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Taking Fruit Granola as a Snacks can Affect Post-Dinner Glucose Levels and Sleep Quality

Hirofumi Masutomi[1], Katsuyuki Ishihara[1], Kazuko Hirao[2] and Akiko Furutani[2*]

[1]Calbee, Inc. Research & Development Division, Kiyohara-Kogyodanchi, Utsunomiya, Tochigi, Japan

[2]Aikoku Gakuen Junior College, Faculty of Home Economics, Nishikoiwa, Edogawa-ku, Tokyo, Japan

***Corresponding author:** Akiko Furutani, Aikoku Gakuen Junior College, Faculty of Home Economics, Nishikoiwa, Edogawa-ku, Tokyo, Japan, Tel: +81-03-5668-7240, E-mail: furutani@aikoku-jc.ac.jp

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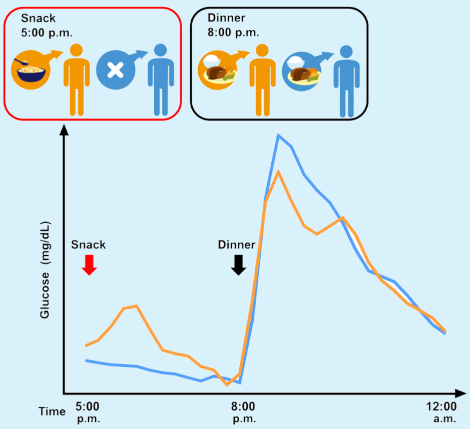
Abstract

Prolonged fasting is known to be a factor in blood glucose spikes, suggesting that a snacks may be useful in suppressing blood glucose spikes at dinner. Cereals are often eaten primarily at breakfast, and their effects as a snack are unknown. Therefore, we examined postprandial glucose level and sleep quality when eating fruit granola snacks prior to dinner. The subjects were recruited at Aikoku Gakuen Junior College and their snacking test schedule and dinner contents were randomly allocated. The subjects were involved in a crossover study (fruit granola as snacks, glucose snacks, no snack, and fruit granola added to dinner (no snack)) and glucose levels and sleep quality were measured. The fruit granola snack reduced the increase in postprandial glucose levels at the time of snack consumption compared with the glucose snack. The fruit granola snack was able to suppress the increase in postprandial glucose level at dinner compared to the glucose snack and no snack. In addition, the frequency of waking in the night was lower when the fruit granola snack was eaten compared to no snack. We found that eating fruit granola as a snack suppressed the increase in postprandial glucose levels after dinner, and possibly affected sleep quality.



Keywords: Glucose; Snack; Second Meal; Sleep Quality; Fruit Granola

Introduction

Various physiological phenomena such as body temperature, food intake, and the sleep–wake cycle are under the control of an endogenous circadian clock [1]. From studying the circadian clock, it is known that the timing of meals has an effect, and the academic field based on the function of food, nutrition, and the circadian clock is called chrononutrition [2]. A balanced diet is important for restricted feeding-induced entrainment of the peripheral clock rhythm, and balanced foods that lead to high blood glucose levels are suitable for peripheral clock entrainment. Mouse experiments showed that a better-balanced diet, rather than single nutrient intake, is more effective at resetting the circadian clock [3]. The idea of the second meal effect has become a topic of discussion in recent years. The second meal effect occurs when a first meal is consumed that slows the increase in blood glucose levels and reduces the sudden increase in blood glucose levels when a second meal is consumed [4]. Although the detailed mechanism of the second meal effect remains to be elucidated, a longer fasting time is associated with more glucose release into the blood, and its involvement in fatty acids causing insulin resistance has been reported [5,6].

When a blood glucose spike occurs, insulin is secreted, and the action of converting the carbohydrate to fat becomes excessive, leading to obesity [7]. According to the International Diabetes Federation Guidelines for the Management of Postprandial Glucose Levels, postprandial and post-load hyperglycemia are considered risk factors for vascular disease [8]. Inhibiting blood glucose spikes has also been implicated as an important factor for vascular disease because it affects prognosis [9]. Prolonged fasting is also known to be a factor in blood glucose spiking [10]. Previous studies have examined postprandial glucose variability after dinner by eating snack meals, showing that eating between lunch and dinner is associated with a slower increase in blood glucose after dinner compared with not eating snack meals, and stimulates good quality sleep [11]. Conversely, it has been reported that eating high-glycemic-index foods at dinner may worsen sleep quality [12].

The relationship between granola and blood glucose level has been reported. Granola is a general term for several types of grains, such as oats mixed with syrup and baked, which is eaten in Europe, the United States, and Japan. According to a systematic review of oat cereals, the average across 27 reports on the glycemic index of granola and muesli was 56 (range: 39–70) [13]. Postprandial blood glucose level and insulin levels were suppressed when granola was served as breakfast in an Asian population [14]. A randomized crossover double-blind study of a muesli containing 4 g of oat grain also reported the suppression of postprandial blood glucose levels compared to cornflakes [15].

However, granola, which is one of the cereals, is mainly eaten at breakfast, and there are few studies investigating the effects of eating fruit granola between lunch and dinner. Therefore, we examined postprandial glucose level and sleep quality when eating fruit granola snacks prior to dinner, focusing on active snacks.

Materials and Methods

Study Method

The subjects were recruited at Aikoku Gakuen Junior College and selected as follows: (1) healthy persons aged 18 years and older; (2) persons who provided written consent for participation. Excluded from the study were (1) individuals who were allergic to the food used in the study; (2) individuals with glucose intolerance (abnormal at medical examination for the past 2 years); (3) individuals with a fasting blood glucose of < 110 mg/dL; (4) individuals with a Body Mass Index (BMI) of >30; (5) patients with severe liver disease, kidney disease, heart disease, lung disease, psychiatric disease, blood disease, etc.; (6) individuals who took drugs such as antihypertensive drugs; (7) those who wished to become pregnant, or were pregnant/breastfeeding during the study; and (8) those who were judged by the study supervisor to be inappropriate for participation.

