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ScienceDirect
Nutrition Research 28 (2008) 304–308
Nutrition Research
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Raisins are a low to moderate glycemic index food with a correspondingly low insulin index

Yeonsoo Kim[a], Steven R. Hertzler[b], Heidi K. Byrne[c], Craig O. Mattern[c,*]

[a]*The Ohio State University, Interdisciplinary Nutrition Program, Columbus, OH 43210, USA*
[b]*Abbott Laboratories, Ross Product Division, Columbus, OH 43215, USA*
[c]*Department of Physical Education and Sport, Exercise Physiology Concentration, State University of New York College at Brockport, Brockport, NY 14420, USA*

Received 1 January 2008; revised 26 February 2008; accepted 29 February 2008

Abstract

The objective of this study was to determine the glycemic index (GI) and insulin index (II) of raisins and evaluate if these values are similar in different populations. The study subjects consisted of 10 healthy sedentary individuals (S; age, 25.7 ± 1.3 years; body mass index [BMI] = 23.3 ± 1.7 kg/m^2), 11 aerobically trained adults (A; age, 23.1 ± 1.0 years; BMI = 24.1 ± 0.3 kg/m^2), and 10 prediabetic adults (P; age, 50.0 ± 2.6 years; BMI = 32.6 ± 1.9 kg/m^2). Subjects consumed 50 g of available carbohydrate from raisins and from a glucose solution (reference food) on 2 separate occasions. Serum glucose and insulin concentrations were measured from capillary fingerstick blood samples at baseline and at 15, 30, 45, 60, 90, and 120 minutes (and 150 and 180 minutes for P group) postprandially. The GI of raisins was low (GI, ≤55) in the S (49.4 ± 7.4) and P (49.6 ± 4.8) groups and was moderate (GI, 55-69) in the A group (62.3 ± 10.5), but there were no differences among the subject groups (P = .437). The II of raisins was 47.3 ± 9.4, 51.9 ± 6.5, and 54.4 ± 8.9 for the S, A, and P groups, respectively. On average, the A group secreted 2- to 2.5-fold less insulin per gram of carbohydrate compared with the S and P groups (P < .05). Thus, raisins are a low to moderate GI food, with a correspondingly low II. The lower insulin response in the A group compared with the other groups suggests enhanced insulin sensitivity.

Keywords: Raisins; Glycemic index; Sports nutrition; Athletes; Insulin index; Human subject
Abbreviations: A, endurance athlete subject group; AUC, area under the curve; BMI, body mass index; GI, glycemic index; II, insulin index; P, prediabetic subject group; S, sedentary subject group.

1. Introduction

Raisins are a nutritious snack, containing dietary fiber, antioxidants, potassium, and iron [1]. Raisins are also a concentrated source of carbohydrate (a 2-tablespoon, or 18-g, portion counts as a fruit exchange in the Exchange Lists for Meal Planning) [2]. As such, there could be potential concerns about raisins causing a high postprandial glycemic response, especially in persons with diabetes or prediabetes. However, both the glycemic index (GI) of a carbohydrate source and the absolute amount of carbohydrate in the food portion influence the postprandial glycemic response [3]. Although raisins are a concentrated source of carbohydrate, roughly half of their available carbohydrate is fructose [4], which has a low GI value of 19 (glucose = 100) [5]. Jenkins et al [3] reported a GI value for raisins of 64 ± 11 (glucose = 100) in healthy adults, and another study reported a GI value of 65.7 ± 5.8 (glucose = 100) in women with gestational diabetes [6]. Some important limitations of these 2 studies,

* Corresponding author. Tel.: +1 585 395 5343; fax: +1 585 395 2771.
E-mail address: cmattern@brockport.edu (C.O. Mattern).

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doi:10.1016/j.nutres.2008.02.015

however, include a small sample size of 6 subjects in the former study, the use of nonstandard blood sampling times in the latter study, and no measurement of the insulin response in either study.

