# Effects of a sugar-reduction intervention on diet and continuous blood glucose in adolescents on the remote Pacific island of Kiritimati: a pilot randomized controlled trial

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## Abstract

# Background

Kiritimati is a remote Pacific Island estimated to have high rates of overweight/obesity (~ 81%) and type 2 diabetes (T2DM; ~27%), potentially related to high sugar consumption starting early in life. We aimed to determine the feasibility and effectiveness of a short-term dietary sugar-reduction intervention on sugar consumption and glucose control in Kiritimati adolescents.

# Methods

A school-based pilot randomized controlled trial over two weeks. The two high schools on Kiritimati were randomized to the control school and the intervention school. Inclusion criteria was enrollment at one of the two high schools on the island. Exclusion criteria was age > 18 years. 63 students enrolled (n = 26 control; n = 37 intervention). The intervention consisted of installing a water filter at the school, providing reusable water bottles, and a 30-minute group dietary education session. Beverage frequency questionnaires and 24-hour diet recalls were conducted at baseline and follow-up. Continuous blood glucose monitors (CGMs; FreeStyle Libre Pro) measured indices of blood glucose control over 14 days (one-week pre-intervention, one-week post-intervention). A statistically significant effect of the intervention was considered a time x group interaction term of $p < 0.05$.

# Results

The total sample at baseline was 16.5 ± 1.2 years old of which 45.5% were male and 60.3% had overweight or obesity. Added sugar consumption decreased in the intervention group (131 ± 77 to 47 ± 49 g/day), with no change in the control group ($p_{interaction}$=0.001). However, there were no significant effects of the intervention on any of the CGM measures, which were normal at baseline. No adverse events were noted.

# Conclusions

A 7-day sugar-reduction intervention significantly reduced sugar intake but had no effects on CGM measures in Kiritimati adolescents at high risk for obesity and T2DM. This pilot study suggests a simple sugar-reduction intervention could improve diet quality in adolescents on Pacific Islands with high rates of obesity/T2DM.

# Trial Registration:

ClinicalTrials.gov NCT04319003. Registered March 24 2020 – retrospectively registered, clinicaltrials.gov/ct2/show/NCT04319003

## Background

Kiritimati (or "Christmas Island") is an isolated coral atoll in the Pacific Ocean, located 144 miles north of the equator and 1340 miles south of Honolulu, and is one of the 32 islands that comprise the Republic of Kiribati [1].

Kiritimati has an estimated population of 6,500 inhabitants, who have extremely limited resources and persevere in a subsistence economy [2]. Similar to other Polynesian and Micronesian nations, the Republic of Kiribati has one of the world's highest rates of obesity and type 2 diabetes (T2DM) [3]. The World Health Organization (WHO) reports that 81.1% of the adult population have overweight/obesity (BMI ≥ 25 kg/m$^2$) and 28.1% of the population have diabetes (fasting glucose ≥ 6.1 mmol/L) [4, 5]. The International Diabetes Federation reports that Kiribati has the second-highest age-adjusted prevalence of diabetes in the world, after the Marshall Islands [6].

In a 2016 analysis of global trends, it was estimated that the Republic of Kiribati was the highest ranked country for childhood overweight/obesity, with a prevalence of 56.9% [7]. However, this number was based on projections and interpolations from surveys encompassing a variety of methods, and not on actual measurements of height and weight. No studies of childhood obesity, blood glucose, or diet have ever been conducted on any Kiribati island. As such, it is unknown at what age obesity and T2DM arise, or their causes. This information is crucial, as intervention at an early age likely represents the greatest opportunity for obesity and T2DM delay or prevention [8].

Since 2010 members of our team have visited Kiritimati on a number of occasions to provide clinical aid. During our previous visits, we noticed that consumption of plain water was very low, due to its poor taste and smell. Well water is first boiled to be made potable and then sugar is added to mask off flavors. This sugar sweetened water (SSW) is referred to by the locals simply as "sugar" (*tioka* in the local language). Other sugar-sweetened beverages (SSBs) were also common, including ice-block (frozen sugar sweetened water with food coloring), toddy (coconut tree sap), and *Tang*™ prepared from powder. We hypothesized that provision of clean filtered water and dietary education might improve diet and reduce obesity and T2DM risk. The aims of this exploratory study were: 1) to provide the first objective measurements of childhood overweight/obesity, diabetes status, and diet on Kiritimati; 2) to explore the feasibility of increasing fresh water consumption and reducing sugar intake in a short-term (1-week) school-based intervention; and 3) To determine the effects of the intervention on diet and continuous glucose monitoring (CGM) metrics. We conducted this pilot study in high school students, as they were old enough to understand the procedures of the study and provide informed consent. We hypothesized that the intervention would significantly increase plain water intake, reduce added sugar intake, and reduce glycemic variability.