Publicly recruited subjects were randomly assigned (Table 1, Figure 1A, and Supplemental Table 1) for the study methods and dinner dietary content. The subjects were randomized by random number list and primary sponsor. In this study, we defined “snacks” that eat fruit granola or glucose at 5:00 p.m. Fruit granola (26 g, 114 kcal, Calbee Inc., Tokyo, Japan) and glucose (34 g, 114 kcal, Nippon Garlic Co, Gunma, Japan) were prepared for the snacks (Table 2). Glucose was weighed and 34.0 g was dissolved in 280 mL of water (Suntory, Tokyo, Japan) to be provided to subjects. Rice (Sato foods Co., Ltd., Niigata, Japan) and four kinds of main dishes (hamburger steak, simmered mackerel with miso, hamburger steak in cheese, and fried chicken) (Nichirei foods Inc., Tokyo, Japan) were prepared for dinner (Table 3). The dinner were prepared 551 kcal – 574 kcal and randomized to be unbiased. Supervision confirmed that the subject had completed the meal. The study was conducted over 14 days, and subjects wore a glucose meter (Freestyle Libre Pro; Abbott Japan LLC, Tokyo, Japan) and an activity meter to measure sleep quality (Fitbit

Table 1: Test schedule

Group	N	5:00 p.m.	8:00 p.m.
F	28	FGR	Dinner
G	28	Glucose	Dinner
N	28	-	Dinner
A	28	-	Dinner + FGR

FGR: fruit granola; F, fruit granola snacks; G, glucose snacks;
N, no snack; A, fruit granola added to dinner (no snack)

Table 2: Nutrition information for snacks

Nutrients	FGR	Glucose
Volume (g)	26	34
Energy (kcal)	114	114
Protein (g)	2.1	0.0
Fat (g)	3.9	0.0
Total Carbohydrates (g)	18.9	28.5
-Sugar (g)	16.2	28.5
-Dietary fiber (g)	2.7	0.0

Table 3: Nutrition information for dinner

	Hamburger steak	Simmered mackerel with miso	Hamburger steak in cheese	Fried chicken	Reference: Dietary Reference Intakes for Japanese (/day)
Dinner Contents	Rice, Hamburger steak, tomato sauce, omelets, mashed potatoes, spinach and corn soy, broccoli	Rice, simmered mackerel with miso, stewed daikon radish, simmered hijiki, Japanese pumpkin, Japanese green pea and eggs, Japanese spinach with sesame seeds, and simmered taro	Rice, hamburger steak in cheese, broccoli, spinach and bacon sooty, potato salad, branches and egg sweeteners, vegetables and tomato sauce	Rice, fried chicken, broccoli, konnyaku and ninjin no kinpira, okra and corn salads, chinese cabbage and shiitake bean paste, spinach ohitashi, and vegetables cooked together	
Energy (kcal)	559	568	574	551	2000
Protein (%Energy)	13.1	12.5	13.5	12.6	20–13
Fat (%Energy)	22.1	25.7	26.2	24.5	30–20
Total Carbohydrate (%Energy)	63.8	60.8	59.3	61.9	65–50
- Sugar (g)	87.5	83.6	82.6	83.6	-
- Dietary fiber (g)	3.4	5.3	4.6	3.4	18 >
Sodium (mg)	673	646	741	682	2559
Potassium (mg)	542	422	524	407	2000
Calcium (mg)	218	87	268	73	650
Phosphorus (mg)	183	177	203	163	800
Iron (mg)	1.9	1.6	1.8	1.1	6.5

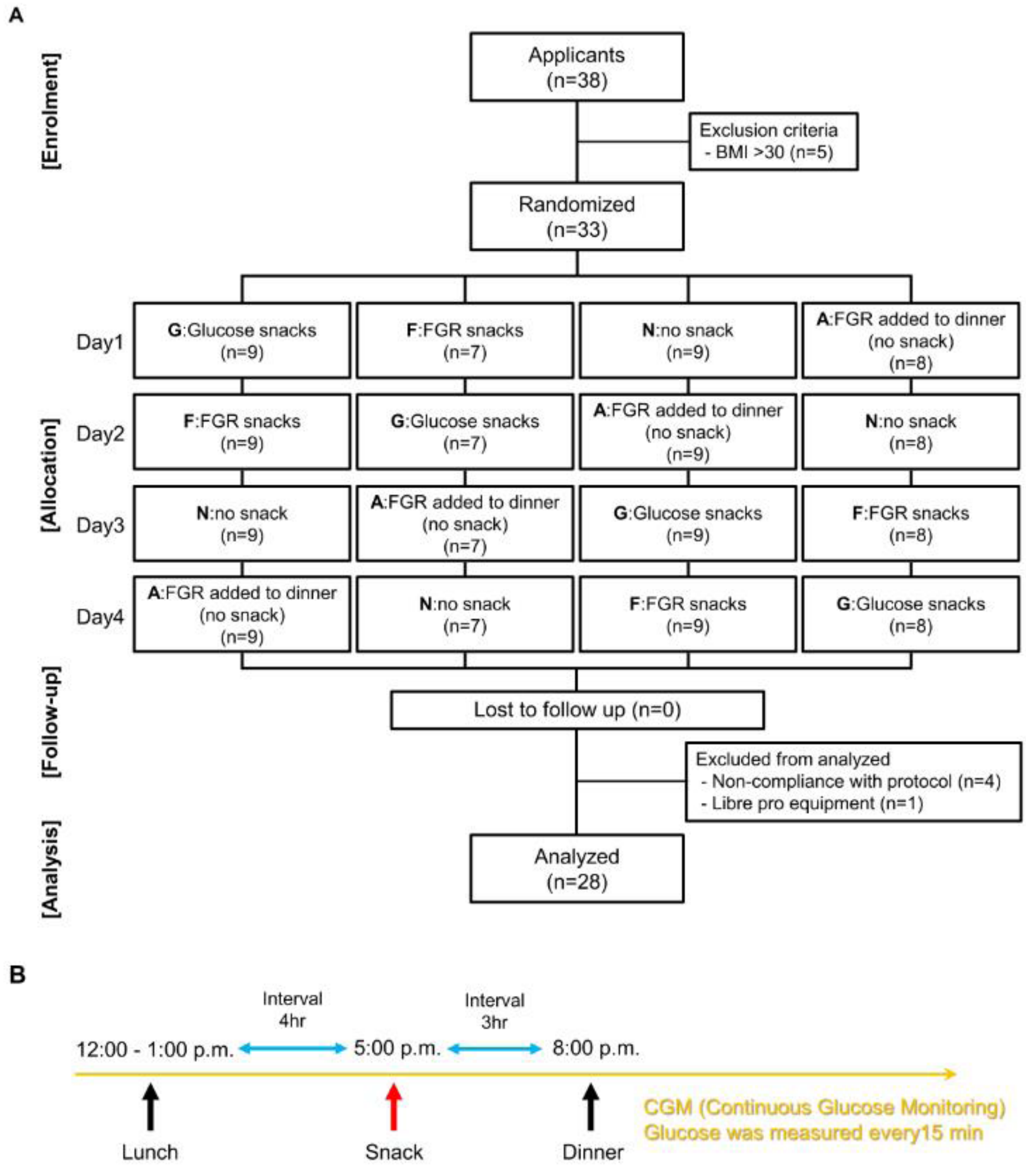


Figure 1: Study design**;** Randomized and screening of subjects (A). Study protocol (B)

