Effects of caffeine consumption on resting metabolic rate in college-aged females

Allyson Butts, Olivia Crews, Peyton Ellis, and Baylee Short

This project does not attempt to produce generalizable knowledge. It is dedicated to the practice of developing skills and demonstrating understanding of the research process.

INTRODUCTION

Over the past decade, the health industry has increasingly targeted young females with supplements and nutrition products. Energy drinks such as Reign Inferno market themselves as "thermogenic fuel," promising to increase caloric expenditure at rest. The primary ingredient of products like Reign Inferno is caffeine. According to Belza et al. (2009), caffeine exerts a thermogenic response that can cause acute increases in resting metabolic rate (RMR).

Resting metabolic rate (RMR) is measured via indirect calorimetry, which uses measures of oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) to approximate caloric expenditure from oxidative metabolism. At rest, $\dot{V}O_2$ should be approximately 3.5 milliliters of oxygen per kilogram of bodyweight per minute (mL/kg/min), or 1 MET. RMR is used to calculate resting energy expenditure (REE), the body's energy needs expressed in kilocalories per day (kcal//day). According to McArdle et al. (2015), primary determinants of resting metabolic rate are age, gender, stature, total body mass, and fat free mass. Respiratory quotient (RQ) is calculated by dividing $\dot{V}CO_2$ by $\dot{V}O_2$. RQ reflects fuel usage at a cellular level. An RQ of 1.0 indicates carbohydrate usage, while an RQ of 7.0 indicates fat is the sole fuel source. This is due to fatty acids' larger hydroge cotet, which requires more oxyge for complete breakdown (McArdle et al., 2015).

Given that caffeine has a therogenic effect, the first objective of this experiment was to test the claim of the energy drink Reign Inferno by analyzing its effects on resting energy expenditure and other metabolic variables, including $\dot{V}O_2$, minute ventilation ($\dot{V}E$), RQ, and heart rate (HR). According to Nehlig (2018), regular caffeine drinkers develop tolerance to peripheral actions of caffeine, such as its effects on hormonal responses and heart rate. Therefore, a secondary objective of this study was to determine compare metabolic responses in females who regularly consume more than 300 mg of caffeine (caffeine group) to those who consume less than 300 mg of caffeine daily (non-caffeine group). It is hypothesized that ingestion of a bodyweight-corrected amount of Reign Inferno energy drink will elevate resting metabolic rate in college-aged females, but will have a greater effect on those who consume less than 300 mg of caffeine daily.

METHOD

Participants were 6 college-aged females; separation into caffeine group (n =3) and non-caffeine group (n = 3) was based on self-reported caffeine consumption of either more or less than 300 mg of caffeine daily, respectively. Participant demographics are described in Table 1. Participant body weight and height were collected and used to determine Reign Inferno dosage. A ratio of 3 mg of caffeine per kg of bodyweight was used. One fluid ounce of Reign Inferno corresponds to 18.75 g of caffeine. Participants were outfitted with Polar heart rate monitors or pulse oximeters.

Participants rested in a supine position for 5 minutes prior to the beginning of data collection. During this time, the Parvo Medics True One 2400 Metabolic System, tubing, and bells were assembled and tested for functionality. The system was calibrated according to manufacturer specifications prior to participant arrival. During data collection, values for $\dot{V}O_2$, $\dot{V}E$, RQ, and REE were collected.

After 5 minutes, data collection began. The pre-caffeine testing period lasted 15 minutes. Heart rate was reported every minute and participants were asked to give a thumbs up signal every 5 minutes. At minute 15.0, participants drank specified amount of Reign Inferno at their own pace. The post-caffeine testing period lasted 30 minutes. Heart rate was reported every minute and participants were asked to give a thumbs up signal every 5 minutes. Participants were shadowed for 5 minutes after data collection.The first 5 minutes of data for the pre- and post-caffeine testing period were discarded.

