Original Article

Acute Capillary Glucose Responses to Sweetened Beverages, Spice Infusions, and Mineral-Rich Water in Healthy Young Adults: A Randomized Parallel-Group Study

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ABSTRACT

Objective: To compare the acute capillary glucose responses to sweetened beverages, unsweetened cinnamon and ginger infusions, mineral-rich Zamzam water, and plain bottled water in healthy young adults after an overnight fast

Study Design: Randomized, controlled, parallel-group study

Place and Duration of Study: This study was conducted at the Jouf University, Sakaka, Saudi Arabia, from 1st February 2020 to April 2023.

Methodology: A total of 144 healthy university students aged 19-25 years were assigned equally to receive 250 mL of orange juice, a honey drink, a ginger infusion, a cinnamon infusion, Zamzam water, or plain bottled water after an overnight fast.

Results: Capillary glucose was measured before and 60 min after consumption, with 24 participants in each group. Mean glucose increased most after honey (+20.09 mg/dL) and orange juice (+17.33 mg/dL). Changes after cinnamon (-3.58 mg/dL), ginger (-3.91 mg/dL), and plain water (-2.84 mg/dL) were small. Zamzam water showed a modest increase (+9.83 mg/dL). Overall change differed among groups ($p<0.0001$).

Conclusion: The spice-infusion do not establish glucose-lowering effects, and the Zamzam result cannot establish a mineral-mediated mechanism.

Key Words: Blood Glucose, Beverage Intervention, Honey, Orange Juice, Cinnamon, Ginger, Mineral-Rich Water.

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INTRODUCTION

Type 2 diabetes and related metabolic disorders continue to impose a substantial global health burden.[1] Dietary carbohydrate quality and quantity influence glycemic exposure, and beverages are particularly relevant because liquid sugars can be consumed rapidly and provide limited satiety. Habitual intake of sugar-sweetened beverages has been associated with weight gain and cardiometabolic risk,[2] while fruit juice has also been associated with incident type 2 diabetes in prospective evidence.[3]

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Acute glucose excursions are therefore relevant when comparing beverages, although a single post-consumption value should not be equated with a diagnostic glucose-tolerance test or long-term glycemic variability.[4]

Cinnamon and ginger are commonly used in traditional and functional beverages. Experimental work suggests that cinnamon-derived compounds may influence insulin signaling and carbohydrate-digesting enzymes,[5] and trials in people with type 2 diabetes have reported modest improvements in selected glycemic outcomes after sustained cinnamon supplementation.[6] Gingerols may promote glucose uptake in experimental models,[7] and longer-term ginger supplementation has been studied in people with diabetes.[8,9] These findings do not establish that a single serving of an unsweetened spice infusion lowers glucose in healthy fasting adults. In the absence of a carbohydrate challenge, a neutral response may simply reflect the lack of digestible sugar.

Mineral composition may also influence metabolic physiology, but evidence that drinking water acutely alters glucose regulation is limited.[10] Zamzam water is naturally mineral-rich groundwater obtained from the Zamzam well in Makkah, Saudi Arabia. Published

analyses report variable composition according to source and analytical method.[11,12] Any acute difference therefore requires direct compositional measurement and an appropriate mineral-matched comparator before it can be attributed to total dissolved solids (TDS) or to an individual mineral.

The purpose of this study is to compared the acute capillary glucose response to two carbohydrate-containing beverages (honey drink and orange juice), two unsweetened spice infusions (cinnamon and ginger), mineral-rich Zamzam water, and plain bottled water after an overnight fast. We expected the carbohydrate-containing beverages to produce the largest increases, while the responses to the unsweetened beverages would be smaller. The comparison involving Zamzam water and the assessment of unintended events were exploratory objectives.

METHODOLOGY

This randomized, controlled, parallel-group, exploratory intervention study recruited 144 healthy university students at Jouf University, Saudi Arabia, from 1st February 2020 to 30th April 2023 letter No. JU-LCBE-8-18-9-40 dated 23/05/2019. All participants provided written informed consent before study procedures, and the study was conducted in accordance with the Declaration of Helsinki. Participants were recruited through campus advertisements and screened before written consent. Inclusion criteria were current enrollment at Jouf University, age 19-25 years, self-reported good health, ability to complete the required overnight fast, and willingness to consume any of the six study beverages. Exclusion criteria were diabetes or impaired glucose regulation; chronic endocrine, metabolic, renal, hepatic, or gastrointestinal disease; acute illness at the study visit; use of medication or supplements known to affect glucose metabolism; or allergy or intolerance to any study-beverage ingredient.