## Methods

# Trial Design

This prospective parallel pilot trial took place over two weeks in September 2018. Study design is depicted in Fig. 1. We recruited participants by visiting the schools and holding an assembly in which we (E.B. and S.S.) informed the students about the procedures of the study and invited them to participate approximately one month prior to the beginning of the study. At this time, informed consent forms in both English and the native language of Kiribati were distributed to ensure both the participant and their guardian had time to read over and understand the procedures of the study. The only inclusion criterion was enrollment in one of the two high schools on Kiritimati. The only exclusion criterion was age > 18 years. All procedures and data collection occurred at school during school hours.

# Participants

Informed consent was obtained from all participants and their guardian in either English or the native language of Kiribati. Participants were provided $20USD compensation and each school also received $1000USD. The Institutional Review Board at the University of Southern California approved the study which was conducted according to the protocol registered at ClinicalTrials.gov (NCT04319003). The study was overseen by the local representative of the Kiribati Ministry of Health and Medical Services and conformed to the principles embodied in the Declaration of Helsinki.

# Randomization and masking

We used a random number generator in Microsoft Excel (function: =RANDBETWEEN(1,2)) to assign the two high schools on the island as the control school (1) and the intervention school (2). No one was blinded to the allocation, although schools/students were not specifically told of the allocation. Participants were, however, blinded to their CGM readings, as only the investigators had access to the CGM readers. J.P. and C.R. conducted the procedures of the study.

# Intervention

We conducted the intervention one-week after baseline measures were taken in the intervention school. The intervention consisted of: 1) installation of a no-power water filtration system at the intervention school (LifeStraw Community, Vestergaard Frandsen Inc., Washington, DC); 2) the provision of colorful insulated stainless steel water bottles to students (DHGate.com Vacuum Insulated Water Bottle KKA2155, China); and 3) a 30-minute presentation given at school assembly (with students and teachers present) by a registered dietitian on the role of sugar in the pathogenesis of T2DM and how sugar reduction can reduce risk.

# Outcomes

Height and weight were measured in duplicate and then averaged using a Tanita BC-549 scale (Tanita Corporation, Arlington Heights, IL) and a Seca 213 stadiometer (Seca, Chino, CA). Participants wore light clothing and no shoes. Gender and birthdate were self-reported. BMI categories (underweight, normal weight, overweight, and obese) were determined based on the WHO definition (overweight: > +1 standard deviation (SD) and obese: > +2SD from the mean BMI for the age and sex of the child) using the *AnthroPlus* packagefor R [9]. Height-for-age z-scores were also calculated using this package.

Continuous glucose monitors (CGMs; Abbott FreeStyle Libre Pro, Chicago, IL) were attached on the first day of the study and covered by an adhesive patch to prevent accidental loss. (SIMPATCH, New York, NY). In the event that a CGM fell off, students were asked to retain the CGM so data could be downloaded, and another CGM was attached. To assess accuracy of the CGM, we also conducted a random fingerstick measurement on a calibrated glucometer (Contour NEXT EZ, Ascensia Diabetes Care, Parsippany, NJ) during the second week of the study. We developed a beverage frequency questionnaire of common Kiribati drinks by asking the participants and teachers about the different types of drinks available on the island, and by visiting local stores during a previous visit to the island. For each drink, we verbally asked, “how many days in the last week did you drink each beverage listed below” (0, 1–2, 3–4, 5–6, or 7 days) and “how much of this drink did you drink each day” (0.5, 1, 1.5, 2, or 3 cups) and recorded responses on a worksheet that also included pictures of drink amounts which we pointed to. From this, an estimate of servings/week was calculated, where a serving was considered to be 1 cup

(8 oz). In addition, 24-hour diet recalls were conducted in a subset of participants (every second participant to complete the beverage recall at baseline) by an experienced registered dietitian using pen/paper, and subsequently entered into Nutrition Data System for Research software version 2018, developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN, upon return to the United States. We were only able to conduct 24-hour recalls on a subset due to the time-consuming nature of the procedure (~ 20 minutes per participant) within the context of the school day. Recipes for frequently consumed drinks on the island including “tioka” and “ice block” were obtained from study participants as well as teachers and other community members who often prepared and provided the drinks to the students. These recipes were then entered as custom recipes into NDSR.

One-week after the intervention, CGMs were removed and the data was downloaded to a portable hard-drive. The control school was provided with the intervention upon completion of the study.