Inspire HR; Fitbit, San Francisco, America) on the first day of the study. A over 1-day observation period was set for glucose monitoring stabilization [16] [17]. We set four randomized crossover trials after the run-in period as one cycle {fruit granola snacks (F), glucose snacks (G), no snack (N), and fruit granola added to dinner (no snack) (A)} (Table 1, Figure 1A, Supplemental Table 1). A group eat 26 g fruit granola as same F group. Subjects ate snacks at 5:00 p.m. and dinner at 8:00 p.m. (Figure 1B). The foods permitted lunch, snacks and dinner and subjects were fasting other meals from lunch until the next morning. The only drinks permitted were water or Japanese tea (0 kcal) and both were prohibited from lunch until the next morning. The study protocol was registered with the University-Hospital Health Information Network-Clinical Trials Registry System (UMIN-CRT) (registration number: UMIN000041223). This study was conducted with respect for the human rights of the participants, based on the Declaration of Helsinki, and with approval from the Ethics Review Committee of Aikoku Gakuen Junior College (approval number: 2019-R04). Subjects were verbally informed of the outline, purpose, investigation content, protection of personal information, etc., of this study, and gave written consent. In doing so, they were also told that all data obtained were coded and individuals could not be identified, that data were analyzed in a population, that they would not be used for purposes other than research, that subjects would not be disadvantaged, and that they would be free to participate in the research or not.

Glucose levels

The glucose levels of the subjects were monitored using FreeStyle Libre Pro. FreeStyle Libre Pro is an instrument capable of measuring interstitial glucose levels every 15 minutes for 14 consecutive days. Blood glucose levels from fingertips and interstitial blood glucose levels were reported to be correlated [18]. The FreeStyle Libre Pro device was placed on the upper arm of the subject by a physician. After completion of the study, the devices were retrieved and data were read by a dedicated device. Three-item analyses were conducted: (1) glucose level every 15 minutes after snack and dinner consumption; (2) maximal glucose level change; (3) area under the curve (AUC). The glucose levels were monitored and analyzed every 15 minutes from 5:00 p.m. to 3:00 a.m. The maximum change in glucose level at snack was set to 0 at 5:00 p.m. and the amount of change was analysis from 5:00 p.m. to 8:00 p.m. The AUC at snacks was accumulated from 5:00 p.m. to 8:00 p.m. The maximum change in glucose level at dinner was set to 0 at 8:00 p.m. and the amount of change was analysis from 8:00 p.m. to 1:00 a.m. The AUC at dinner was accumulated from 8:00 p.m. to 1:00 a.m. The AUC was calculated by the trapezoidal method [19].

Questionnaire Survey

A questionnaire survey was administered that consisted of five items to assess the subjects: feeling hungry until dinner, concentration until dinner, goodness of subjective sleep, subjective deep sleep, and good subjective awakening in the morning. The Likert scale was used for the questionnaire survey, and it was created based on the five guidelines for constructing measurement means using the Likert scale [20] [21]. In this study, a point formula evaluation of 1 to 5 points was adopted, and the subjects were instructed to enter the points the day after the test. This evaluation method was analyzed by a nonparametric test because it is unclear whether the respondents felt that the intervals between adjacent options were evenly spaced across 5 points [22].

Sleep Quality

The Fitbit Inspire HR (Fitbit, San Francisco, America) was used to measure sleep quality. The Fitbit is a type of activity tracker, and it is possible to measure the quality of sleep (sleep onset time, stage of sleep, wakefulness, etc.) from the heart rate measurements taken by the device [23]. Subjects were instructed to wear the Fitbit consistently, including when sleeping, for 14 consecutive days. Fitbits were then retrieved after the completion of the study and an analysis tool dedicated to Fitbit was used. In this study, the following five items were analyzed: (1) the percentage of waking hours during sleep (%); (2) the percentage of rapid eye movement (REM) sleep (%); (3) the percentage of non-REM sleep (light); (4) the percentage (%) of non-REM sleep (deep); (5) the number of awakenings during sleep.

Statistical Analysis

A two-way repeated ANOVA was used to analyze hourly glucose data, and Dunnett's test was used for multiple comparisons. An one-way repeated ANOVA was used for the analysis of maximal glucose change, AUC, and sleep quality, and Dunnett's test was used for multiple comparisons. The questionnaire-based survey used Friedman ranking, and the Dunn method was used for multiple comparisons. We used G power to determine the sample size. Graph Pad Prism 8.4.3 was used as the statistical software for analysis, and the level of statistical significance was set at $p < 0.05$.

Results

Screening

Among the participants who volunteered to participate, 38 agreed. The internal exclusion criterion, BMI of >30, excluded five individuals (Figure 1A). Within this protocol, non-adherence was found for four persons, and the inability to measure glucose level due to poor measurement instrument performance occurred for one person. In total, the results from 28 participants were analyzed. There were no adverse events in this study. All subjects were women, with a mean age of 32.0 ± 13.6 years (range: 19–64 years) and BMIs of 22.3 ± 3.2 (range: 17–29). The average value of two tests was adopted for glucose levels and the questionnaire to ensure reproducibility.

Glucose levels

At first, when we examined the changes in glucose levels during the snack meals, the postprandial glucose levels in the F and G groups were elevated (Figure 2A, Supplemental Table 2). The breadth of the glucose increase during the dinner meal in group F was suppressed compared to group G (F:26.5±10.1, G:47.3±14.4) (Figure 2A, Supplemental Table 2). Glucose levels in groups N and A (no snack meals) were not elevated. Compared with the change in maximal glucose level during the meal, group F showed a lower level and a suppressed increase in glucose level compared with group G (Figure 2B, Supplemental Table 3). The AUC similarly showed lower levels and inhibition of the increase in glucose levels compared to group G (F:11526 ± 1616, G: 12781±1742) (Figure 2C, Supplemental Table 3).