After an overnight fast and baseline glucose measurement, participants consumed the assigned 250 mL beverage under staff observation. Orange juice was a commercial 250 mL KDD pack (The Kuwaiti Danish Dairy Co. K.S.C.C, Kuwait; FJUQL6ORNGRP),[13] with 50 g sugar reported by the source record but not analytically verified. The honey drink contained approximately 50 g Black Forest honey in 250 mL water; the ginger infusion approximately 12 g fresh ginger in 250 mL water (48 g/L); and the cinnamon infusion 2.6 g cinnamon in 250 mL water (10.4 g/L). Zamzam water was a 250 mL commercially bottled product with label-reported TDS below 600 mg/L; the comparator was 250 mL Nova water with label-reported TDS of 120 mg/L. The waters were not chemically analyzed and product-lot information was unavailable.

Capillary whole-blood glucose was measured using six Contour glucometers and compatible test strips. Quality-control checks were performed with Contour control solution according to the manufacturer's procedure; the recorded test-strip lot was 2020. Standard hand preparation, lancing, and medical-waste procedures were followed. Three replicate readings were obtained at each time point and averaged. Measurements were taken immediately before beverage consumption and 60 min afterward. This assessment was not considered an oral glucose tolerance test because a standardized oral glucose load was not administered.

The primary outcome was the within-participant change in capillary glucose, calculated as the mean 60-min post-consumption glucose minus the mean fasting baseline glucose (Delta glucose, mg/dL). The 60-min post-consumption glucose value was the secondary outcome. No diagnostic classification was assigned to post-consumption values because a single capillary measurement after a non-standardized beverage challenge is not a diagnostic test.

Potential harms included symptoms or events related to fasting, beverage consumption, or finger-prick testing, including dizziness, nausea, allergy or intolerance, pain, bleeding, or bruising. Participants were observed during the session and asked about symptoms at 60 min. The anticipated physical risk was minimal, and no extended harms follow-up was planned.

Analyses used GraphPad software (San Diego, CA, USA). Within-group baseline and 60-min values were compared by paired t-test, and one-way analysis of variance compared change scores among groups. The original record referred to Tukey multiplicity adjustment, but complete diagnostic output, the exact F statistic, and adjusted pairwise estimates were not retained. Tests were two-sided, with $p < 0.05$ considered significant.

RESULTS

Overall, 144 received the assigned intervention, completed the 60-min assessment, and were included in the per-protocol primary analysis (24 per group). Mean fasting capillary glucose ranged from 79.17 mg/dL in the Zamzam-water group to 91.33 mg/dL in the cinnamon-infusion group (Table 1).

The two carbohydrate-containing beverages produced the largest mean increases: +20.09 mg/dL after the honey drink and +17.33 mg/dL after orange juice. Mean changes after cinnamon infusion (−3.58 mg/dL), ginger infusion (−3.91 mg/dL), and plain bottled water (−2.84 mg/dL) were small. The Zamzam-water group showed a mean increase of +9.83 mg/dL. The reported one-way analysis of variance indicated that mean change differed among the six groups ($p < 0.0001$). The confidence intervals and paired-test results for all groups are shown with corresponding 95% confidence intervals (Figure 1).

Table No. 1: Capillary glucose before and after beverage consumption in the analyzed sample (n = 24 per group)

Beverage	Baseline, mg/dL	Post, mg/dL	Mean change	95% CI of change	Paired p value
Honey drink	89.83±7.20	109.92±9.79	+20.09	+15.50 to +24.68	<0.0001
Orange juice	86.50±9.42	103.83±17.26	+17.33	+6.10 to +28.56	0.0058
Zamzam water	79.17±6.09	89.00±5.17	+9.83	+5.20 to +14.46	0.0003
Plain water	88.42±10.45	85.58±8.69	-2.84	-11.18 to +5.50	0.48
Cinnamon infusion	91.33± 6.88	87.75±6.89	-3.58	-9.62 to +2.46	0.22
Ginger infusion	88.73±9.73	84.82±8.53	-3.91	-12.22 to +4.40	0.33

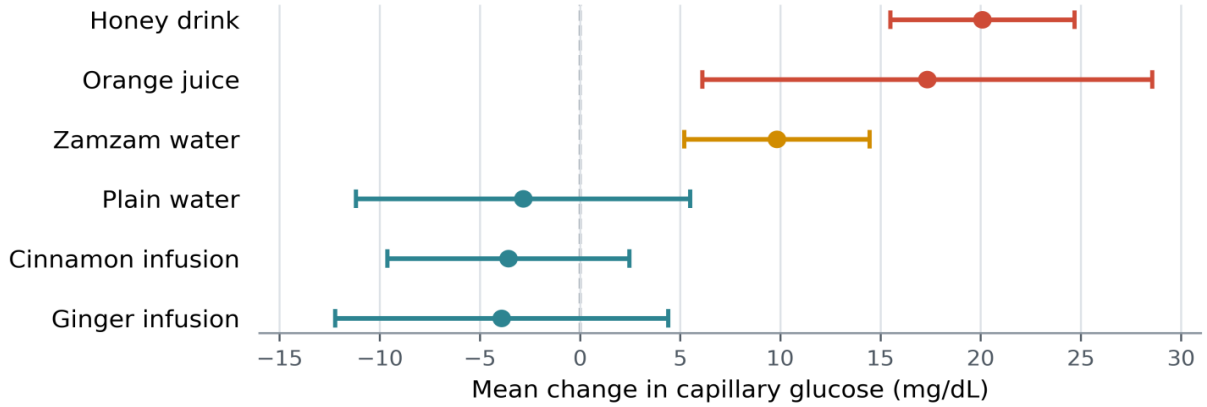


Figure No. 1: Mean within-group change in capillary glucose after beverage consumption. Positive values indicate an increase from fasting baseline

