Original research article

An examination of consumer exposure to caffeine from commercial coffee and coffee-flavoured milk

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Abstract

A cross-section of Australian "Espresso/short black" coffee and coffee-flavoured milk samples were purchased and analysed for their caffeine content using micellar electrokinetic capillary chromatography (MEKC). Coffees were collected using convenience cluster sampling across four major cities. Packaged coffee-flavoured milks were collected from national grocery distributors. In all, 131 espresso samples and 20 coffee-flavoured milks were analysed. The mean (±SD) quantity of caffeine from espresso coffee was 107±37 mg/serving with a concentration of 2550±1030 mg/L. The mean (±SD) quantity of caffeine from coffee-flavoured milk was 99±50 mg/carton with a concentration of 193±90 mg/L. There was considerable variation in caffeine content across both categories and within the same espresso brand purchased at different locations. In total, 42 samples (27.5%) contained ≥120 mg per serving of caffeine, and 20 samples (13.1%) exceeded 165 mg per serving. The expanded caffeine data supports our original findings which indicated that the probability of consumer exposure to high caffeine doses from popular coffee beverages in Australia is greater than previously reported.

Keywords: Caffeine; Coffee; Variability; Consumer exposure: Food safety; Food analysis; Food composition

1 Introduction

Caffeine is probably the most widely used pharmacologically active substance in the world, and its influence on human health has been studied and discussed extensively (Committee on Toxicology, 2001; Desbrow et al. 2007; Nawrot et al. 2003; Scientific Committee on Food, 1999; Smith et al. 2000). The debate regarding the impact of caffeine on health relies initially on the strength of establishing an epidemiological link between caffeine consumption level and concurrent health events which occur across a defined population and period. The accurate estimation of caffeine consumption relies, in turn, on having reliable information on the frequency of consumption and caffeine content of commonly consumed dietary items.

Although caffeine is found in a number of foods, it is most frequently consumed in coffee, tea and cola beverages (Frary et al. 2005). It is recognised that beverages with caffeine as a natural component will have a wide range of caffeine levels. These variances are likely the result of many factors which include the species of plant origin (Mazzafera and Silvarolla 2010), growing environment, effects of commercial processing and storage along with variances at the retail level such as amount of coffee or tea used, the extraction method (e.g. percolated, drip etc) and the temperature and amount of water used in beverage preparation.

Interestingly, preliminary data from the US demonstrated that a large caffeine variance (259-564 mg/dose) was observed when the same specialty coffee (Starbucks® Breakfast Blend) was purchased on consecutive days (i.e. intra-drink variance) from a single outlet (McCusker et al 2003). This indicates that a significant proportion of caffeine variance remains despite a number of the supply variables being controlled.

To assess likely consumer exposure to caffeine from popular commercial coffee beverages we initially quantified the content and range of caffeine found in commercial espresso coffee (n=97) purchased from different outlets across one geographical region of Australia (i.e. the Gold Coast) (Desbrow et al 2007). These caffeine values were similar to data collected on commercial coffee prepared throughout the United Kingdom (Food Standards Agency, 2004). The wide range of caffeine concentrations and number of heavily caffeinated samples differentiated these findings from frequently cited textbook values reporting the caffeine content of commercial coffee. Consequently, we concluded that individual or population based quantification of caffeine intake when those under consideration purchase retail coffee or use ground coffee varieties at home was prone to large errors and, more importantly, a potential underestimation of caffeine intake because of early lower estimates of caffeine dose.

In Australia, caffeine is now added (often in the form of guarana) to some already caffeinated foods (e.g. coffee-flavoured milks, which are popular pre-packaged, ready-to-consume drinks) as a “functional” ingredient by some manufacturers. This example of a change to the food supply will only serve to further complicate our ability to clarify consumer level exposure to caffeine.