RESULTS

All measured metabolic variables ($\dot{V}O_2$, $\dot{V}_E$, RQ, HR, and REE) increased post-caffeine consumption for both caffeine and non-caffeine groups (Table 2). While caffeine consumption elevated metabolic rate for all participants, the caffeine group showed a greater response than the non-caffeine group. The caffeine group saw an increase in mean REE from 1770 kcal/day to 1924 kcal/day after caffeine ingestion, an 8.7% increase. In contrast, the non-caffeine group's mean REE increased from 1636 kcal/day to 1755 kcal/day, a 7.3% increase. The whole group experienced an 8.0% increase in REE.

Whole group, caffeine group, and non-caffeine group data showed a decrease in mean REE throughout the pre-caffeine testing period. REE then rapidly increased during minutes 21.0-25.0 and 31.0-35.0 before declining through the rest of the post-caffeine testing period (Figure 1). REE was positively correlated with heart rate (r = 0.73) and oxygen consumption ($r = 0.48$).

Table 1 *Participant demographics*

Variable	Age, years	Height, cm	Weight, kg	Caffeine, mg
Whole group (n = 6)	19.5	166.8	64.4	193.2
Caffeine group (n = 3)	19.3	164.0	64.2	192.6
Non-caffeine group (n = 3)	19.7	169.7	64.5	193.5

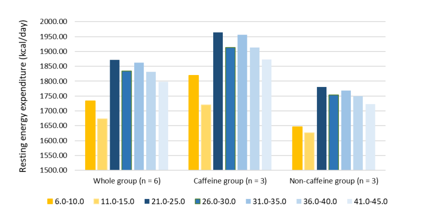
Note. Abbreviations: cm = centimeters; kg = kilograms; mg = milligrams

Table 2 *Metabolic response to caffeine consumption*

	$\dot{V}O_2$ (mL/kg/min)	$\dot{V}_E$ (L/min)	RQ	HR (bpm)	REE (kcal/day)
Whole group (n = 6)					
Pre-caffeine	3.70 (0.31)	34.01 (5.28)	0.96 (0.08)	69 (15)	1703 (303)
Post-caffeine	3.95 (0.28)	33.97 (4.97)	1.04 (0.06)	68 (16)	1840 (263)
Caffeine group (n = 3)					
Pre-caffeine	3.81 (0.13)	32.38 (6.02)	1.00 (0.09)	76 (18)	1770 (426)
Post-caffeine	4.10 (0.08)	32.25 (5.74)	1.08 (0.05)	78 (18)	1924 (371)
Non-caffeine group (n = 3)					
Pre-caffeine	3.60 (0.44)	35.64 (5.05)	0.93 (0.06)	61 (7)	1636 (188)
Post-caffeine	3.80 (0.35)	35.68 (4.45)	0.99 (0.00)	59 (5)	1754 (117)

Note. Values are displayed as mean (standard deviation) of pre-caffeine testing period (minutes 6.0-15.0) and post-caffeine testing period (minutes 20.0-45.0). Abbreviations: $\dot{V}O2$ = oxygen consumption; mL/kg/min = milliliters per kilogram of bodyweight per minute; $\dot{V}E$ = minute ventilation; L/min = liters per minute; RQ = respiratory quotient; HR = heart rate; bpm = beats per minute; REE = resting energy expenditure; kcal/day = kilocalories per day.

Figure 1 *REE before and after caffeine consumption*



DISCUSSION

According to Nehlig (2018), caffeine may elevate RMR by increasing levels of glucocorticoids such as cortisol, which regulate metabolism. Vaughan et al. (2012) note that caffeine also increases cyclic adenosine monophosphate (cAMP), which promotes fat oxidation. Increases in REE during this study reflect such physiological mechanisms. Nehlig (2018) also noted that caffeine tends to increase heart rate, an effect seen in this study. According to Clark et al. (2020), thermogenic fitness drink formulas with both 100 mg and 140 mg of caffeine increased REE while decreasing resting fat oxidation. Both the caffeine and non-caffeine groups experienced an increase in RQ, reflecting a shift toward greater carbohydrate usage.