Raw CGM data from each participant was separated into two files: pre-intervention and post-intervention, each approximately one-week in duration. In the event that more than one CGM was used for a student, the data was manually stitched together using Microsoft Excel. Statistics were then calculated for each file using GlyCulator [10]. GlyCulator is an online tool for analyzing CGM data, and generates measures of glucose variability including mean glucose, estimated HbA1c, standard deviation (SD), J-index, area under the curve (AUC), MAGE (Mean amplitude of glycemic excursions) for the entire duration of measurement [10]. Diabetes was defined as an estimated HbA1c ≥ 6.5% (≥ 48 mmol/mol) and prediabetes was defined as an estimated HbA1c in the range of 5.7–6.4% ( 39–47 mmol/mol) [11].

# Sample size

As this was a pilot trial, and there was no existing data on diet or blood glucose in Kiritimati adolescents, we did not conduct a power calculation. Instead, we attempted to enroll as many students as were interested in participating. We intend that the data gathered from this pilot will be used to inform a power calculation for future, larger studies.

# Patient and public involvement in research

The protocol of this study was designed with input from members of the Kiribati public, including doctors, nurses, and teachers on the island, and members of the Ministry of Health. On previous trips to the island, we enquired about the following: 1) biggest concerns facing the population with regards to high T2DM rates; 2) barriers to a healthy diet; and 3) factors they believed would improve their metabolic health. The taste and smell of water on the island was determined to be a major barrier contributing to high SSB consumption. We designed the intervention with this in mind – specifically the water filter installed in the school (where many students not only learn, but actually live) and the provision of individual insulated water bottles. As stated previously, we also had input from students and teachers in creating the beverage frequency questionnaire.

# Statistical Methods:

All statistical analyses were performed using R Studio version 1.2.5001 [12], with significance assumed at $p < 0.05$. To account for any baseline differences between the two schools, we conducted a difference-in-differences analysis, in which only the time x group interaction term was considered [13, 14], according to the following formula:

$$Y = \beta 0 + \beta 1*[\text{Time}] + \beta 2*[\text{Group}] + \beta 3*[\text{Time*Group}] + \varepsilon$$

Where Y represents the dependent variable, β0 represents the baseline average, β1 represents the time trend in the control group, β2 represents the difference between the two groups pre-intervention, β3 represents the difference in changes over time, and ε is the error term.

For outcomes, outliers were assessed as any value outside 1.5 x inter-quartile range. These values were then capped – meaning observations outside the lower limit were replaced with the value of the 5th percentile, and those above the upper limit were replaced with the value of the 95th percentile. We used the *gvlma* function in R to test the assumptions of linear regression: skewness, kurtosis, link function, and heteroscedasticity. Where data violated these assumptions, a box-cox transformation was applied, and the p-value represents the transformed data. However, the data itself remains untransformed in tables for clarity. Post-intervention data are included regardless of whether the participant was present on the day of the educational presentation (intention-to-treat principle)[15].

# Results

*Participant Flow*

Participant flow for a pilot and feasibility trial, as outlined in the CONSORT 2010 guidelines [16], is provided in **Figure 2**. Out of 195 potential enrollees, 11 were excluded due to being over 18 years of age, and 121 declined to participate. The remaining 63 provided informed consent to participate in the study and had baseline measures collected. Of these, the numbers that completed follow-up measurements are provided within the tables throughout the results. The participants lost-to-follow-up were not at school when follow-up measurements were taken.

*Baseline Demographics*

Sample characteristics are presented in **Table 1**. The total sample at baseline (n = 63) was 16.5 years old of which 45.5% were male, and 60.3% had overweight or obesity. There were baseline differences between the two schools in height and weight, which was attributable to more males in the control school. However, there were no differences between the groups in age, BMI, or estimated HbA1c. All participants had normal blood glucose (mean estimated HbA1c of 4.71%), with no participants classified as having prediabetes or T2DM.

*Effects of the intervention*

The effects of the intervention on relevant dietary factors are presented in **Table 2**. Of the participants 13 control and 24 intervention participants who provided 24-hour diet recalls at baseline, 11 control and 20 intervention participants provided 24-hour diet recalls at follow-up.