Given the natural variation in caffeine content of coffee, the increasing national popularity of coffee consumption (in all its forms) (ABS 2007) and the current food labelling regulations (Australian manufacturers are not required to state caffeine concentrations on products with naturally occurring caffeine (FSANZ 2010) there is a need to have accurate and independent information on the caffeine content of common coffee beverages.

Therefore the aims of this study were to a) broaden the geographical spread of espresso coffee samples collected within Australia; b) describe the extent of caffeine variance occurring when the same espresso brand is purchased at different locations (intra-drink variance); and c) to quantify the caffeine content of popular commercially prepared coffee-flavoured milk beverages and to reconcile these values against the manufacturer's reported values. The clarification of caffeine content and the extent of its variance in retail coffees will a) improve the accuracy of estimations of caffeine consumption in Australia and consequently any likely association with ill-health, b) result in more reliable advice from health care providers concerning beverage recommendations and health risks and c) enable greater awareness within the population as to potential exposure of an individual to a given caffeine dose.

2 Methods

2.1 Study Design

A cross-section of "Espresso/short black" coffee and coffee-flavoured milk samples were purchased. Hot espresso coffees were collected using convenience cluster sampling across four major cities. Cold coffee-flavoured milks were collected from national grocery distributors.

2.2 Sample Collection

Espresso Samples: A single "Take-away Espresso/short black" coffee sample was purchased from retail vendors housing an espresso machine. The original data sample included 97 espressos collected on the Gold Coast (Desbrow et al 2007). An additional 34 samples were subsequently collected using the same sampling method from retail outlets in the central business districts of Brisbane (n=10), Sydney (n=10) and Melbourne (n=14). Briefly, the samples were served in the vendors' own cups and subsequently decanted into vials that were chilled then weighed and volume determined prior to freezing and subsequent caffeine analysis. To standardise the sampling method, the researchers, if asked, would indicate "single shot" espressos, otherwise no further instruction was provided. The rationale for only collecting espresso coffee was that it limits many variables (e.g. serving size, milk, plain water, sugar etc) in the coffee making procedure and that the espresso "shot" often forms the basis of many other types of retail coffee (e.g. lattes, cappuccinos etc) and therefore the caffeine dose found in an espresso will be equal to (if not less than) those found in larger beverages.

Coffee-Flavoured Milk Samples: 20 varieties of commercial iced coffee were purchased on 3 occasions (i.e. different production dates) from national grocery distributors located on the Gold Coast. Samples were kept cold prior to subsequent caffeine analysis and standard serving sizes where recorded to estimate likely consumer exposure (i.e. concentration x volume). Drink manufacturers were contacted to provide the reported caffeine content of each drink.

2.3 Sample preparation

A milk coffee sample (10 mL) was added to a centrifuge tube (50 mL), followed by ethanol (10 mL), gently but thoroughly mixed and allowed to stand (15 minutes) until precipitation of solids occurs. The tube was centrifuged at 2000 rpm for 3 minutes. The supernatant (2 mL) was placed in a 13x100 mm culture tube and the ethanol was evaporated under a stream of nitrogen at room temperature. To the resultant residue of around 1 mL was added approximately 2 mL of deionized water followed by 0.75mL of 0.1M H3PO4, 0.75mL 0.05M Sodium dodecyl sulphate and 0.5mL dehydroacetic acid as internal standard (500ppm) and finally made up to 5.0mL with deionized water. The solutions were mixed thoroughly and filtered through a polyvinylidenedifluoride (Millex HV) membrane (0.45 μm) before analysis.

2.4 Standards preparation

Standard solutions of caffeine containing constant amounts of dehydroacetic acid were prepared. Caffeine concentrations of 10, 20, 30, 40 and 50 milligram/kilogram (mg/L) together with a constant 50 (mg/L) of dehydroacetic acid were employed.

2.5 Sample Analysis

The caffeine analysis was performed using Micellar Electrokinetic Capillary Chromatography (MEKC) according to the procedure reported by Thompson and co-workers (Thompson et al. 1995). The instrument employed was a Beckman Coulter MDQ Capillary Electrophoresis Unit fitted with an uncoated fused-silica capillary column (57cm x 75 μm) with an inlet to window length of around 50cm and employing a diode array detector.

