**Research Article**

# The acute effects of coffee consumption on blood glucose and it's relationship with serum cortisol and insulin in females

Yusni Yusni[1], Hanifah Yusuf[2]

1 *Department of Medical Physiology, Faculty of Medicine, Universitas Syiah Kuala, 23111 Banda Aceh, Aceh, Indonesia*

2 *Department of Pharmacology, Faculty of Medicine, Universitas Syiah Kuala, 23111 Banda Aceh, Aceh, Indonesia*

Corresponding author: Yusni Yusni (yusni@unsyiah.ac.id)

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## Abstract

This research was aimed at analyzing the acute effects of Arabica black coffee consumption on blood glucose, insulin, and serum cortisol levels, as well as determining the pharmacological effects of black coffee as an antihyperglycemic. A randomized control trial with healthy female subjects was used in this study. There were 20 volunteers in total: 9 as the control group and 11 as the trial group. The treatment included brewing 10 grams of Gayo Arabica black coffee powder with 150 ml of boiling water. Blood glucose, insulin, and cortisol levels were measured twice, before and after 60 minutes of coffee consumption. An independent sample t-test ($p < 0.05$), Pearson correlation test ($p < 0.05$), and simple linear correlation test ($p < 0.05$) were used to analyze the data. Blood glucose levels and serum cortisol levels decreased significantly after coffee consumption in the trial group ($p = 0.002^*$ and $p = 0.001^*$). There was no significant negative correlation between glucose and insulin levels ($r = -0.122$; $p = 0.721$). On the other hand, there was a significant positive correlation between cortisol levels and blood glucose ($r = 0.651$; $p = 0.002^*$). In conclusion, a single cup of Gayo Arabica black coffee reduces blood sugar and serum cortisol levels, but does not increase serum insulin levels. Blood glucose levels correlate positively with serum cortisol levels in healthy female.

## Keywords

## Introduction

Coffee is the most popular beverage consumed worldwide, and it is widely believed to have health benefits as well as the ability to prevent a number of diseases, lowers mortality and morbidity, and increases life expectancy (Keefe et al. 2013; Bae et al. 2014; Farah and Lashermes 2018; Lopez-Garcia 2018; Cornelis 2019; Yamakawa et al. 2019). Coffee has been shown in studies to reduce stress and depression, with many claiming that it reduces the risk of death from depression by 13% (Keefe et al. 2013;

Bae et al. 2014). On the other hand, coffee improves physical performance, and therefore, most young people begin their day with a cup of coffee (Keefe et al. 2013; Ballis 2019; Cosoet al. 2020). More than half of all Americans (Bae et al. 2014) and roughly 37% of Acehnese youth drink coffee every day (based on our preliminary unpublished research). Coffee consumption is not only a male-dominated lifestyle, but it is also a daily ritual for females (Lopez-Garcia 2011).

Coffee has been shown to prevent and reduce the risk of several chronic diseases, including hypertension, heart

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disease, arrhythmia, liver cancer, obesity, and type 2 diabetes (Keefe et al. 2013; Bae et al. 2014; Poole et al. 2017; Walter 2022). Coffee has a variety of pharmacological effects, including the ability to act as an antihyperglycemic agent (Bae et al. 2014). Coffee contains over 1000 phytochemicals, including caffeine, chlorogenic acid (CGA), alkaloids, phenolics, lactones, diterpenes, cafestol, kahweol, niacin, carbohydrates, fats, vitamin B3, magnesium, and potassium (Peterson 2008; Bae et al. 2014; Poole et al. 2017). A cup of Arabica coffee contains 50–100 mg of caffeine, 35–100 mg of chlorogenic acid/100 mL, 10 mg of nicotinic acid, and 40–50 mg of trigonelline (Ballis 2019). Caffeine is a xanthine alkaloid as a bioactive compound that improves long-term memory and stimulates the central nervous system (Alshawi 2020). Xanthine is a substance that can stimulate the nervous system and produce a state of alertness in a short period of time (Antonio et al. 2019). Methylxanthines are competitive antagonists of adenosine A1 and A2 receptors found throughout the body, including the heart, peripheral vessels, platelets, lungs, and brain (Antonio et al. 2019).

