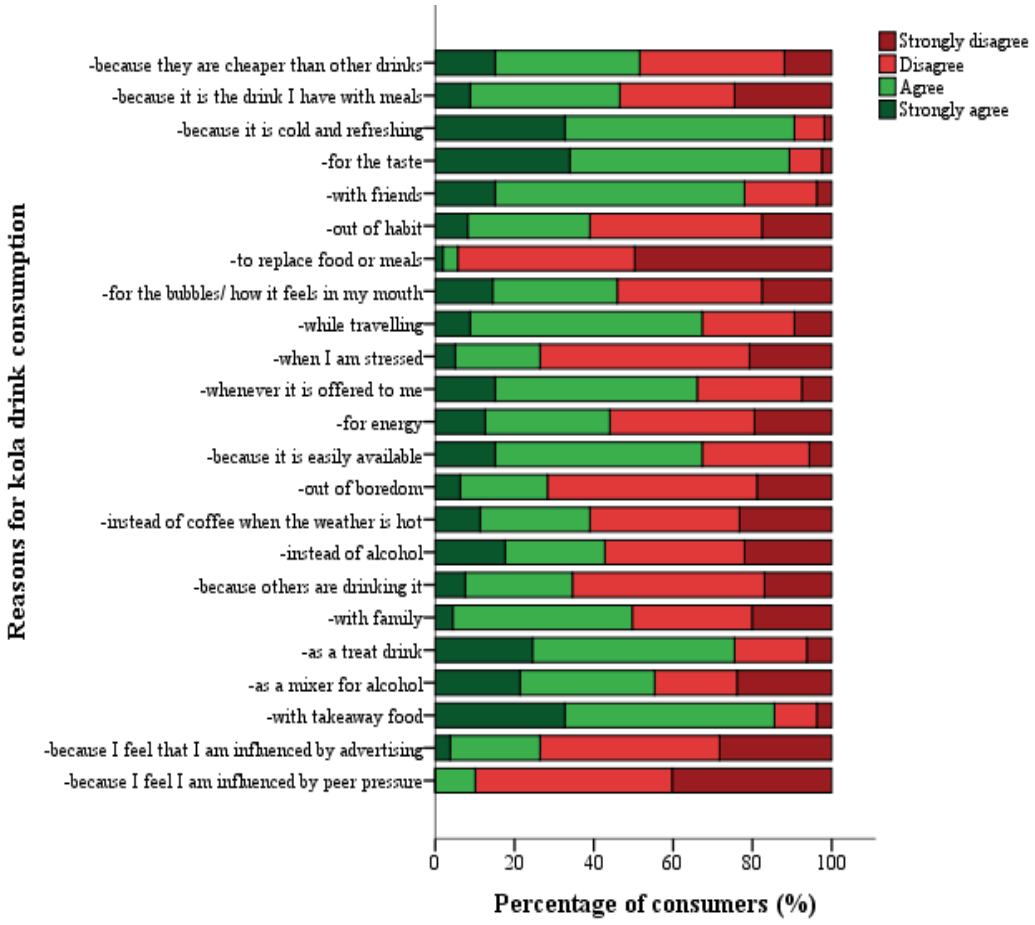

Figure 4.7: Stacked bar graph showing 4 point Likert scale responses to reasons for kola drink consumption (n= 156)

Reasons for energy drink consumption

The main reasons for energy drink consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.8) were; “for energy” (90.6%), “to stay awake” (89.1%), “to wake up” (85.2%), “for mental energy” (84.3%), “for physical energy” (70.3%), “because they are cold and refreshing” (66.5%), and “for the taste” (65.7%). The reasons for consumption of kola drinks which had the least influence were “while smoking” (7.8%), “with family” (9.4%), “because I feel I am influenced by peer pressure” (10.2%), “because it is the drink I have with food” (16.4%). When looking at just smokers, 31% of those who consume energy drinks, report that they do so when they are smoking.

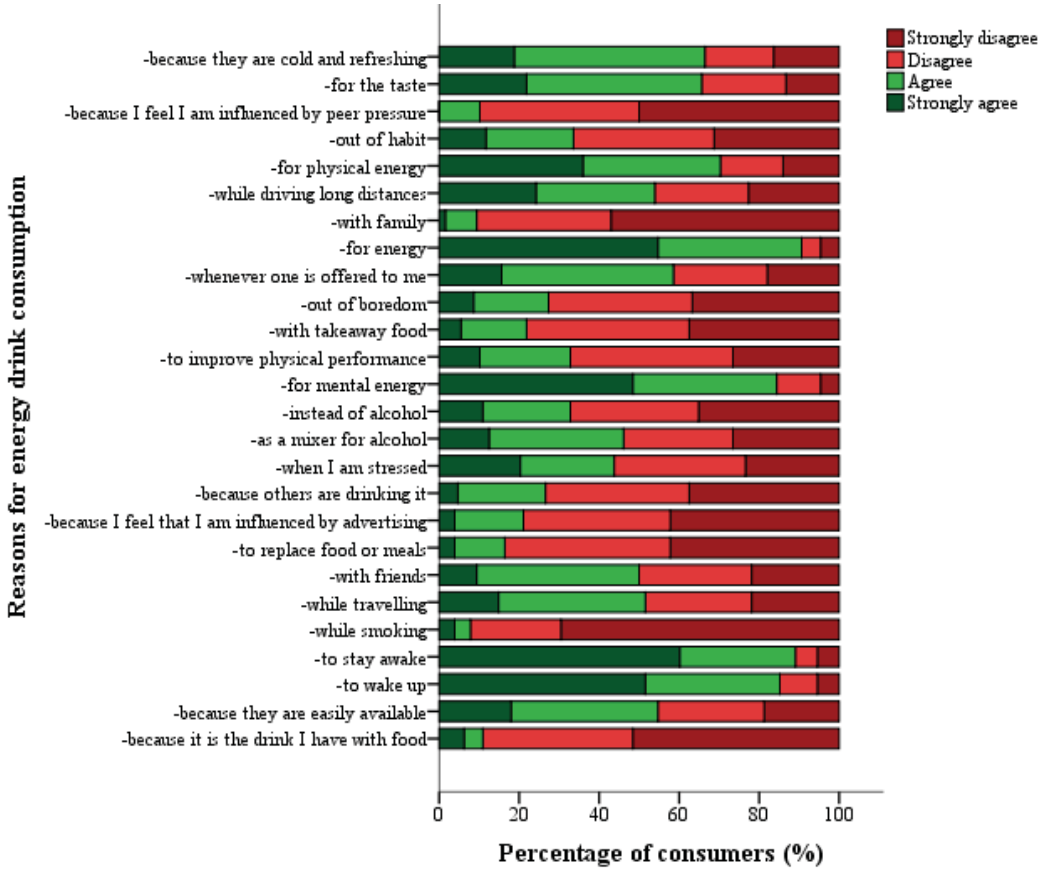

Figure 4.8: Stacked bar graph showing 4 point Likert scale responses to reasons for energy drink consumption (n= 128)

Reasons for caffeinated RTD consumption

The main reasons for caffeinated RTD consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.9) were, “with friends” (91.8%), “for the alcohol content” (85.2%), “because others are drinking them” (78.7%), “whenever one is offered to me” (77.1%), “because I know how much alcohol is in them” (72.1%), “for the taste” (70.5%), “because they are cheaper than other alcoholic drinks” (62.3%). The reasons for consumption of caffeinated RTDs which had the least influence were “to replace food or meals” (6.5%), “because I feel that I am influenced by advertising” (11.5%), “for physical energy” (14.7%), and “while travelling” (16.4%).

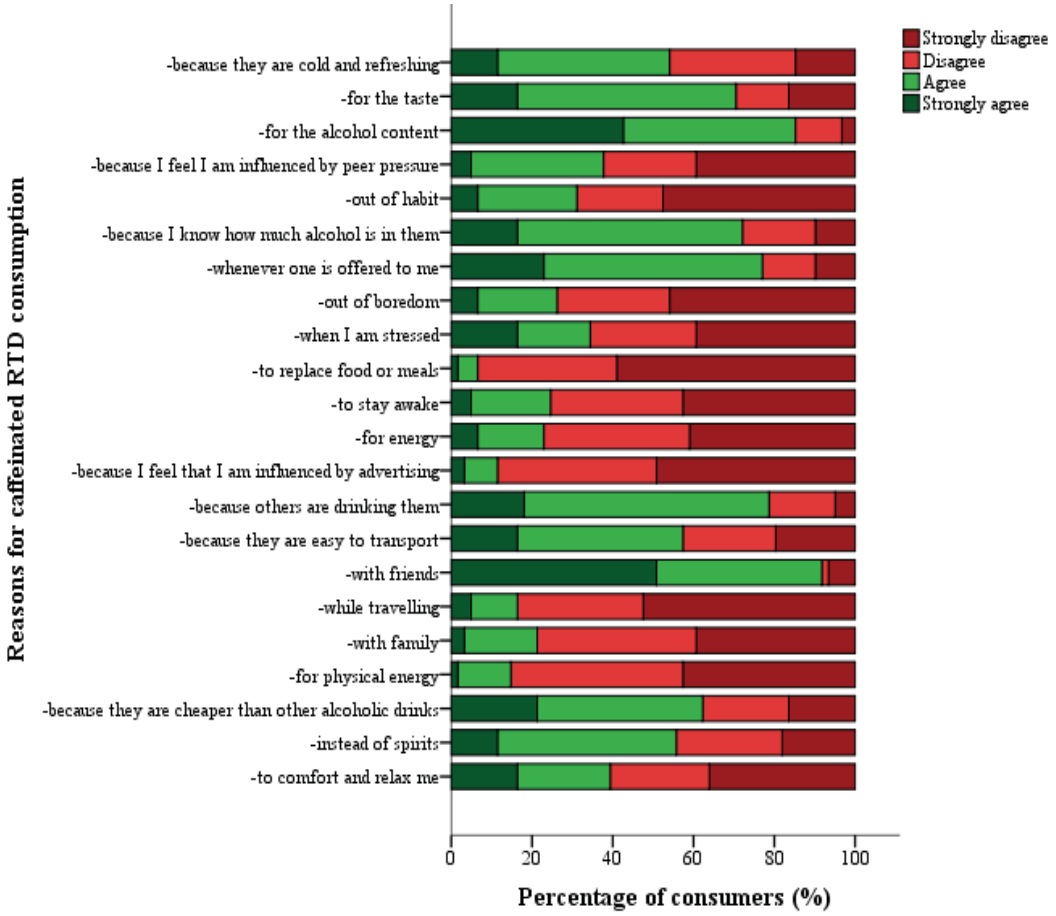

Figure 4.9: Stacked bar graph showing 4 point Likert scale responses to reasons for caffeinated RTD consumption (n= 58)
RTD- Ready to drink alcoholic beverage

Reasons for consumption of caffeine-containing sports supplements

The main reasons for caffeine-containing sport supplement consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.10) were; "to improve physical performance" (86.3%), "for energy" (86.3%), "for physical energy" (81.8%), "as they are convenient to take" (59.1%). The reasons for consumption of caffeine-containing sport supplements which had the least influence were "because of peer pressure" (4.5%), and "because of pressure from coaches/trainers" (4.5%).

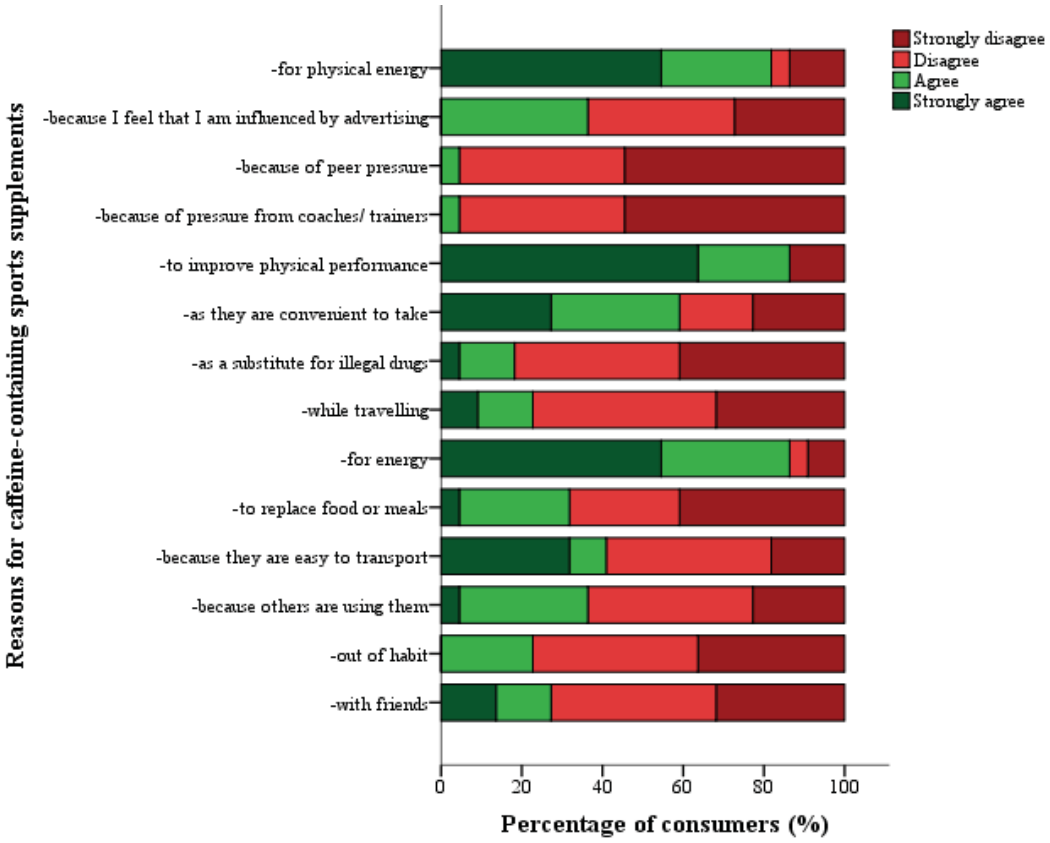

Figure 4.10: Stacked bar graph showing 4 point Likert scale responses to reasons for caffeine-containing sports supplements consumption (n= 21)

Reasons for consumption of caffeine tablets

The main reasons for caffeine tablet consumption (according to accumulative % of agreement on a four-point Likert scale; Figure 4.11) were; “for energy” (90.9%), “for mental energy” (90.9%), “to stay awake” (81.8%), “to wake up” (81.8%), “as they are convenient to take” (63.7%), and “for physical energy” (54.6%). The reasons for consumption of caffeine-containing sport supplements which had the least influence were “because of pressure from coaches/ trainers”, “to replace food or meals”, “as a substitute for illegal drugs”, and “because I feel that I am influenced by advertising”, none of which were agreed to by any of the participants.

