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# Effect Of Coconut Water on Blood Glucose and Insulin in Humans Depends on Their Metabolic Status

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## ABSTRACT

Coconut water, a popular health food in Asia, is gaining popularity in the US due to its low glycemic index and is being promoted as a good beverage alternative to sugary drinks for people preferring a low carbohydrate diet or who are on intermittent fasting regimens. Given its increased popularity and confusing information in the public domain, some suggesting no impact on blood glucose, we aimed to establish the effect systematically. We hypothesized that coconut water may mildly increase blood glucose and insulin in all subjects as it contains at least ~9 g of total carbohydrates. We conducted a clinical study in humans (n=11, ages 16 and above) wherein fasting blood glucose and insulin were measured at baseline and again at 40 min and 120 min after drinking 250 mL of either fresh or bottled coconut water. As hypothesized, coconut water increased blood glucose and insulin in the majority of subjects in 45 min, and returned to baseline by 2 h post consumption. The mean increase from baseline was 8.90 mg/dL for glucose and 9.53 uIU/mL for insulin. Further, there was a clear trend of higher increase in prediabetic subjects (n=5) compared to the normal subjects (n=5), with insulin increase being statistically significant. There was no difference in the response to fresh versus bottled coconut water. In conclusion, the effect of coconut water on blood glucose and insulin was mild, however, the magnitude may depend on a person's baseline metabolic status.

## Introduction

Obesity, diabetes, and metabolic syndromes are major health crises in the modern world. The National Center for Chronic Disease Prevention and Health Promotion notes that approximately 96 million U.S. adults aged 18 years and older (38% of the adult population) are prediabetic. Not just the adult population, but teens are also facing a rapid rise in diagnosis of obesity and consequently, Type 2 diabetes.

Type 2 diabetes arises from reduced insulin sensitivity due to a sustained high level of blood glucose and insulin. One popular way of improving insulin sensitivity without medical interventions is low carbohydrate diet and intermittent fasting. Coconut water contains approximately 9 g of sugar and therefore considered to be a low-carbohydrate food (Ref: USDA, "Nuts, coconut water") and has promoted by Asian dieticians to be useful in intermittent fasting, without raising blood glucose or insulin (Ref: ADORE trust). However, there is no clinical study demonstrating the effect of coconut water on blood glucose as well as insulin and the information available in the literature is anecdotal and conflicting with only one systematic study reported so far (O'Brien et al., 2023). This study investigated the glucose and insulin changes in blood following coconut water consumption. The findings will provide important information on whether coconut water serves as a good, low-glycemic index 'cheat food' choice for people following an intermittent fasting regimen or alternatively, simply be a low glycemic index drink as an alternative to sugary drinks for reducing risk of diabetes (Dorans et al., 2022).

## Methods

The protocol, informed consent forms, were submitted to the Cupertino High School based Institutional Review Board, chaired by a U.S. board certified medical doctor, and was reviewed and approved before the study was initiated. Written informed consent for the study was obtained from all subjects before any procedures were carried out.

### Study Participants:

A total of 11 healthy, non-smoking volunteers, men and women, aged 16 to 75 years were screened to assess their eligibility to participate in this study. Subjects who were in generally good health with no ongoing, unstable medical conditions were allowed to participate. Subjects with well controlled hypertension and type II diabetes and stable on medications for at least 1 month were allowed on the study. Type I diabetic patients requiring insulin were not allowed due to interference with the insulin assessments in the study. Participation in other clinical studies or donation of blood within the one month of participation in this study was prohibited. Subjects were asked to maintain the same level of diet and activity for a week prior to the study day and to maintain regular level of activity on the day of the study.