DISCUSSION

In healthy young adults studied after an overnight fast, the carbohydrate-containing beverages produced the largest acute increases in capillary glucose. Plain bottled water and the unsweetened cinnamon and ginger infusions showed little mean change. Mineral-rich Zamzam water showed a modest within-group increase, but the parallel-group design and available analysis do not establish a mineral-mediated mechanism. The responses to the honey drink and orange juice are biologically plausible because both supplied rapidly available carbohydrate. This acute experiment is consistent with broader evidence linking sugar-containing beverages with adverse glycemic and cardiometabolic outcomes.[2,3] However, post-consumption values should not be described as prediabetic or pathological: diagnostic thresholds for fasting glucose or standardized oral glucose tolerance testing do not apply to a single capillary measurement after non-standardized beverages.

The neutral responses to cinnamon and ginger require conservative interpretation. The standardized extracts or supplements over weeks or months in people with diabetes.[14,15] In this study, the infusions were unsweetened and contained fresh ginger at approximately 48 g/L or cinnamon at 10.4 g/L; no carbohydrate challenge was co-administered. The results therefore show that these drinks did not acutely increase mean glucose. They do not demonstrate active glucose lowering, enhanced insulin sensitivity, inhibition of carbohydrate digestion, or prevention of a glycemic spike.

The Zamzam-water observation is hypothesis-generating. Approximately 18.5-42 mg/L magnesium, 56.5-93 mg/L calcium, and 67.1-210 mg/L sodium, with values varying by sampling source and analytical method.[11,12] Magnesium participates in insulin signaling and glucose transport, while calcium contributes to pancreatic beta-cell insulin secretion. Biological variation in capillary glucose also warrants consideration when interpreting a modest change from a single baseline measurement.[16] Nevertheless, the administered water was not analyzed, and insulin and circulating mineral concentrations were not measured and baseline imbalance and regression to the mean also remain plausible explanations. The present study therefore cannot attribute the observed change to magnesium, calcium, sodium, TDS, or another mineral pathway.

Acute human trials show that beverage composition, comparator selection, and sampling schedule influence observed glycemia. Glycemic responses differed among honey varieties even when available carbohydrate was standardized.[17] Orange-pomace fiber attenuated the acute glycemic response to sugar-matched orange juice.[18] Cinnamon consumed with a carbohydrate meal reduced postprandial glucose and delayed gastric emptying in a small crossover trial,[19] while a standardized ginger aqueous extract was evaluated

using repeated postprandial measurements in nondiabetic adults.[20,21] These protocols illustrate why exact ingredient dose, beverage composition, comparator selection, and multiple sampling times should be documented.

Several limitations materially affect interpretation. First, demographic and clinical characteristics by group, a formal a priori power calculation, detailed pretest dietary and activity standardization, complete adherence reasons, and systematic group-specific harms data were not retained. The trial was not prospectively registered, and no publicly accessible protocol or statistical analysis plan is available. Second, although ingredient concentrations were documented, the botanical species, full infusion conditions, product lots, and nutritional and mineral composition of the administered beverages were not analytically verified. Third, capillary glucose was measured at only one post-consumption time point; the study cannot characterize peak response, incremental area under the curve, glycemic variability, or insulin dynamics. Glucose-meter user technique and strip-lot variability can affect measurements, although quality-control checks and triplicate readings were used. Fourth, the exact ANOVA statistics, complete assumption diagnostics, updated precision estimates for two groups, and multiplicity-adjusted pairwise comparisons were unavailable. Finally, exclusion of 36 randomized participants from the per-protocol analysis may introduce attrition bias, and the healthy student sample limits generalizability to older adults and people with impaired glucose regulation.

CONCLUSION

After an overnight fast, the honey drink and orange juice produced the largest acute increases in capillary glucose. The small changes after unsweetened cinnamon and ginger infusions are compatible with their lack of added sugar but do not establish an antihyperglycemic effect. The modest within-group rise after Zamzam water is hypothesis-generating and cannot be attributed to mineral content because the administered water and relevant circulating biomarkers were not analyzed. Future trials should directly characterize beverages, use a crossover or baseline-adjusted design, obtain venous glucose and insulin at multiple time points, and prespecify analyses in a registered protocol.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Hassan Almarshad
Drafting or Revising Critically:	Hassan Almarshad
Final Approval of version:	The above author
Agreement to accountable for all aspects of work:	The above author

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