Caffeine is an ergogenic substance that improves physical performance (Antonio et al. 2019; Coso et al. 2020). Caffeine counteracts the effects of adenosine, and moderate doses (40–200 mg) increase alertness, reduce fatigue, and shorten reaction time (Ballis 2019; Dam et al. 2020). Adenosine is a vasodilator, and its inhibition causes sympathetic reflexes to be activated (Pradhan et al. 2022). Caffeine works by blocking adenosine receptors A1 and A2, as well as influencing the autonomic nervous system (ANS), preventing adenosis, which results in central nervous system (CNS) activity via catecholamine release (Pradhan et al. 2022). Caffeine has an anti-obesity effect because it suppresses appetite, improves energy balance, basal metabolic rate, and thermogenesis by enhancing expression of uncoupling protein-1 in brown fat tissue and stimulating the sympathetic nervous system (Dam et al. 2020). Caffeine is also beneficial for weight loss because it suppresses appetite (Walter 2022). Caffeine intake of 6 mg/kg repeated throughout the day increased 24-hour energy expenditure by 5% (Dam et al. 2020).

Chlorogenic acid and caffeine play a role in regulating glucose metabolism (Peterson 2008; Bae et al. 2014; Poole et al. 2017). Coffee polyphenols have also been shown to protect against hepatic steatosis and fibrogenesis by increasing fat homeostasis and decreasing oxidative stress (Dam et al. 2020). Polyphenols act as anti-aging agents by inhibiting the formation of free radicals in the skin (Affonso et al. 2016).

Coffee consumption has been linked to metabolic, endocrine, and cardiovascular disease. Consuming black coffee reduces the risk of dyslipidemia, coronary heart disease, prediabetes, and type 2 diabetes, all of which are associated with genetic polymorphisms (Alshawi 2020; Abalo 2021). The mechanism through which coffee reduces the risk of type 2 diabetes is still undisclosed, and more research is needed. Long-term regular coffee consumption may reduce the risk of developing type 2 diabetes, but the evidence is still inconclusive (Peterson 2008; Keefe et al. 2013; Bae et al. 2014). Coffee has a variety of effects on glucose metabolism, including the activity of certain hormones (Dam et al.

2020). Short-term and long-term coffee consumption may have different effects on glucose metabolism, and this study only looked at the acute effects of coffee consumption. Therefore, this study was conducted to investigate the acute effects of coffee consumption on blood glucose levels and their relationship to serum insulin and cortisol levels. This study also discovered some disagreement regarding the acute effects of coffee consumption on cortisol levels. Coffee has been shown to lower cortisol levels in the blood, therefore, coffee can aid in relaxation. Caffeinated coffee has an acute effect on serum cortisol levels but has no effect on blood glucose levels (Gavrieli et al. 2011).

Caffeine's effect on blood glucose is caused by its euglycemic properties, which reduce short-term insulin sensitivity while inhibiting muscle glycogenesis due to increased epinephrine release (Dam et al. 2020). Coffee may improve insulin sensitivity in healthy male subjects (Reis et al. 2018). Coffee consumption reduces insulin sensitivity for 100–180 minutes (Dam et al. 2004). In a four-week study of healthy people, coffee consumption increased insulin secretion but had no effect on blood glucose levels (Dam et al. 2004). Bilge et al., discovered that coffee consumption affects plasma glucose and leptin levels but not plasma insulin and cortisol levels (Bilge et al. 2017). Coffee also increases pancreatic beta cell insulin secretion by increasing the secretion of glucagon-like peptide 1 (GLP-1), a hormone secreted by the intestines that plays a role in insulin stimulation (Fujii et al. 2015). Coffee lowers not only blood glucose levels but also HbA1c in diabetics and non-diabetics via the hormone adiponectin (Mayya and Shantaram 2015).

Coffee is considered anti-stress because it lowers cortisol secretion, which reduces stress and depression (Papakonstantinou et al. 2016). However, some argue that it causes stress and depression (Wachamo 2017). Caffeine has neuroprotective properties, such as lowering the risk of depression and suicide, dementia, and stroke, but high doses (1200 mg or more) consumption is likely to cause sleep disorders, severe anxiety, palpitation, and elevated blood pressure. Caffeine increases catecholamine secretion, which stimulates autonomic nervous system (ANS) activity (Pradhan et al. 2022).