### Study Procedures

The study procedures involve standard glucose and insulin tests that can be conducted in any commercial clinical or pathology laboratory (e.g. Quest and Metropolis). Therefore, a decentralized process was implemented, that is, the subjects did not go to a central clinical facility, but visited their local, GLP certified pathology lab for their glucose and insulin assessments. The subjects fasted overnight for at least 8 hours after their evening meal. At the clinical laboratory facility, fasting glucose and insulin samples were taken, following which subjects drank 250 mL of coconut water. Two additional post-prandial blood samples were collected after 45 min and 2 h after consumption of coconut water (see Figure 1 for schematic for study day procedure). No additional food or drink was allowed until the last sample collection was completed. The blood samples were collected in standard red top or SST tubes and serum was analyzed by locally certified clinical laboratories and reports were sent to the study investigator electronically for data analysis. In addition, HbA1c was also measured, if a recent assessment was not available in the subject's medical history. Subjects were allowed to drink 250 mL of either fresh or bottled coconut water. The Sources of fresh coconuts were either from Mexico or India. The bottled coconut water brand used was Zico™ sourced from Trader Joe's™ store.

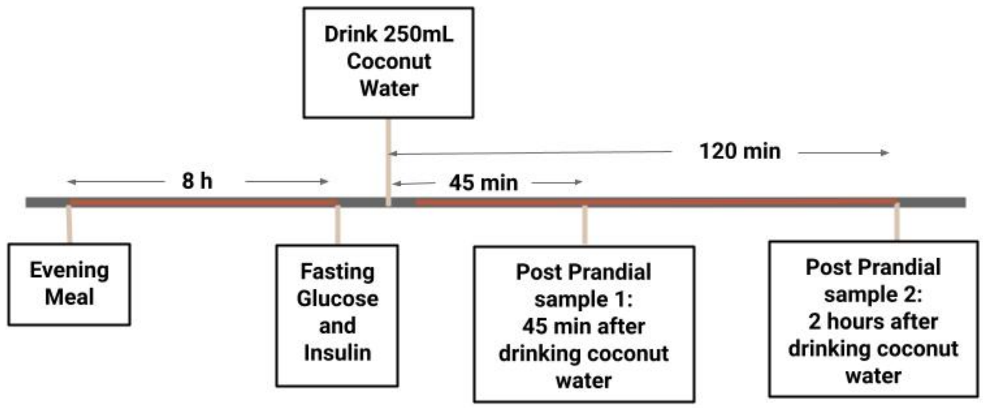


**Figure 1.** Schematic for study day procedures

## Data Analysis

Sample size for the study was not based on a power calculation. Exploratory food studies are often small in size, and since the same subjects serve as their own controls by providing a before and after coconut water consumption samples, and therefore, a smaller sample size was considered acceptable for an exploratory analysis. The Arithmetic mean change in blood glucose and insulin was calculated at 45 min and 2 h postprandial timepoints by comparing the values to the fasting values. The change from pre- to post- coconut water consumption data were compared by student's t-test for statistical significance at alpha = 0.05. The data were also explored with HbA1c as a stratification factor.

# Results

## Subject Demographics

Eleven subjects were enrolled and of them, ten completed the study procedures. The median age of all enrolled subjects was 46 years (range 16 to 75 years). One subject only completed the baseline and the 45 min time point. The available data was still considered relevant and was included in the data analysis. Of the enrolled subjects, four were males and seven females. The mean body weight for enrolled subjects was 151 kg (range 110 to 180 lbs).
Demographics are detailed in Table 1 below.

**Table 1.** Subject demographics

| **Total (n =11)** | **Mean** | **Range** |
|---|---|---|
| Males (n = 4) | NA | NA |
| Females (n = 7) | NA | NA |

| Total (n =11) | Mean | Range |
|---|---|---|
| Age | 46 | 16-74 |
| Height (in) | 64 | 58-72 |
| Weight (lbs) | 151 | 110-180 |
| HbA1C (%) | 5.79 | 5.3 - 6.8 |

## HbA1c Levels

HbA1c, or glycated hemoglobin, was used to categorize the subjects as diabetic, prediabetic or normal based on pre-determined cut off values as follows based on WHO guidelines (John et al., 2012):

Normal: Below 5.7%
Prediabetes: 5.7% to 6.4%
Diabetes: 6.5% or higher

Based on this classification, 1/11 patient was diabetic, 5/11 were prediabetic and 5/11 were normal. These categories were used to provide a context for the glucose and insulin changes observed.