The intervention was associated with decreased total sugar consumption from 147 ± 71.2 to 51.3 ± 49.3 g/day with no change in the control group (128 ± 90.2 to 134 ± 101 g/day; $p_{interaction}$=0.003) and decreased added sugar consumption from 131 ± 77g/day to 47 ± 49g/day with no change in the control group (124 ± 90 to 127 ± 105g/day; $p_{interaction}$=0.008). This translated to a significant decrease in energy intake from total (21.1 ± 7.7 to 9.5 ± 9.1 %kcal vs. 18.9 ± 10.9 to 19.5 ± 10.2 %kcal) and added sugar (19.2 ± 9.2 to 8.4 ± 8.6%kcal vs. 18.2 ± 10.9 to 18.2 ± 10.9 %kcal). There was no effect of the intervention on total energy, carbohydrate, or water consumption. Of the 24 control and 38 intervention participants who provided baseline beverage frequency questionnaires, 18 control and 26 intervention participants provided beverage frequency questionnaires at follow-up. From the beverage frequency questionnaires, we found that the intervention was associated with significantly decreased SSW (4.39 ± 0.58 to 1.00 ± 1.03 vs. 1.25 ± 1.46 to 1.29 ± 1.46 servings/day), ice block (2.09 ± 1.84 to 0.41 ± 0.65 vs. 0.83 ± 1.15 to 0.46 ± 1.04 servings/day), and soda consumption (0.27 ± 0.32 to 0.02 ± 0.13 vs. 0.13 ± 0.27 to 0.11 ± 0.25 servings/day), but no other SSBs.

A summary of the effects of the intervention on CGM measures is presented in **Table 3.** There was no effect of the intervention on any of the CGM measures. **Figure 3** shows the high correlation between random fingerstick measurements of blood glucose and CGM readings (±7.5 minutes – as the FreeStyle Libre Pro measures interstitial glucose every 15 minutes), suggesting that the CGMs were recording glucose concentrations accurately.

*Harms*

No harms were noted relating to the study.

## Discussion

To our knowledge, this is the first study to directly assess obesity, diabetes, and diet in adolescents in the Republic of Kiribati. Similarly, it is the first study to pilot an intervention, with the ultimate aim of reducing the high rates of obesity and T2DM on Kiritimati and Kiribati as a whole. Further, it is the first study that we are aware of to use CGMs to compare blood glucose and glycemic variability before and after an intervention in any population in the world. We found evidence for a high rate of overweight/obesity amongst Kiritimati adolescents (60.3%), but no evidence of prediabetes or T2DM. We also found that a one-week sugar reduction intervention successfully reduced sugar consumption and increased water consumption; but did not affect blood glucose or glucose variability, as discussed below.

# Prevalence of overweight and obesity

In our sample of Kiritimati adolescents, the overall prevalence of overweight and obesity was 60.3%. This is higher than previous childhood estimates of the Republic of Kiribati as a whole (56.9%, reported in 2016 [7]) – although it is important to note that this prior estimate came from a survey rather than actual height and weight data as reported here. If our sample of Kiritimati is representative of Kiribati as a whole, our data would place Kiribati as the highest rank country for childhood overweight and obesity in the world (the next highest – Samoa – is estimated at 46% [7]). Our data therefore suggests that childhood obesity on Kiritimati/Kiribati is a significant public health issue that, if verified and confirmed, needs to be urgently addressed.

# Prevalence of diabetes

While diabetes rates in Kiribati adults are high (reported to be 27% compared with the global average of ~ 6% [4, 6].), we did not find high rates of pre-diabetes or T2DM in our sample of Kiritimati adolescents. This suggests that T2DM in this population manifests later in life. Given the high rates of overweight/obesity in our sample, our data suggests that early intervention is required to lower BMI and reduce the risk of progressing to T2DM [17]. This is particularly important on an island such as Kiritimati, where medication is difficult to source [5], meaning severe complications related to diabetes are common [18]. Further, while our sample showed normal blood glucose concentrations, recent data from the RISE consortium suggests that young people with seemingly normal blood glucose may have hyperinsulinemia, which with time may lead to insulin resistance, beta-cell failure, and T2DM [19]. Future studies could assess this possibility by measuring plasma insulin in response to an oral glucose tolerance test in this population.

# Pre-intervention diet

In our sample, baseline sugar intake averaged 128 g/day of total sugars and 124 g/day added sugars representing 18.9% and 18.2% of total calories, respectively. These numbers are nearly double the WHO recommendations for limiting sugar intake to < 10% of total calories [20]. As we hypothesized, sugar-sweetened beverages (SSB) were a major source of dietary sugars. SSW, ice block, Tang™, toddy, soda, juice, and fruit drinks combined averaged 11.5 cups/day. This is notable because sugars – and particularly SSBs – are major contributors to obesity and T2DM [20]. Further, water consumption at baseline was relatively low, averaging approximately 4 cups/day at baseline, compared with the WHO recommendation of 8.5 cups/day [21]. These findings suggest that interventions to improve clean water access and quality and reduce SSB consumption are indeed required.