Caffeine absorption depends on the form in which it is ingested, but tends to take effect within 15-20 minutes; a single dose of caffeine reaches its highest levels in 1 to 2 hours, with a half-life ranging from 2.5 hours to 9.9 hours (Nehlig, 2018). Figure 1 shows that both groups saw a spike in REE during minutes 31.0-35.0 This time segment represents 15 minutes post caffeine ingestion. Decreases in REE from minutes 36.0-45.0 contradict expectation that caffeine peaks in 1 to 2 hours.

According to Nehlig (2018) notes that regular caffeine consumption increases tolerance to its behavioral effects and impact on blood pressure, heart rate, and hormone levels. However, according to de Salles Painelli et al. (2021), habitual consumption of caffeine does not interfere with the effects of acute caffeine consumption on endurance and strength performance. Low (20- mg/day), moderate (80-100 mg/day), and high (280+ mg/day) caffeine consumers showed similar increases in performance, challenging the long-standing caffeine habituation paradigm. This may explain why the caffeine and non-caffeine group participants in this study experienced similar patterns of metabolic responses (8.7% and 7.2% increase in REE, respectively).

One limitation of this study is that the post-caffeine testing period only lasted for 30 minutes, while the effects of caffeine peak in 1 to 2 hours (Nehlig, 2018). A longer post-caffeine testing period would provide more concrete conclusions about the effects of caffeine on RMR. Further, changes in REE could reflect other factors, such as stress or acute exercise responses. However, the first five minutes of data were eliminated for both testing periods, ensuring that any elevation did not reflect activity-related increases in oxygen consumption. Another limitation was limited subject number, with no comparison based on body composition or training status, which influence RMR and metabolic responses (McArdle et al., 2015).

CONCLUSION

In college-aged females, ingestion of caffeine from energy drinks like Reign Inferno elevates resting metabolic rate in the 30 minutes following caffeine consumption. It also elevates heart rate, ventilation, oxygen consumption, and RQ. This effect exists regardless of whether females are regular caffeine consumers or tend to consume less caffeine. This suggests that the claim of energy drinks like Reign Inferno to elevate REE is true. However, marketing may exaggerate the magnitude and duration of effects. Further directions for study could expand on the long-term effects of caffeine from energy on resting metabolic rate, beyond the acute effects observed in this study. They could also compare caffeine response based on individual body composition and training status.

REFERENCES

Belza, A., Toubro, S., & Astrup, A. (2009). The effect of caffeine, green tea and tyrosine on thermogenesis and energy intake. *European Journal of Clinical Nutrition, 63*(1), 57-64. doi:10.1038/sj.ejcn.1602901

de Salles Painelli, V., Teixeira, E. L., Tardone, B., Moreno, M., Morandini, J., Larrain, V. H., & Pires, F. O. (2021). Habitual caffeine consumption does not interfere with the acute caffeine supplementation effects on strength endurance and jumping performance in trained individuals. International Journal of Sport Nutrition and Exercise Metabolism, 31(4), 321-328. doi:10.1123/ijsnem.2020-0363

Clark, N. W., Wells, A. J., Coker, N. A., Goldstein, E. R., Herring, C. H., Starling-Smith, T. M., Varanoske, A. N., Panissa, V. L. G., Stout, J. R., & Fukuda, D. H. (2020). The acute effects of thermogenic fitness drink formulas containing 140 mg and 100 mg of caffeine on energy expenditure and fat metabolism at rest and during exercise. Journal of the International Society of Sports Nutrition, 17(1), 10-10. doi:10.1123/ijsnem.2020-0363

McArdle, W.D., Katch, F.I., and Katch, V.L. (2015). *Exercise physiology: Nutrition, energy, and human performance* (8th edition). Lippincott Wiliams & Williams.

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

Vaughan, R. A., Garcia-Smith, R., Bisoffi, M., Trujillo, K. A., & Conn, C. A. (2012). Effects of caffeine on metabolism and mitochondria biogenesis in rhabdomyosarcoma cells compared with 2,4-dinitrophenol. Nutrition and metabolic insights, 5, 59–70. https://doi.org/10.4137/NMI.S10233