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Original article

Effect of Water Intake with Meals on Postprandial Plasma Glucose Levels Among Healthy College Students in Derna, Libya

Saria Arhaim[1], Hameda Asrafe[2], Ghada Otman[3], Retaj Belaid[1], Aom Alkhier Aldersi[1], Faraj Ben Arous[1]

[1]Public Health Department, College of Medical Technology, Derna, Libya
[2]Laboratory Medicine Department, College of Medical Technology, Derna, Libya
[3]Higher Institute of Medical Professional, El-Beyda, Libya
Email. sariaerhaim30@gmail.com

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ABSTRACT

Postprandial blood glucose is an important indicator of glucose metabolism and may be influenced by dietary and behavioral factors, including the timing of water consumption in relation to meals. However, limited evidence is available regarding the effect of water intake with meals on postprandial glucose among healthy young adults. This study aimed to investigate the effect of water intake at different times in relation to meal consumption on postprandial blood glucose levels among healthy college students in Derna, Libya. An experimental study was conducted among 35 healthy college students aged 18–25 years. Participants consumed a standardized carbohydrate-containing meal under different water-intake conditions: meal alone, 500 mL of water consumed with the meal, 500 mL consumed 30 minutes before the meal, and 500 mL consumed 30 minutes after the meal, along with an additional experimental condition involving water intake. Blood glucose levels were measured at 30, 60, 90, and 120 minutes after meal consumption. Data were analyzed using SPSS version 26 with descriptive and inferential statistics, with a *p*-value ≤ 0.05 considered statistically significant. Blood glucose responses varied according to the timing of water consumption. The group consuming 500 mL of water with the meal showed the highest early postprandial glucose response, reaching its peak at 30 minutes, whereas the other groups generally peaked at 60 minutes. A statistically significant difference in the postprandial glucose response over time was observed between the water-with-meal group and the meal-alone group (*p* = 0.019). Differences among the other water-intake conditions were not statistically significant. These findings suggest that consuming 500 mL of water with a meal may influence the timing and pattern of the acute postprandial blood glucose response in healthy college students. Larger studies examining different water volumes and timing intervals, together with insulin and other metabolic markers, are recommended.

Introduction

Blood glucose concentration refers to the amount of glucose circulating in the blood and is a key component of metabolic homeostasis. Glucose is a simple carbohydrate that serves as a major source of energy for many tissues, particularly the brain. In a healthy adult weighing approximately 70 kg, only a small amount of glucose, approximately 4 g, is present in the circulating blood at any given time. Despite this relatively small quantity, blood glucose levels are tightly regulated to maintain normal physiological function. Excess glucose is stored primarily as glycogen in the liver and skeletal muscles, while during fasting, hepatic glycogen stores contribute to maintaining blood glucose within a relatively stable range [1].

Blood glucose is transported through the circulation from the gastrointestinal tract and liver to tissues throughout the body. The uptake and utilization of glucose by cells are regulated largely by insulin, a hormone secreted by the pancreatic β-cells. The brain has a particularly high demand for glucose and accounts for a substantial proportion of glucose utilization during fasting conditions. Persistently elevated blood glucose concentrations can contribute to glucose toxicity, cellular dysfunction, and the development of complications associated with diabetes mellitus [1].

Repeated elevations in postprandial blood glucose may be associated with adverse metabolic outcomes, including obesity, type 2 diabetes mellitus, and cardiovascular disease [2]. These conditions represent major global health challenges and contribute substantially to morbidity, mortality, and economic burden in both developed and developing countries. In addition, maternal postprandial glucose concentrations have been reported to be associated with fetal growth and birth weight, highlighting the importance of postprandial glycemic regulation during pregnancy [3].

Over recent decades, considerable research has focused on identifying factors that influence postprandial glucose responses. These factors include the amount and type of carbohydrates consumed, meal composition, and physical characteristics of food, such as temperature, viscosity, and consistency. In addition to these food-related characteristics, the water content of a meal may also influence the rate and magnitude of the postprandial plasma glucose response [4].

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Behavioral and physiological factors may further contribute to variations in postprandial glucose levels. For example, body position and physical activity following a meal may affect glucose metabolism and the subsequent glycemic response [5]. Maintaining an appropriate postprandial glycemic response is important for overall metabolic health, particularly among individuals at risk of impaired glucose regulation or diabetes. Understanding whether the timing of water consumption in relation to meals influences postprandial blood glucose could provide useful information regarding simple dietary behaviors that may affect the glycemic response. Therefore, the present study aimed to investigate the effect of water intake at different times in relation to meal consumption on postprandial blood glucose levels among healthy college students in Derna, Libya.

Methods

Study Area

The study was conducted at the College of Medical Technology, Derna, Libya, between January and February 2024.