# Post-intervention diet

Our short-term intervention was highly successful at reducing sugar intake (down to 51.3 g/day total sugars and 46.9 g/day added sugars or 9.5% and 8.4% of total calories, respectively), and even decreased to within the WHO sugar recommendations [20]. Intervention was also associated with increased plain water intake (from approximately 4 cups/day to 9 cups/day – also within WHO water recommendations [21]) although this increase did not reach statistical significance ($p_{interaction}$ = 0.07). We consider the most likely reason our intervention was so successful at stimulating diet change to be because of the school's involvement. We found that most of the SSBs being consumed by the students at baseline were provided by the school. However, after our intervention, the school stopped providing students with SSBs and instead encouraged use of the water filter. This suggests that interventions such as these should be sure to include teachers, parents, and guardians in their messaging, as they are the ones usually making dietary decisions for children. While our results are promising, future research is required to determine the long-term feasibility and effectiveness of such an intervention on diet.

# Effects of intervention on continuous glucose metrics

Despite the dramatic effects of the intervention on diet, there was no effect of the intervention on any of the blood glucose metrics obtained from the CGM. There are several potential reasons for this. As previously stated, estimated HbA1c amongst this sample was normal, suggesting this young population had normal glycemic control and thus nothing for the intervention to improve. Unfortunately, there are no guidelines on normal reference range of glycemic variability in children to compare our results to. Therefore, future studies of normal glycemic variability in children across different ethnicities/populations are required. Another possible reason for the lack of effects of the intervention on CGM metrics is that the intervention was too short to see changes in blood glucose or glycemic variability. It is possible that with a longer-term intervention/follow-up, glycemic variability would be reduced, and progression to T2DM would decrease.

# Strengths and limitations

This study has several strengths. We have provided the first data on BMI in adolescents on any Kiribati island. We have also provided the first characterization of diet amongst Kiribati school students, including both 24-hour diet recalls and beverage frequency questionnaires. Further, this is one of the first studies to use CGMs in adolescents without diabetes, and, to our knowledge, the first to assess the effects of a dietary intervention on CGM metrics. The major weakness of this study is its short time-frame. The total duration of the study was 2 weeks, with only 1 week of follow-up after the intervention. As a result, we are unable to assess the long-term feasibility or efficacy of the intervention. However, our intervention was simple and highly cost-efficient (~$500USD/school for water filter and bottles), suggesting that a relatively small expense could greatly improve health outcomes in Kiribati children. It would be beneficial to conduct a longer-term intervention and follow-up in the future, with a more sensitive analysis of diabetes in these children, including oral glucose tolerance testing and/or measures of plasma insulin concentrations [22]. Another limitation is that our sample only included high-school students aged 14–18. Therefore, the conclusions drawn may not accurately represent younger students. We hope to develop strategies to reach and investigate these pupils in future endeavors.

# Conclusions

This study is the first to quantify overweight/obesity rates and examine the effect of a sugar-reduction intervention on continuous blood glucose and diet in Kiritimati high school students. We found that overweight/obesity rates were very high, but that glucose metrics on continuous glucose monitoring were overall normal. We also found our short-term sugar reduction intervention to be very effective at reducing sugar consumption. While continuous blood glucose measures were unaffected by the intervention, this was likely due to normal blood glucose in the participants and the short-term nature of the intervention. Given the low cost of the intervention and the high rates of obesity and T2DM on Kiritimati, longer-term studies are justified.

# Abbreviations

AUC
Area under curve
BMI
body mass index
CGM
continuous glucose monitors
%CV
percentage coefficient of variation (ratio of SD to mean)
MAGE
Mean amplitude of glycemic excursions
SSBs
sugar-sweetened beverages
SSW

sugar-sweetened water
T2DM
type 2 diabetes mellitus

# Declarations

### *Ethics approval and consent to participate*

This study was approved by the Institutional Review Board of the University of Southern California (HS-18-00505) and the Kiribati Ministry of Health. Informed consent was obtained from both students and guardians in both English and the local language of Kiribati. The research conformed to the principals embodied in the Declaration of Helsinki.

### *Consent for publication*

N/A

### *Availability of data and materials*

Data is available by emailing Dr. Michael Goran at mgoran@chla.usc.edu

### *Competing interests*

The authors declare that they have no competing interests

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### *Authors contributions*

J.P wrote the protocol, conducted the study, performed the statistical analysis, and primarily wrote the manuscript. C.R. helped design the study, and conducted the study. P.B., R.J., T.A. were involved in designing the study and in the interpretation of results. S.S. helped to conduct the study and interpret results. T.B. helped to design and conduct the study on Kiritimati. E.B. designed and conducted the study and helped in interpretation of results. M.G. designed and oversaw the study and interpretation of results. All authors read and approved of the final manuscript.