A key tenet of GI methodology is that factors such as the presence of diabetes or differences in the exercise habits and physical conditioning of the subjects will not affect the GI value. This is because the glycemic response to the test food is compared with the glycemic response to a reference food (glucose solution or white bread) within the same subject in a GI study [7,8]. However, recent investigations have suggested that the GI of some carbohydrate sources may be substantially lower when measured in endurance-trained vs untrained adults [9,10].

Therefore, the first objective of this study was to measure the glycemic and insulinemic indexes of raisins according to standardized methodology. The second objective was to test the hypothesis that the GI of raisins would be significantly lower in a group of young aerobically trained adults compared with a group of sedentary young and healthy adults or a group of adults with prediabetes.

2. Methods and materials

2.1. Subjects

The study protocol was reviewed and approved by The Ohio State University Institutional Review Board Human Subjects Committee. All subjects provided written informed consent for the study and completed appropriate privacy authorization.

The study groups were composed of 10 healthy sedentary individuals (S), 11 aerobically trained adults (A), and 10 prediabetic adults (P). During a screening visit, subjects responded to questions designed to ascertain their appropriateness for enrollment in the study. Subjects that were enrolled in groups S and A reported no history of glucose intolerance, diabetes, gastrointestinal disorders, or recent use of antibiotics. Subjects in the S group reported that they did not perform any vigorous exercise in the past 6 months and performed less than 3 hours per week of moderate-intensity activity such as walking. The subjects in the A group reported, by virtue of their responses to a questionnaire, [11] that they had trained aerobically at a moderate to high intensity of greater than 8 hours per week for the past 6 months. Three subjects in the A group were rowers, 7 were swimmers, and 1 was a runner. The subjects in the P group had a history of glucose intolerance.

During the screening visit, height was measured using a stadiometer, whereas weight was determined using a balance scale, such that body mass index (BMI) could be calculated. Finally, fasting blood glucose was measured via a fingerstick blood sample and analyzed using an Accu-Chek Advantage glucometer (Roche, Indianapolis, IN). To be enrolled in the S or A group, subjects were required to have a fasting blood glucose value of less than 100 mg/dL. All subjects in the P group demonstrated fasting plasma glucose levels between 100 and 125 mg/dL [12].

The mean age (±SE of the mean) of the S group was 25.7 ± 1.3 years, with a BMI of 23.3 ± 1.7 kg/m^2. The mean fasting plasma glucose level of the S group was 87.2 ± 1.7 mg/dL. The mean age of the A group was 23.1 ± 1.0 years. This group had a normal mean BMI (24.1 ± 0.3 kg/m^2) and a normal fasting plasma glucose level (87.6 ± 2.3 mg/dL). The mean age of the P group was 50.0 ± 2.6 years, with a mean BMI of 32.6 ± 1.9 kg/m^2 and a mean fasting plasma glucose level of 110.5 ± 2.6 mg/dL.

2.2. Feeding protocol

The study was a 2-treatment, randomized, crossover study with a minimum of 3 days between each treatment visit. Per usual clinical practice before an oral glucose tolerance test, subjects were asked to consume at least 150 g per day of carbohydrate for 3 days before testing [13]. This sufficient carbohydrate intake was confirmed by 3-day dietary records. Subjects were also asked to refrain from vigorous exercise for 12 hours before each visit.

For each visit, subjects arrived at the laboratory after having fasted overnight for at least 10 hours. A baseline capillary blood sample was collected via a finger puncture in the fasting state. The subjects then consumed either 360 mL of a glucose tolerance test beverage containing 50 g of glucose (SunDex; Fisher Health Care, Houston, Tex) or a 69-g portion of raisins (Sun-Maid, Kingsburg, Calif) that was calculated to provide 50 g of available carbohydrate (total carbohydrate minus dietary fiber) based on the nutrition label information. The order of the test meals was randomized. The energy and macronutrient compositions of the 50-g available carbohydrate portion of raisins were as follows: energy, 937.2 kJ (224 kcal); fat, 0 g; protein, 1.7 g; carbohydrate, 53.5 g; dietary fiber, 3.5 g; and sugar, 50 g. The glucose solution provided 836.8 kJ (200 kcal) (50 g of carbohydrate as glucose, 0 g of protein, and 0 g of fat).