## Change In Glucose and Insulin After Coconut Water Consumption

At baseline, ten out of eleven subjects had normal fasting glucose of <100 mg/dL. At baseline, insulin levels for all subjects ranged from 5.3 mg/dL to 14.4 mg/dL. Only one patient with type II diabetes had a fasting glucose of 110 mg/dL and this subject is excluded from some of the summary statistics due to higher than normal baseline glucose. All other subjects showed a mild increase in blood glucose and insulin following coconut water consumption, with a mean increase of 8.9 mg/dL for glucose and a mean increase of 9.53 IU/mL for insulin at 45 min. Both glucose and insulin levels returned to baseline or close to baseline by 2 hours in all the subjects. The change in blood glucose levels in prediabetic subjects was almost 2-fold higher at 14.6 mg/dL versus 7.50 mg/dL for normal subjects. Similarly, change in the blood insulin levels in prediabetic subjects was almost 2-fold higher at 15.28 IU/mL versus 8.60 IU/mL for normal subjects. The highest increase in glucose observed was 29 mg/dL, wherein the subject went from 94 mg/dL at baseline to 123 mg/dL at 45 min. The maximum increase in insulin was observed for the same subject at 32.7 IU/mL and went from 14.4 IU/mL at baseline to 47.1 IU/mL at 45 min. Both glucose and insulin levels returned to baseline levels by 2 h timepoint. The inter-subject variability in the assessment was generally high. Figure 2A and 2B depict the changes in glucose and insulin, respectively, for all subjects.

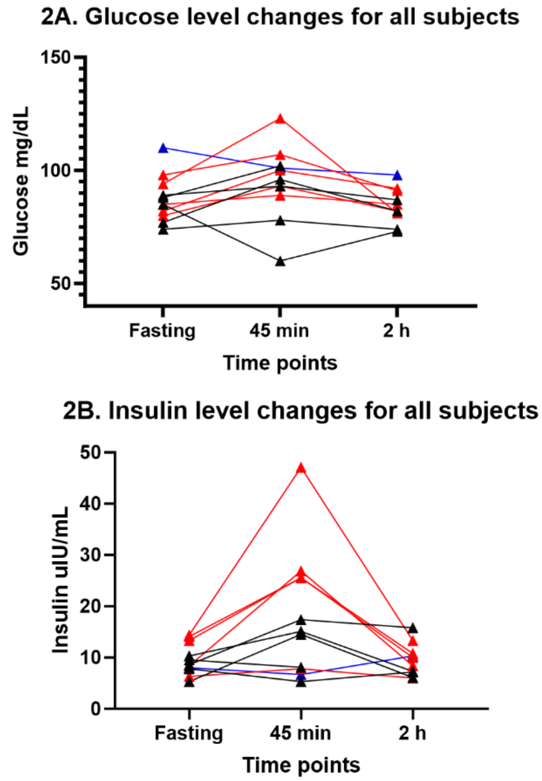


**Figure 2.** Glucose (A) and Insulin (B) levels for all patients at baseline, 45 min and 2 h postprandial
Legend: Black: normal subjects; Red: prediabetic subjects; Blue: diabetic subject

## Statistical Analysis

Two tailed, paired student's t-test with equal variances was employed to see if there was a significant increase in blood glucose and insulin at 45 min or 120 min postprandial timepoint. Considering all the eleven subjects together, at alpha of 0.05, the increase in insulin at the 45 min time point was statistically significant (p-value of 0.01), but increase in glucose was not. When insulin was separately compared between prediabetes versus normal subjects, prediabetic subjects still demonstrated statistically significant increases in insulin at 45 min (p value of 0.01), but normal subjects did not. At 2 h time point, neither insulin nor glucose was significantly different from baseline, consistent with the observation that the levels returned to be close to baseline at 2 h time point. Figure 3A and 3B shows the arithmetic mean and standard deviation in glucose and insulin changes.