The run buffer consisted of SDS (25 mM) and disodium tetraborate (12.5 mM, pH 9.2). The test sample was loaded under a pressure of 0.5 psi for 5 seconds and the instrument operated at 20 kV and 27 degrees C. Analytical quality control included the analysis of duplicate and spiked samples, whilst recent participation in interlaboratory proficiency studies on caffeine has provided a good measure of analytical competence.

2.6 Statistical Analysis

Descriptive statistics of caffeine dose and concentration (mean, SD, coefficient of variation (CV), range) were determined. Variance from manufacturers reported caffeine intake in coffee-flavoured milk beverages is illustrated via Bland-Altman plot. One way analysis of variance (ANOVA) was applied to assess if mean espresso caffeine concentrations of samples differed between geographical collection points.

2.7 Ethics

The study was reviewed and approved by the Griffith University Human Research Ethics Committee.

3 Results

Espresso Samples: Table 1 provides a descriptive summary (mean, median, SD, CV and range) of the espresso analysis results; in all, 131 espresso samples were collected. The mean (±SD) caffeine concentration was 2550±1030 mg/L, and ranged from 580 to 7000 mg/L. Thirty four samples (25.9%) contained 120 mg/serving of caffeine or higher. No statistical significance was demonstrated ($p=0.719$) between caffeine content and its location of origin. Table 2 describes the variability in caffeine when the same espresso sample was ordered at different outlets of the same retail vendor (note: data are included only where ≥4 outlets were sampled).

Coffee-Flavoured Milk Samples: Table 3 provides a descriptive summary (mean, SD and range) of the analysis results. 58 samples were analysed (i.e. 19 varieties on 3 occasions + 1 variety on 1 occasion). The mean (±SD) caffeine concentration was 1930±90 mg/L, the median was 1745 mg/L and values ranged from 660 to 3290 mg/L. The average CV across production dates was 8.4% and ranged from 1.0 to 19.0%. Caffeine per serving (concentration x volume) ranged from 33 to 197 mg/serving; 17 of 20 beverages had caffeine concentrations in excess of the manufacturer's claims. Figure 1 is a Bland-Altman plot indicating the strength of relationship between the measured and manufacturer's claimed caffeine content. Five of these beverages (25% of the sample) had >19% more caffeine than claimed (that is, in excess of the maximum CV observed with production date variance).

4 Discussion

This study aimed to expand the database of independently tested caffeine values derived from popular coffee-based products available to Australian consumers. The main finding of this study was that the caffeine content of popular coffee-based sources was highly variable and could result in higher than anticipated caffeine intakes. The expanded caffeine analysis conducted on commercial espresso coffee confirms that the mean caffeine content (107 mg/serving) is higher than earlier international reports of 78, 35, 85 and 62 mg/serving, respectively by Barone and Roberts (1996), Harland (2000), Knight et al. (2004) and Mandel (2002). These Australian values are in agreement with values found in retail coffees from the United Kingdom (105 mg/serving) (Food Standards Agency, 2004) and on home-prepared retail market coffee in Portugal (98mg/serving) (Candeias et al 2009). Consequently, any individual or population based quantification of caffeine intake where those involved purchase retail coffee or use ground coffee varieties at home is prone to potential errors. Furthermore, the potential for a significant underestimation of caffeine intake if relying on historical caffeine content values clearly exists.