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# Tables

**Table 1. Sample descriptives at baseline. Data presented as mean (SD) or n (%).**

| | Overall (n = 63) | Control School (n = 26) | Intervention School (n = 37) | Group difference p-value |
| --- | --- | --- | --- | --- |
| Age, years | 16.5 (1.23) | 16.7 (1.16) | 16.4 (1.27) | 0.69 |
| Gender (n, (%) male) | 30 (45.5) | 20 (76.9) | 10 (25.0) | **0.03** |
| Height (cm) | 163 (8.0) | 167 (6.3) | 159 (7.5) | **$5.12 \times 10^{-5}$** |
| Weight (kg) | 67.4 (10.4) | 72.1 (9.13) | 64.1 (10.1) | **0.002** |
| BMI-for-age z-score | 1.23 (0.74) | 1.30 (0.83) | 1.18 (0.69) | 0.53 |
| Height-for-age-z-score | -0.73 (0.82) | -0.59 (0.77) | -0.82 (0.86) | 0.28 |
| BMI category# | | | | |
| Normal | 25 (39.7) | 10 (38.5) | 15 (40.5) | |
| Overweight | 28 (44.4) | 11 (42.3) | 17 (45.9) | |
| Obese | 10 (15.9) | 5 (19.2) | 5 (13.5) | |
| Diabetes* | (n = 49) | (n = 23) | (n = 26) | |
| Estimated HbA1c | 4.61 (0.30) | 4.71 (0.27) | 4.52 (0.31) | 0.13 |
| No diabetes | 49 (100) | 23 (100) | 26 (100) | |
| Pre-diabetes | 0 | 0 | 0 | |
| Diabetes | 0 | 0 | 0 | |

#Defined as a BMI-for-age z-score of ≥+1 for overweight, ≥+2 for obese

*Using estimated HbA1c, where normal <5.7%, pre-diabetes 5.7-6.4%, diabetes 6.5%+

Table 2. Group x time interactions for diet outcomes pre- and post- intervention. Data presented as mean (SD).

| | Control School | | Intervention School | | |
|---|---|---|---|---|---|
| | Pre-intervention | Post-intervention | Pre-intervention | Post-intervention | Group x time interaction p-value |
| **24-h Diet Recall** | n = 13 | n = 11 | n = 24 | n = 20 | |
| Energy (kcal/day) | 2640 (869) | 2594 (794) | 2808 (983) | 2390 (870) | 0.39^ |
| Total carbohydrates (g/day) | 393 (149) | 408 (171) | 423 (148) | 322 (135) | 0.13^ |
| Total sugars (g/day) | 128 (90.2) | 134 (101) | 147 (71.2) | 51.3 (49.3) | **0.003^** |
| Added sugars (g/day) | 124 (90.9) | 127 (105) | 131 (77.1) | 46.9 (49.2) | **0.008^** |
| % calories from carbohydrates | 60.3 (8.15) | 63.0 (10.6) | 62.0 (8.04) | 56.4 (9.75) | 0.07 |
| % calories from total sugars | 18.9 (10.9) | 19.5 (10.2) | 21.1 (7.70) | 9.46 (9.05) | **0.01** |
| % calories from added sugars | 18.15 (10.9) | 18.2 (10.9) | 19.2 (9.18) | 8.44 (8.62) | **0.03** |
| Water – all sources (g/day) | 2233 (712) | 2738 (866) | 2314 (671) | 3016 (1328) | 0.73 |
| Unsweetened drinking water (servings/day) | 4.62 (2.55) | 6.32 (3.12) | 3.83 (2.83) | 8.72 (4.54) | 0.07 |
| **Beverage Frequency*** | n = 24 | n = 18 | n = 38 | n = 26 | |
| SSW(servings/day) | 1.25 (1.46) | 1.29 (1.46) | 4.39 (0.58) | 1.00 (1.03) | **$2.21x10^{-8}$^** |
| Tang (servings/day) | 0.97 (1.78) | 0.77 (1.66) | 1.33 (2.00) | 0.24 (0.87) | 0.21^ |
| Toddy (servings/day) | 0.49 (0.97) | 0.33 (1.06) | 1.83 (2.2) | 0.43 (1.22) | 0.09^ |
| Ice block (servings/day) | 0.83 (1.15) | 0.46 (1.04) | 2.09 (1.84) | 0.41 (0.65) | **0.02^** |
| Soda (servings/day) | 0.13 (0.27) | 0.11 (0.25) | 0.27 (0.32) | 0.02 (0.13) | **0.04^** |
| Juice (servings/day) | 0 (0) | 0 (0) | 0.02 (0.06) | 0.01 (0.03) | 0.31^ |
| Fruit drinks (servings/day) | 0 (0) | 0 (0) | 1.57 (2.12) | 1.17 (1.97) | 0.54 |