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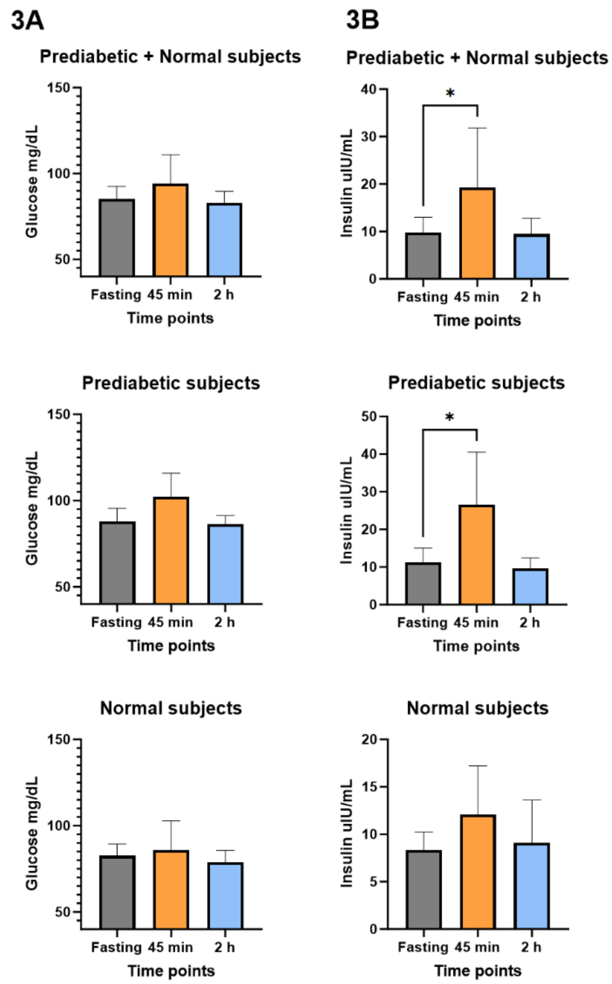


**Figure 3:** Fasting and postprandial glucose (A) and insulin (B) levels as mean and standard deviations in prediabetic and normal subjects. (* indicates statistical significance by t-test)

## Adverse Reactions

Ten out of eleven subjects completed all three sampling time points (predose, 45 min and 2 h postprandial) without any adverse reactions or problems. One subject withdrew consent after 45 min time-point due to local discomfort of venous blood draw. There were no reportable adverse reactions to coconut water consumption in the study.

## Additional Mechanistic Assessments

If the coconut water had not shown any increase in blood glucose or insulin, additional assessments were planned to check if high magnesium and potassium content of coconut water played a role. Since this was not the case, we only completed and reported the coconut water portion of the study.

## Discussion

Coconut water is a popular health food in Asian and other tropical countries and is considered to be a good low carbohydrate alternative to sugary sports drinks and fruit juices. This study was undertaken to establish the true effect of coconut water on blood glucose and insulin. We have shown that consistent with reported low glycemic index of coconut water, drinking a serving of 250 mL fresh or bottled coconut water results in a mild and transient increase in both blood glucose and insulin at the 45 min time point, which returns to normal baseline levels in 2 h.

The timepoints selected for this study were based on prior reported studies, where 30 to 45 min is typically the timeframe for peak levels after a meal (Bao et al., 2009, Östman et al., 2005). Similarly, for most individuals without uncontrolled diabetes, the glucose levels return to baseline in 2 h (Eyth et al., 2023). A typical glucose tolerance test is based on this premise of 2 h being sufficient for normalizing glucose if glucose homeostasis is normal. Insulin kinetics are usually reported to be similar to glucose kinetics, which is what we observed in this study as well, with insulin showing a transient increase at 45 min, which returned to be close to baseline in majority of the subjects by 2h. However, the changes in insulin were statistically significant, but ones in glucose were not. This could be due to several reasons. The intra-subject variability of glucose may be higher than that of insulin or the glucose assay could be inherently more variable than insulin assay. Given that these were decentralized measurements, and while all laboratories were certified, some laboratory to laboratory difference could be a source of variability.