The extent of caffeine variance observed when a consumer purchases a commercial coffee (inter-drink variance) is large (current range 25-214 mg/serving). This range is likely to reflect the variable nature of the retail coffee environment (i.e. the numerous coffee roasting wholesalers who supply a wide variety of coffee blends) as well as any variance in the method and technique of the barista (i.e. amount of coffee, amount and temperature of water etc). It now appears that the intra-drink caffeine variance (i.e. the variance observed when the same drink is either purchased from different locations (current study) or from the same location on different days (McCusker et al 2003) is also considerable. The current results indicate when the same brand of espresso coffee was purchased on ≥4 occasions from different locations the coefficient of variation was typically >15% and that for 5 brands this variation was ≥30%. Intra-drink variances of this magnitude make any estimates of caffeine consumption at the individual level very difficult, even when the individual's commercial coffee purchasing patterns are consistent.

In Australia, pre-packaged coffee-flavoured milks are supplied by a number of manufacturers and are likely to contribute to the caffeine intake of many individuals including children and adolescents (personal observation). National food labelling requirements do not make it mandatory for manufacturers of such drinks (with naturally occurring caffeine) to quantify the caffeine content of beverages, making it problematic for consumer to compare products on a caffeine content basis. It has been suggested however, that the caffeine levels in foods with naturally occurring caffeine will not normally exceed 100 mg in a standard serving (Smith et al. 2000). Fifteen (75%) of the 20 coffee-flavoured cold milk varieties included within present comparison contained ≤120 mg/serving of caffeine. This indicates that these varieties are in accordance with the previous suggestion as they contain similar amounts of caffeine to that found in the hot coffee drinks. Of some public health concern is that the remaining five samples contained concentrations of caffeine approaching (or exceeding) the upper limit of caffeine permissible within Australian formulated energy drinks (i.e. 32 mg/100mL) (FSANZ 2010). Given that these coffee beverages are served in large volumes (≤500 ml) they represent a significant caffeine source that may not be recognised as such by inadvertent consumers or their guardians.

It appears that the production of commercial coffee-flavoured milks produces substantially less intra-drink caffeine variance (average CV 8.4%) than commercial espresso coffee. This result is not surprising and most likely reflects the reduction in methodological variables associated with mass-scale coffee production. However, despite this relatively small day-to-day variance in caffeine content, manufacturers of coffee-flavoured milks were typically poor at reporting (usually underestimating) the caffeine content of their drinks. Eight (40%) of the drinks contained more caffeine than could be explained by the CV of that beverage when purchased on three separate occasions. Five (25%) drinks contain more caffeine than the maximum 19% CV observed by the most “inconsistent” drink sampled. Taken collectively, some coffee-flavoured milks provide the potential for consistently high caffeine exposures to unwitting consumers. Consequently it is our recommendation that coffee-flavoured milk beverages be required to conform to the same labelling requirements as those required for formulated energy drinks. This change would increase consumer capacity to make informed choices regarding the caffeine content of beverages and for the accuracy of the such labelling to be regulated by independent authorities.

Of further public health concern is the potential for exposure to higher than recommended amounts of caffeine in vulnerable population groups (e.g., reproductive-age women and children). In an environment of uncertainty regarding the effects of caffeine on health the prudent public health approach is to remain conservative. The present data further indicate that it is difficult for health care professionals to provide any reliable advice other than to “abstain, drink decaffeinated beverages or have no more than one caffeinated retail ground coffee per day” if, for example, they wish to ensure their pregnant clients stay below a level of 300 mg/day of caffeine (Nawrot et al 2003), or when providing advice to parents for children to “avoid cold iced coffee beverages” if they wish to keep caffeine intakes ≤2.5 mg/kg body weight as is also recommended (Nawrot et al 2003).

5 Conclusion

This study provides further information on the caffeine content and the extent of its variance in popular Australian retail coffee products. The data will enable health professionals and their clients to have a more informed understanding of the likely caffeine exposures associated with commercial coffee consumption. Furthermore, the reliability of estimations of caffeine consumption in Australia and consequently its relationship with ill-health can henceforth be achieved with greater confidence.

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289 **Figure captions**

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291 **Figure I: Bland-Altman plot (95% limits of agreement) between the measured and**
292 **manufacturer's claimed caffeine content.**

Table 1
Sample numbers, mean, standard deviation and range of caffeine (mg/serve) content of espresso coffees purchased at different locations.