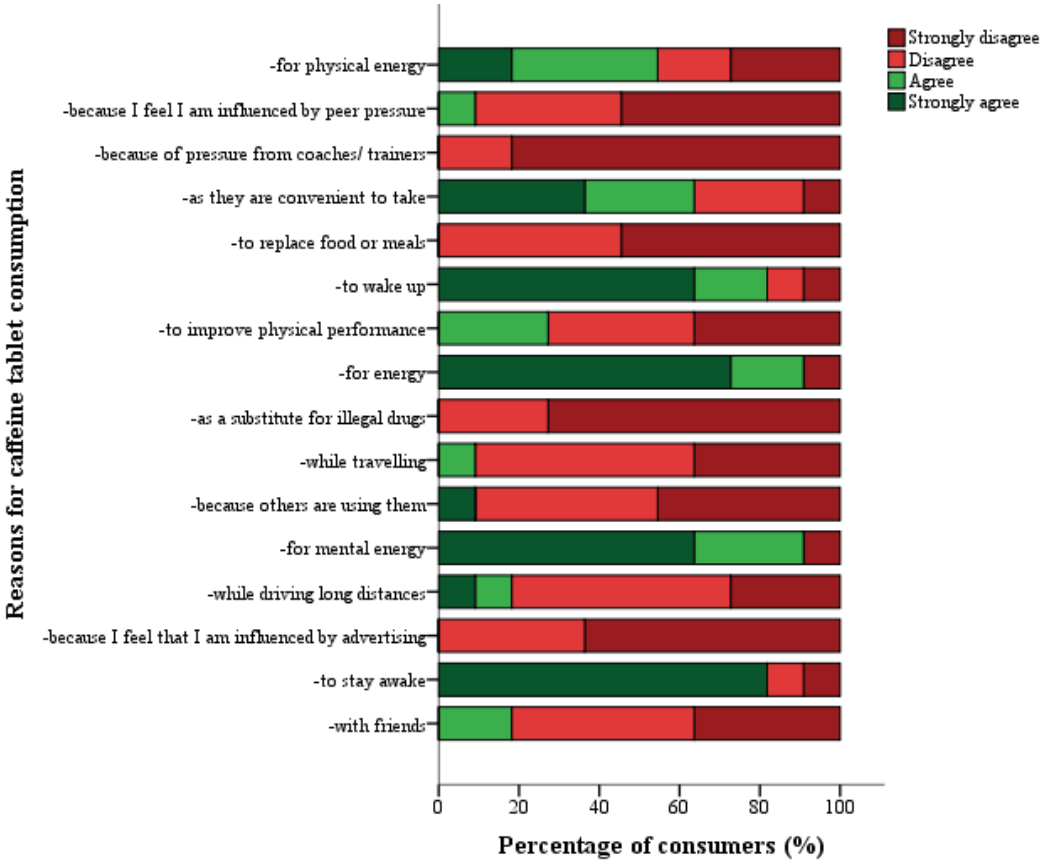

Figure 4.11: Stacked bar graph showing 4 point Likert scale responses to reasons for caffeine tablet consumption (n= 11)

4.4 Reasons for Not Consuming Caffeine-Containing Products

Figure 4.12 highlights the reasons survey respondents[2] gave for not consuming particular caffeine-containing products. The most common reason for not consuming tea was “I don’t like the flavour” (41.7% of respondents), followed by “I don’t want to be dependent on it” (28.3% of respondents). The most common reason for not consuming coffee was “I don’t want to be dependent on it” (48.1% of respondents), followed by “I don’t like the flavour” (23% of respondents) and “It’s too expensive” (22.2% of respondents). The two most common reasons for not consuming chocolate, kola and energy drinks was the same for all three products: “It has too much sugar in it” (55.3%, 60.3% and 50.2% of respondents respectively), and “It isn’t ‘good’ for me” (38.1%, 40.4% and 42% of respondents respectively). The most common reason for not consuming RTDs, sports supplements and caffeine tablets were also the same: “I have never considered taking it” (49%, 65.6% and 67.7% of respondents respectively). For caffeinated RTDs, “It isn’t ‘good’ for me”, “There is too much sugar in it”, and “I don’t like the flavour” were also reasonably common reasons for not consuming this product (28.2%, 24.1% and 19.4% of respondents respectively). The least common reason for non-consumption of all products was “I don’t consume it due to medical reasons” (0.7-2.4% of respondents).

[2] The word respondent is used as these questions were open to be answered by all participants, not just consumers.

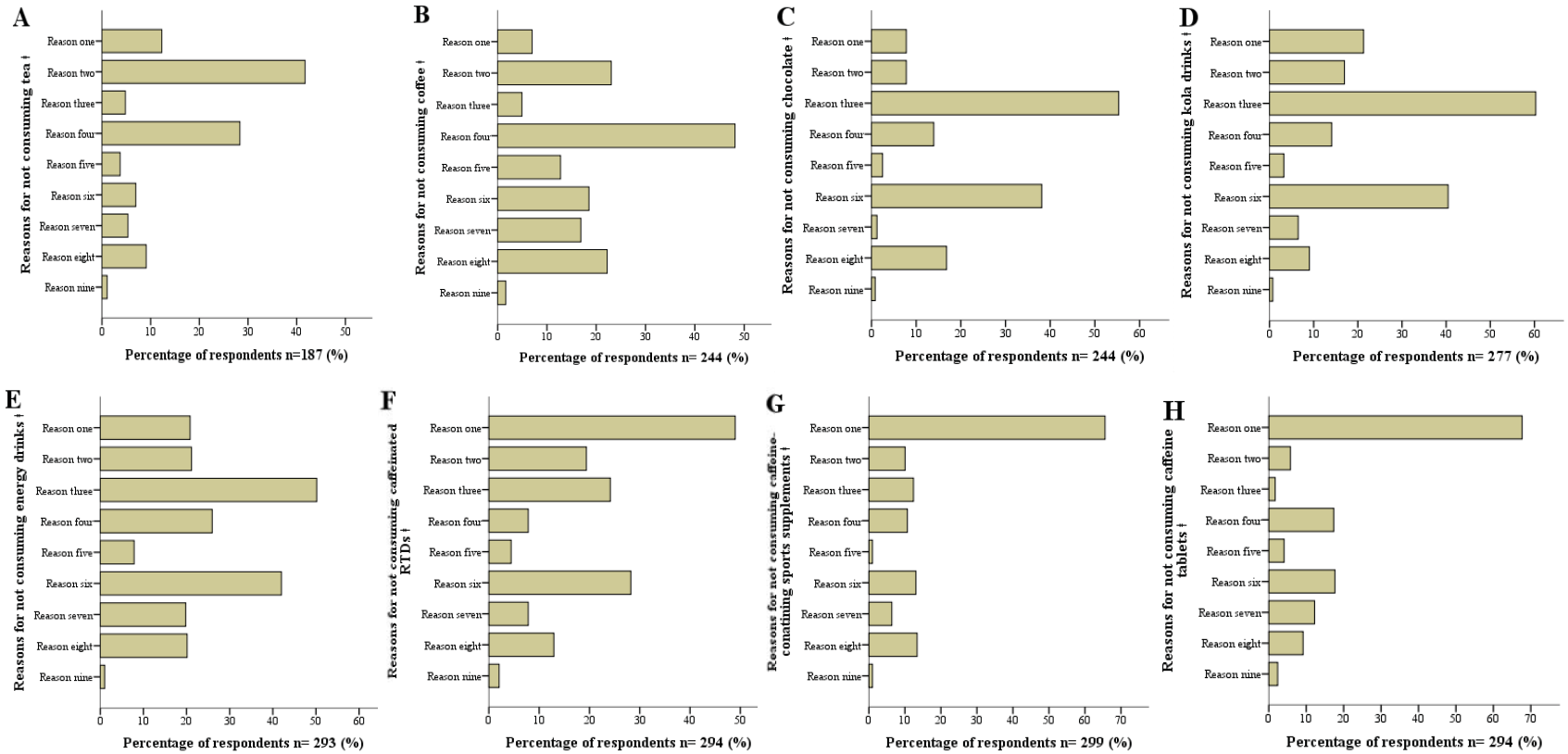

Figure 4.12: Reasons for not consuming caffeine-containing products

A- Tea; B- Coffee; C- Chocolate; D- Kola drinks; E- Energy drinks; F- Caffeinated RTDs; G- Caffeine-containing sports supplements; H- Caffeine tablets

RTD- Ready to drink alcoholic beverage

ǂ - Reason one – "I have never considered taking it"; Reason two – "I don't like the flavour"; Reason three – "There is too much sugar in it"; Reason four – "I don't want to be dependent on it"; Reason five – "I react badly to it"; Reason six – "It isn't 'good' for me"; Reason seven – "It has too much caffeine in it"; Reason eight – "It's too expensive"; Reason nine – "I don't consume it due to medical reasons"

4.5 Co-ingestion of Caffeine and Alcohol

Of the total participants, 27.4% (n= 87) reported that they consumed kola drinks with alcohol, 18.6% (n= 59) reported that they consumed energy drinks with alcohol and a further 18.3% (n= 58) reported consuming caffeinated RTDs. In total, co-ingestion of caffeine and alcohol was carried out by 38.5% (n= 122) of the participants. Those with paid employment were 1.72 times more likely to co-ingest caffeine and alcohol than those who did not (47.2% vs 34.1%, p= 0.024; Table 4.15). Participants who smoked were 3.43 times more likely to co-ingest caffeine and alcohol than those who did not (63.8% vs 34%, p< 0.001). No other participant demographic or characteristic was associated with the co-ingestion of caffeine and alcohol (p> 0.05), however, the relationship between age group and co-ingestion of caffeine and alcohol (p= 0.059) is worthy of further research in a higher powered study.

When exploring the co-ingestion of energy drinks with alcohol, employment status and smoking status were the only two participant demographics/characteristics which were associated (Table 4.16). Participants with paid employment were 2.94 times more likely than those without paid employment to co-ingest energy drinks with alcohol (30.2% vs 12.8% p< 0.001), and those who smoked were 3.88 times more likely to co-ingest energy drinks and alcohol than those who did not (40.4% vs 14.9%, p< 0.001).

Table 4.15: Co-ingestion of caffeine and alcohol by participant demographic and characteristics

Participant demographic/ characteristic	Participants who co-ingest caffeine and alcohol (%)	Pearson Chi-square value (χ^2)	p value
Gender			
- **Male (n= 148)**	38.5	0.000	0.992
- **Female (n= 169)**	38.5		
Age group			
- **16-18 years old (n= 51)**	41.2		
- **19-30 years old (n= 236)**	40.7	7.144[b]	0.059[b]
- **31-50 years old (n= 25)**	20		
- **51+ years old (n= 5)**	0		
Living situation			
- **Living alone (n= 23)**	30.4		
- **Living with family (n= 174)**	36.8	4.202[b]	0.379[b]
- **Flatting with others (n= 108)**	40.7		
- **Hall of residence (n= 7)**	71.4		
- **Living with partner (n= 5)**	40		
Working status			
- **Paid work (n= 211)**	47.2	5.073	0.024
- **No paid work (n= 106)**	34.1		
Smoking status			
- **Smokes (n= 47)**	63.8	15.085	<0.001
- **Does not smoke (n= 270)**	34		
Participation in sport			
- **Plays sport (n= 189)**	37.6	0.167	0.683
- **Does not play sport (n= 128)**	39.8		

[b]Fisher's exact test (Minimum expected count <5)

Table 4.16: Co-ingestion of energy drinks and alcohol by participant demographic and characteristics

Participant demographic/ characteristic	Participants who co-ingest alcohol and energy drinks (%)	Pearson Chi-square value (χ^2)	p value
Gender			
- **Male (n= 148)**	21.6	1.660	0.198
- **Female (n= 169)**	16		
Age group			
- **16-18 years old (n= 51)**	21.6		
- **19-30 years old (n= 236)**	19.9	4.862[b]	0.169[b]
- **31-50 years old (n= 25)**	4		
- **51+ years old (n= 5)**	0		
Living situation			
- **Living alone (n= 23)**	13.0		
- **Living with family (n= 174)**	18.4	1.430[b]	0.857
- **Flatting with others (n= 108)**	21.3		
- **Hall of residence (n= 7)**	14.3		
- **Living with partner (n= 5)**	0		
Working status			
- **Paid work (n= 211)**	30.2	14.090	< 0.001
- **No paid work (n= 106)**	12.8		
Smoking status			
- **Smokes (n= 47)**	40.4	17.082	< 0.001
- **Does not smoke (n= 270)**	14.9		
Participation in sport			
- **Plays sport (n= 189)**	19.0	0.059	0.809
- **Does not play sport (n= 128)**	18.0		

[b]Fisher's exact test (Minimum expected count <5)

4.6 Estimated Daily Caffeine Consumption

Daily caffeine consumption for each participant was estimated by combining product consumption frequency data and caffeine content information (See Section 3.6). Calculations in Section 4.6 were based on caffeine consumers only, therefore it was valid to remove three participants who did not consume any caffeine. Based on data from 314 participants, the median estimated total daily caffeine consumption from all sources was 146.73 $mg \cdot day^{-1}$. Figure 4.13 shows the distribution of estimated individual daily caffeine intakes from each source in the form of a box plot. The maximum estimated total by a single person was 1988.14 $mg \cdot day^{-1}$. For this participant, this high caffeine consumption was mostly attributed to daily consumption of 4-5 double shot espressos (providing an estimated 945 mg caffeine). This participant (outlier) was not excluded from analysis as the data was non-parametric and therefore its influence on the statistical results was minimal. The lowest estimated total caffeine consumption from all sources was 0.07 $mg \cdot day^{-1}$. The only caffeine this participant regularly consumed was a cup of hot chocolate consumed less than once a month.

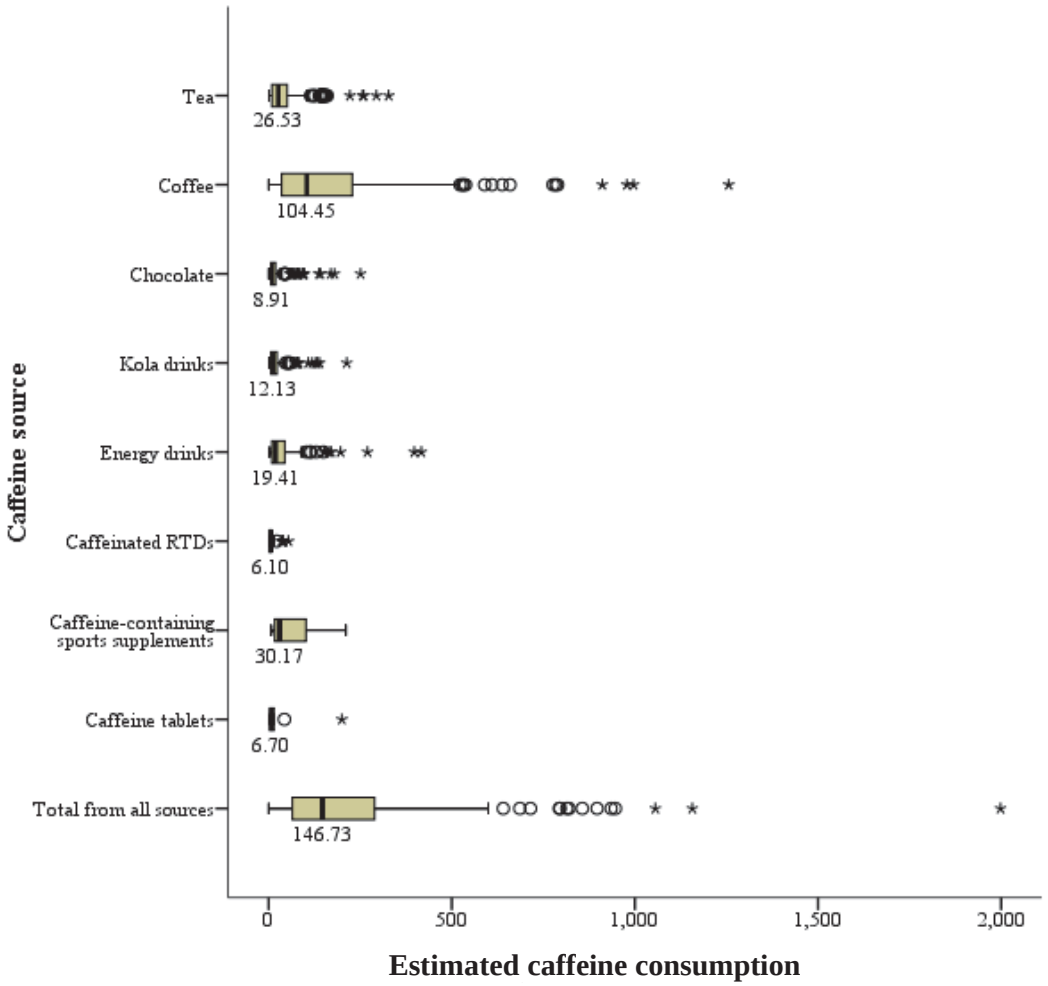

Figure 4.13: Boxplot[+] showing the distribution of estimated daily caffeine consumption (mg· day^{-1}) from the different caffeine-containing dietary sources (n= 314)

RTD- Ready to drink alcoholic beverage

[+] A boxplot (also known as a box and whisker plot) provides a visual representation of the distribution and location of a set of scale data. The thick middle line of the box represents the median value.The lower line represents the lower quartile (also known as 25th percentile), where 25% of the observations fall below this value. The upper line represents the upper quartile of the data (also known as the 75th percentile), where 75% of the observations are below this line. The width of the box is the inter-quartile range, where 50% of the observations fall within this. The whiskers (i.e. the lines extending from the box), represent the highest and lowest observations which fall within one and a half times the inter-quartile range. Observations that are greater or less than one and a half times the inter-quartile range (represented by ○), are referred to as outliers, and observations that are greater or less than three times the inter-quartile range (represented by *) are referred to as extreme values.

Coffee contributed the greatest amount to total daily caffeine intake (61.4%), followed by tea (14.4%), energy drinks (8%), chocolate (7.3%), kola drinks (5.3%), caffeine-containing sports supplements (2.4%), caffeinated RTDs (0.8%), and caffeine tablets (0.5%).

For the participants who provided body weight data (n= 281) the median relative daily caffeine consumption was 2.25 mg· kgbw^{-1}· day^{-1}with an interquartile range of 1.01-4.31 mg· kgbw^{-1}· day^{-1}. The maximum relative daily caffeine consumption was 23.51 mg· kgbw^{-1}· day^{-1}, whilst the minimum was 0.02 mg· kgbw^{-1}· day^{-1}.

Estimated total caffeine consumption (absolute and relative to body weight) by gender

There was no significant difference in estimated total daily caffeine consumption between males and females (p> 0.05). However, when expressed on a per kg of body weight basis, daily caffeine consumption was significantly higher in females than males (U= 8289, p= 0.041, r= -0.123; Figure 4.14).