The general trend of increase in glucose and insulin was further looked at from the standpoint of each subject's metabolic status using HbA1c values. which reflects the average level of blood glucose over the past 2 to 3 months. It measures levels of glycated hemoglobin and is an indicator of how well blood sugar levels have been controlled over that period. A higher HbA1c level indicates poorer blood sugar control and an indicator of diabetes or prediabetes based on well established cut off values used in clinical diagnosis (John et al., 2012).

The effect on glucose and insulin in prediabetic subjects was higher than normal subjects. This is an important reminder that studies done in normal subjects may not be directly translatable to prediabetic and diabetic patients. A prediabetic patient needs to be more vigilant in their food intake, especially in intermittent fasting or in a low carbohydrate diet, since the same amount of sugars can cause a bigger impact. Prediabetic patients are at a risk of developing Type II diabetes, and are losing their insulin sensitivity, and therefore, more insulin is required for processing the glucose spike (Alvarez et al., 2023). A continuous glucose monitor will be ideal to monitor and ascertain if prediabetic subjects would have larger area under glucose-time curve compared to normal subjects. The only one subject who had Type II diabetes controlled by medications had fasting glucose higher than 100 mg/dL and therefore the results for this subject should be interpreted with caution. The glucose and insulin levels in this patient continued to decrease without a transient increase at 45 min as observed with other subjects. Therefore, the true effect of coconut water consumption in diabetic patients cannot be concluded from this study and should be evaluated in future studies.

Comparison of fresh versus bottled coconut water was not an endpoint of this study, and three of the eleven participants opted for bottled coconut water, two of whom were prediabetic and one normal. Since all three subjects showed a mild and transient change in blood glucose, we cautiously conclude that the effect of bottled versus fresh coconut water is likely to be similar and likely, only a function of the amount of total sugar content. Natural coconut water is more prone to variations in sugar than bottled versions, although sugar content in bottled versions do vary from brand to brand and this will have an impact on glucose and insulin increases.

Systematic food studies are not commonly reported in the literature and many of the studies measuring impact on glucose or insulin are several decades old. More systematic food studies with continuous glucose monitoring are needed and may help those at risk of diabetes make better food choices and the data can improve predictions about various foods, quantities and time of intake on glucose levels using machine learning approaches in the future.

## Conclusion

Overall, we have satisfactorily completed the assessment of effect of coconut water consumption on blood glucose and insulin and demonstrated that the mild, trasient increase is observed, with effect being higher in prediabetic subjects compared to normal subjects. These findings will prove useful for people to make an informed choice about incorporating coconut water as a part of their personalized nutrition in intermittent fasting or low carbohydrate lifestyles.

## Limitations

Continuous glucose monitoring would have been a better way to manage diabetes (Cureus et al., 2023) and also to study the glucose changes more closely, but this was prohibitive for logistical reasons in our study. Insulin sensitivity is the basis for diabetes risk, and therefore measuring insulin dynamics was important for this study. Since insulin does not have a continuous monitor or even a home-based test, the patients needed venous blood draw, which could only be done at a phlebotomy lab, and it was more convenient to measure both glucose and insulin from the same blood draw time point. Secondly, a continuous glucose monitor needs several days of stabilization before a reliable reading could be obtained, which was deemed infeasible due to the increased logistics and cost of the study.

A second drawback of our study is the limited demographic makeup of the participants. The recruited subjects were all Asian, likely because coconut water as a drink is more popular in this demographic leading to cultural affinity towards its consumption. Secondly, prevalence of prediabetes is high in Asians and understanding coconut water impact was important for the recruited subjects (Shah et al., 2020). While we do not anticipate the response to coconut water to be different in different racial groups, future studies should be aimed at including more diversity in the demographics for a holistic evaluation.

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