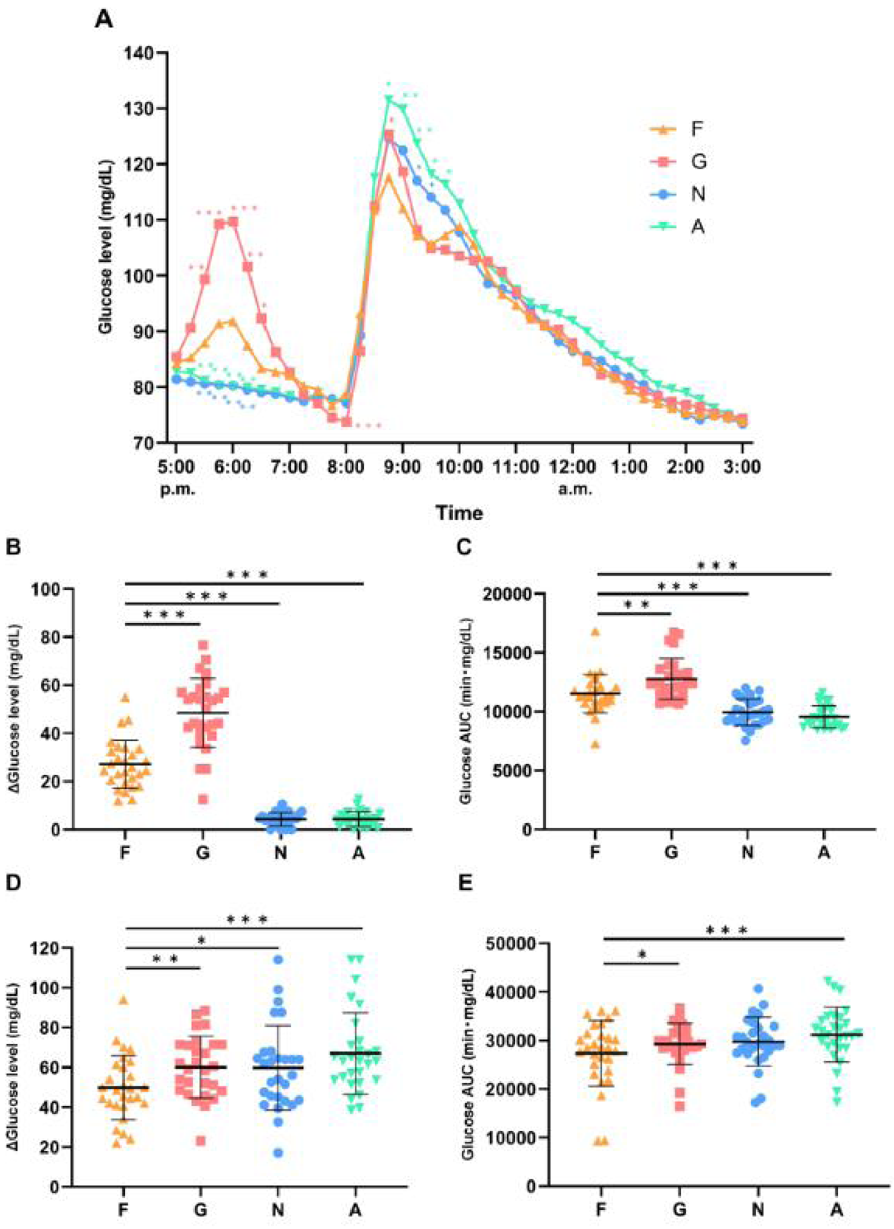


Figure 2: Response of glucose levels; Responses of glucose levels after the snack and dinner (A). Change in maximum glucose after snack intake (B). Area under the curve (AUC) of glucose levels after snack intake (C). Change in maximum glucose after dinner intake (D). AUC of glucose levels after dinner intake (F). Values are means ± standard deviation. Statistics vs. F group, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. F, fruit granola snacks group; G, glucose snacks group; N, no snack group; A, fruit granola added to dinner (no snack) group

Next, when analyzing the glucose level variability at dinner, the pre-dinner glucose level in group G was significantly lower than in group F at 8:00 p.m. (F:78.9±10.0, G:73.7±10.2) (Figure 2A, Supplemental Table 2). The postprandial glucose level in group G was significantly higher compared to group F at 8:45 p.m. (F:117.6±20.0, G:125.3±24.8). The postprandial glucose level in group N was significantly higher than in group F at 9:15 and 9:30 p.m. (9:15; F:107.2±19.6, N:117.1±26.7, 9:30; F:105.6±18.1, N:114.1±26.6). Postprandial glucose levels in group A were significantly higher than in group F at 8:45, 9:00, 9:15, 9:30, and 9:45 p.m. (A: 8:45;131.5±31.2, 9:00;129.8±31.5, 9:15;123.7±29.0, 9:30;118.2±25.9, 9:45;116.4±20.8). The maximal glucose level change in group F was significantly lower than in groups G, N, and A, and the group F increase in postprandial glucose level was suppressed (F:48.6 ± 16.2, G:58.5 ± 15.4, N:58.4 ± 21.4, A:65.4 ± 20.4) (Figure 2D, Supplemental Table 3). For the AUC at dinner, group F showed significantly lower values compared with groups G and A (F:27352±6770, G: 29277±4223, N: 29730±5053, A: 31162±5654) (Figure 2E, Supplemental Table 3).

Questionnaire Survey

When analyzing the questionnaire survey regarding hunger and concentration until dinner, hunger in group F was lower compared to groups G, N, and A (Supplemental Figure 1, Supplemental Table 4). Concentration was also significantly higher in group F than in groups G, N, and A.

When analyzing the questionnaire survey regarding sleep, the subjective quality of sleep was better in group F compared to group A. For subjective depth of sleep, group F reported higher values compared to group N. Good subjective awakening showed higher values in group F compared to groups N and A.

Sleep Quality

When analyzing sleep quality as measured by the Fitbits, the percentage of waking hours during sleep, the percentage of rapid eye movement (REM) sleep, and the percentages of non-REM sleep (light, deep) were not significantly different between groups (waking; F:45.9 ± 62.3, G:37.7 ± 72.5, N:54.1 ± 57.6, A:35.5 ± 40.7. REM; F:26.0 ± 19.9, G:29.7 ± 15.0, N:27.5 ± 19.2, A:20.6 ± 14.9. non-REM (light); F:45.9 ± 62.3, G:37.7 ± 72.5, N:54.1 ± 57.6, A:35.5 ± 40.7. non-REM (deep); F:26.0 ± 19.9, G:29.7 ± 15.0, N:27.5 ± 19.2, A:20.6 ± 14.9) (Figure 3A–D, Supplemental Table 5). The number of awakenings during sleep was significantly lower in group F compared to groups N and A (F:1.6 ± 1.2, G:2.8 ± 2.1, N:3.0 ± 1.8, A:3.2 ± 2.5) (Figure 3E, Supplemental Table 5).