Caffeine has different effects on cortisol levels depending on whether they are acute or chronic. After four weeks, regular caffeine consumption has no effect on cortisol levels (Lovallo et al. 2008). Caffeinated coffee reduces cortisol secretion in healthy people in the short term (Gavrieli et al. 2011). According to this study, coffee may have anti-diabetic and anti-stress properties, as a single cup of black coffee Arabica consumption reduced cortisol levels in healthy females.

# Materials and methods

## Research subjects and randomization

The subjects were females aged 18–20 years, physically and mentally healthy based on anamnesis and physical examination by a doctor, non-coffee drinkers or did not

regularly consume coffee (consumption was less than a cup of coffee every day and no routine), and had adequate rest or sleep for 6–8 hours within 24 hours before the study. The subjects were divided into two groups: the control group and the trial group. The control group is the group that did not receive treatment and the trial group is the group that did receive treatment (as a trial group).

The subjects were 40 nursing students from the same class. Fig. 1 depicts the subject grouping and randomization. It was discovered that 12 men were excluded as subjects, and 6 women refused to participate as subjects because they refused to drink coffee. As a result, 18 people were ruled out as subjects. Initially, 22 subjects were recruited for this study, and then randomization was used to divide them into two groups: 11 females (n = 11) as a control group and 11 females (n = 11) as a trial group. The research assistant team performed randomization without being noticed by the research team. The randomization technique used simple random sampling via a lottery. All of the subjects' names were written on small pieces of paper, rolled up, and placed in a small tin to be shaken. The first eleven names were used as the control group, while the remaining eleven names were used as the experimental group.

One day before the examination and treatment, each subject's group was determined. Subjects were also required to sign a written consent indicating their willingness to participate in this study. Subjects are uncompelled volunteers who have the option to resign at any time. For unknown reasons, two subjects from the control group were absent on the day of the study, bringing the total number of subjects to 20 females (n = 20), with the following information: The control group consisted of nine females (n = 9) and the trial group consisted of up to eleven females (n = 11). All subjects were not permitted to consume coffee or other caffeinated beverages the day before the exam, such as tea, soft drinks, or energy drinks.

## Research design and treatment

This study was a randomized controlled trial (RCT). Arabica coffee beans were roasted and finely ground into powder. Caffeinated coffee was brewed with 150 ml of boiling water, no sugar, and a dose of 10 g. The coffee dose was calculated using Aceh's average daily coffee consumption. The coffee was from Gayo (Bener Meriah Village, Central Aceh, Aceh Province, Indonesia). In this study, Gayo Arabica black coffee was used. 1 gram of Gayo Arabica coffee powder contains
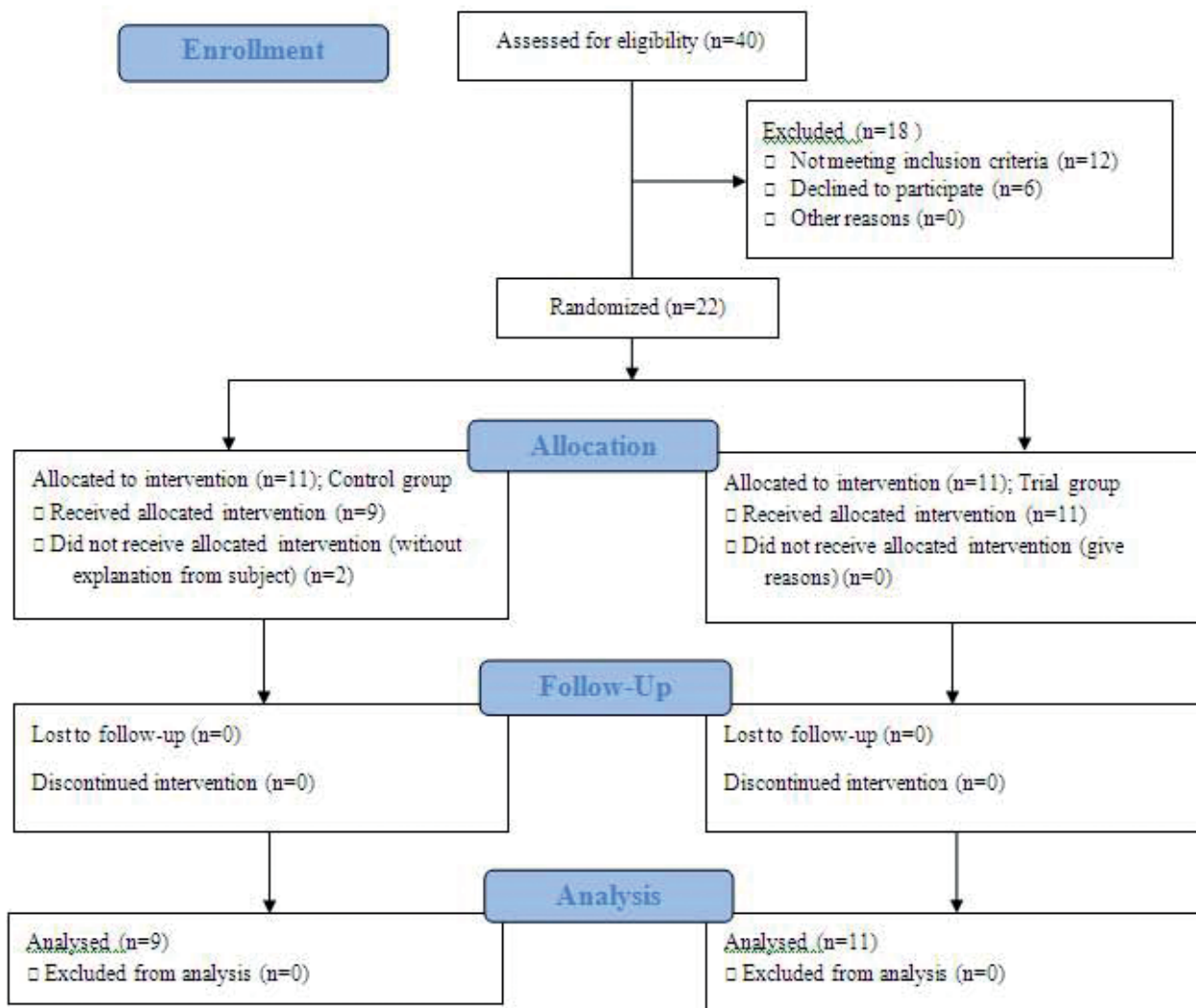