Study Participants

A total of 35 apparently healthy students were recruited using a simple random sampling technique. The participants comprised 10 males and 25 females, aged between 18 and 25 years. Participants were eligible for inclusion if they were apparently healthy, aged 18–25 years, and had a normal fasting blood glucose concentration of 70–99 mg/dL. Students who were smokers or had a known medical condition were excluded from the study. Participants were also instructed to avoid strenuous physical activity and excessive food intake on the day preceding the experiment.

Upon reporting for the study, each participant's body weight and height were measured, and body mass index (BMI) was calculated. Before participation, the study procedures were explained to all participants, and oral informed consent was obtained. Permission and Ethical Approval to conduct the study was granted from the College of Medical Technology, Derna, Libya.

Experimental Design and Sample Collection

A bottle of drinking water (500 mL; 120 TDS, 12 mg/L Ca^{2+}, 10 mg/L Mg^{2+}, pH 8.0, and zero calories) and a croissant filled with chocolate and hazelnut paste were used as the test beverage and meal, respectively. Each participant consumed the entire 500 mL bottle of water according to the assigned experimental condition.

Following an overnight fast of approximately 10–12 hours, capillary blood glucose was measured using the VivaChek Ino Performa blood glucose monitoring system. Approximately 0.6 µL of capillary blood was required for each glucose measurement. Participants were assigned to five experimental groups according to the timing of water consumption relative to meal intake. Group 1 consumed one croissant without additional water. Group 2 consumed one croissant together with the entire 500 mL bottle of water within 10 minutes. Group 3 consumed the entire 500 mL bottle of water 30 minutes before consuming the croissant. Group 4 consumed the croissant first and the entire 500 mL bottle of water 30 minutes later. Group 5 consumed one croissant, followed 30 minutes later by a second croissant consumed together with the entire 500 mL bottle of water. Participants remained seated in a relaxed position throughout the experimental period and were instructed to avoid additional food or beverages and any physical activity during the measurements.

Table 1. Nutrition information of the croissant filled with chocolate and hazelnut paste sample.

Nutrient	Per 100 g
Protein	7.4 g
Fat	27 g
Saturated fat	14 g
Trans fat	0.25 g
Carbohydrate	48 g
Energy	463 kcal

Statistical analysis

Blood glucose was measured at baseline (0 min) immediately before consumption of the test meal, and subsequently at 30, 60, 90, and 120 minutes after the start of meal consumption. For Group 4, an additional blood glucose measurement was obtained immediately before water consumption at 30 minutes. The collected data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS), version 26. Descriptive statistics were used to summarize the data, including frequencies, percentages, means, ranges, and standard deviations. The independent-samples *t*-test was used to compare the means between two independent groups. A *p*-value ≤ 0.05 was considered statistically significant.

Results

A total of 35 apparently healthy students, including 10 males (28.6%) and 25 females (71.4%), participated in the study

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between January and February 2025. The mean age of the participants was 21.17 ± 1.71 years, with a range of 18–24 years. The mean BMI was 21.31 ± 1.98 kg/m^2, with values ranging from 19 to 25 kg/m^2. All participants were apparently healthy and had normal fasting blood glucose levels at baseline. None reported using medications known to affect appetite, gastrointestinal function, energy intake, or blood glucose levels.

Table 2. Changes in blood glucose levels among the experimental groups at different time intervals

Group	Experimental condition	30 min	60 min	90 min	120 min
G1	No water	98.14 ± 4.67	107.71 ± 9.66	102.29 ± 6.85	93.57 ± 9.68
G2	Water at 0 min	112.86 ± 12.34	114.43 ± 15.02	104.71 ± 10.69	94.71 ± 7.95
G3	Water at 30 min	102.71 ± 9.07	119.43 ± 18.85	107.43 ± 14.68	96.00 ± 10.02
G4	Water at −30 min	102.57 ± 12.12	89.57 ± 10.89	87.57 ± 9.24	80.86 ± 7.20
G5	Two croissants	106.86 ± 11.41	102.29 ± 13.40	96.43 ± 6.35	97.29 ± 12.35

Postprandial blood glucose concentrations in the five experimental groups at 30, 60, 90, and 120 minutes are presented in Table 3. At 30 minutes, the highest mean blood glucose concentration was observed in G2 (112.86 ± 12.34 mg/dL), in which water was consumed together with the croissant. This was followed by G5 (106.86 ± 11.41 mg/dL), G3 (102.71 ± 9.07 mg/dL), G4 (102.57 ± 12.12 mg/dL), and G1 (98.14 ± 4.67 mg/dL).