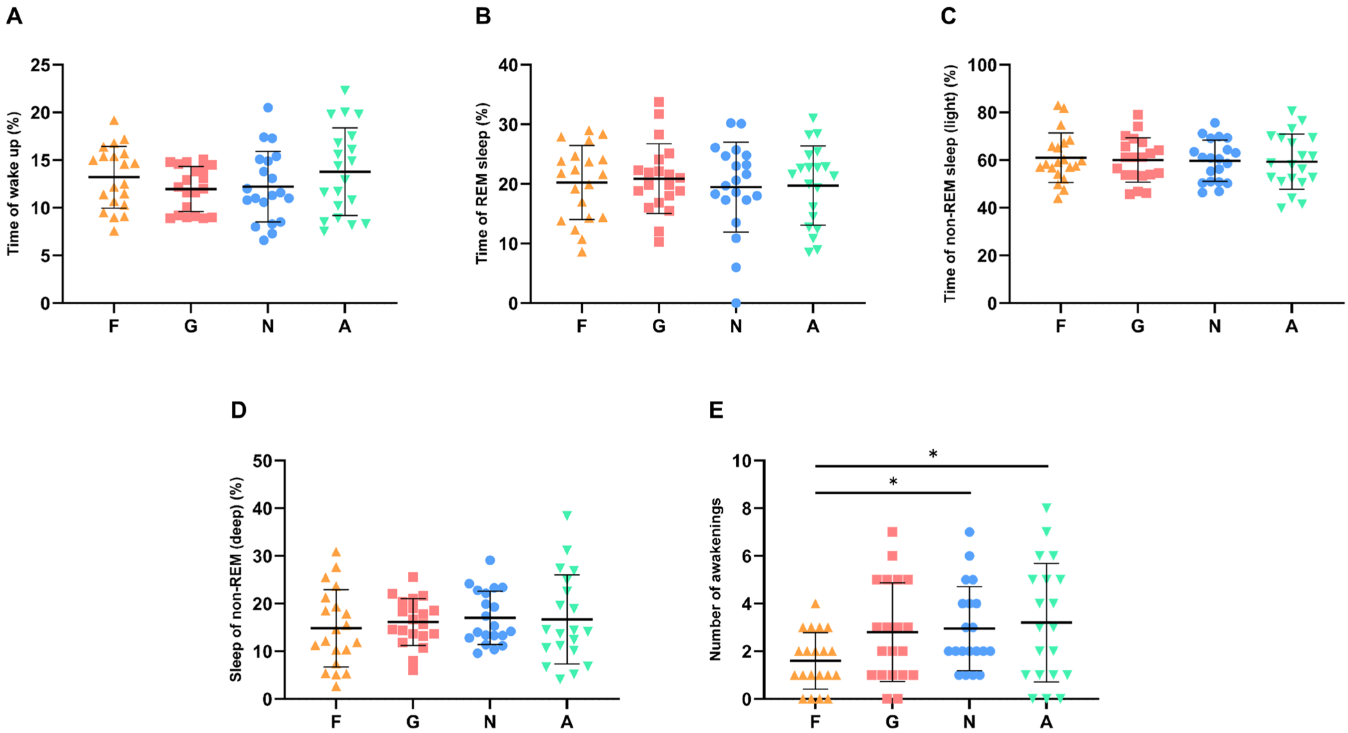


Figure 3: Analysis of sleep quality by Fitbit; Time of wake up (%) (A), duration of rapid eye movement (REM) sleep (%) (B), duration of non-REM sleep (light) (%) (C), duration of non-REM sleep (deep) (%) (D), and number of awakenings (E). Values are means ± standard deviation. Statistics vs. F group, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. F, fruit granola snack group; G, glucose snacks group; N, no snack group; A, fruit granola added to dinner (no snack) group

Discussion

In this study, we found that (1) the fruit granola snack significantly suppressed the increase in postprandial glucose level at the time of snack consumption compared with the glucose snack; (2) the postprandial glucose rise with dinner was significantly suppressed in the fruit granola snack group compared with groups G, N and A; (3) a significantly lower number of awakenings occurred during sleep in the fruit granola snack group than in groups N and A (no snack).

The postprandial glucose level at the time of the snacks was significantly suppressed in the fruit granola group compared to the glucose group (Figure 2A–C). The caloric counts of the fruit granola and glucose snacks were the same, at 114 kcal, but the increase in glucose levels was likely suppressed in the fruit granola group due to differences in the carbohydrate content (Table 2). Cereals that suppress elevated blood glucose levels include foods high in dietary fiber, such as barley and oats. Dietary fiber includes insoluble dietary fiber and water-soluble dietary fiber. Water-soluble dietary fiber is highly viscous and has been reported to slow the rate of movement of food from the stomach to the small intestine and the rate of digestion of glucoses in the small intestine, and to gently increase blood glucose levels [24]. Fruit granola (26 g per serving) contains 2.7 g of dietary fiber, plus β glucan, another water-soluble dietary fiber. Oat β-glucan was reported to have a mild effect on glucose absorption, and it is possible that the fruit granola group experienced a slower increase in postprandial blood glucose level due to the intake of dietary fiber [25].

A fruit granola snack may be a valuable instrument to suppress postprandial glucose elevation at dinner (Figure 2A, D–E). In a study by Kuwahara, *et al.*, a snack of biscuits containing leaves of morula and barley 4 hours prior to dinner suppressed the increase in postprandial blood glucose levels during dinner [26]. A report stated that the longer the fasting time, the higher the blood glucose level [10]. In this study, the environment in which the post-dinner increase in glucose was measured must be considered, because the fasting time was 3 hours longer without meals than with snacks. Therefore, groups N and A (without the snack) experienced increased postprandial glucose level at dinner compared with the fruit granola snacks group. For groups G and F (which subsequently ate snacks at 5:00 p.m.), group G had significantly higher maximal glucose levels at dinner than group F (Figure 2A, D). As mentioned above, fruit granola contains a large amount of dietary fiber. In water-soluble dietary fiber, such as β glucan, there is a direct glucose absorption suppression effect by viscosity and an indirect suppression of blood glucose increase through intestinal bacteria [27] [28]. Intestinal bacteria in the large intestine grow on the basis of water-soluble dietary fiber and produce short-chain fatty acids such as butyrate and acetic acid [28]. Short-chain fatty acids stimulate L cells in the small intestine and gut to secrete hormonal glucagon-like peptide (GLP) -1 [29]. GLP-1 can stimulate the secretion of insulin, and the second meal effect in which the sustained insulin secretion before dinner suppresses the postprandial blood glucose rise after dinner was considered [30]. In addition, glucose levels in the glucose group at the beginning of dinner were significantly lower than those in the fruit granola snack group (Figure 2D). Differences in glucose levels at the start of dinner may also be one of the factors that resulted in differences in the maximal glucose changes between the glucose and fruit granola snack groups. From the above, it seems to be desirable to consume foods high in dietary fiber as snacks. In addition, the blood monitoring of insulin should be examined as a future problem, because insulin secretion seems to strongly affect the second meal effect.

The glycemic index of granola and muesli is 56 (range: 39–70) [13]. When granola was served as a snack compared to glucose, postprandial blood glucose level and insulin levels were also suppressed [31]. In addition, there was a correlation between blood glucose level and insulin level in the second meal effect when eating a snack high in dietary fiber [32]. The postprandial glucose level at the time of the snacks and dinner was significantly suppressed in the fruit granola snack group compared to other groups (Figure 2A-B,D). We perhaps that the insulin level decreased in the participants of this study. Insulin is a hormone that lowers blood glucose levels, and insulin monitoring is extremely important for understanding blood glucose fluctuations. The inability to measure insulin is a limitation of this study.