	N	Mean	Median	SD	Min	Max
Gold Coast	97	106	96	38	25	214
Brisbane	10	113	107	37	73	189
Sydney	10	112	105	34	54	168
Melbourne	14	108	105	33	63	168
TOTAL	**131**	**107**	**99**	**37**	**25**	**214**

ANOVA Caffeine vs Location P=0.719

Table 2
Sample numbers, mean, standard deviation, coefficient of variation (CV) and range of caffeine (mg/serve) content of espresso coffees purchased from the same retailer across different locations.

Coffee Chain*	n	Mean	SD	CV(%)	Max	Min
Coffee Club®	7	113	38	33.6	177	82
Gloria Jeans®	6	145	11	7.6	162	130
Muffin Break®	6	137	49	35.8	186	68
Donut King®	6	134	51	38.1	214	82
BB's®	5	115	42	36.5	189	81
Starbucks®	4	79	13	16.5	91	63
McDonalds®	4	70	13	18.6	83	54
Zarraffas®	4	62	11	17.7	75	49
Goldstein's®	4	91	27	29.7	114	54

* Only samples collected at ≥4 locations were included within this analysis.

Table 3
Mean, standard deviation and range of caffeine (mg/100mL and mg/serve) content of coffee-flavoured milk purchased from national grocery distributors.

Brand	Mean (Caffeine(mg)/100mL)	SD*	Container Volume	Caffeine/serve	Manufacturer's Report (Caffeine(mg)/100mL)	% Difference to Manufacturer
Breaka Strong®	32.9	0.8	600	197.4	28	17.5
Dare Double Espresso®	35.4	1.9	500	177.2	20	77
Ice Break Loaded®	34.4	2.0	500	171.8	32	7.5
Rush Intense Coffee®	30.8	3.5	500	153.8	27	14
Ice Break®	28.1	2.6	500	140.7	23.2	21
Dare Espresso®	24.0	2.4	500	119.8	14	71
Farmers Union®	19.1	1.2	600	114.8	18	6
Jacaranda®	19.1	1.1	600	114.6	11	74
Farmers Union Light®†	17.8	-	600	106.8	18.8	-5.5
Big M Double Strength®	19.2	2.7	500	96.0	20	-4
Breaka®	17.1	2.7	500	85.5	14.8	15.5
Big M Edge®	17.0	0.7	500	84.8	15	13
Breaka Lite®	14.7	2.8	500	73.5	13.1	12
Dare Capuccino®	12.9	1.4	500	64.5	12	7.5
Rush Wicked Latte®	12.4	1.4	500	61.8	10	24
Rush Mocha Kenya®	12.0	0.1	500	60.2	11	9
Dare White Chocolate Mocha®	9.7	1.1	500	48.7	N/A	N/A
Oak®	12.4	0.9	300	37.3	15	-17
Woolworth's Iced Coffee®	11.2	0.3	300	33.6	N/A	N/A
Browne's Cappuccino®	6.6	0.4	500	33.0	N/A	N/A
Average(SD)*	**19.3(8.7)**			**99(50)**		

*Indicates SD of samples from one brand across three production dates. N/A indicates Not available from manufacturer.† Indicates only purchased on one occasion.