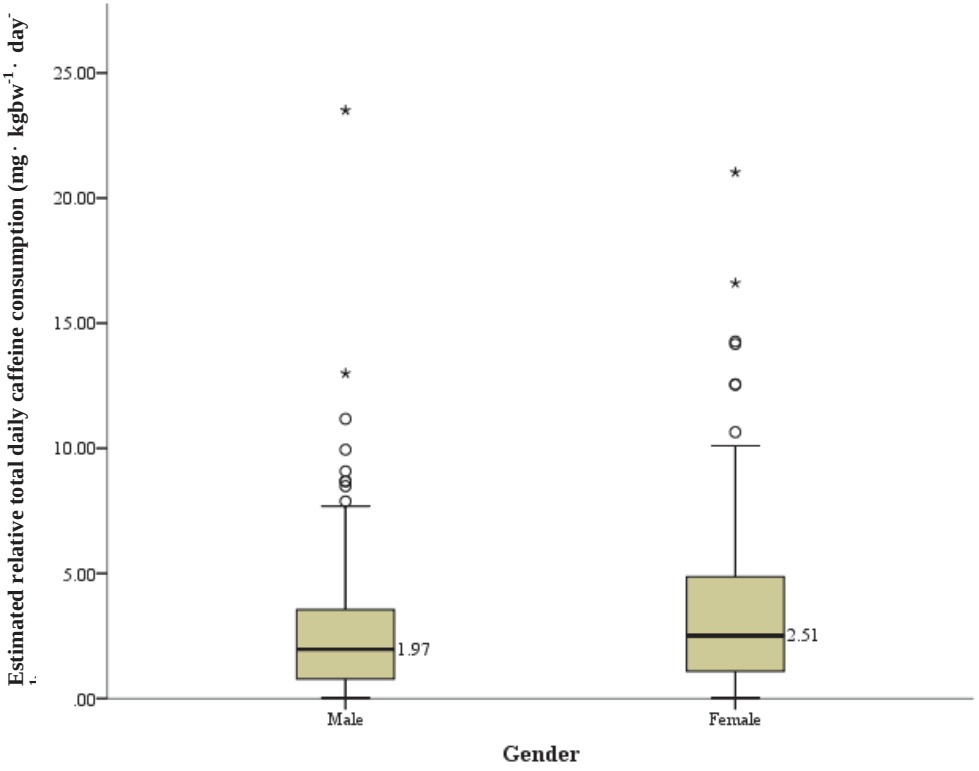

Figure 4.14: Distribution of estimated relative daily caffeine consumption (mg· kgbw^{-1}· day^{-1}) by gender (n= 282)

Caffeine contribution from different sources by gender

Daily consumption of caffeine from kola drinks (U= 2046.0, p< 0.001, r= -0.283), energy drinks (U= 1191.0, p< 0.001, r= -0.360), and caffeinated RTDs (U= 275.0, p= 0.022, r= -0.301) was higher in males than females (Table 4.16). There was no difference between males and females for daily consumption of caffeine from any other sources (p> 0.05).

Table 4.17: Estimated daily caffeine consumption from different caffeine sources by gender (n= 314)

Caffeine source	Male (mg· day^{-1})	Female (mg· day^{-1})	Mann-Whitney test statistic (U)	p value
Tea	26.43	26.53	6207.5	0.996
Coffee	100.00	108.76	6825.0	0.496
Chocolate	8.91	8.88	8112.0	0.864
Kola drinks	15.31	9.94	2046.0	< 0.001
Energy drinks	32.20	11.54	1191.0	< 0.001
Caffeinated RTDs	6.10	3.00	275.0	0.022
Caffeine-containing sports supplements	90.52	19.34	31.0	0.176
Caffeine tablets	3.30	6.70	8.5	0.282

RTD- Ready to drink alcoholic beverage

Estimated total caffeine consumption (absolute and relative to body weight) by age group

Figure 4.15 shows the distribution of estimated daily caffeine consumption according to age group in the form of a box plot. There was a significant association between age group and total daily caffeine consumption (χ^2 (3) = 9.787, p = 0.020). Post-hoc testing showed that the 19-30-year-old age group had a higher total daily caffeine consumption than the 16-18-year-old age group (U= 4460, p= 0.008, r = -0.16). The total daily caffeine consumption levels in the 51+ age group appeared much higher (310.98

mg· day^{-1}) than the other age groups (≤196.74 mg· day^{-1}), however there were only five participants in this age group, making this result statistically non-significant. When expressed on a per kg of body weight basis (Figure 4.16), there was a significant association between estimated relative daily caffeine consumption and age group (X^2 (3) = 9.934, p= 0.019). Specifically, the 31-50-year-old age group had a higher estimated relative daily caffeine consumption than the 16-18-year-old age group (U= 304, p= 0.008, r= -0.326).

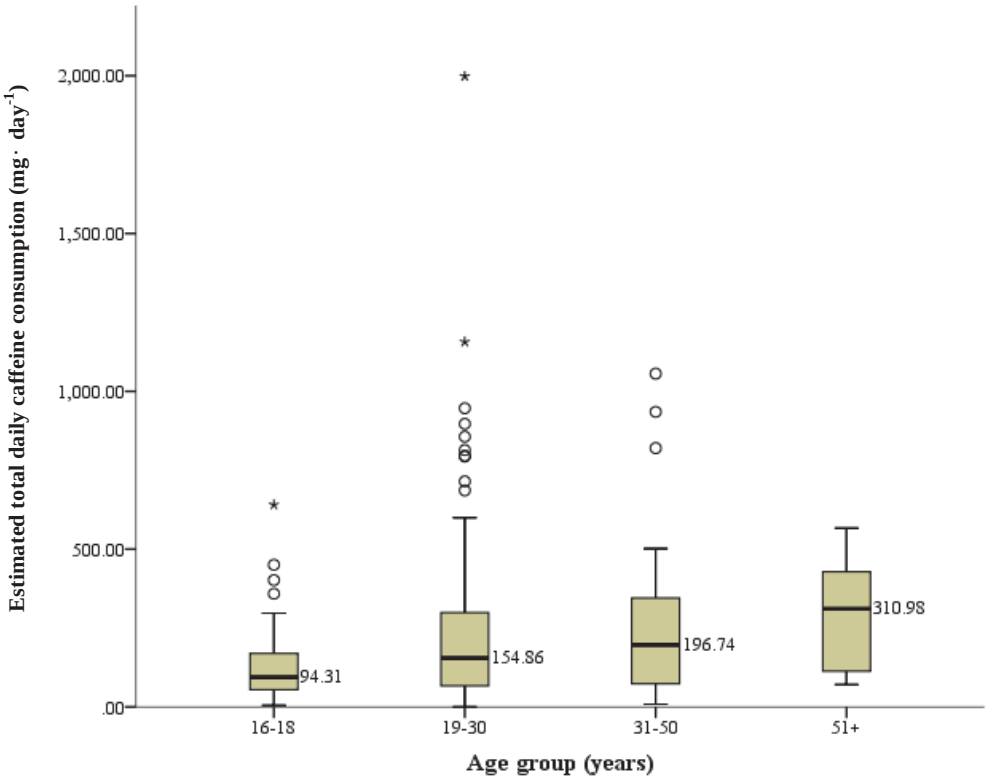

Figure 4.15: Distribution of estimated total daily caffeine consumption (mg· day^{-1}) by age group (n= 314)

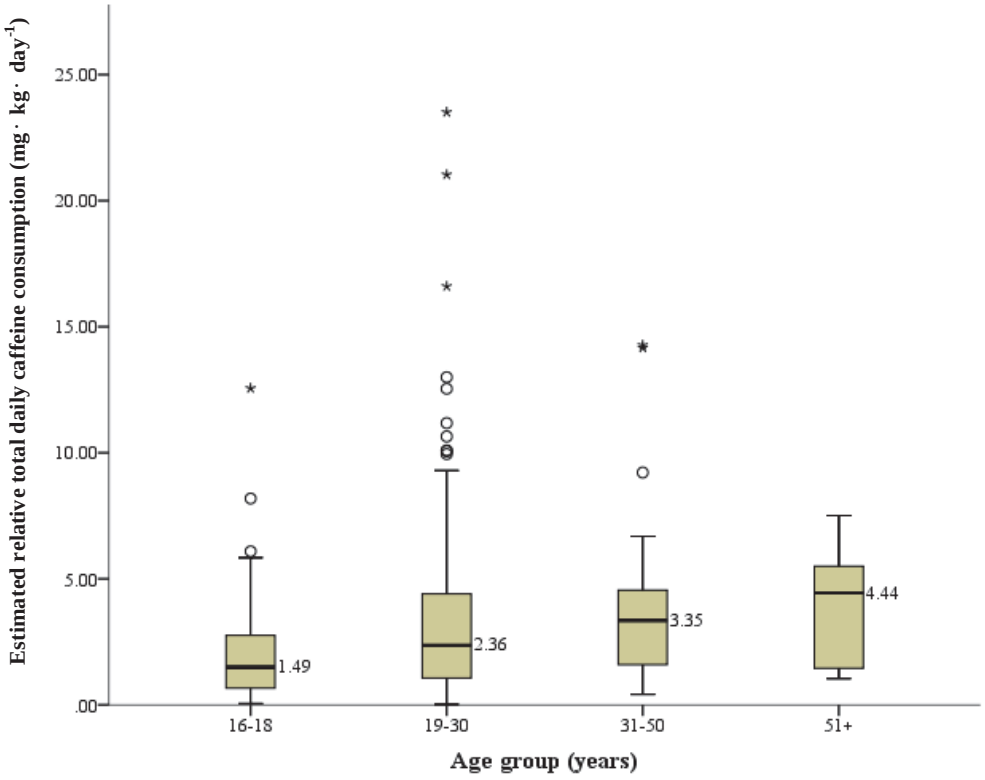

Figure 4.16: Distribution of estimated relative daily caffeine consumption (mg· kgbw^{-1}· day^{-1}) by age group (n= 282)

Caffeine contribution from different sources by gender age group

There was an association between estimated daily consumption of caffeine from coffee and age group (H= 17.940, p< 0.001; Table 4.18). The 31-50-year-old age group had a higher estimated daily caffeine consumption from coffee than the 16-18-year-old age group (U= 152.5, p< 0.001, r = -0.486). Daily caffeine consumption from coffee was also significantly higher in the 19-30-year-old age group than the 16-18-year-old age group (U= 2012.5, p= 0.01, r= -0.234). There was no association between age group and daily consumption of caffeine from any other caffeine sources (p> 0.05).

Table 4.18: Estimated median daily caffeine consumption from different caffeine sources by age group (n= 314)

Caffeine source	16-18 years (mg· day^{-1})	19-30 years (mg· day^{-1})	31-50 years (mg· day^{-1})	51+ years (mg· day^{-1})	Kruskal-Wallis test statistic (H)	p value
Tea	33.74	26.25	25.61	108.31	3.306	0.347
Coffee	38.07	109.35	183.10	220.73	17.940	< 0.001
Chocolate	8.76	8.88	11.35	46.18	4.202	0.240
Kola drinks	9.43	12.96	9.94	2.19	5.641	0.130
Energy drinks	24.88	17.80	16.69	7.72	3.100	0.376
Caffeinated RTDs	9.29	6.01	4.55	0	3.279	0.194
Caffeine-containing sports supplements	0	30.17	16.70	0	0.838	0.360
Caffeine tablets	6.70	0	0	0	-	-

RTD- Ready to drink alcoholic beverage

Estimated total caffeine consumption by participant BMI

There was a significant positive correlation between BMI and daily caffeine consumption from kola drinks (r= 0.129, p= 0.026). However, there was no association between BMI and daily consumption of caffeine from any of the other sources (p> 0.05). There was also no association between the BMI categories (i.e. underweight, healthy weight, overweight and obese) and daily caffeine consumption from the different caffeine sources (p> 0.05).

Estimated total caffeine consumption (absolute and relative to body weight) by participant living situation

There was no association between total daily caffeine consumption and living situation (χ^2 (4) = 3.330, p= 0.504). When this is expressed on a per kg of body weight basis, there was still no significant association between estimated relative daily caffeine consumption and living situation (p= 0.569).

Caffeine contribution from different sources by living situation

There was an association between living situation and daily consumption of caffeine from chocolate (χ^2 (4) = 15.026, p= 0.005) and also energy drinks (χ^2 (4) = 9.586, p= 0.048; Table 4.19). Participants living alone had a higher estimated daily caffeine consumption from chocolate than those living with family (U= 712, p= 0.001, r = -0.266) and those who flat with others (U= 418, p= 0.004, r= -0.276). Post-hoc testing did not reveal any significant pairwise comparisons between estimated daily caffeine consumption from energy drinks and living situation. There was no association between living situation and daily consumption of caffeine from any of the other sources (p> 0.05).

Table 4.19: Estimated daily caffeine consumption from different caffeine sources by living situation (n= 314)

Caffeine source	Living alone (mg· day^{-1})	Living with family (mg· day^{-1})	Flatting (mg· day^{-1})	Hall of residence (mg· day^{-1})	Living with partner (mg· day^{-1})	Kruskal-Wallis test statistic (H)	p value
Tea	29.30	26.43	23.67	37.05	102.88	7.518	0.111
Coffee	141.09	96.64	123.81	80.94	78.15	2.986	0.560
Chocolate	23.66	8.60	8.91	17.63	9.11	15.026	0.005
Kola drinks	6.95	12.57	13.40	6.53	4.46	5.417	0.247
Energy drinks	11.70	22.22	22.99	6.18	7.72	9.586	0.048
Caffeinated RTDs	6.51	6.10	4.43	4.55	3.00	3.291	0.510
Caffeine-containing sports supplements	211.00	93.08	30.17	0	0	2.953	0.228
Caffeine tablets	0	6.70	10.50	0	0	0.345	0.557

RTD- Ready to drink alcoholic beverage

Estimated total caffeine consumption (absolute and relative to body weight) by working status

Figure 4.17 shows the distribution of estimated daily caffeine consumption according to working status. There was no significant relationship between working status and consumption of caffeine per day (U= 9486, p= 0.058), even when expressed on a per kg of body weight basis (p = 0.069; Figure 4.18). However this relationship is worthy of further research in a higher powered study.

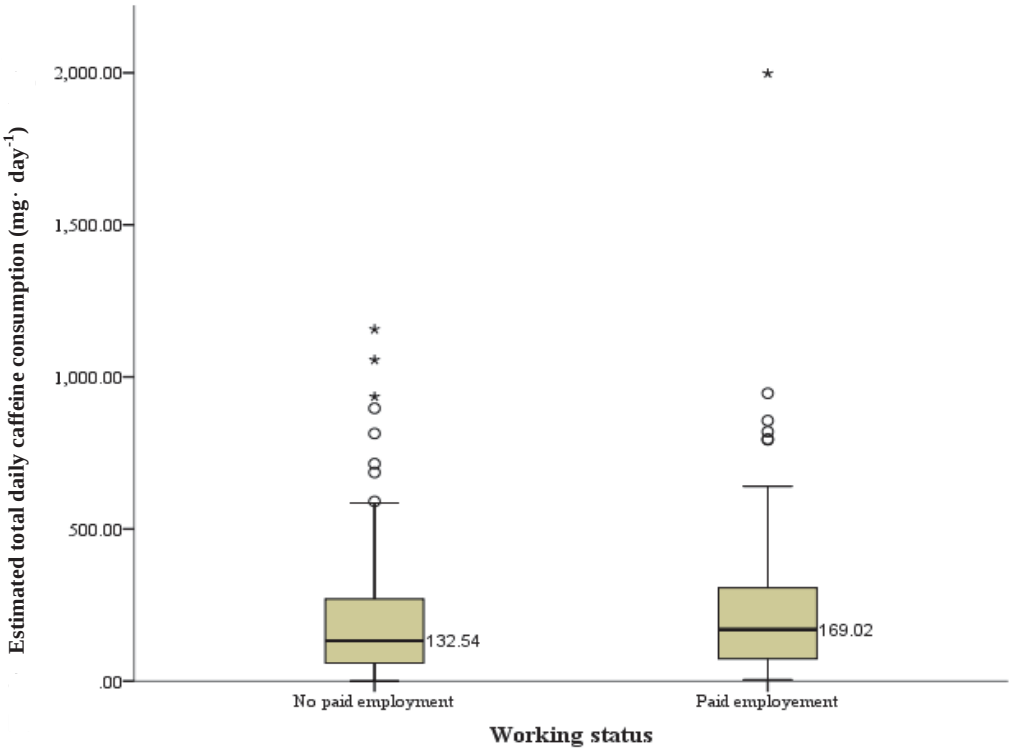

Figure 4.17: Distribution of estimated total daily caffeine consumption (mg· day^{-1}) by working status (n= 314)