From the questionnaire, the fruit granola snack group experienced low hunger before dinner and high concentration (Supplemental Figure 1A-B). Previous studies have reported that a lack of energy supplementation with breakfast is associated with a stronger sense of hunger and reduced work efficiency in subjects [33]. Groups N and A, which did not eat a snack, had low glucose levels, and because energy supplementation was not possible, the results show a strong sense of hunger and low concentration. Subsequently, in the glucose-to-glucose diet, a sharp increase in blood glucose was observed after glucose ingestion. Hypoglycemic states caused by large amounts of insulin have been reported to cause hunger, irritation, sleepiness, insomnia, and decreased concentration [33]. Insulin secretion rises according to the sudden increase in the blood glucose level. Therefore, we found that group G reported stronger hunger and less concentration than group F in this study. The Likert scale is a valid evaluation method, but it is also subjective. As such, the answers provided may not be truly reflective of the respondents.

The fruit granola snack group reported significantly less frequent awakenings during sleep. Sleep is divided roughly into REM sleep and non-REM sleep; in addition, stages I–IV exist for non-REM sleep depending on the depth of the sleep (stages 1–2 are shallow sleep, stages 3–4 are deep sleep) [34]. Within this stage, it is the deep non-REM sleep of stage IV that recovers the fatigue of the brain. It has been reported that the processing of waste products in the brain involves not only blood flow, but also cerebrospinal fluid flow, and that processing is mostly performed during non-REM sleep. In this study, no changes were found in the percentages of REM sleep and non-REM sleep duration between the groups (Figure 3A–D). Wakefulness during sleep has been reported to interfere with good sleep quality [35]. A study also reported that eating between lunch and dinner is associated with a slower increase in glucose levels after dinner compared with no meal [26]. Eating snacks between lunch and dinner is associated with a slower increase in blood glucose after dinner compared with not eating snacks, and stimulates good quality sleep [11]. We found a significantly lower number of awakenings during sleep in group F of eating fruit granola snacks (Figure 3E). The lower number of awakenings during sleep in group F may have influenced the outcome of subjective sleeping assessments (Supplemental Figure 1C–E). Nevertheless, since the survey was a subjective evaluation, it may contain bias.

Conclusions

We found that fruit granola as a snacks may suppress the increase in postprandial glucose levels at dinner. In addition, the frequency of awakenings during sleep was lower in the fruit granola snack group compared to groups with no snack, and the possibility of affecting sleep quality was also indicated. These results are expected to contribute to the development of blood glucose control and sleep research by snacks in the future.

Author Contributions

Conceptualization, HM and AF; methodology, HM, KI, KH, and AF; validation, HM and AF; formal analysis, HM and AF; investigation, HM and AF; writing and editing, HM, AF; supervision, KI and KH; project administration, AF. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

HM, and KI are employees of Calbee, Inc. KH and AF reports no conflicts of interest in this work.

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Supplemental

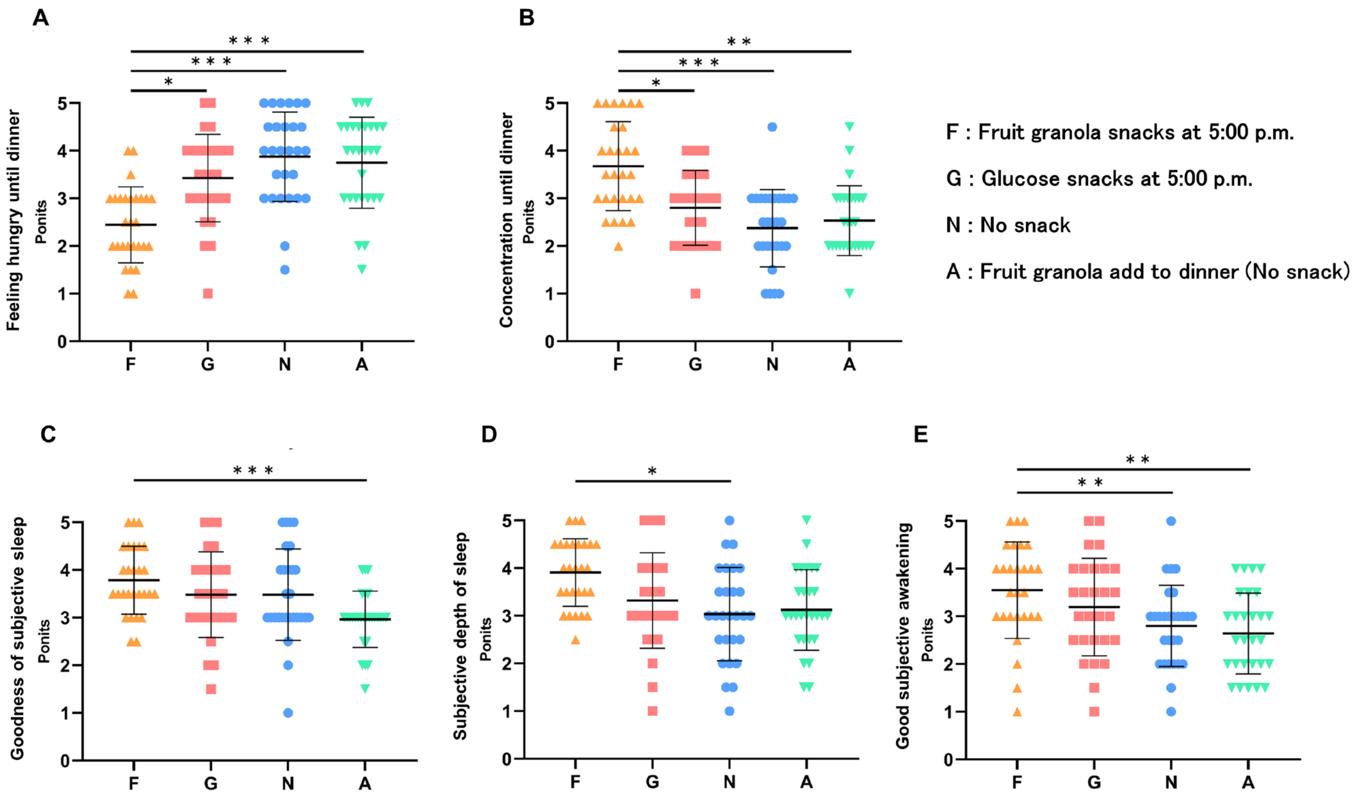

Figure 1: Questionnaire survey; Feeling hungry until dinner (A). Concentration until dinner (B). Goodness of subjective sleep (C). Subjective depth of sleep (D). Good subjective awakening (E). Values are means ± standard deviation. Statistics vs F group, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1: Randomized of test schedule and dinner contents