| | | | | | |
|---|---|---|---|---|---|
| Coffee/tea (servings/day) | 0.88 (1.58) | 0.92 (1.56) | 0.79 (1.57) | 0.07 (0.22) | 0.11 |

*1 serving = 8 oz

SSW = sugar sweetened water (“sugar” or “tioka” in local language)

^p-value represents box-cox transformed data

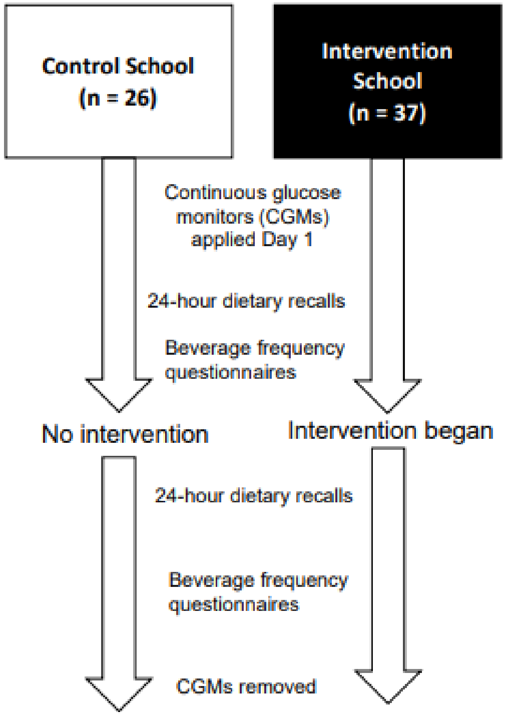
### Table 3. Group x time interactions for continuous monitoring glucose outcomes pre and post intervention. Data presented as mean (SD).

| | Control School | | Intervention School | | |
|---|---|---|---|---|---|
| | Pre-intervention n = 23 | Post-intervention n = 18 | Pre-intervention n = 26 | Post-intervention n = 24 | Group x time interaction p-value |
| Mean glucose (mg/dL) | 88.8 (7.6) | 88.1 (8.3) | 83.46 (8.90) | 85.72 (8.60) | 0.40 |
| Standard deviation (mg/dL) | 22.27 (3.62) | 20.27 (3.29) | 21.52 (4.76) | 21.14 (5.58) | 0.48^ |
| CV (%) | 25.18 (3.71) | 23.09 (3.56) | 25.88 (5.11) | 24.54 (5.49) | 0.73^ |
| J-index | 12.45 (2.18) | 11.8 (2.15) | 11.19 (2.70) | 11.46 (2.51) | 0.39 |
| AUC | 88.5 (7.66) | 87.46 (7.79) | 83.3 (8.93) | 85.6 (8.59) | 0.34 |
| MAGE (mg/dL) | 44.92 (11.8) | 39.7 (10.7) | 47.37 (15.49) | 46.53 (14.59) | 0.48 |

MAGE: Mean amplitude of glycemic excursions; %CV: percentage coefficient of variation (ratio of SD to mean); AUC: Area under curve; J-index (0.001 x (mean + SD)). CGM measures acquired using Glyculator [10].