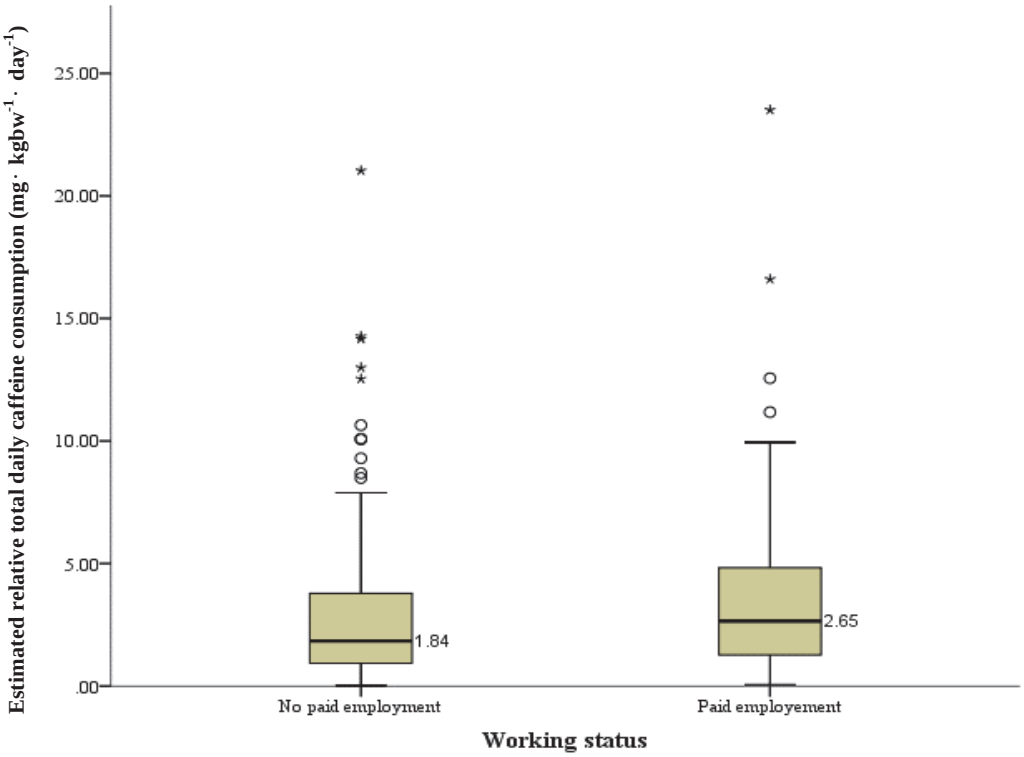

Figure 4.18: Distribution of estimated relative daily caffeine consumption (mg· kgbw^{-1}· day^{-1}) by working status (n= 282)

Caffeine contribution from different sources by working status

Daily consumption of caffeine from kola drinks was higher in those with paid employment than those with no paid employment (U= 2050.0, p= 0.029, r= -0.175) (Table 4.20). There was no significant relationship between daily consumption of caffeine from coffee and working status (U= 5830.5, p= 0.092), however this relationship is worthy of further research in a higher powered study. There was no difference in daily consumption of caffeine from any other caffeine sources between those with paid employment and those without (p> 0.05).

Table 4.20: Estimated daily caffeine consumption from different caffeine sources by working status (n= 314)

Caffeine source	No paid employment (mg· day^{-1})	Paid employment (mg· day^{-1})	Mann-Whitney test statistic (U)	p value
Tea	26.33	26.94	5290.5	0.799
Coffee	96.64	117.47	5830.5	0.092
Chocolate	8.86	8.91	7333.0	0.794
Kola drinks	10.87	14.29	2050.0	0.029
Energy drinks	16.69	22.99	1877.5	0.594
Caffeinated RTDs	6.05	6.10	380.5	0.660
Caffeine-containing sports supplements	60.35	30.17	40.5	0.523
Caffeine tablets	5.00	6.70	5.5	0.393

RTD- Ready to drink alcoholic beverage

Estimated total caffeine consumption (absolute and relative to body weight) by smoking status

Total daily caffeine consumption was higher in those who smoked than those who did not (U= 3785, p< 0.001, r = -0.243; Figure 4.19). Estimated daily caffeine consumption was also higher in those who smoked than those who did not when expressed on a per kg of body weight basis (U= 2745, p< 0.001, r= -0.265; Figure 4.20).

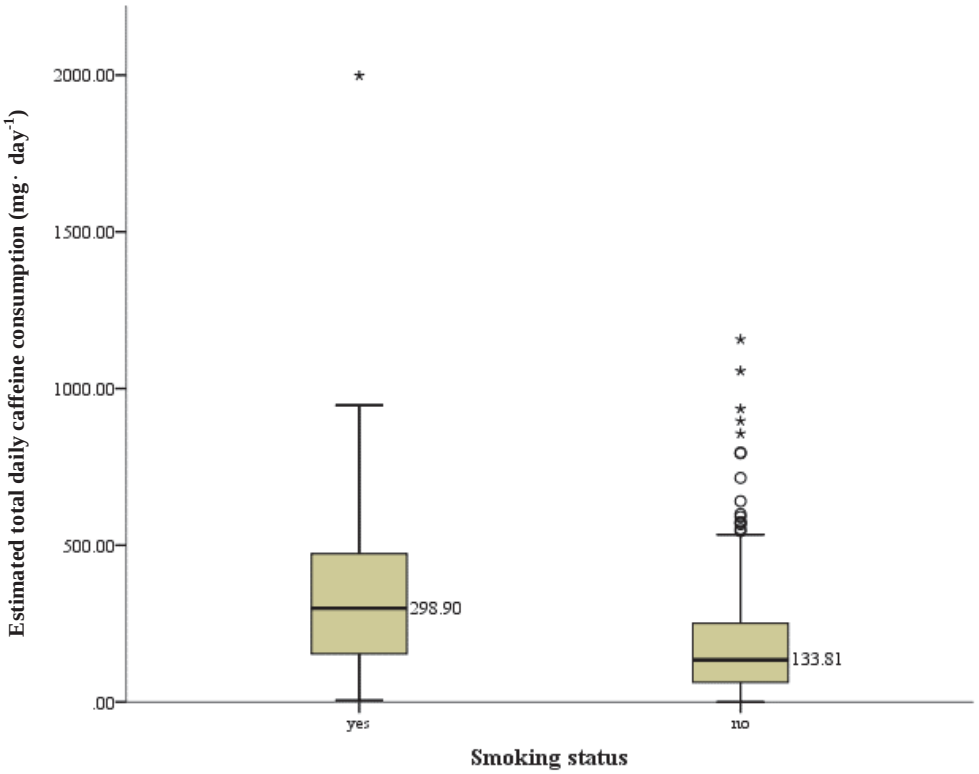

Figure 4.19: Distribution of estimated total daily caffeine consumption (mg· day^{-1}) by smoking status (n= 314)

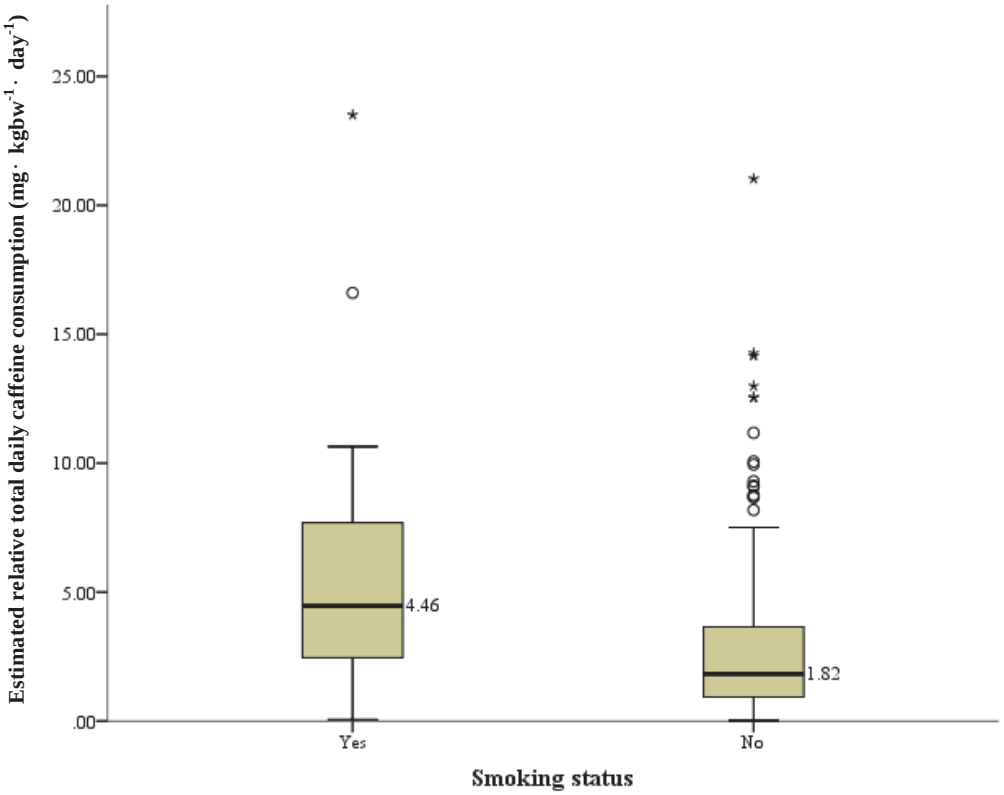

Figure 4.20: Distribution of estimated relative daily caffeine consumption (mg· kgbw^{-1}· day^{-1}) by smoking status (n= 282)

Caffeine contribution from different sources by smoking status

Daily consumption of caffeine from coffee (U= 2964.0, p= 0.002, r= -0.203) and energy drinks (U= 1055.0, p= 0.030, r= -0.192) was higher in those who smoked than those who did not (Table 4.21). There was no difference in daily consumption of caffeine from any of the other sources between those who smoked and those who did not (p> 0.05).

Table 4.21: Estimated daily caffeine consumption from different caffeine sources by smoking status (n= 314)

Caffeine source	Smokes (mg· day^{-1})	Does not smoke (mg· day^{-1})	Mann-Whitney test statistic (U)	p-value
Tea	25.79	26.53	2720.0	0.678
Coffee	214.33	97.10	2964.0	0.002
Chocolate	10.22	8.86	3703.0	0.627
Kola drinks	16.13	11.22	1656.0	0.259
Energy drinks	24.87	16.69	1055.0	0.030
Caffeinated RTDs	6.10	4.43	296.0	0.169
Caffeine-containing sports supplements	24.76	90.52	26.0	0.470
Caffeine tablets	6.70	6.70	11.0	0.833

RTD- Ready to drink alcoholic beverage

Estimated total caffeine consumption (absolute and relative to body weight) by participation in sport

There was no difference in estimated total daily caffeine consumption between those who were involved in sport and those who were not (U= 11498, p= 0.661). There was also no association between estimated caffeine consumption and participation in sport when expressed on a per kg of body weight basis (p= 0.945).

Caffeine contribution from different sources by participation in sport

There was no difference in daily caffeine consumption from different caffeine sources between those who play sport and those who do not (p>0.05) (Table 4.22).

Table 4.22: Estimated daily caffeine consumption from different caffeine sources by participation in sport (n= 314)

Caffeine source	Plays sport (mg· day^{-1})	Does not play sport (mg· day^{-1})	Mann-Whitney test statistic (U)	p-value
Tea	27.36	25.53	5812.5	0.413
Coffee	101.70	109.95	6922.5	0.837
Chocolate	9.02	8.86	7900.5	0.697
Kola drinks	12.32	11.73	2823.5	0.599
Energy drinks	17.19	21.42	1810.0	0.494
Caffeinated RTDs	6.10	6.05	342.5	0.295
Caffeine-containing sports supplements	30.17	30.17	9.5	0.934
Caffeine tablets	5.00	6.70	12.0	0.695

RTD- Ready to drink alcoholic beverage

4.7 Daily Caffeine Intakes Exceeding the 'Adverse Effect Level' (3 mg· kgbw^{-1}· day^{-1})

Of the total sample of caffeine consumers, over a third (34.4%; n= 108) had an estimated relative daily caffeine intake exceeding the reported 'adverse effect level' of 3 mg· kgbw^{-1}· day^{-1} (Thomson et al., 2014). Smokers were 3.34 times more likely to consume daily caffeine above this level than those who did not smoke (χ^2 (1) = 15.680, p< 0.001). Fisher's exact test showed that there was an association between age group and the likelihood of exceeding 3mg· kgbw^{-1}· day^{-1} of caffeine (p= 0.002). Post hoc testing revealed that the 19-30-year-old age group was 2.94 times more likely to exceed the 'adverse effect level' than the 16-18-year-old age group (p= 0.006), whereas the 31-50-year-old age group was 5.88 times more likely than the 16-18-year-old age group to

exceed the ‘adverse effect level’ (p= 0.002). No other demographic factor or participant characteristic was significantly associated with likelihood of exceeding the 3 $mg \cdot kgbw^{-1} \cdot day^{-1}$ ‘adverse effect level’ for caffeine (p> 0.05).

An association was seen between the consumption of certain caffeine containing products and the likelihood of exceeding the ‘daily adverse effect level’. Caffeine tablet consumers were 9.38 times more likely to exceed $3mg \cdot kgbw^{-1} \cdot day^{-1}$ than those who did not consume caffeine tablets (p= 0.001). Coffee consumers were 8.38 times more likely to exceed the $3mg \cdot kgbw^{-1} \cdot day^{-1}$ intake level than those who did not consume coffee (p< 0.001). Consumers of tea and RTDs were 1.88 times (p= 0.023) and 1.91 times (p= 0.026) respectively more likely to exceed the ‘adverse effect level’ of 3 $mg \cdot kgbw^{-1} \cdot day^{-1}$ than those who did not consume these caffeine sources. No other sources of caffeine were associated with caffeine intake exceeding 3 $mg \cdot kgbw^{-1} \cdot day^{-1}$ (p> 0.05).

4.8 Daily Caffeine Intakes Exceeding the Suggested ‘Safe Limit’ (400 $mg \cdot day^{-1}$)

Of the total sample of caffeine consumers, 14.3% (n= 45) had an estimated total daily caffeine intake exceeding the suggested safe caffeine consumption limit of 400 $mg \cdot day^{-1}$, with participants who smoked being 3.58 times more likely to exceed this level (χ^2 (1) = 11.694, p= 0.001). Fisher’s exact test showed that there was an association between age group and the likelihood of caffeine-consumers exceeding 400 $mg \cdot day^{-1}$ (p= 0.04). Once post hoc tests were carried out, this significant association was no longer seen (p> 0.05). No other demographic factor or participant characteristic was significantly associated with likelihood of exceeding the daily caffeine ‘safe limit’ (p> 0.05).

The consumption of coffee was associated with the likelihood of participants exceeding 400 mg· day^{-1} of caffeine, with those who consumed coffee being 16.29 times more likely to exceed this level than those who did not (χ^2 (1) = 13.752, p< 0.001). This association was also seen for the consumption of RTDs, with those who consumed RTDs being 2.26 times more likely to exceed 400 mg· day^{-1} than those who did not (χ^2 (1) = 5.303, p= 0.025). No other sources of caffeine were associated with caffeine intake exceeding the daily caffeine 'safe limit' (p> 0.05).

4.9 Perceived 'Adverse Symptoms' Post Caffeine Consumption

Of the total sample of caffeine consumers, 84.7% (n= 265) of participants reported at least one 'adverse symptom' post-caffeine consumption. The most common reported 'adverse symptoms' after caffeine consumption were "needing to pee a lot" (42.5% of caffeine consumers), "unable to sleep" (38%) and feeling "excited" (37.4%; Figure 4.21). Of those who reported at least one 'adverse symptom', 25.7% (n= 68) reported that these effects had a negative impact on their social life, work life or caused some kind of distress.