**Figure 1.** CONSORD diagram for the randomization of research subjects

up to 9.70 mg/gram of caffeine (Aprilia et al. 2018). The coffee was only given once (a single cup of coffee) because the goal of this study was to determine the acute response to the consumption of Gayo Arabica black coffee.

## Physical and laboratory examination

Data for the study was gathered through anamnesis, physical examination, and laboratory blood tests. Anamnesis is used to determine the health and identity of the subject. The height and weight measurements are used to calculate the body mass index (BMI) as an overview of the subject's anthropometry. The anamnesis and examination of the subject were conducted by a doctor who was not a member of the research team to ensure the objectivity of the research data. This study took three months to complete, beginning with ethical approval, determining the subject of research, preparing tools and materials for research, and conducting research. Prior to the research, from August to October 2019.

In laboratories, blood glucose, insulin, and cortisol levels are measured. Subjects fasted for 10–12 hours before their blood was collected for laboratory tests. A total of 6 mL of blood was collected in the morning between 7:30 and 8:30 a.m. and was taken twice before and one hour after coffee consumption. Serum insulin levels were measured using the Chemiluminescent Immunoassay (CLIA). Serum cortisol levels were measured using the Enzyme-Linked Immunosorbent Assay (ELISA).

## Ethical approval

The study's implementation was approved by the Medical Research Ethics Committee (KEPK), Faculty of Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia, under the number 261/EA/FK-RSUDZA/2019. All subjects were informed about the study protocol, objectives, benefits, and side effects before signing a written informed consent form. Subjects had the option to refuse or withdraw from the study at any time with no consequences.

## Statistical analysis

Computer software is used to analyze research data. This study's statistical analysis included an independent sample t-test (p < 0.05), a Pearson correlation test (p <0.05), and a simple linear correlation test (p < 0.05). An independent sample t-test was used to compare the effects of coffee on blood glucose, insulin, and cortisol levels in each control and treatment group. The findings of this study will provide an overview of the effects of coffee consumption on serum glucose, cortisol, and insulin levels.