Pattern	N	Day 1	Day 2	Day 3	Day 4
Aa	4	**Glucose** Hamburger steak	**FGR** Fried chicken	**Non snack** Hamburger steak in Cheese	**Dinner + FGR** Simmered mackerel with miso
Ab	2	**Glucose** Simmered mackerel with miso	**FGR** Hamburger steak	**Non snack** Fried chicken	**Dinner + FGR** Hamburger steak in Cheese
Ac	1	**Glucose** Hamburger steak in Cheese	**FGR** Simmered mackerel with miso	**Non snack** Hamburger steak	**Dinner + FGR** Fried chicken
Ad	2	**Glucose** Fried chicken	**FGR** Hamburger steak in Cheese	**Non snack** Simmered mackerel with miso	**Dinner + FGR** Hamburger steak
Ba	3	**FGR** Hamburger steak	**Glucose** Fried chicken	**Dinner + FGR** Hamburger steak in Cheese	**Non snack** Simmered mackerel with miso

Bb	1	**FGR** Simmered mackerel with miso	**Glucose** Hamburger steak	**Dinner + FGR** Fried chicken	**Non snack** Hamburger steak in Cheese
Bc	1	**FGR** Hamburger steak in Cheese	**Glucose** Simmered mackerel with miso	**Dinner + FGR** Hamburger steak	**Non snack** Fried chicken
Bd	2	**FGR** Fried chicken	**Glucose** Hamburger steak in Cheese	**Dinner + FGR** Simmered mackerel with miso	**Non snack** Hamburger steak
Ca	1	**Non snack** Hamburger steak	**Dinner + FGR** Fried chicken	**Glucose** Hamburger steak in Cheese	**FGR** Simmered mackerel with miso
Cb	2	**Non snack** Simmered mackerel with miso	**Dinner + FGR** Hamburger steak	**Glucose** Fried chicken	**FGR** Hamburger steak in Cheese
Cc	4	**Non snack** Hamburger steak in Cheese	**Dinner + FGR** Simmered mackerel with miso	**Glucose** Hamburger steak	**FGR** Fried chicken
Cd	2	**Non snack** Fried chicken	**Dinner + FGR** Hamburger steak in Cheese	**Glucose** Simmered mackerel with miso	**FGR** Hamburger steak
Da	1	**Dinner + FGR** Hamburger steak	**Non snack** Fried chicken	**FGR** Hamburger steak in Cheese	**Glucose** Simmered mackerel with miso
Db	3	**Dinner + FGR** Simmered mackerel with miso	**Non snack** Hamburger steak	**FGR** Fried chicken	**Glucose** Hamburger steak in Cheese
Dc	3	**Dinner + FGR** Hamburger steak in Cheese	**Non snack** Simmered mackerel with miso	**FGR** Hamburger steak	**Glucose** Fried chicken
Dd	1	**Dinner + FGR** Fried chicken	**Non snack** Hamburger steak in Cheese	**FGR** Simmered mackerel with miso	**Glucose** Hamburger steak

Upper: test schedule contents (Bold). Lower: dinner contents. FGR: fruit granola

Table 2: Glucose level

Time	F	G	N	A
5:00 p.m.	85.3 ± 10.5	90.6 ± 12.4	81.0 ± 9.8	82.5 ± 8.1
5:15	87.9 ± 9.0	99.3 ± 16.5	80.6 ± 9.8	81.1 ± 8.8
5:30	91.4 ± 12.5	109.3 ± 22.7**	80.4 ± 9.6**	80.3 ± 9.1**
5:45	91.8 ± 15.1	109.7 ± 23.4***	80.3 ± 9.6**	80.0 ± 9.8**
6:00	87.5 ± 12.9	101.6 ± 22.4***	79.6 ± 9.5**	79.8 ± 9.9**
6:15	83.4 ± 11.7	92.3 ± 20.9**	79.1 ± 9.3**	79.5 ± 8.5**
6:30	82.7 ± 14.9	86.2 ± 19.9*	78.8 ± 8.8	79.1 ± 8.7
6:45	82.2 ± 15.2	82.7 ± 15.7	78.1 ± 8.1	78.3 ± 9.3
7:00	80.5 ± 12.4	80.2 ± 13.7	77.6 ± 8.5	77.6 ± 9.2
7:15	80.3 ± 12.6	78.6 ± 13.7	77.5 ± 8.5	77.8 ± 9.7
7:30	79.5 ± 12.8	77.1 ± 11.4	78.4 ± 8.5	79.0 ± 10.2
7:45	76.7 ± 10.7	74.6 ± 10.4	77.9 ± 9.3	77.4 ± 9.5
8:00	78.9 ± 10.0	73.7 ± 10.2***	77.1 ± 9.5	78.0 ± 9.3
8:15	93.2 ± 13.0	86.5 ± 12.8	89.3 ± 13.2	92.0 ± 13.6
8:30	111.8 ± 17.5	112.4 ± 19.7	112.6 ± 18.2	117.5 ± 23.2
8:45	117.6 ± 20.0	125.3 ± 24.8*	124.6 ± 22.2	131.5 ± 31.2*
9:00	112.1 ± 21.2	118.6 ± 23.6	122.5 ± 26.9	129.8 ± 31.5**
9:15	107.2 ± 19.6	108.2 ± 22.6	117.1 ± 26.7*	123.7 ± 29.0**
9:30	105.6 ± 18.1	105.0 ± 22.0	114.1 ± 26.6*	118.2 ± 25.9*
9:45	107.2 ± 19.2	104.7 ± 19.5	111.7 ± 27.4	116.4 ± 20.8*
10:00	108.8 ± 19.8	103.5 ± 17.9	107.8 ± 27.0	112.8 ± 20.0
10:15	105.6 ± 17.0	102.7 ± 18.1	102.7 ± 25.6	107.4 ± 19.7
10:30	100.3 ± 16.0	102.5 ± 17.2	98.6 ± 22.6	102.0 ± 20.5
10:45	96.8 ± 17.5	100.7 ± 17.5	97.6 ± 18.9	99.4 ± 19.3
11:00	94.8 ± 17.8	97.1 ± 15.7	96.5 ± 15.5	97.4 ± 16.7
11:15	92.3 ± 17.6	93.0 ± 14.1	94.0 ± 14.5	95.0 ± 15.1
11:30	91.0 ± 16.3	91.1 ± 15.0	91.0 ± 14.4	93.9 ± 15.0
11:45	89.5 ± 15.7	90.3 ± 15.7	88.2 ± 14.1	93.1 ± 15.4
12:00 a.m.	86.9 ± 16.1	87.9 ± 13.9	86.5 ± 14.4	91.9 ± 14.8
12:15	85.1 ± 15.4	84.8 ± 12.7	85.7 ± 14.1	89.9 ± 14.2
12:30	83.5 ± 14.7	82.3 ± 12.7	84.7 ± 13.8	87.5 ± 13.0
12:45	81.7 ± 14.0	81.6 ± 12.4	83.2 ± 13.9	85.6 ± 11.8
1:00	79.6 ± 13.0	80.5 ± 11.6	81.7 ± 13.8	84.4 ± 11.4
1:15	78.0 ± 12.7	79.3 ± 11.4	80.5 ± 12.4	82.3 ± 10.9
1:30	77.1 ± 12.1	78.3 ± 11.7	78.6 ± 11.7	80.4 ± 9.8
1:45	76.3 ± 11.8	77.4 ± 11.5	76.6 ± 12.0	79.7 ± 10.1
2:00	75.4 ± 11.9	76.9 ± 11.4	75.0 ± 11.9	79.0 ± 9.7
2:15	75.1 ± 11.9	76.4 ± 10.7	74.2 ± 12.0	77.8 ± 9.4
2:30	75.0 ± 11.7	75.3 ± 9.6	74.9 ± 14.8	76.1 ± 9.4
2:45	74.6 ± 10.9	74.6 ± 8.9	74.5 ± 12.7	75.1 ± 10.1
3:00	73.9 ± 10.3	74.4 ± 9.6	73.4 ± 11.4	74.4 ± 10.4