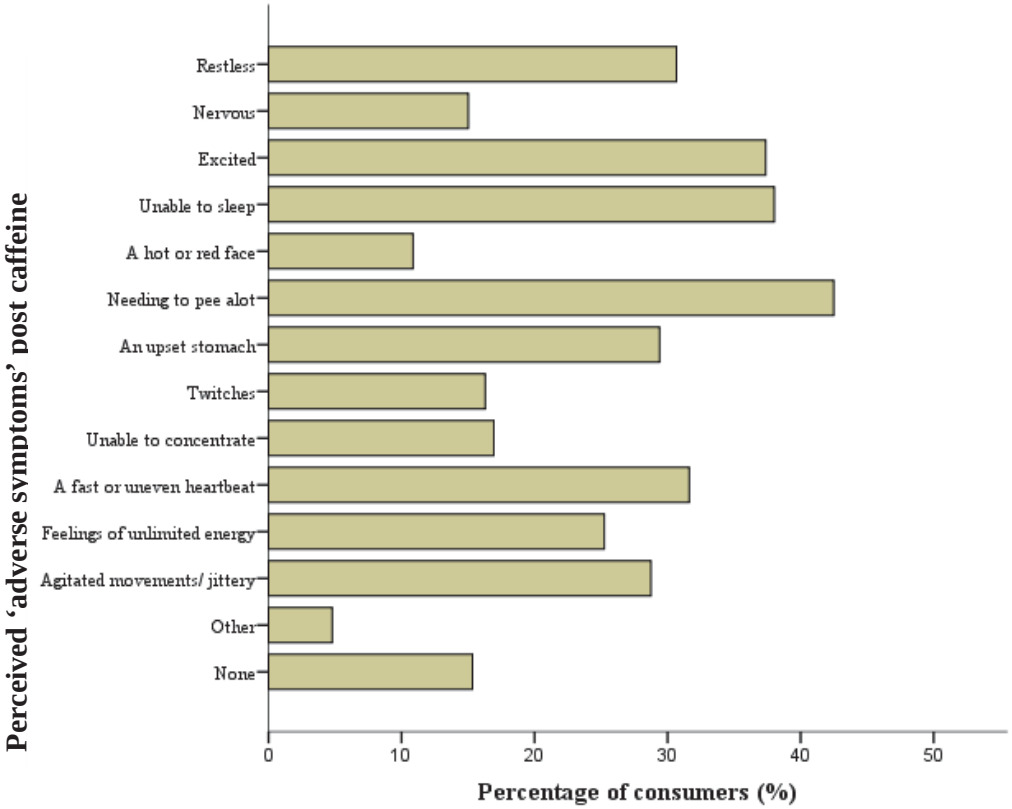

Figure 4.21: Perceived 'adverse symptoms' post consumption of caffeine (n= 314)

The caffeine sources with the highest percentage of participants who reported at least one 'adverse symptom' post-consumption, but that participants still regularly consumed these products, were energy drinks (77.3%) and coffee (76.9%). Similarly, the same caffeine sources had the highest percentage of 'non-consumers' who reported at least one 'adverse symptom' post-consumption (Coffee 26.7%; Energy drinks 14.8%).
For all caffeine sources, regular consumers were significantly more likely to report at least one 'adverse symptom' post-consumption than non-consumers ($p < 0.05$; Table 4.23).

Table 4.23: Likelihood of reporting at least one 'adverse symptom' post consumption of a caffeine source according to regularity of consumption (n= 317)

Caffeine source	Regularly consumes (% who report at least one 'adverse symptom' post consumption)	Does not regularly consume (% who report at least one 'adverse symptom' post consumption)	Pearson Chi-square value (χ^2)	p value	Odds ratio
Tea	29.5	5.6	21.076	< 0.001	7.12
Coffee	76.9	26.7	63.391	< 0.001	9.13
Chocolate	18.9	5.2	5.566[a]	0.018[a]	4.28
Kola drinks	26.3	5.0	27.541	< 0.001	6.82
Energy drinks	77.3	14.8	124.261	< 0.001	19.63
Caffeinated RTDs	43.1	6.6	51.914[a]	< 0.001[a]	10.78
Caffeine-containing sports supplements	61.9	2.7	-	< 0.001[b]	58.5
Caffeine tablets	63.6	2.3	-	< 0.001[b]	74.75

RTD- Ready to drink alcoholic beverage
[a]Yates continuity correction (Minimum expected count <10)
[b]Fisher's exact test (Minimum expected count <5)

The adverse symptoms experienced after consuming each specific caffeine sources are shown in Table 4.24. “Needing to pee a lot” was the most common adverse symptom experienced post consumption of tea (62.5%) and kola drinks (36.7%). The most common adverse symptom after consuming coffee was also “needing to pee a lot” (45.1%) but this was closely followed by “unable to sleep” (43.7%) and “excited” (39.8%). “Excited” was the most common adverse symptom experienced after consuming chocolate (38.5%), caffeinated RTDs (42.9%), and caffeine-containing sports supplements (38.1%). The most common adverse symptom experienced after consuming caffeine tablets (64.3%) and energy drinks was “unable to sleep” (40.2%), however for energy drinks this was closely followed by “needing to pee a lot” (39.4%), “excited” (38.6%), “restless” (37.0%), “a fast or uneven heart beat” (37.0%), and “feelings of unlimited energy” (36.2%).

Table 4.24: Perceived participant symptoms post consumption of different caffeine sources

	Adverse symptoms post consumption (% of respondents)										
Caffeine source	**Restless**	**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 or jittery**
Tea (n= 72)	8.3	12.5	25.0	11.1	62.5	18.1	4.2	1.4	6.9	9.7	5.6
Coffee (n= 206)	34.0	39.8	43.7	11.2	45.1	35.0	18.0	18.4	33.5	26.7	33.0
Chocolate (n= 52)	13.5	38.5	19.2	3.8	13.5	28.8	7.7	9.6	9.6	13.5	11.5
Kola drinks (n= 49)	16.3	28.6	28.6	6.1	36.7	26.5	8.2	6.1	8.2	12.2	12.2
Energy drinks (n= 127)	37.0	38.6	40.2	9.4	39.4	18.9	21.3	16.5	37.0	36.2	27.6
Caffeinated RTDs (n= 42)	16.7	42.9	33.3	14.3	33.3	23.8	11.9	14.3	23.8	16.7	11.9
Caffeine-containing sports supplements (n= 21)	9.5	38.1	19.0	4.8	23.8	9.5	9.5	4.8	23.8	19.0	4.8
Caffeine tablets (n= 14)	21.4	50.0	64.3	7.1	14.3	14.3	21.4	7.1	21.4	21.4	14.3

RTD- Ready to drink alcoholic beverage

N.B. the symptom “nervousness’ was omitted from this table as it was not reportedly linked to any specific caffeine source but was reported post caffeine consumption as a whole

Participants who reported “Excited” (U= 8109, p< 0.001, r= -0.245), “Unable to sleep” (U= 9073, p= 0.001, r= -0.180) and “Needing to pee a lot” (U= 10076, p= 0.017, r= -0.135) had a higher median daily caffeine than those who had no adverse effects (Table 4.25). There was a lower median daily intake of caffeine by participants who did not report any adverse symptoms post consumption of caffeine (U= 4128, p< 0.001, r= -0.219).

Table 4.25: Median daily caffeine intake vs perceived participant adverse symptoms (n= 314)

Perceived adverse symptoms post consumption	**Median daily caffeine intake of participants reporting adverse symptoms (mg· day^{-1})**	**Median daily caffeine intake of participants reporting no adverse symptoms (mg· day^{-1})**	**Mann-Whitney test statistic (U)**	**p value**
Restless	188.43	136.30	8527	0.011
Nervousness	168.49	140.69	5620	0.270
Excited	196.74	119.05	8109	< 0.001
Unable to sleep	181.79	132.57	9073	0.001
A hot or red face	164.79	145.75	4134	0.222
Needing to pee a lot	167.69	129.65	10076	0.017
An upset stomach	154.22	145.75	10152	0.985
Twitches	177.25	143.28	5793	0.133
Unable to concentrate	161.10	141.81	6465	0.479
A fast or uneven heartbeat	144.84	149.14	10367	0.761
Feelings of unlimited energy	154.12	146.73	8246	0.152
Agitated movements/ jittery	144.80	148.86	9551	0.504
Other	154.12	146.73	2132	0.763
None	61.36	159.81	4128	< 0.001

When total daily caffeine was expressed relative to body weight, intake was higher in those who reported “Excited”, “Unable to sleep”, and “Needing to pee a lot” post consumption in comparison to those who did not report these symptoms (Table 4.26).

Table 4.26: Median estimated daily caffeine intake expressed on a per kg body weight basis vs. perceived participant adverse symptoms (n= 314)

Perceived adverse symptoms post consumption	**Median daily caffeine intake of participants reporting adverse symptoms ($mg \cdot kgbw^{-1} \cdot day^{-1}$)**	**Median daily caffeine intake of participants reporting no adverse symptoms ($mg \cdot kgbw^{-1} \cdot day^{-1}$)**	**Mann-Whitney test statistic (U)**	**p value**
Restless	2.86	1.87	6725	0.006
Nervousness	2.41	2.24	4893	0.479
Excited	2.93	1.71	6526	< 0.001
Unable to sleep	2.84	1.75	7049	0.002
A hot or red face	2.69	2.24	3714	0.323
Needing to pee a lot	2.66	1.84	7873	0.014
An upset stomach	2.66	2.02	7443	0.290
Twitches	2.82	2.24	4817	0.297
Unable to concentrate	2.51	2.24	5162	0.480
A fast or uneven heartbeat	2.23	2.27	8136	0.719
Feelings of unlimited energy	2.30	2.25	6927	0.471
Agitated movements/ jittery	2.41	2.18	7598	0.372
Other	2.44	2.25	1774	0.801
None	0.99	2.45	3324	< 0.001

4.10 Caffeine Dependence

Of the total sample of caffeine consumers, 64.2% (n= 201) of participants reported dependence on at least one caffeine source. The caffeine sources which had the highest reported consumer dependence were coffee (59.3%) and energy drinks (32.8%) (Table 4.27). The caffeine source with the lowest reported dependence (1.74%) was caffeinated RTDs.

Table 4.27: Proportion of participants who reported dependence on caffeine sources

Caffeine source	Proportion of participants who are dependent[c] (%)
Tea (n= 227)	24.8
Coffee (n= 242)	59.3
Chocolate (n= 259)	19.8
Kola drinks (n= 156)	8.3
Energy drinks (n= 128)	32.8
Caffeinated RTDs (n= 58)	1.7
Caffeine-containing sports supplements (n= 21)	19
Caffeine tablets (n= 11)	18.2

RTD- Ready to drink alcoholic beverage
[c] of those who consume the product

4.11 Withdrawal Symptoms

Over half of the participants (52.7%; n= 165) reported that they did not suffer from any withdrawal symptoms shortly after stopping consumption of caffeine. The most common caffeine withdrawal symptom was “marked tiredness or drowsiness” which was reported by 31.3% of participants (Figure 4.22). More than one withdrawal symptom was reported by 13.4% (n= 42) of the participants who consumed caffeine. These withdrawal symptoms negatively impacted on social life, work life or caused

some kind of distress in almost half (45.9%; n= 68) of the participants who reported them.

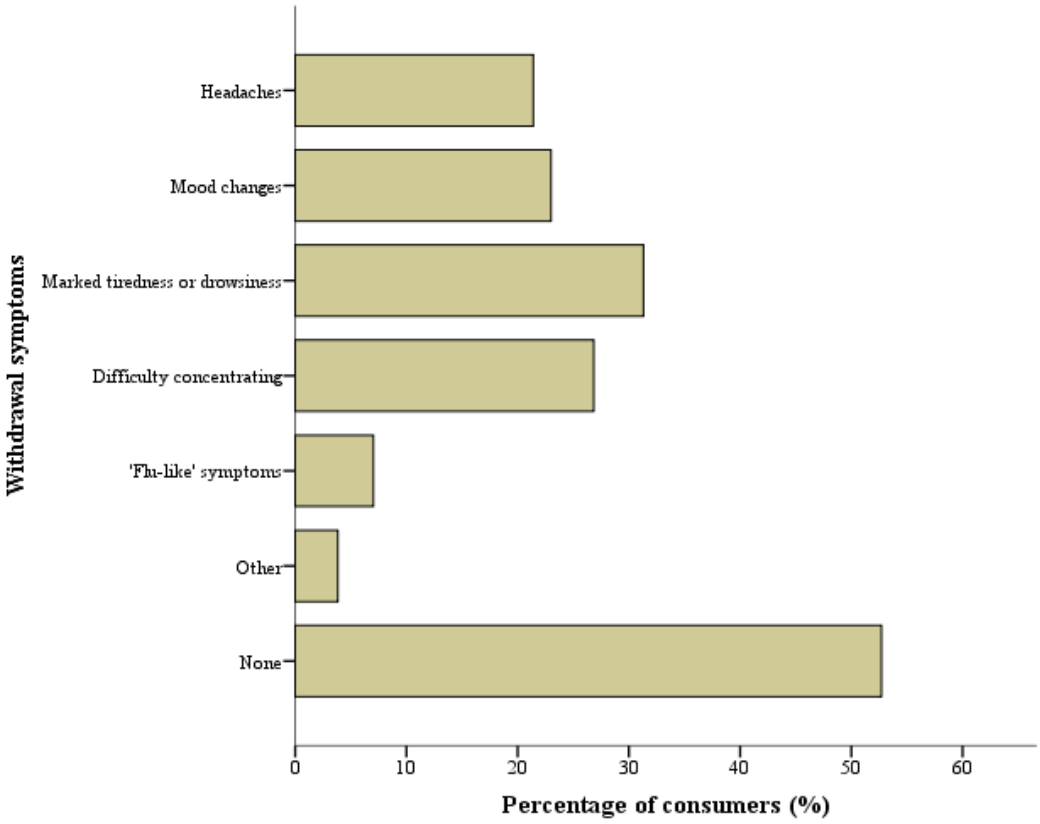

Figure 4.22: Withdrawal symptoms after stopping consumption of caffeine in the diet (n= 317)

Chapter 5

5.0 Discussion

This study sought to examine the caffeine consumption habits, motivations and experiences of New Zealand tertiary students in order to determine any possible caffeine-related health-risk in this population.

5.1 Overall Caffeine Consumption Habits

The majority (99.1%) of tertiary students who participated in this study reported that they regularly consumed at least one source of caffeine in their diet. This consumption prevalence is slightly higher than previously reported by Thomson et al. (2014), where 88% of New Zealand adults (≥15 years old) were estimated to be regular caffeine consumers. This discrepancy may be due to an overall increase in caffeine consumption over this time period or may be due to tertiary students being more likely to regularly consume caffeine. Studies from other countries which have examined caffeine consumption in tertiary students show the majority (87.8 - 98%) regularly consume caffeine from one or more sources (Lee et al., 2009; Lieberman et al., 2015; Mackus, van de Loo, Benson, Scholey, & Verster, 2016; Norton, Lazev, & Sullivan, 2011; Tannous & Al Kalash, 2014). It is also possible that the present study may report a slightly higher proportion of caffeine consumers as a result of the study recruitment procedures used. The advertisement posters (displaying a cup of coffee; Appendix C) and rewards for participation (i.e. receipt of personal caffeine-related genetic information and a research summary) may have been attention-grabbing and more attractive to caffeine consumers than non-caffeine consumers.

5.2 Main Sources of Caffeine Consumed and Contribution to Total Caffeine Intake

Chocolate, coffee, and tea were the caffeine sources consumed with the highest prevalence (81.7%, 76.3% and 71.9% respectively). Although chocolate was the most commonly consumed caffeine product, it only contributed 7.4% of the total daily caffeine intake due to its low caffeine content and low intake frequency. Previous research on chocolate has focused more on determining the reasons for consumption rather than the levels consumed, however the 1997 National Nutrition Survey (Russell et al., 1999) found that 35% of New Zealanders 15 years and over, consumed chocolate one or more times a week. Although our data is not directly comparable to this value due to our consumption frequency data being categorized by type/size of chocolate, we can say that at least 48.8% (largest percentage consumption; small milk chocolate bar) of New Zealand students consume chocolate one or more times a week. This larger percentage of regular consumption may reflect an increased consumption of chocolate in New Zealand overall, or that tertiary students are more likely to regularly consume chocolate than the general population, however further research would be required to determine this. Consumption of coffee was second to chocolate and was the largest caffeine contributor, providing an estimated two thirds (61.4%) of daily caffeine intake. Research in other countries also suggests high coffee consumption is common among tertiary students. Among psychology students in the US (Norton et al., 2011), coffee and espresso/lattes (reported as separate categories) were the most commonly consumed caffeine sources. Similarly, Mackus (2016) reported that in Dutch tertiary students' coffee contributed 50.8% towards total caffeine consumption. Although this value is lower than the current study's estimate, the Dutch study had only gathered caffeine consumption information over the past 24 hours and only included beverages. A study

in medical students in South Africa (Lee et al., 2009) showed coffee was the most commonly consumed caffeinated product (88.2%) and contributed about 80% of total caffeine intake (Lee et al., 2009). However, this same study measured prevalence of consumption of caffeine-containing products merely for academic purposes whereas the present study examined caffeine consumption for all purposes which may explain the differences in results. In summary, although studies have used different methods to assess caffeine consumption, it is evident that coffee is the largest contributor to caffeine intake in tertiary students in several countries.

Tea was the third most commonly consumed caffeine product, and contributed the second highest amount (14.4%) to total caffeine consumption. This result is in agreement with a US study that found that tea consumption had the second highest influence on total caffeine after coffee, although this contribution was lower in tertiary students than the general population (Brice & Smith, 2002). However, our results cannot be directly compared to this study as it did not include all caffeine-containing products (i.e. energy drinks/ shots, RTDs, sports supplements and caffeine tablets were not included).