A Pearson correlation analysis was performed to determine the relationship between blood glucose, insulin, and serum cortisol levels. Its analysis will show whether the relationship between insulin and cortisol levels and serum glucose levels is positive or negative. A linear correlation analysis was used to determine the strength of the relationship between insulin and cortisol levels and

serum glucose levels. The strength of this relationship is divided into five categories: 0.80 = very strong, 0.60–0.799 = strong, 0.40–0.599 = medium, 0.20–0.399 = weak, and 0.00–0.199 = very weak.

# Results

## Characteristic of subject

As shown in Table 1, no significant differences (p > 0.05) were found between the control and trial groups in terms of study subject characteristics such as age, weight, height, and BMI. Both groups of subjects were between the ages of 18 and 20, and their characteristics were similar. The average BMI of the subjects was within the normal range.

**Table 1.** Characteristic of research subject.

| Data | Groups | n | Mean ± SD | Minimun | Maximum | p-value |
|---|---|---|---|---|---|---|
| Age (year) | Control | 9 | 18,89 ± 0,61 | 18 | 20 | 0,75 |
| | Trial | 11 | 18,82 ± 0,63 | 18 | 20 | |
| Weight (kg) | Control | 9 | 47,39 ± 7,65 | 45 | 62,50 | 0,07 |
| | Trial | 11 | 53,77 ± 7,03 | 44.50 | 58,00 | |
| Height (cm) | Control | 9 | 154,61 ± 4,63 | 150 | 162 | 0,25 |
| | Trial | 11 | 157,00 ± 4,31 | 152 | 165 | |
| BMI (kg/cm²) | Control | 9 | 19,81 ± 3,02 | 17.22 | 27,05 | 0,16 |
| | Trial | 11 | 21,86 ± 3,19 | 17.38 | 29,43 | |

BMI = Body Mass Index.

## Differences in blood glucose, insulin, and cortisol in the control and trial groups

Table 2 shows the differences in blood glucose, insulin, and cortisol levels before and after coffee treatment in the control and trial groups. In the control group, blood glucose levels did not differ between before and after treatment (p > 0.05). The trial group experienced a significant decrease in blood glucose after consuming coffee (p = 0.02*). This study's findings suggest that drinking coffee can lower blood glucose levels in healthy women. Coffee consumption significantly reduced not only blood glucose levels but also blood cortisol levels in the trial group (p = 0.001*), as shown in Table 2.

**Table 2.** Analysis of independent sample t-test to determine differences in the values of blood glucose, insulin, and cortisol in the control and treatment groups.

| Variable | Groups | Treatment | Means ± SD | P value |
|---|---|---|---|---|
| Blood Glucose (mg/dL) | Control (n = 9) | Before | 83,56 ± 4,91 | 0,23 |
| | | After | 84,00 ± 4,38 | |
| | Trial (n = 11) | Before | 83,73 ± 4,71 | 0,01* |
| | | After | 79,18 ± 4,89 | |
| Insulin (uIU/mL) | Control (n = 9) | Before | 10,29 ± 7,44 | 0,38 |
| | | After | 10,14 ± 7,44 | |
| | Trial (n = 11) | Before | 9,45 ± 2,47 | 0,04* |
| | | After | 11,15 ± 3,28 | |
| Cortisol (µg/dL) | Control (n = 9) | Before | 13,54 ± 3,22 | 0,10 |
| | | After | 13,99 ± 2,98 | |
| | Trial (n = 11) | Before | 12,56 ± 1,97 | 0,001* |
| | | After | 8,96 ± 2,89 | |

*Independent sample t-test; significantly on the level of error of 5% (p < 0.05).

Cortisol levels decreased after drinking coffee in the trial group (p < 0.05), but did not change in the control group (p > 0.05). Insulin levels in the trial group increased slightly but not statistically significantly (p > 0.05), whereas insulin levels in the control group did not change before and after treatment. This study revealed that the acute response of black coffee consumption in healthy women was a decrease in blood glucose levels and serum cortisol levels, but it had no effect on the increase in serum insulin levels.

## Relationship between glucose levels with insulin and cortisol in the trial group

The Pearson correlation analysis (r) results are shown in Table 3. Based on the results of the independent sample t-test analysis, changes in glucose, insulin, and cortisol levels after treatment occurred only in the trial group. According to the Pearson correlation test, there was no significant negative correlation between blood glucose levels and serum insulin levels (r = -0.122; p = 0.721).