Glucose (mg/dL) was measured by FreeStyle Liber Pro. Group F; 5:00 p.m. Fruit granola snack, 8:00 p.m. Dinner. Group G; 5:00 p.m. Glucose snack, 8:00 p.m. Dinner. Group N; 5:00 p.m. No snack, 8:00 p.m. Dinner. Group A; 5:00 p.m. No snack, 8:00 p.m. Dinner + Fruit granola. Values are means ± standard deviation. Two way-repeated-ANOVA (Group; $F(2.967, 80.11) = 82.83$, $p < 0.001$, Time; $F(2.466, 66.59) = 2.878$, $p = 0.05$, Interaction; $F(7.016, 126.3) = 7.94$, $p < 0.001$.) was used for blood glucose data, and Dunnet's was used for multiple testing vs F group, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Values of glucose response

	Analysis	F	G	N	A	F value	P value
Snack	Maximal BG (mg/dL)	26.5 ± 10.1	47.3 ± 14.4***	4.3 ± 2.7***	4.3 ± 3.0***	F (1.862, 50.27) = 197.4	p < 0.001
	AUC (min*mg/dL)	11526 ± 1616	12781 ± 1742**	9952 ± 1115***	9555 ± 923***	F (2.202, 59.46) = 67.1	p < 0.001
	IAUC (min*mg/dL)	1136 ± 507	2263 ± 893***	138 ± 122***	142 ± 143***	F (1.585, 42.79) = 132.6	p < 0.001
Dinner	Maximal BG (mg/dL)	48.6 ± 16.2	58.5 ± 15.4**	58.4 ± 21.4*	65.4 ± 20.4***	F (2.804, 75.72) = 9.68	p < 0.001
	AUC (min*mg/dL)	27352 ± 6770	29277 ± 4223*	29730 ± 5053	31162 ± 5654***	F (2.092, 56.47) = 9.16	p < 0.001
	IAUC (min*mg/dL)	6415 ± 2242	7795 ± 2712**	7068 ± 2934	8977 ± 3645**	F (2.130, 57.52) = 7.89	p < 0.001

Values are means ± standard deviation. AUC; area under the curve. One way-repeated-ANOVA was used for maximal glucose, AUC of glucose levels and Dunnet's was used for multiple testing vs F group, * p < 0.05, ** p < 0.01, *** p < 0.001. F, fruit granola snacks; G, glucose snacks; N, no snack; A, fruit granola added to dinner (no snack)

Table 4: Values of questionnaire survey

Analysis	F	G	N	A	F value	P value
Hunger until dinner	2.4 ± 0.7	3.4 ± 1.0*	3.9 ± 0.9***	3.8 ± 1.0***	F = 34.67	p < 0.001
Concentration until dinner	3.7 ± 0.7	2.8 ± 0.7*	2.4 ± 0.7***	2.5 ± 0.5**	F = 22.66	p < 0.001
Goodness of subjective sleep	3.8 ± 0.7	3.5 ± 0.7	3.5 ± 0.8	3.0 ± 0.5***	F = 18.43	p < 0.001
Subjective depth sleep	3.9 ± 0.7	3.3 ± 0.9	3.0 ± 0.9*	3.1 ± 0.7	F = 14.07	p < 0.01
Good subjective awakening	3.6 ± 0.6	3.2 ± 0.9	2.8 ± 0.5**	2.6 ± 0.8**	F = 21.37	p < 0.001

Values are means ± standard deviation. The questionnaire-based survey used Friedman ranking, and Dunn was used for multiple testing vs F group, * p < 0.05, ** p < 0.01, *** p < 0.001. F, fruit granola snacks; G, glucose snacks; N, no snack; A, fruit granola added to dinner (no snack)

Table 5: Values of sleep quality

Analysis	F	G	N	A	F value	P value
Waking (%)	12.2 ± 3.7	12.0 ± 2.4	13.2 ± 3.3	13.8 ± 4.6	F (2.589, 49.19) = 1.53	p = 0.22
REM-sleep (%)	19.5 ± 7.6	20.9 ± 5.9	20.3 ± 6.2	19.7 ± 6.7	F (2.472, 46.97) = 0.37	p = 0.75
Non-REM sleep (light) (%)	59.7 ± 8.6	60.1 ± 9.3	61.0 ± 10.4	59.4 ± 11.6	F (2.126, 40.39) = 0.17	p = 0.86
Non-REM sleeping (deep) (%)	17.0 ± 5.6	16.1 ± 4.9	14.8 ± 8.1	16.7 ± 9.3	F (2.382,45.25) = 0.53	p = 0.63
Number of awakenings	1.6 ± 1.2	2.8 ± 2.1	3.0 ± 1.8*	3.2 ± 2.5*	F (2.393, 45.47) = 3.26	p < 0.05

REM; rapid eye movement. Values are means ± standard deviation. One way-repeated-ANOVA was used for sleep quality and Dunnet's was used for multiple testing vs F group, * p < 0.05, ** p < 0.01, *** p < 0.001. F, fruit granola snacks; G, glucose snacks; N, no snack; A, fruit granola added to dinner (no snack)