Overall, energy drinks were consumed by 40.4% of tertiary students (15+ years old) and contributed 8% to total caffeine consumption. This is higher than the estimated prevalence of energy drink consumption of adult New Zealanders (15+ years old) reported in a sub-analysis of the Adult Nutrition Survey 2008/09 (3.1%; n= 138/4452) (Thomson et al., 2014). A rise in energy drink consumption over this time period is expected as worldwide energy drink consumption reportedly doubled between 2006 and 2012 (Global Data, 2015). Additionally, previous research has suggested that energy drink consumption is generally higher in tertiary students than in the general population (Norton et al., 2011; Pettit & DeBarr, 2011). When comparing to previous research

(Thomson et al., 2014), our results may indicate that the consumption frequency of energy drinks differs between tertiary students and the general population. The majority of the energy drink consumers in the present study only consumed them 1-3 times per month, whereas Thomson et al. (2014) found that 79.9% of energy drink consumers consumed one serving per day.

Kola drinks were consumed by just under half (49.2%) of the participants and contributed 5.3% towards the total caffeine intake. This is a much lower prevalence than that found in US tertiary students (81%) (Norton et al., 2011).

Caffeine-containing sports supplements were not commonly consumed (only 6.6% of participants) and only contributed 2.4% towards the total caffeine consumption. In addition, caffeine tablets had the lowest prevalence of consumption (3.5%) and contributed only 0.5% towards the estimated total daily caffeine intake. To our knowledge these products have not been included in any other caffeine-related research.

5.3 Prevalence of Consumption in Different Groups and Reasons for Consumption by Each Type of Product

Chocolate

Females were 2.35 times more likely to regularly consume chocolate than males. Previous research has found that females report a stronger level of liking and craving towards chocolate than males (Rozin, Levine, & Stoess, 1991), with craving levels reported to peak during the premenstrual period for about half of females who crave chocolate. Over half of the female participants in the present study reported consuming more chocolate during menstruation, which provides additional evidence towards a possible hormonal link to chocolate cravings (Zellner, Garriga-Trillo, Centeno, &

Wadsworth, 2004). Rozin et al. (1991) reported that sensory aspects are the chief motivation for chocolate consumption. This is confirmed in the present study where motivations for chocolate consumption for both genders were mainly sensory related (i.e. agreement "for the taste" - 95.4%; "as a treat or luxury food" – 88.8%; and "to comfort and relax myself" – 79.6%). Chocolate was consumed in greater amounts by those who live alone than those who live with family or flat with others. This could be due to chocolate's role as a 'comfort food' as it has been suggested that both sensory aspects and social situations contribute significantly to foods becoming 'comfort foods' (Weingarten & Kulikovsky, 1989).

Coffee

Overall, prevalence of coffee consumption was higher in females than males. This may be because the act of "going out for coffee" is more likely a female pleasure (Cowan, 1991), although the percentage of males and females who reported that they consume coffee with friends is not different (86.2% of females vs 79.1% of males; p= 0.214). The youngest age group (16-18 year-olds) consumed significantly less caffeine from coffee than the 19-30 and 31-50 year-old age groups. A number of different reasons could explain this result, for example, it is possible that since the younger age respondents are more likely to be in their first year of tertiary study than the other age groups, they may have a lower academic load (Ríos et al., 2013), resulting in a lesser need for consumption of caffeine in order to cope with academic stress. Additionally, they may not yet have acquired a strong coffee drinking habit. Only 40% of the 16-18 year-olds reported drinking coffee out of habit, whereas, 61% and 71.4% of 19-30 and 31-50 year-olds, respectively, reported drinking coffee out of habit.

Smokers were 3.73 times more likely to consume coffee than non-smokers and were more regular consumers of coffee, a finding consistent with that of similar studies (Klesges, Ray, & Klesges, 1994; Swanson, Lee, & Hopp, 1994). Total caffeine consumption in smokers was also higher than that of non-smokers, which is to be expected as coffee was the main contributor to total daily caffeine consumption in this study. Caffeine metabolism is increased by 30-50% in those who smoke tobacco (Murphy et al., 1988) and caffeine is therefore cleared from the body quicker than in non-smokers, thus reducing the risk of experiencing adverse side effects. There is also evidence that smoking blocks the subjective arousal effects of caffeine (Rose, 1987), hence causing smokers to consume more caffeine in order to achieve the arousing effects.

Tea

Prevalence of tea consumption was higher in females, which, as for coffee, may be due to tea drinking being considered more of a feminine than a masculine act (Kowaleski-Wallace, 1994). Klesges et al. (1994) also found that tea consumption was higher in females than males, however this was in the general population.

Tea was also more commonly consumed in those who did not have paid employment than those who had paid employment. To our knowledge, this finding has not been reported in any other studies and may reflect an income barrier to purchasing coffee. This is supported by the fact that 42.5% of participants with no paid employment reported consuming tea because it is cheaper than other hot drinks (versus 29% of those with paid employment).

Energy drinks

Although there was no difference in the prevalence of consumption of energy drinks according to gender, males regularly consumed higher amounts of caffeine from energy

drinks than females. Pettit and DeBarr (2011) also noted a higher energy drink consumption in males relative to females, however this study had a smaller sample size (n= 136), a disproportionate sample (61% female) and a narrower age range (18-24 years) than the current study. The current study therefore provides stronger evidence for the relationship between gender and energy drink consumption. K. E. Miller (2008), also reported a relationship between gender and energy drink consumption, and suggested the higher levels of conformity to masculine norms and higher risk-taking behaviour in males are positively associated with higher energy drink consumption. It should also be noted that the main reasons for not consuming energy drinks, as found in the current study, related to negative health aspects and high sugar content, although the percentage of responses for this reason was similar for males and females. A higher consumption of energy drinks was also associated with a higher consumption of kola drinks and caffeinated RTDs.

It is possible that tertiary students may consume energy drinks for an energy boost even though they understand they are not conducive to long-term health. A previous study reported that a focus group participant (tertiary student) stated they used energy drinks "To help pick me up, not for the taste. I know they're terrible for you, but sometimes you've got to do it, I find anyway" (Jensen, Forlini, Partridge, & Hall, 2016). This theory is supported by the main reasons for energy drink consumption reported in this study; "for energy" (90.6% of consumers), "to stay awake" (89.1% of consumers), "to wake up" (85.2% of consumers), and "for mental energy" (84.3% of consumers). In addition, the main reasons for not consuming energy drinks were related to negative health consequences (i.e. "There is too much sugar in it" and "It isn't 'good' for me"). As energy drinks are often marketed towards 18-35 year olds it is expected that consumption is more prevalent among this age group (Malinauskas et al., 2007).

However, only 21.1% of energy drink consumers reported being influenced by advertising, which suggests advertising either does not affect consumption patterns to a great extent or that the effect of this advertising is subliminal (Köster, 2009). In the current study there was a trend (p= 0.066) for a higher prevalence of consumption among those aged (16-18 and 19-30 years) versus those aged (31-50 and 51+ years). However, compared to the other age groups, the 31-50 and 51+ age brackets are under-represented in our study and also in relation to the tertiary student population statistics (Education Counts, 2016) ,therefore, this result may become significant with more participants in this age group.

As with coffee, those with paid employment were more likely to consume energy drinks than those without paid employment. The 'transactional model of stress and coping' provides an explanation for this relationship (Lazarus & Folkman, 1984). According to Dufour (2015), conflicting working and studying time schedules may mean the student is required to study late at night or the student is physically and mentally exhausted after expending a large amount of energy on academic work and must stay awake and alert during paid work situations and therefore uses caffeine as a coping method to achieve their goals. As mentioned earlier, energy drinks are mainly reported to be consumed for their expected energising and cognitive outcomes in this study making this theory plausible.

Kola drinks

Males consumed higher amounts of kola drinks than females. As with energy drinks, this may be due to men making poorer dietary choices as they are less weight conscious than women (Wardle et al., 2004).

Of all the caffeine sources, only kola drinks showed a significant positive correlation with BMI (r= 0.129; p= 0.026). The high sugar content and low levels of satiety that these drinks offer is thought to contribute to weight gain (DiMeglio & Mattes, 2000). Our study found a stronger relationship between kola drinks and BMI than previous studies (r= 0.05 and r= 0.09) (Vartanian, Schwartz, & Brownell, 2007), which analysed the association between BMI and all soft drinks including kola drinks (i.e. also those which do not contain caffeine). The larger effect size seen in our study, may be due to the caffeine content of kola drinks as there is evidence that the caffeine content of some soft drinks increases their consumption (Keast, Swinburn, Sayompark, Whitelock, & Riddell, 2015). The present study also included diet varieties of kola drinks, whereas previous studies have not. A larger effect size for the relationship between kola drinks and BMI may be achieved if diet varieties were not included in the same category. However, a number of factors, including SES, taste preference and availability, could influence the consumption of kola and diet kola drinks, therefore further research would be needed to determine whether kola drinks truly have a stronger relationship with BMI than soft drinks as a whole. In addition males had a significantly higher BMI than females in the present study, therefore we cannot be sure whether the relationship between BMI and higher kola drink consumption and gender and higher kola drink consumption occur independent of each other.

Those with paid employment had a higher consumption of kola drinks than those without paid employment. Existing evidence shows that a lower SES is associated with a higher consumption of soft drinks (including kola drinks) (Mishra, Ball, Arbuckle, & Crawford, 2002) and also with working more hours per week in the student population (Robotham, 2012). Therefore SES may act as a third variable which increases the likelihood of carrying out both behaviours, hence paid employment and kola drink

consumption may not have a direct relationship. This relationship could also be due to those with paid employment having more disposable income.

Smokers were more likely to consume kola drinks, energy drinks and RTDs. Smoking and other unhealthy behaviours are generally linked (Revicki, Sobal, & DeForge, 1991), therefore it is not surprising that smokers consume more of these sugar-sweetened beverages (SSB) than non-smokers. In addition, Schulze, Fung, Manson, Willett, and Hu (2006) found that this relationship is reciprocated where those who consume more SSB tend to smoke more. The present study did not gather information regarding smoking frequency, therefore cannot comment on whether this applies to the studied population.

Sports supplements

The respondents who participated in sport were more likely to consume caffeine-containing sports supplements. This result was expected as sports supplements are specifically formulated and marketed for use during sport/physical activity. A surprising finding however was that the median estimated daily consumption from caffeine containing sports supplements did not differ between those who play sport and those who do not. However, there was only one participant who consumed sports supplements but did not play sport, therefore this result is not likely to be representative of the actual situation.

Caffeine tablets

Two thirds (68%) of the participants who consumed caffeine tablets reported “I have never considered taking it” which suggests the product is not widely known or perhaps other products are preferred due to additional hedonic properties. As with energy drinks, those with paid employment were more likely to consume caffeine tablets. Since the main reasons for consumption of caffeine tablets match that of energy drinks (i.e.

mainly for the expected energising and cognitive outcomes), the same explanation in regards to a higher prevalence in those with paid employment can be given (i.e. the transactional model of stress and coping) (Dufour, 2015).

5.4 Estimated Daily Caffeine Consumption and Caffeine-Related Risk

The median estimated total daily caffeine consumption in New Zealand tertiary students was 146.73 mg· day^{-1} (mean of 212.8 mg· day^{-1}), which corresponds to 2.25 mg· $kgbw^{-1}$· day^{-1}. Although this average estimate is below the adverse effect level (3 mg· $kgbw^{-1}$· day^{-1}) suggested by Thomson et al. (2014), 34.4% of participants in this study exceeded this amount daily. In 2008/2009 the caffeine consumption of all adult New Zealanders (15+ years) averaged 196 mg· day^{-1} (2.6 mg· $kgbw^{-1}$· day^{-1}) (Thomson et al., 2014), hence 30% of adult New Zealanders were reported to exceed the adverse effect level daily. This value also included pregnant women for whom the adverse effect level was 200 mg· day^{-1}.

In this study, consumption of caffeine tablets, coffee, tea and caffeinated RTDs were associated with the proportion of participants who exceeded a caffeine intake of 3 mg· $kgbw^{-1}$· day^{-1}. Thomson et al. (2014) did not include caffeinated RTDs or caffeine tablets in their estimates, therefore this may explain why our estimate of those exceeding this level is higher. The youngest age group (16-18 year-olds) was less likely to exceed the adverse caffeine effect level than the 19-30 and 31-50 year-old age groups. This can be explained by the fact that the consumption of caffeine from coffee was higher in the 19-30 and 31-50 year-old age groups than the 16-18 year old age group and coffee was the greatest contributor to total caffeine intake.

Although it makes sense to compare the estimated caffeine risk in tertiary students to that of the population as a whole, the 400 mg· day^{-1} benchmark for risk is considered a more appropriate measure of risk for this study. Our estimates based on consumption per kg of body weight are not as reliable as the absolute estimate, as not all participants provided weight information (data available for 89.5% of caffeine consumers). Additionally, in the present study, weight and height measurements were self-reported in order to reduce participant burden. The median BMI of the participants (22.9 kg· m^{-2}) was lower than the mean BMI found in the 2008/09 National Nutrition Survey (27.6 kg· m^{-2}). This may be due to participant under reporting, or the fact that those with higher education are more likely to have a lower BMI (Molarius, Seidell, Sans, Tuomilehto, & Kuulasmaa, 2000).

The maximum estimated daily caffeine intake for an individual was 1988.14 mg· day^{-1}, and when expressed relative to body, was an extraordinary intake of 23.51 mg· kgbw^{-1}· day^{-1}. Of the total sample, 14.3% of participants exceeded the 400 mg· day^{-1} 'safe intake limit'. Smokers not only had a higher total daily caffeine consumption than non-smokers, they also were more likely to exceed an intake of 400 mg· day^{-1} (31.9% vs 11.6%), however only 14.8% of the total sample of participants were smokers. RTD consumers (24.1% vs 12.4%) and coffee consumers (18.6% vs 1.3%) were also more likely to exceed a caffeine intake of 400 mg· day^{-1}.

Although there was no difference in the proportion of participants exceeding 400 mg· day^{-1} or in total estimated daily caffeine consumption according to gender, relative daily consumption by weight was significantly higher in females than males. This is perhaps due to the fact that BMI was significantly higher in males than females and males were 2.51 times more likely to be overweight than females. Metabolism of caffeine in females is 20-30% faster than that of males (Nawrot et al., 2003), therefore

in theory females are likely to be able to consume relatively higher amounts of caffeine without adverse symptoms than males.

5.5 Experiences Regarding Caffeine Consumption

The majority (84.7%) of caffeine consumers in this study reported experiencing at least one symptom post caffeine consumption, and at least a quarter (25.7%) of these participants reported that these symptoms had a negative impact on their social life, work life, or caused some kind of distress. Although a wide range of symptoms were reported, the only symptoms which were associated with a higher daily consumption of caffeine were “excited”, “unable to sleep”, and “needing to pee a lot”. These symptoms were also three of the four most commonly reported symptoms in this study (not including “nervousness”). A study on college students in the USA also found that these three symptoms plus “restlessness” were the most common syptoms experienced post caffeine consumption (McIlvain et al., 2011). In the present study there was no association in the proportion of those experiencing these symptoms and whether they were regular consumers of the caffeine source or not, which suggests that these symptoms are not a significant factor in the decision to regularly consume caffeine products. This is also supported by a low response of “I react badly to it” from participants who do not consume different caffeine sources.

The caffeine sources for which the highest proportion of participants reported symptoms post consumption were energy drinks (77.3%) and coffee (76.9%). These were also the two caffeine sources which had the highest levels of self-reported dependence (32.8% and 59.3% of consumers respectively). These results may be related to the relatively high caffeine content of these products or the fact that they are commonly known to

contain high caffeine (Mackus et al., 2016) and therefore the participants expected these symptoms.

Less than half of the total participants (47.3%) reported suffering withdrawal symptoms after stopping consumption of caffeine, but almost half of these participants (45.9%) reported that withdrawal symptoms had an impact on their social life, work life or caused some kind of distress. A review of experimental studies estimated the prevalence of experiencing caffeine withdrawal symptoms to be between 25 – 100 % (Griffiths & Woodson, 1988). McIlvain et al. (2011) found that the prevalence of withdrawal symptoms was 51%, whilst Dews, Curtis, Hanford, & O'Brien (1999) reported this to be 11%, with 25% of these participants reporting that these were severe enough to affect aspects of daily life. The most common withdrawal symptom in the present study was "marked tiredness or drowsiness" (31.3%). Previous studies have found fatigue and/or headache to be the most common withdrawal symptoms reported (Bernstein, Carroll, Thuras, Cosgrove, & Roth, 2002; Dews et al., 1999; Griffiths & Woodson, 1988).

Chapter 6

6.0 Conclusion

6.1 Summary of Results/ Main Findings

In conclusion, coffee is the biggest contributor to daily caffeine intake in New Zealand tertiary students and the primary reason for consumption is for increased wakefulness and enhanced energy. Approximately 15% of the sample participants reported consuming above the 400mg daily ‘safe limit’ which suggests a potential public health issue. The information from this study contributes to understanding the motivations behind caffeine consumption in New Zealand tertiary students and provides the basis for developing a strategy to reduce caffeine risk in this group.