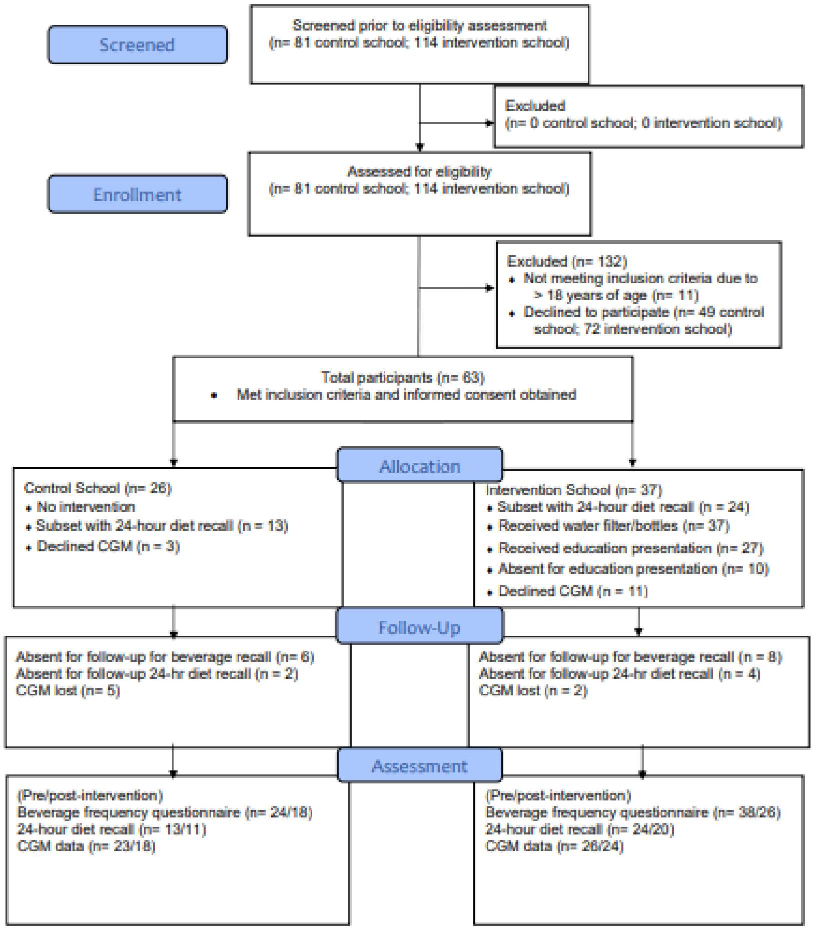
^p-value represents box-cox transformed data

# Figures




### Figure 1

Study design. 26 participants in the control school, and 37 participants in the intervention school, enrolled at baseline. Continuous glucose monitors, 24-hour dietary recalls, and beverage frequency questionnaires were conducted at baseline. One week later, the intervention school received the intervention (a school water filter, reusable water bottles, and dietary education). One week following introduction of the intervention, 24-hour dietary recalls, beverage frequency questionnaires were collected again, and CGMs were removed.




## Figure 2

CONSORT pilot and feasibility trials flow diagram

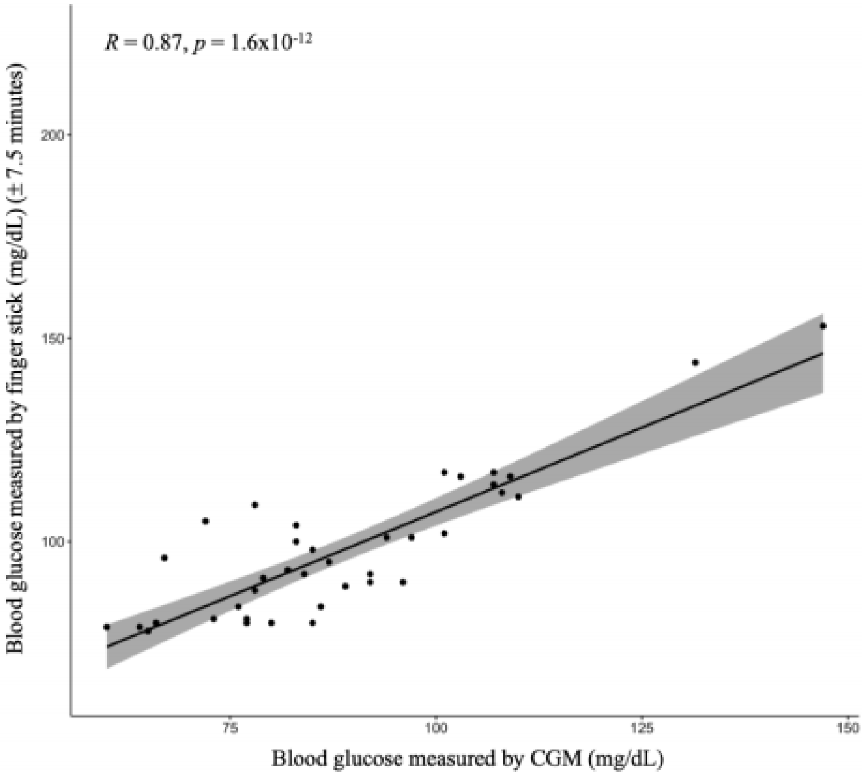



**Figure 3**

Correlation between finger stick blood glucose readings using a traditional glucometer and readings at approximately the same time ( 7.5 minutes) on continuous glucose monitors (CGMs) in the same individual.

# Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CONSORTchecklist.doc