At 60 minutes, the highest mean blood glucose concentration was observed in G3 (119.43 ± 18.85 mg/dL), followed by G2 (114.43 ± 15.02 mg/dL), whereas the lowest concentration was observed in G4 (89.57 ± 10.89 mg/dL). At 90 minutes, mean blood glucose levels ranged from 87.57 ± 9.24 mg/dL in G4 to 107.43 ± 14.68 mg/dL in G3. At 120 minutes, the lowest mean blood glucose concentration was observed in G4 (80.86 ± 7.20 mg/dL), while the highest was observed in G5 (97.29 ± 12.35 mg/dL).

Overall, the results indicate that the highest mean glucose concentration at 30 minutes occurred when the croissant was consumed together with water (G2). However, the highest mean glucose concentration at 60 and 90 minutes was observed in G3, in which water was consumed 30 minutes before the meal (Table 1).

Table 2 demonstrates that the mean postprandial blood glucose level at 30 minutes was significantly higher among participants who consumed the croissant together with water (G2) compared with those who consumed the croissant without water (G1) (112.86 ± 12.34 vs. 98.14 ± 4.67 mg/dL, p = 0.019). However, no statistically significant differences were observed between G2 and G3 (p = 0.105), G2 and G4 (p = 0.142), or G2 and G5 (p = 0.364).

Table 3. Comparison of blood glucose levels at 30 minutes between G2 and the other experimental groups

Comparison	Mean ± SD (mg/dL)	p-value
G1 vs. G2	98.14 ± 4.67 vs. 112.86 ± 12.34	**0.019**
G3 vs. G2	102.71 ± 9.07 vs. 112.86 ± 12.34	0.105
G4 vs. G2	102.57 ± 12.12 vs. 112.86 ± 12.34	0.142
G5 vs. G2	106.86 ± 11.41 vs. 112.86 ± 12.34	0.364

Discussion

Postprandial blood glucose (PPG) is an important indicator of glucose metabolism and provides useful information about the acute glycemic response to food intake. The present experimental study investigated the effect of consuming 500 mL of water at different times in relation to a meal on postprandial blood glucose levels among healthy participants. The findings demonstrated differences in the pattern of blood glucose response according to the timing of water consumption.

The highest blood glucose response was observed when 500 mL of water was consumed together with the meal (G2), compared with the condition in which the meal was consumed without additional water (G1), or water was consumed 30 minutes before (G3) or after the meal (G4). In G2, the peak blood glucose level was observed at 30 minutes, whereas the other groups generally reached their highest mean glucose levels at 60 minutes. These findings suggest that consuming water together with the meal was associated with a significantly higher 30-minute postprandial blood glucose level compared with consuming the meal alone, whereas the differences observed under the other water-consumption conditions did not reach statistical significance.

The statistical analysis demonstrated a significant difference in the postprandial blood glucose response over time between G2 and G1 (p = 0.019). This finding suggests that the timing of water consumption in relation to food intake may influence the early postprandial glucose response. However, because the present study assessed an acute response in healthy participants, the observed increase should not be interpreted as evidence that drinking water with meals directly increases the long-term risk of diabetes mellitus, obesity, or cardiovascular disease.

The findings of the present study are consistent with previous research investigating the effects of solid and liquid carbohydrate-containing foods on postprandial pancreatic endocrine function. Schusdziarra et al. (1981) reported

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differences in the endocrine response following consumption of solid and liquid carbohydrates, suggesting that the physical form of carbohydrate-containing foods may influence the postprandial metabolic response. These findings provide a possible basis for considering how the combination of food and fluid intake may affect postprandial glucose and insulin responses [6]. Similarly, Torsdottir and Andersson (1989) reported that consumption of 300 mL of water together with food following a 12-hour fasting period increased blood glucose and insulin concentrations in apparently healthy individuals, while an increase in glucose concentration was observed in well-controlled diabetic patients[7]. These findings are broadly consistent with the present study, particularly regarding the possibility that water consumed together with food may modify the postprandial glucose response.

Previous studies have also investigated the effects of water consumption before meals, although their primary outcome was energy intake rather than postprandial glucose. Van Walleghen et al. (2007) reported that pre-meal water consumption reduced meal energy intake in older but not younger adults[8]. Similarly, Davy et al. (2008) found that water consumption before breakfast reduced energy intake among obese older adults. Although these findings do not directly assess postprandial glucose, they indicate that the timing of water consumption relative to food intake may influence physiological responses to meals[9].

The findings of the present study are also comparable with those reported by Robbert and Jerry (2018), who investigated the effect of drinking water together with a jelly-filled doughnut on postprandial blood glucose in healthy young individuals. Their findings indicated a time-dependent effect of consuming water with the food, with the greatest increase in glucose observed when the doughnut was consumed together with water [10]. This is broadly consistent with the present finding that simultaneous water consumption was associated with an earlier and higher postprandial glucose response. Nevertheless, differences in the type and carbohydrate content of the meal, volume of water, participant characteristics, and experimental procedures should be considered when comparing the two studies.