6.2 Strengths

To our knowledge, this is the most extensive investigation on caffeine consumption in New Zealand tertiary students. Previous studies have not measured all the major caffeine products in a single study. This is important as we could examine the contribution of different caffeine products to the total caffeine consumption. In this way we are able to determine which caffeine products may require special attention in regards to ameliorating caffeine-related risk.

The current study provides reasons for consumption and non-consumption separately for each product, whereas most other studies report the reasons for caffeine consumption collectively. This is an issue, as all caffeine products cannot be treated the same since most products provide additional ingredients and factors which may impact on reasons for and against consumption (e.g sensory and social aspects).

6.3 Limitations

Retrospective data collection relies on accuracy of the participants' memory, which can lead to inaccuracy, however for any data collection involving questionnaires, some level of recall error is unavoidable (Coughlin, 1990).

There is difficulty in obtaining accurate and current data on the caffeine content of the wide range of products. Although this was minimised as much as possible, there will be inevitable error in the consumption estimates due to difficulty ascertaining the exact caffeine content and the consumption patterns of the wide range of products.

Among the tertiary population caffeine consumption habits and motivations may differ at times during the year in relation to periods of higher academic stress (e.g. exam period). Kopacz, Wawrzyniak, Hamulka, and Górnicka (2013) provide evidence for this, where 63% of tertiary students tended to increase their caffeine consumption during exam periods. We were unable to account for this factor due to time restrictions on data collection, however the consumption frequency of the products ("how often… on average") in the questionnaire items may reduce the confounding temporal effect.

Another limitation of the present study is that some ethnic groups are underrepresented (Maori – 5.4% study sample vs 22.8% tertiary population statistics; Pasifika – 4% study sample vs 9.94% tertiary population statistics), whilst others are overrepresented (Asian – 31.9% study sample vs 13.05% tertiary population statistics) (Education Counts, 2016). Previous research shows that the rate of caffeine clearance differs significantly between some ethnic groups (Asian and African slower than Caucasians) (Gunes & Dahl, 2008), which may impact on the amount of caffeine consumed. It is also known that ethnicity can influence food and beverage choice (Contento, Michela, & Goldberg, 1988; Devine, Sobal, Bisogni, & Connors, 1999) and therefore the results we have

obtained may not be representative of the true population. Although the present study gathered information on the ethnicity of the participants, differences were not explored due to low sample sizes in some ethnic categories, and further, ethical approval did not cover this analysis. Future studies are warranted to explore ethnic differences in caffeine consumption.

6.4 Use of the Findings

The public health consequences of caffeine consumption can only be determined once data is available on the amount of caffeine currently being consumed by New Zealanders (as the benefits and risks are dose dependent). Research also suggests that in order to reduce the risk of substance-related harm (such as caffeine intoxication) it is important to have an understanding of the consumers' motivations for its use. The present study provides useful information for multiple stakeholders (e.g. the scientific community, public health professionals, regulatory agencies, consumers, retailers and the food industry) in regards to caffeine consumption habits and the motivations behind caffeine consumption by tertiary students in New Zealand. This study provides a deeper understanding of the complex relationship between the factors that drive caffeine consumption particularly in regards to consumer demographics and characteristics. Armed with this information, strategies can be put into place (e.g. improved labelling, consumer education, additional regulations etc.) in order to ameliorate caffeine-related risk in this population group.

6.5 Future Directions

- A nationwide study using the validated CaffCo questionnaire is warranted. It is important to use the same methodology in order to accurately compare caffeine consumption habits and motivations between different population groups.
- A wider range of recruitment methods should be applied when expanding the data collection nationwide (e.g mall stands, community groups, marae visits etc.) in order to obtain a representative sample of New Zealanders.
- Since New Zealand is an ethnically diverse nation, analysis according to ethnicity should be applied in the future. By using a wider range of recruitment procedures (as suggested above) we are more likely to obtain an ethnically diverse sample.
- The saliva samples collected during this study should be genetically analysed and further statistical analysis should be carried on the tertiary student population in order to determine genetic associations and how these affect caffeine related factors such as consumption habits and experiences. In addition, any future studies using the CaffCo questionnaire should be carried out in conjunction with genetic testing.

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Appendices

Appendix A: Massey University Human Ethics Committee approval letter

Date: 03 February 2016

Dear Saskia Stachyshyn

Re: Ethics Notification - **SOA 15/76 - Caffeine consumption and the impact of genetic variants on caffeine-related responses in New Zealanders**

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 Wednesday, 3 February.

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

Dr Brian Finch
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
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Appendix B: Participant Information Sheet

School of Food and Nutrition
Massey University
Private Bag 102904
North Shore City 0745, Auckland, New Zealand

Does genetics affect caffeine intake habits of New Zealanders?

PARTICIPANT INFORMATION SHEET

Invitation to participate in research

We are looking for individuals over 15 years of age to take part in a study looking at caffeine consumption.

Researcher Introduction

Hello, my name is Saskia Stachyshyn and I am currently studying towards a Master of Science degree in Nutrition and Dietetics at Massey University. I am undertaking this research project as it is a requirement in partial fulfilment of my degree. My supervisors are Dr Kay Rutherfurd-Markwick, Dr Ajmol Ali and Dr Carol Wham. Together, the supervisors have an extensive background of research in the fields of nutrition, biochemistry, physiology and public health

Project Description

The positive effects of caffeine intake are well known, whereas the negative effects of caffeine intake aren't as widely recognized. Recently it has been found that the risk of

side effects has a large genetic basis. One of the most studied caffeine related genes is CYP1A2 which codes for the enzyme that metabolises caffeine- cytochrome p450. This enzyme is also responsible for the metabolism of multiple other drugs. There are three variations of this gene which determine whether an individual is a slow, intermediate or fast metaboliser of caffeine. Slow metabolisers are considered to have a higher risk of the negative effects of caffeine due to caffeine remaining in the blood stream for a longer period of time. One variant of this gene has been associated with an increased risk of myocardial infarction (heart attack). Another gene with an established relationship to caffeine is the adenosine receptor gene, ADORA2A. A variation of this gene has been found to be associated with Panic Disorder. This same variant has been associated with caffeine-induced anxiety, sleep changes and caffeine sensitivity. There is currently very little information about caffeine intake and the reasons behind the consumption of caffeine in New Zealand. New Zealand has an ever-growing supply of caffeinated products on the market, making this is a very important research area. This study aims to gather information on the caffeine consumption habits, knowledge, beliefs and responses of New Zealanders with the use of a questionnaire. In addition, genetic testing will be carried out with the use of saliva samples. This information will help to determine groups who are at the most risk of suffering the ill-effects of caffeine consumption.

Participant recruitment and involvement

We are looking for approximately 400 participants to take part in this study in order to obtain sufficient statistical power. As we require a representative, unbiased sample, a range of recruitment strategies will be used. This may include social media (e.g. Facebook), news and print media, on-line recruitment agencies, posters and flyers at

popular venues, interactive displays at shopping malls, community and church groups and by word of mouth. To take part in this study you must be:

- 15 years of age or older
- Competent in reading English
- Willing to provide a saliva sample
- Willing to complete a questionnaire.

We will invite you to fill out a questionnaire and provide a saliva sample. Completing the questionnaire will take approximately 20 minutes. Providing the saliva sample will take approximately 5 minutes.

At the completion of the study, you will receive a summary of the results and will have the option to receive your caffeine-related genetic information. This will include the caffeine-related genes tested, your particular genotype and an explanation of what this means. The decision whether to receive your genetic information will be made at the time of the completion of the consent form, however we will allow a three month period from the time of analysis in the case of a change in mind (after the three month period is over the genetic results will be anonymized and therefore cannot be linked back to the participant). Please contact the researcher if after completing the consent form you have changed your mind in regards to receiving your genetic information. Your name will also be placed into a random draw where you will have the chance to receive an iPad.

Project procedures

Screening

Potential participants will receive a hard copy or link to the information sheet and screening questionnaire. The screening questionnaire will determine whether you meet

the criteria to participate and whether you would like to complete the questionnaire in hard or soft (online) copy. If you meet the criteria, you will be asked to fill out a consent form before progressing. If you're aged 15-17 years old you will also need parental consent to take part in the study.

Questionnaire

You will have the choice of whether to fill out the questionnaire at the data collection stand or at home. If you chose to complete the questionnaire at home, you will be given a link to the questionnaire and a unique identifier code.

Saliva collection

A 0.5-1mL saliva sample will be required in order to carry out genetic analysis. We ask that you refrain from eating or drinking for 30 minutes prior to collection. The collection will be carried out by drooling into a sterile tube. A preservation buffer must then be added into the saliva in a ratio of 1:1. The saliva sample must have a turnaround time of ~20 days from when the saliva is deposited to when the sample is received in the lab.

Data Management

All data and materials will be solely used for this study. Only the researchers and supervisors will have access to the data and consent forms. Hard copies of data will be kept in a locked filing cabinet on campus at Massey University Albany, Oteha Rohe campus. Soft copies will be stored on password protected computers in password protected files, where the password is only known to the research team.

In order to maintain confidentiality, a coding system will be used where each participant is given a unique identifier. This code will be used to link together your questionnaire,

saliva sample, and consent form data. This means that although you will not be anonymous (to the research team), all data will be anonymised.

Saliva samples will be analysed and transformed into soft form data at the first chance possible. Saliva samples will be disposed of as soon as analysis is complete by Dr Austen Ganley and Lisa Mill. This could take up to three months after receiving the sample. The completely anonymised raw results data will be kept for 5 years, after which will be disposed of by Dr Ajmol Ali or another member of staff.

Participant's Rights

You are under no obligation to accept this invitation. Should you choose to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study up until submission of the questionnaire;
- ask any questions regarding the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the study findings when research has been concluded;
- If you feel concerned about the possible effects on you of your caffeine consumption, you may request a copy of your genetic information. Note: Before agreeing to this you should be aware that under New Zealand law an insurance company could ask you to disclose such information should you apply for life or health related insurance – such as medical cover. You could be obliged to disclose it even if the insurer does not ask for it expressly. Not disclosing it could result in the insurer not having to pay out under the policy. Should you choose not to receive this information for your protection should

the current insurance situation change, the possibility of identifying your genetic information will be removed three months after it becomes available.

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.

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 15/76. If you have any concerns about the conduct of this research, please contact Mr Jeremy Hubbard, Chair, Massey University Human Ethics Committee: Southern A, telephone 04 801 5799 x 63487, email humanethicsoutha@massey.ac.nz.

Project Contacts

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

Saskia Stachyshyn (School of Food and Nutrition)

Email: caffeinestudy@outlook.co.nz

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Appendix C: Advertisement poster

Does genetics affect caffeine intake habits of New Zealanders?

Help us find out by participating in an exciting study and be in the draw to receive an iPad!

Participants must be:

- 15 years of age or older
- Competent in reading English
- Willing to provide a saliva sample
- Willing to complete a questionnaire

We will provide:

- A summary of the findings once research is complete
- Your caffeine-related genetic information if you wish to receive it

Contact:

Saskia Stachyshyn
School of Food and Nutrition
Massey University
Email: caffeinestudy@outlook.co.nz
Phone: 021 02308536

Appendix D: Paper copy of CaffCo questionnaire

please note

- Questions 6-8 are screening questions. If the participant is 15 years old and has completed the screening questions online then there is no need to include them.

- If the participant has completed the screening questions and is 15 years old, only send out parts of the questionnaire that correspond with the products they have selected as consuming.

- Questions 9-12 are questions included on the online questionnaire for those participants aged 15 years old to choose how they would like to receive the paper copy of the questionnaire, and do not need to be included in the paper version.

CaffCo – Caffeine Consumption Habits Questionnaire

Q1

Caffeine Habits Questionnaire

Thank you for taking the time to complete this questionnaire
This questionnaire examines the reasons for consumption of various caffeine-containing beverages and foods found in New Zealand.
The questionnaire has been designed to be completed by people aged 15 years and over.

Data collected from this questionnaire is confidential.

Further information can be found in the information sheet included; please read this before continuing with the questionnaire.

The questionnaire will take around 15-20 minutes to complete.

Q2 **INFORMATION SHEET HERE**

Q3 **ETHICS STATEMENT HERE**

Q4
I have read and understand the information sheet provided and agree to participate in the study under the terms laid out in the information sheet.

- ❍ Yes
- ❍ No

Q5
Please enter your study identification number
……
……

Q6
Which of these items do you drink / eat? Include those that you only consume occasionally.

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

Q7
What age group do you fit into?
- ❍ 14 years or under
- ❍ 15 years old
- ❍ 16-18 years old
- ❍ 19-30 years old
- ❍ 31-50 years old
- ❍ 51-70 years old
- ❍ 71 years or over

Q8
What is your gender?
- ❍ Male
- ❍ Female
- ❍ Other

Q9
Thank you for expressing your interest to participate in this survey.
Due to your age, we would like to send you a paper copy of the questionnaire to fill out.
A prepaid return envelope will be included to send the survey back.
Alternatively, this can be emailed to you, printed and filled out and then scanned and sent back to us.

Q10
Please select below how you would like to receive the questionnaire.
- ❍ By email
- ❍ By post

Answer If Please select below how you would like to receive the questionnaire. By email is selected

Q11 Please enter your email address below
……
…….

Answer If Please select below how you would like to receive the questionnaire. By post is selected

Q12 Please enter your name and postal address below
……
…….

Tea

Q13

How often do you drink the following types of tea (on average)?

	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) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q14 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	❍	❍	❍	❍
- when I am stressed	❍	❍	❍	❍
- because I feel that I am influenced by advertising	❍	❍	❍	❍
- because it is easily available	❍	❍	❍	❍
- to wake up	❍	❍	❍	❍
	Strongly Agree	Agree	Disagree	Strongly Disagree
- 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	❍	❍	❍	❍
- while travelling	❍	❍	❍	❍
- because I think coffee has too much caffeine in it	❍	❍	❍	❍

Q15
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

Q16
In which environments do you drink tea? Select all that apply.

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

Coffee
Q17
How often do you drink the following types of coffee (on average)?

	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) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

	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
Large espresso coffee (double shot) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Decaffeinated coffee (1 cup) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Iced coffee (1 glass) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q18 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	❍	❍	❍	❍
- for energy				
- while travelling	❍	❍	❍	❍
- with family	❍	❍	❍	❍
- when I am stressed	❍	❍	❍	❍
- while driving long distances	❍	❍	❍	❍
- for physical energy	❍	❍	❍	❍
- for mental energy	❍	❍	❍	❍
	Strongly Agree	Agree	Disagree	Strongly Disagree
- 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	❍	❍	❍	❍

Q19 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

Q20 In which environments do you drink coffee? Select all that apply.

- ❑ A home environment (your own or others)
- ❑ A cafe environment
- ❑ A work environment
- ❑ A study environment
- ❑ A socialising environment
- ❑ A physical exercise environment
- ❑ Other (please specify) _____

Decaf tea and coffee
Q21
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'.

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):
……
……
…….....

Chocolate

Q22 How often do you eat the following types of chocolate (on average)?

The pictures below include some examples of products, chose the one closest to what you consume.

	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) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q23
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 (females)	❍	❍	❍	❍
- 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	❍	❍	❍	❍
- while travelling	❍	❍	❍	❍
- to replace other food or meals	❍	❍	❍	❍
- whenever it is offered to me	❍	❍	❍	❍
- out of boredom	❍	❍	❍	❍
- when I am stressed	❍	❍	❍	❍
	Strongly Agree	Agree	Disagree	Strongly Disagree
- because others are eating it	❍	❍	❍	❍
- out of habit	❍	❍	❍	❍
- because it is easily available	❍	❍	❍	❍

Q24
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

Q25
Which pattern of eating chocolate describes your own? You may choose more than one option.

- ❑ 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) _____

Q26
In which environments do you eat chocolate? Select all that apply.

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

Kola-flavoured drinks

Q27

How often do you drink the following types of kola-flavoured drinks (on average)? This includes brands such as Coca-Cola, Pepsi and other brands of kola-flavoured drinks. 'Diet', 'Zero', 'Max' varieties are included in their own category below ('diet'), rather than with 'regular' kola drinks.

	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 kola drink (250ml) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 can of regular kola drink (355ml) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 small bottle of regular kola drink (600ml) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

	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 DIET / ZERO / MAX kola drink (250ml) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

1 can of DIET / ZERO / MAX kola drink (355ml) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
1 small bottle of DIET / ZERO / MAX kola drink (600ml) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q28
Think about **your own reasons** for drinking kola drinks (including 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 kola drinks (including 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	❍	❍	❍	❍
- while travelling	❍	❍	❍	❍
- when I am stressed	❍	❍	❍	❍
- whenever it is offered to me	❍	❍	❍	❍
- for energy	❍	❍	❍	❍
- because they are easily available	❍	❍	❍	❍
- out of boredom	❍	❍	❍	❍
- instead of coffee when the weather is hot	❍	❍	❍	❍
	Strongly Agree	Agree	Disagree	Strongly Disagree
- 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	❍	❍	❍	❍

Q29 What time of day do you drink kola 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

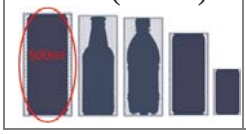
Q30 In which environments do you drink kola drinks (both regular and diet)? Select all that apply.