**Table 3.** Relationship between glucose levels and insulin and cortisol in the trial group.

| Varible | Pearson Correlation (r) | t | p-value |
|---|---|---|---|
| Relationship between blood glucose and insulin | -0,122 | -0,367 | 0,721 |
| Relationship between blood glucose and cortisol | 0,651 | 0,303 | 0,002* |

* = there is a significant relationship at the 5% error level (p < 0.05)
Correlation (r): ≥ 0.80 = very strong, 0.60–0.799 = strong, 0.40–0.599 = medium, 0.20–0.399 = weak and 0.00–0.199 = very weak

According to the findings of this study, decreased insulin levels after coffee consumption do not result in an increase in blood glucose levels in the coffee drinker group. Table 3 shows that there was a significant positive correlation between cortisol levels and blood glucose (r = 0.651; p = 0.002*). These findings suggest that an increase in cortisol levels after drinking coffee causes an increase in blood glucose levels. Vice versa, a decrease in serum cortisol levels causes a decrease in blood glucose levels.

Table 4 shows the effects of the hormones insulin and cortisol on blood glucose levels. The simple linear regression equation: Y = a + b X was used to explain the relationship between glucose levels, insulin, and cortisol in the trial group.

X = levels of insulin and cortisol (independent variable)
Y = blood glucose level (dependent variable)

**Table 4.** The simple linear regression equation for the relationship between glucose levels with insulin and cortisol in the trial group.

| Variable | Regression Equation |
|---|---|
| Relationship between blood glucose and insulin | Y = 80,544 – 0,122 X |
| Relationship between blood glucose and cortisol | Y = 70,428 + 0,970 X |

As shown in Table 4, simple linear regression equation analysis was used to determine the functional relationship between blood glucose levels and insulin after coffee consumption. According to this table, every decrease in insulin levels of 1 uIU/mL is followed by
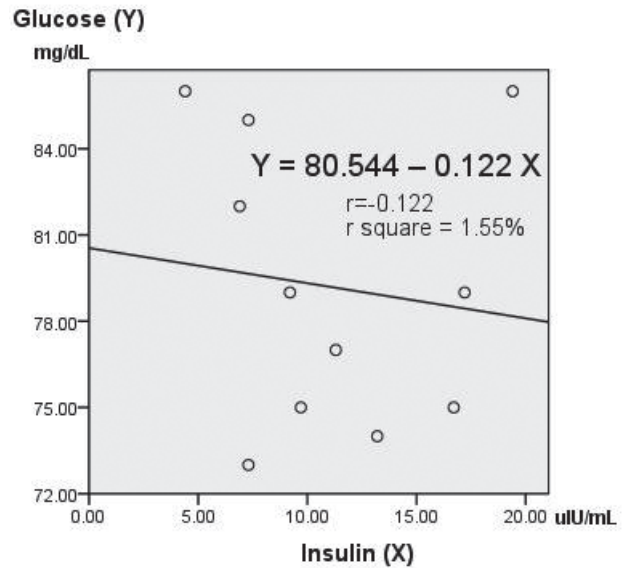


**Figure 2.** Simple linear regression equation regarding the relationship between glucose and insulin levels in a trial group.

an increase in blood glucose levels of 0.122 mg/dL. In contrast, an increase in cortisol levels of 1 g/dL is accompanied by an increase in blood glucose levels of up to 0.970 mg/dL.

Fig. 2 depicts a very low (r = 0.00–0.199) functional relationship between insulin levels and blood glucose in the trial group (r = -0.12). On the other hand, Fig. 3 shows a strong functional relationship between cortisol levels and blood glucose in the trial group. There was a strong functional relationship (r = 0.60–0.799) between cortisol levels and blood glucose (r = 0.651*). These findings suggest that an increase in cortisol levels is followed by an increase in blood glucose levels, and vice versa, a decrease in cortisol levels is followed by a decrease in blood sugar levels. According to the findings of this study, coffee consumption decreased serum cortisol levels, which was followed by a decrease in blood glucose levels.
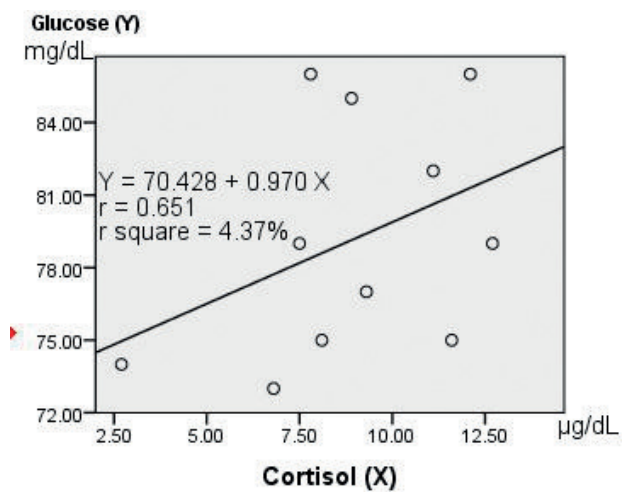