In contrast, Benozzi et al. (2018) reported no significant changes in glucose concentration under fasting conditions following water intake[11]. This finding differs from the present study and may be partly explained by differences in the experimental conditions. The current study specifically assessed postprandial glucose following food consumption, whereas Benozzi et al. (2018) investigated biochemical parameters under fasting conditions[11]. Therefore, the presence of food and the timing of water intake may be important considerations when evaluating the relationship between water consumption and glucose concentration. Other research has reported findings in the opposite direction. Vanessa et al. (2018) reported that an additional 450 mL of plain water consumed after a meal was associated with a lower two-hour postprandial blood glucose level in healthy subjects[12]. However, the timing of water consumption within the two-hour period was not specifically investigated, making direct comparison with the present study difficult. Differences in water volume, timing of consumption, meal composition, participant characteristics, and duration of glucose monitoring may account for some of the differences between these findings and those of the present study.

One possible explanation for the findings of the present study is that water consumed simultaneously with a meal may modify the physical characteristics of gastric contents and potentially influence gastric emptying and the rate at which nutrients become available for absorption. However, these mechanisms cannot be confirmed by the present study because gastric emptying, insulin, and other relevant metabolic hormones were not measured. Therefore, these possible mechanisms should be considered as hypotheses requiring confirmation through further experimental investigation.

Overall, the findings of the present study suggest that the timing of water consumption in relation to a meal may influence the acute postprandial blood glucose response in healthy individuals. The significant difference observed between G2 and G1 indicates that consuming 500 mL of water together with the meal produced a different early glucose response compared with consuming the meal without additional water. The present findings are generally consistent with some previous studies, although contrasting results have also been reported. These differences highlight the need for further controlled research examining the effects of water volume, timing, meal composition, and metabolic characteristics of participants on postprandial glucose responses.

Limitations

The present study has several limitations that should be considered when interpreting the findings. First, the sample size was relatively small, which may limit the statistical power and generalizability of the results. Second, only healthy participants were included; therefore, the findings cannot be directly generalized to individuals with diabetes mellitus, impaired glucose tolerance, obesity, or other metabolic disorders.

Third, the study assessed blood glucose concentrations only and did not measure insulin, glucagon, vasopressin, or other hormones involved in glucose and fluid regulation. Consequently, the physiological mechanisms responsible for the observed differences in postprandial glucose responses cannot be established from the present data. Fourth, the study evaluated the short-term response over the postprandial period and therefore cannot determine whether the observed changes have any long-term metabolic or clinical consequences.

Further studies involving larger and more diverse populations, including both healthy individuals and patients with diabetes, are recommended. Measurement of insulin and vasopressin responses, together with blood glucose, would provide a

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better understanding of the mechanisms through which water consumption may influence postprandial glycemic regulation. Future research should also investigate different volumes and timings of water consumption and consider other factors such as meal composition and carbohydrate content. Despite these limitations, the present study contributes to the limited body of evidence concerning the relationship between water consumption and postprandial glucose responses and provides a basis for further investigation.

Conclusion

The findings of this experimental study suggest that the timing of water consumption in relation to a meal may influence the acute postprandial blood glucose response in healthy individuals. Consumption of 500 mL of water together with the meal was associated with the highest observed blood glucose response and an earlier peak at 30 minutes, whereas the other experimental conditions generally showed their highest mean glucose levels at 60 minutes. A statistically significant difference in the postprandial glucose response over time was observed between the group consuming water with the meal and the group consuming the meal without additional water ($p = 0.019$). These findings indicate that water consumption with a meal may affect the pattern of postprandial glucose regulation. However, the present study does not establish that drinking water with meals increases the long-term risk of diabetes, obesity, or cardiovascular disease. Therefore, the results should be interpreted as evidence of an acute change in postprandial glucose response rather than a direct indication of long-term disease risk.

Recommendations

Based on the findings of the present study, further research should be conducted using larger sample sizes and including both healthy individuals and participants with diabetes or impaired glucose regulation to confirm the observed effects of water consumption on postprandial blood glucose. Future studies should measure insulin, vasopressin, and other relevant metabolic parameters alongside blood glucose to better understand the physiological mechanisms underlying the observed responses. In addition, different volumes and timings of water consumption before, during, and after meals should be investigated, while controlling for meal composition and carbohydrate content. Long-term studies are also recommended to determine whether repeated changes in postprandial glucose responses associated with water consumption have any clinically meaningful metabolic consequences. Until further evidence is available, recommendations to avoid drinking water with meals should not be made solely on the basis of the present findings.

Conflict of interest. Nil

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