- ❑ A home environment (your own or others)
- ❑ A cafe environment
- ❑ A work environment
- ❑ A party environment
- ❑ A study environment
- ❑ A physical exercise environment
- ❑ A bar environment
- ❑ Other (please specify) _____

Energy Drinks

Q31 Energy drinks include brands such as Red Bull, V, Mother, Monster Energy and others.

Q32 How often do you drink the following types of energy drinks (on average)?

	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) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q33
Think about **your own reasons** for drinking energy drinks.
Read the following statements about the different reasons for coffee consumption and consider whether you 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	❍	❍	❍	❍
	Strongly Agree	Agree	Disagree	Strongly Disagree
- when I am stressed	❍	❍	❍	❍
- because others are drinking it	❍	❍	❍	❍

- because I feel that I am influenced by advertising	❍	❍	❍	❍
- to replace food or meals	❍	❍	❍	❍
- with friends	❍	❍	❍	❍
- while travelling	❍	❍	❍	❍
- while smoking	❍	❍	❍	❍
- with takeaway food	❍	❍	❍	❍
- to stay awake	❍	❍	❍	❍
- to wake me up	❍	❍	❍	❍
- because they are easily available	❍	❍	❍	❍
- because it is the drink I have with food	❍	❍	❍	❍

Q34
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

Q35
In which environments do you drink energy drinks? (Select all that apply)

- ❑ A home environment (your own or others)
- ❑ A cafe environment
- ❑ A work environment
- ❑ A party environment
- ❑ A physical exercise environment
- ❑ A socialising environment
- ❑ A study environment
- ❑ A bar environment
- ❑ Other (please specify) _____

Caffeinated alcoholic RTDs

Q36 Caffeinated alcoholic RTDs are premixed alcoholic drinks with either a **kola base** (e.g. Jack Daniels, Jim Beam, Woodstock, Coruba and kola etc) or with **added caffeine or guarana** (e.g. some Smirnoff Ice, Purple Goanna).
The pictures below include some examples of products, however there may be products not pictured. **Chose the one closest to what you consume.**

Examples of a RTD can:

Examples of an RTD bottle:

Q37 How often do you drink caffeinated RTDs (on average)?

	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)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q38 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 caffeinated 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	❍	❍	❍	❍
- when I am stressed	❍	❍	❍	❍
- 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	❍	❍	❍	❍
	Strongly Agree	Agree	Disagree	Strongly Disagree
- while travelling	❍	❍	❍	❍
- with friends	❍	❍	❍	❍

- with family	❍	❍	❍	❍
- for physical energy	❍	❍	❍	❍
- because they are cheaper than other alcoholic drinks	❍	❍	❍	❍
- instead of spirits	❍	❍	❍	❍
- to comfort and relax me	❍	❍	❍	❍

Q39

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

Q40

In which environments do you drink caffeinated RTDs? (Select all that apply)

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

Caffeinated pre-workout supplements and sports gels

Q41

How often do you take caffeinated pre-workout sports supplements or sports gels (on average)?

	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 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q42
Think about **your own reasons** for using sports supplements.
Read the following statements about the different reasons for sports supplement 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	❍	❍	❍	❍
- while travelling	❍	❍	❍	❍
- for energy	❍	❍	❍	❍
- to replace food or meals	❍	❍	❍	❍
- because they are easy to transport	❍	❍	❍	❍
- because others are using them	❍	❍	❍	❍
- out of habit	❍	❍	❍	❍
- with friends	❍	❍	❍	❍

Q43
The following is a list of different types of physical activities.
Select 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):
……
……
…….....
.....
Q44
In which environments do take caffeinated pre-workout sports supplements or sports gels? (Select all that apply)

- ❑ A party environment
- ❑ A physical exercise environment
- ❑ A socialising environment
- ❑ Other (please specify) _____

Caffeine tablets
Q45
Caffeine tablets in include No Doz, Thermo, AllMax, Caffeine Pro, Inner Amour and others.

Q46 How often do you take caffeine tablets (on average)?

	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) 	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

	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 **200mg** caffeine (e.g. Thermo, AllMax, Myprotein Caffeine Pro, Inner Armor etc)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Other (please specify):

……
……
……
……
……
……

Q47
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	❍	❍	❍	❍
- while travelling	❍	❍	❍	❍
- because others are using them	❍	❍	❍	❍
- for mental energy	❍	❍	❍	❍
- while driving long distances	❍	❍	❍	❍
- because I feel that I am influenced by advertising	❍	❍	❍	❍
- to stay awake	❍	❍	❍	❍
	Strongly Agree	Agree	Disagree	Strongly Disagree
- with friends	❍	❍	❍	❍

Q48
In which environments do you drink take caffeine tablets?

- ❑ A work environment
- ❑ A party environment
- ❑ A physical exercise environment
- ❑ A study environment
- ❑ A socialising environment
- ❑ Other (please specify) _____

Replacing food or meals - Please fill in this question if you ever use tea, coffee, chocolate, kola drinks, energy drinks, caffeinated RTDs, caffeinated sports supplements or caffeine tablets to replace food or meals. **If you do not do this, you do not need to fill in the questions.**

Q49 When I use these products to replace food or meals, I do it because...

	Tea	Coffee	Drinking chocolate	Eating chocolate	Kola 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	❑	❑	❑	❑	❑	❑	❑	❑	❑
I enjoy the product more than food	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q50 Are there any other reasons that you use these products to replace food or meals?

Other (please specify):……
…….....

Feelings of dependency

Q51
Have you ever felt dependent on any of the following products?
For example - you have felt that you needed them to 'feel normal' or to 'get through the day'.

- ❑ Tea
- ❑ Coffee
- ❑ Chocolate
- ❑ Kola-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

Q52
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

If you selected ‘No, I have never experienced any of these’ to Q52, please skip ahead to Q55.

Q53
With which products did these symptoms occur (within a day of when you stopped consuming them)?
Select only the options that apply to you.

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

Other symptoms that occurred within a day of not using these products (please specify):
……
……..……
…….....

Q54
Did these negative effects impact on your social life, work life or cause you any kind of distress?
❍ Yes
❍ No

Q55
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

If you selected 'No, I have never felt any of these effects shortly after consuming caffeinated products' for Q55, please skip ahead to Q61.

Q56
With which products did these symptoms occur **shortly after consuming these products**?

	Tea	Coffee	Chocolate	Kola-flavoured drinks	Energy drinks / shots	Caffeinated sports supplements / sports gels	Caffeine tablets
- 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	❑	❑	❑	❑	❑	❑	❑
	Tea	Coffee	Chocolate	Kola-flavoured drinks	Energy drinks / shots	Caffeinated sports supplements / sports gels	Caffeine tablets
- Feelings of	❑	❑	❑	❑	❑	❑	❑

unlimited energy - Agitated movements	❑	❑	❑	❑	❑	❑	❑

Other (please specify):……
…….....

Q57 Did these negative effects (from Q55) impact on your social life, work life or cause you any kind of distress?

❍ Yes
❍ N

Q58 Have the effects mentioned above ever led to any of the following? Select the options that are relevant.

	I have never had concern about these effects	Worry or concern	Talking to someone about these effects	Seeking help to stop these effects	First aid being applied	Hospitalisation
- Restless	❑	❑	❑	❑	❑	❑
- Nervous	❑	❑	❑	❑	❑	❑
	I have never had concern about these effects	Worry or concern	Talking to someone about these effects	Seeking help to stop these effects	First aid being applied	Hospitalisation
- Excited	❑	❑	❑	❑	❑	❑
- Unable to sleep	❑	❑	❑	❑	❑	❑
- A hot or red face	❑	❑	❑	❑	❑	❑
- Needing to pee a lot	❑	❑	❑	❑	❑	❑
- An upset stomach	❑	❑	❑	❑	❑	❑
- Unable to concentrate	❑	❑	❑	❑	❑	❑
- Twitches	❑	❑	❑	❑	❑	❑

- A fast or uneven heartbeat	❑	❑	❑	❑	❑	❑
- Feelings of unlimited energy	❑	❑	❑	❑	❑	❑
- Agitated movements	❑	❑	❑	❑	❑	❑

Other (please specify):
……
……
……

Please only answer questions Q59 – Q62 if they are relevant to you.

Q59
If you have ever asked for help to try and stop these effects (from Q58), who did you contact?
Select as many options as apply.

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

Q60 Has anyone ever talked to you specifically about your caffeine intake?
- ❍ Yes
- ❍ No

Q61 For the following products, please select the main reasons why you might not 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.

	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 it due to medical reasons
- Tea	❑	❑	❑	❑	❑	❑	❑	❑	❑
- Coffee	❑	❑	❑	❑	❑	❑	❑	❑	❑
- Chocolate	❑	❑	❑	❑	❑	❑	❑	❑	❑
- Kola-flavoured drinks	❑	❑	❑	❑	❑	❑	❑	❑	❑
- Energy drinks / energy shots	❑	❑	❑	❑	❑	❑	❑	❑	❑
- Caffeinated alcoholic RTDs	❑	❑	❑	❑	❑	❑	❑	❑	❑
- Caffeinated sports supplements / sports gels	❑	❑	❑	❑	❑	❑	❑	❑	❑
- Caffeine tablets	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q62 Is there any other reason why you don't consume these products? (Please specify product and reason if applicable):
……
……..

Q63
The following are statements on attitudes and behaviours around caffeinated products. Read the following statements and consider whether you 'agree', 'strongly agree', are ‘unsure’, '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 kola-flavoured drinks in the fridge at home	❍	❍	❍	❍	❍
Kola-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 kola drinks and energy drinks in the morning	❍	❍	❍	❍	❍

Q64
Think 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	❑	❑	❑	❑	❑	❑	❑	❑
- Kola drinks	❑	❑	❑	❑	❑	❑	❑	❑
- Energy drinks / energy shots	❑	❑	❑	❑	❑	❑	❑	❑
- Caffeinated RTDs	❑	❑	❑	❑	❑	❑	❑	❑
- Caffeinated pre-workout sports supplements / sports gels	❑	❑	❑	❑	❑	❑	❑	❑
- Caffeine tablets	❑	❑	❑	❑	❑	❑	❑	❑

Q65
Think about the following items.
Is there a gender that you think of as being the main consumers for each product?

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

Q66
What is your ethnicity?
You may choose as many that apply to you.

- ❑ European
- ❑ NZ European
- ❑ Maori
- ❑ Samoan
- ❑ Cook Islands Maori
- ❑ Tongan
- ❑ Niuean
- ❑ Tokelauan
- ❑ Fijian
- ❑ Southeast Asian
- ❑ Chinese
- ❑ Indian
- ❑ Korean
- ❑ Middle Eastern
- ❑ Latin American
- ❑ African
- ❑ Other (please specify) _____

Q67
Employment status (choose more than one option if applicable):

- ❑ Student
- ❑ Unemployed
- ❑ Part time worker
- ❑ Full time worker

Q68
If employed, does your job involve any of the following?

	Yes	No
Manual labour	❍	❍
Driving long distances	❍	❍
Shift work	❍	❍

Q69
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
- ❍ Bachelors Degree
- ❍ Postgraduate degree

Q70
What is your living situation?

- ❍ Living alone
- ❍ Living in a family home with others
- ❍ Flatting with others
- ❍ Other (please specify) _____

Q71
Do you smoke?

- ❍ Yes
- ❍ No
- ❍ Occasionally
- ❍ Prefer not to answer

Q72 (for female participants)
Are you currently on any type of oral contraceptive?

- ❍ Yes
- ❍ No
- ❍ Prefer not to answer

Q73
How much do you weigh (kg)?
- ❍ Kg - _____
- ❍ Don't know / prefer not to answer

Q74
How tall are you (cm)?
- ❍ Cm - _____
- ❍ Don't know / prefer not to answer

Q75
Thank you for taking your time to complete this questionnaire. Please feel free to contact our researchers for any further inquiries.

STUDY CONTACT DETAILS HERE

Appendix E: Additional results- Frequency of consumption of caffeine-containing products

	Frequency of consumption (% of participants)									
Product	**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) (n= 199)	37.3	14.5	17.4	8.5	11.4	4.1	4.7	2.2	0	0
Black tea (1 cup) (n= 197)	37.9	12.3	9.5	7.9	16.1	4.7	5.0	5.7	0.9	0
Iced tea (1 glass) (n= 153)	51.8	31.2	9.1	4.1	2.5	0.6	0.3	0.3	0	0
Decaffeinated tea (1 cup) (n= 54)	83	5.7	4.4	1.6	3.5	0.9	0.6	0.3	0	0
Instant coffee (made with 1 tsp coffee powder) (n= 182)	42.6	16.7	9.8	6.3	9.5	2.8	5.7	6	0.3	0.3
Plunger/drip coffee (250mL) (n= 156)	50.8	16.1	10.4	4.7	7.6	1.9	6.6	1.9	0	0
Small espresso coffee (single shot) (n= 169)	46.7	12.6	12	7.6	11.4	3.2	4.4	2.2	0	0
Large espresso coffee (double shot) (n= 174)	45.2	13.2	10.4	6.3	9.5	5.4	6.6	2.8	0.6	0
Decaffeinated coffee (1 cup) (n= 58)	81.7	9.1	5.4	1.9	0.9	0	0.6	0	0.3	0

Iced coffee (1 glass) (n= 154)	51.5	30.9	9.8	5.7	1.9	0.3	0	0	0	0
Small milk chocolate bar (50g) (n= 225)	29	22.1	24	11.7	9.1	2.8	0.9	0.3	0	0
Large milk chocolate block (200-250g) (n= 207)	34.7	31.2	17.4	10.1	5.4	0.9	0	0.3	0	0
Small dark chocolate bar (50g) (n= 205)	35.3	24.9	21.8	10.1	5.4	0.9	1.3	0.3	0	0
Large dark chocolate block (200-250g) (n= 176)	44.5	32.5	13.6	4.4	3.5	0.3	1.3	0	0	0
Hot chocolate (1 medium cup) (n= 231)	27.1	28.4	17.7	11	9.1	3.2	3.2	0.3	0	0
1 glass of regular kola drink (250ml) (n= 138)	56.4	14.8	15.8	6	5.4	0.6	0.9	0	0	0
1 can of regular kola drink (355ml) (n= 131)	58.6	17.4	13.2	5.4	3.8	0.9	0.3	0.3	0	0
1 small bottle of regular kola drink (600ml) (n= 123)	61.2	21.1	8.8	5	3.2	0.6	0	0	0	0
1 glass of DIET / ZERO / MAX kola drink (250ml) (n= 87)	72.5	14.2	6.9	3.2	2.2	0.6	0.3	0	0	0
1 can of DIET / ZERO / MAX kola drink (355ml) (n= 78)	75.4	13.9	5.7	3.2	0.9	0.6	0	0.3	0	0

1 small bottle of DIET / ZERO / MAX kola drink (600ml) (n= 69)	78.2	12.3	4.7	2.2	1.6	0.9	0	0	0	0
1 energy shot (n= 37)	88.3	5.7	2.8	0.9	1.6	0.6	0	0	0	0
1 small can of energy drink (250ml) (n= 115)	63.7	15.1	12	3.2	4.4	1.3	0.3	0	0	0
1 small bottle of energy drink (350ml) (n= 99)	68.7	12.9	11.4	2.8	2.8	1.3	0	0	0	0
1 large can / bottle of energy drink (500ml) (n= 81)	74.4	10.7	8.2	2.8	2.5	0.9	0	0.3	0	0
1 caffeinated RTD can (250-330ml) (n= 53)	83.3	5.7	6.3	2.5	1.6	0.6	0	0	0	0
1 caffeinated RTD bottle (330 -350ml) (n= 52)	83.6	7.3	5.0	2.5	1.6	0	0	0	0	0
Pre-workout sports supplements (n= 21)	93.4	0.6	1.9	1.3	1.3	0.3	1.3	0	0	0
Sports gels (n= 7)	97.8	1.3	0.6	0.3	0	0	0	0	0	0
1 caffeine tablet containing 50mg of caffeine (n= 0)	0	0	0	0	0	0	0	0	0	0
1 caffeine tablet containing 100mg of caffeine (n= 10)	96.8	1.3	0.9	0.6	0.3	0	0	0	0	0

1 caffeine tablet containing 200mg caffeine (n= 1)	99.7	0	0	0	0	0	0.3	0	0	0

RTD- Ready to drink alcoholic beverage