**Figure 3.** Simple linear regression equation on the relationship between glucose and cortisol levels in trial group.

# Discussion

Coffee's role as a preventive and therapeutic agent for type 2 diabetes has long been debated. Coffee consumption, both caffeinated and non-caffeinated, lowers the risk of developing type 2 diabetes, but some argue that coffee consumption raises the risk (Greenberg et al. 2006). These results suggest that the acute response to coffee consumption on an empty stomach (without the consumption of other foods) lowers blood glucose levels by decreasing cortisol secretion with a slight increase in insulin levels in healthy women. However, it was discovered that the acute response of coffee consumption to lowering blood glucose levels was only associated with cortisol and not with insulin in healthy women, and this is the mechanism that coffee uses to prevent diabetes. This study contradicts what Bilge et al. discovered, stating that the acute response of coffee does not affect glucose and cortisol levels, but it does affect leptin levels, providing an overview of the mechanism of coffee in reducing the risk of developing diabetes (Bilge et al. 2017).

Coffee contains a lot of soluble fiber, including type II arabinogalactans and galactomannans, which help to keep the gut healthy and lower the risk of diabetes (Ballis 2019). This fiber works to increase food absorption in the intestine while decreasing glucose absorption in the blood, assisting in the control of blood glucose levels (Ballis 2019). Coffee also contains over 1000 chemical compounds, including chlorogenic acid (CGA) and trigonelline, which contribute to blood glucose metabolism through different pathways and mechanisms (Bilge et al. 2017; Wanderley et al. 2017; Farah and Lashermes 2018; Costa and Reis 2019).

One cup of Arabica coffee contains about 35–100 mg of CGA (Ballis 2019). CGA is a phenolic component with an anti-glycemic effect (Formagio et al. 2015; Maurya 2016; Costa and Reis 2019; Zaman et al. 2019). CGA is an inhibitor of pancreatic α-amylase, intestinal α-glucosidase, and glucose-6-phosphatase. glucose uptake in the intestine reduces hepatic glucose output, which ultimately leads to reduced fasting insulin secretion (Bilge et al. 2017; Costa and Reis 2019).

Trigonelline and coffee polyphenols also work to inhibit glucose release in the liver, increase peripheral glucose absorption, and modulate intracellular signaling by influencing enzymes involved in glucose and lipid metabolism, such as carnitine palmitoyltransferase (Farah and Lashermes 2018; Costa and Reis 2019). Caffeinated coffee consumption affects glucose metabolism differently between acute and chronic or long-term effects, which tend to be negative acute effects, while long-term effects of coffee consumption tend to increase glucose metabolism (Costa and Reis 2019). CGA also helps to activate adenosine monophosphate-activated protein kinase (AMPK), an enzyme that regulates cellular energy balance, lipid and glucose metabolism by inhibiting fatty acid synthesis and producing hepatic glucose. This pathway contributes to coffee's ability to prevent diabetes (Costa and Reis 2019).

The effect of coffee consumption on insulin secretion still has pros and cons. Coffee consumption was found to have an acute response in the form of a slight increase in insulin levels and a decrease in cortisol levels. Caffeine is a chemical component in coffee that has pharmacological effects on regulating glucose metabolism. Caffeine (1,3,7-trimethylxanthine) in coffee is known to have a variety of effects on the body, including influencing glycemic response and glucose homeostasis (Zaharieva and Riddell 2013; Mejia and Ramirez-Mares 2014; Messina et al. 2015).