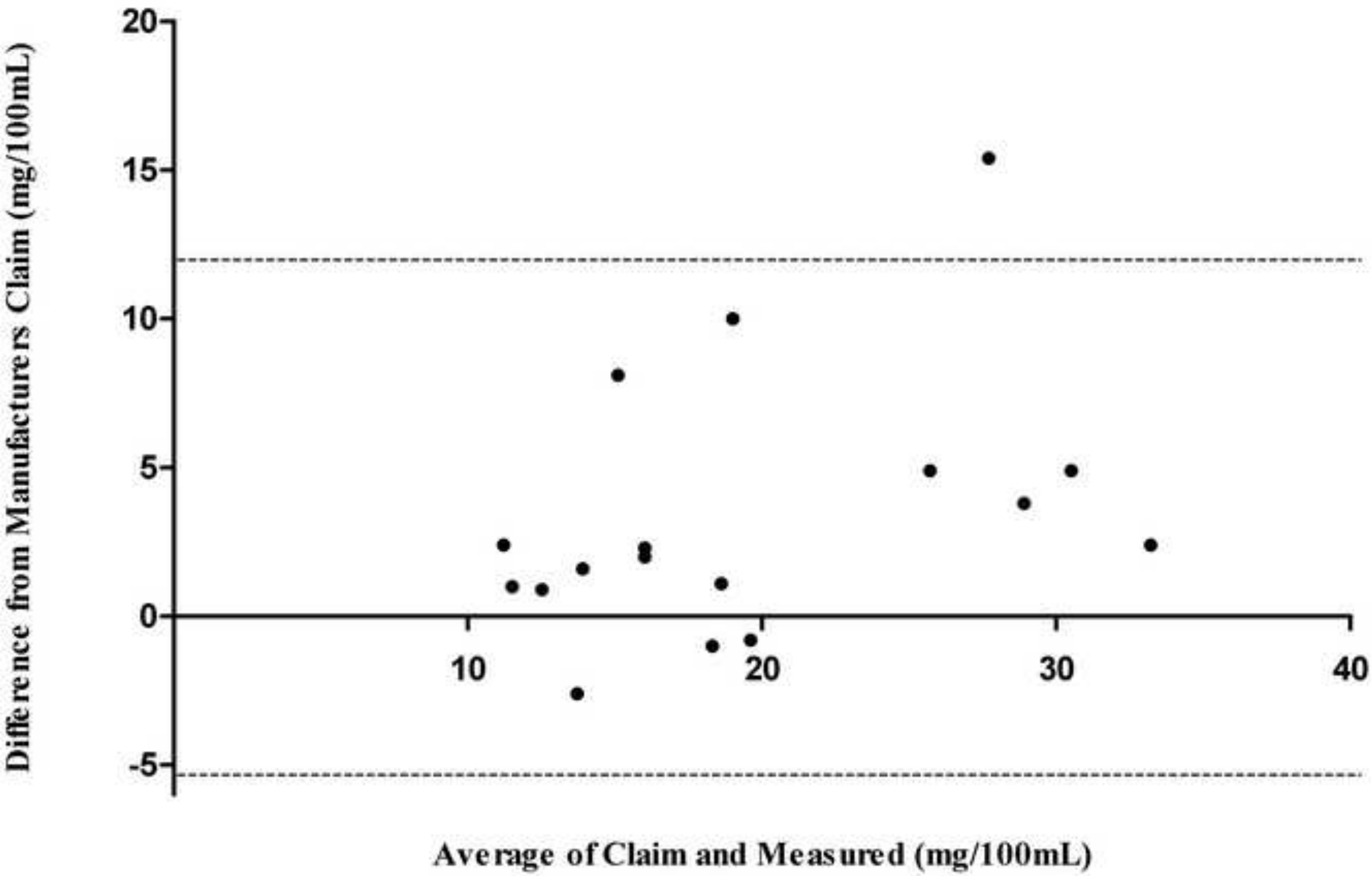
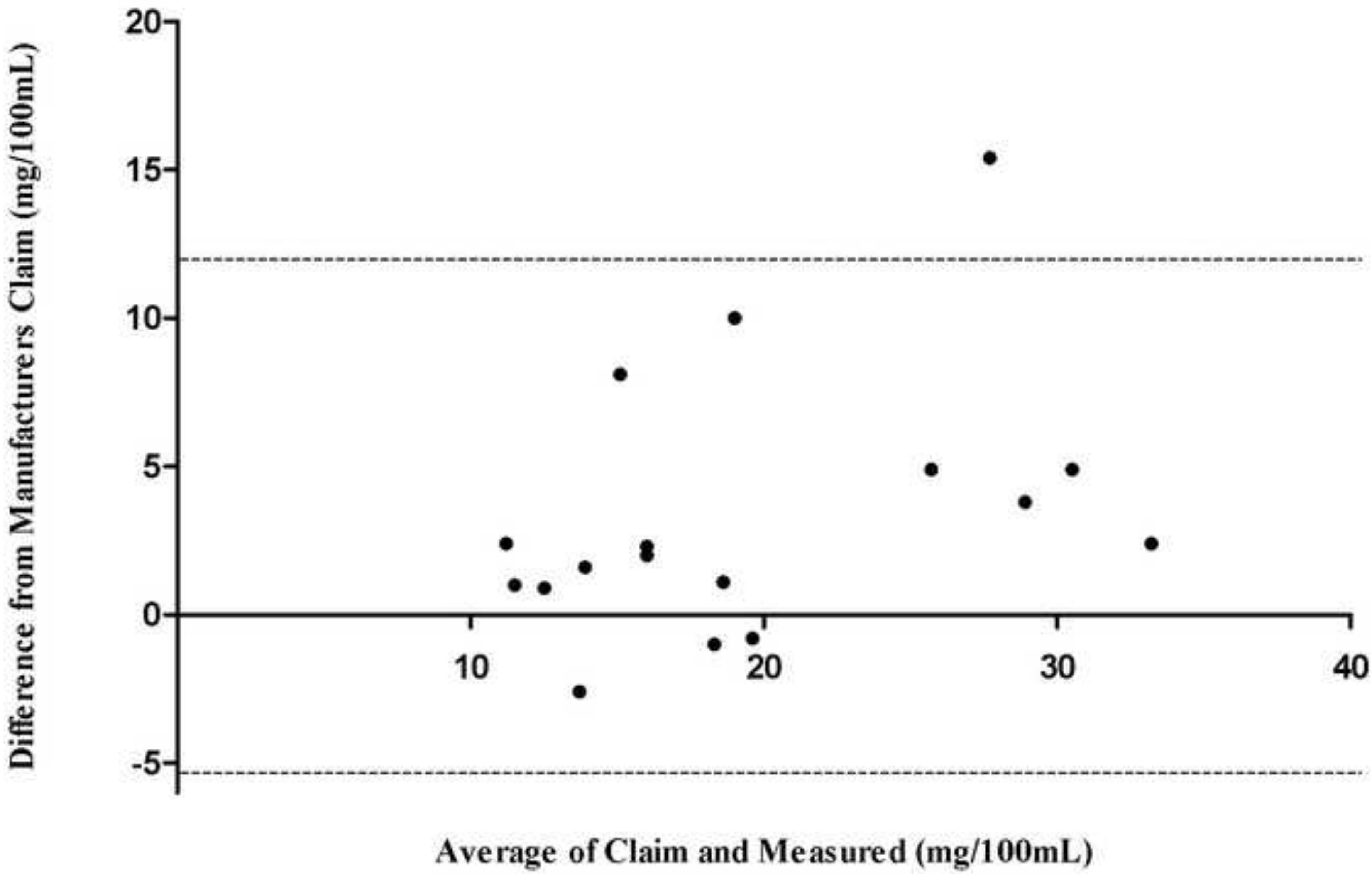

Difference from Manufacturers Claim (mg/100mL)
20
15
10
5
0
-5
10
20
30
40
Average of Claim and Measured (mg/100mL)

Figure1


Difference from Manufacturers Claim (mg/100mL)
20
15
10
5
0
-5
10
20
30
40
Average of Claim and Measured (mg/100mL)

Highlights

- Analysis was conducted on popular hot and cold coffee beverages in Australia.
- The probability of exposure to high caffeine doses greater than historical reports.
- Estimations of caffeine consumption can now be achieved with greater accuracy.
- Assessment of link between caffeine and health can be made with greater confidence.