2.3. Collection and analysis of serum glucose and insulin

Fingerstick capillary blood samples were collected using sterile lancets at baseline (immediately before ingestion of the raisins or glucose solution) and at 15, 30, 45, 60, 90, and 120 minutes (and 150 and 180 minutes for the P group) postprandially. Timing started at the first bite of the raisins/sip of the glucose solution [14]. Approximately 1 mL of whole blood was obtained from each fingerstick and collected into serum separator tubes (Becton Dickinson, Franklin Lakes, NJ). Blood was allowed to clot, centrifuged at 1168*g* for 15 minutes to obtain serum, and then the serum was stored at −20°C until analysis. Serum glucose concentrations were analyzed using the YSI 2700 Select Plus Biochemistry Analyzer (Yellow Springs Instruments, Yellow Springs, Ohio) via the glucose oxidase method. Serum insulin was analyzed by enzyme-linked immunosorbent assay using an Insulin DSL-10-1600 Active kit (Diagnostic Systems Laboratories, Inc, Webster, Tex).

2.4. Calculations of area under the curve

The positive incremental area under the curve (AUC) for serum glucose and insulin was calculated geometrically. Any area beneath the fasting values was ignored [14].

2.5. Statistical analysis

Descriptive statistics were calculated, and normality tests were performed for all variables using the NCSS 2000 software package (NCSS Computing, Kayesville, Utah). Data are displayed as the mean ± SEM. Data that were nonnormally distributed were transformed (square root or logarithmic) before statistical analysis to approximate a normal distribution. An analysis of variance (ANOVA) for a randomized block design, with subject as the random factor and treatment and group status (S, P, or A group) as the fixed factors, was performed at each time point and for AUC data for serum glucose and insulin to determine if global significant differences were present [15]. An independent group ANOVA was used to compare the GI and insulin index (II) values of raisins across the 3 populations [15]. In the event of a significant ANOVA result ($P < .05$), the Tukey-Kramer post hoc test was used for pairwise comparisons [15].

3. Results

The serum glucose and insulin responses to the test foods in groups S, A, and P (left to right) are shown in Fig. 1. There were no significant differences in baseline serum glucose levels for both the glucose solution and raisin meals among the 3 groups. The serum glucose response to the raisins was significantly lower than that of the glucose solution at several postprandial time points in all 3 groups. Although the average glucose responses to the raisins were virtually identical in the S and A groups, the glucose solution resulted in a serum glucose curve that was higher relative to the raisins at 90 minutes in the S group vs the A group.

The glucose AUC, insulin AUC, GI, and II are presented in Table 1. The serum glucose AUC for both the raisins and the glucose solution was not significantly different among the 3 groups. However, the serum glucose AUC of the glucose solution was 14% lower for the S group and 31% lower for the A group compared with that for the P group. The GI of raisins was low (GI ≤55) in the S (49.4 ± 7.4) and P (49.6 ± 4.8) groups and was moderate (GI, 55-69) in the A group (62.3 ± 10.5), but there were no differences among the groups ($P = .437$).

The insulin responses to both the glucose solution and the raisins followed the same trends as the glucose responses in each of the 3 groups, with the raisins resulting in significantly lower insulin values at several time points. As expected, the peak serum glucose and insulin responses for both the raisins and the glucose solution were higher in the P group compared with those in groups S and A. The A group had lower serum insulin AUC for both glucose solution ($P = .002$) and raisins ($P = .008$) than the P group (Table 1).