A cup of coffee or its equivalent in terms of 150 mL contains 65–360 mg of caffeine (Messina et al. 2015). For example, caffeine is beneficial to health in moderate doses (400 mg/day), or the equivalent of 3–4 cups of coffee per day (Mejia and Ramirez-Mares 2014). Caffeine is rapidly absorbed by the body, accounting for 30–45% immediately after consumption and peaking at 100% after 60 minutes (Zaharieva and Riddell 2013; Mejia and Ramirez-Mares 2014). Caffeine concentrations in roasted coffee beans range between 1 and 2% (Biaggioni and Davis 2002).

Acute caffeine administration can result in decreased insulin sensitivity and impaired glucose tolerance (Mayya and Shantaram 2015). This effect differed from the long-term effects and a randomized control trial study that found that consuming 200 mg of caffeine (twice a day) for 7 days could increase insulin and reduce insulin sensitivity by approximately 35% while having no effect on blood glucose levels (Mackenzie et al. 2007). Long-term consumption of caffeine has been shown to improve glucose control and increase adiponectin secretion, which is useful in preventing diabetes complications (Mayya and Shantaram 2015). According to another study, coffee polyphenols can reduce postprandial hyperglycemia but not insulin secretion while increasing glucagon-like peptide 1 (GLP-1) (Fujii et al. 2015; Lee et al. 2017). Coffee also acts as a mediator to stimulate the secretion of several intestinal peptides, such as glucose-dependent insulinotropic polypeptide and glucagon-like peptide-1 (Messina et al. 2015).

Caffeine and polyphenols also improve insulin sensitivity, antioxidant activity, and endothelial vascular activity (Lee et al. 2017). Coffee consumption for four weeks has been shown to raise fasting insulin levels while decreasing insulin sensitivity (Dam et al. 2004). Cafestol in coffee increases insulin secretion in skeletal muscle cells by 34–68 percent while decreasing blood glucose levels (Costa and Reis 2019). Caffeine in coffee has an immediate effect on pancreatic beta cells, increasing insulin secretion, decreasing insulin sensitivity, and decreasing glucose tolerance (Greenberg et al. 2006). Acute consumption of caffeine causes hyperinsulinemia and also hyperlipidemia (Shearer and Graham 2014).

Regular coffee consumption has been observed to lower the risk of type 2 diabetes in Asian men and women in Singapore (Odegaard et al. 2008). Coffee also lowers the risk of type 2 diabetes through other routes by increasing anti-inflammatory biomarkers such as IL-4, IL-10, and the hormone adiponectin (Costa and Reis 2019). Adiponectin plays a role in several metabolic processes, including influencing glucose homeostasis and also fatty acid oxidation (Paredes and Ribeiro 2014; Costa and Reis 2019).

In this study, it was also discovered that coffee consumption causes an acute response in the form of a decrease in serum cortisol levels, which was positively associated with blood glucose levels in healthy women. Cortisol is a catabolic hormone that belongs to the glucocorticoid hormone class. It is involved in glucose metabolism and is linked to the development of diabetes (Paredes and Ribeiro 2014; Stachowicz and Lebiedzin 2016). Cortisol works by inhibiting muscle glucose absorption, stimulating hepatic glucose output, increasing gluconeogenesis, and increasing lipolysis in adipose tissue. Therefore, it helps to raise blood glucose levels (Dinneen et al. 1993; Stachowicz and Lebiedzin 2016).

According to Stachowicz and Lebiedzin (2016), cortisol secretion is not only influenced by the circadian rhythm but also by diet or the consumption of foods such as coffee. Coffee consumption did not result in an acute response to blood glucose but significantly increased cortisol levels (Gavrieli et al. 2011). Other research suggests that the acute response to coffee consumption does not affect salivary cortisol but can activate alpha-amylase (Papakonstantinou et al. 2016). This implies that, in addition to diabetes prevention, coffee may have anti-stress properties (Papakonstantinou et al. 2016). Caffeine reduces cortisol levels in young, healthy women and men who drink coffee every day (Lovallo et al. 2008).

## Conclusion

The acute response to a single cup of Gayo Arabica black coffee decreased blood glucose levels as well as serum cortisol, but had no effect on serum insulin levels. Blood glucose levels were discovered to be positively related to serum cortisol levels but not negatively related to serum insulin levels. A decrease in blood cortisol levels caused a drop in blood sugar levels in healthy females.

## Disclosure

No conflicts of interest were present in this publication.

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