The serum insulin AUC for the glucose solution in the S group was 2.2 times that of the A group, but it was not

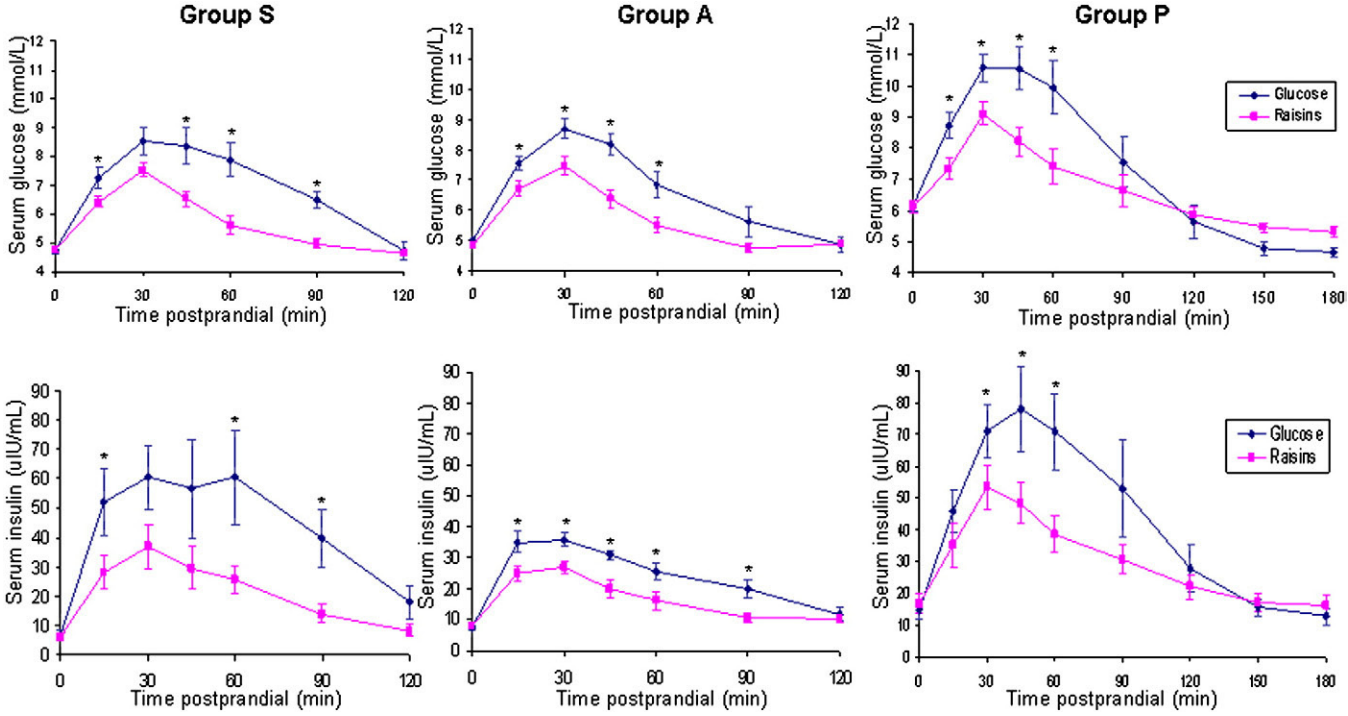

Fig. 1. Serum glucose and insulin responses to raisins and glucose solution in sedentary, aerobically trained, and prediabetic subjects. Group S =sedentary, n = 10; group A = aerobically trained, n = 11; group P = prediabetic, n = 10. Values represent the mean ± SEM. Data were analyzed using an ANOVA followed by a Tukey-Kramer post hoc test. *Significant differences between glucose solution and raisins ($P < .05$).

Table 1
Serum glucose and serum insulin positive incremental AUCs, GI of raisins, and II of raisins in sedentary, aerobically trained, and prediabetic subjects

	Group S		Group A		Group P	
	Raisins	Glucose solution	Raisins	Glucose solution	Raisins	Glucose solution
Serum glucose AUC[a] (mmol·min^{-1}·L^{-1})	125.0 ± 19.6	270.5 ± 33.0	113.3 ± 15.1	217.3 ± 30.5	148.5 ± 23.7	314.2 ± 54.3
Serum insulin AUC[b] (μIU·min^{-1}·L^{-1})	1938 ± 399	4625 ± 1143	1021 ± 125[c]	2068 ± 217[d]	2431 ± 414[c]	5110 ± 851[d]
GI	49.4 ± 7.4	–	62.3 ± 10.5	–	49.6 ± 4.8	–
II	47.3 ± 9.4	–	51.9 ± 6.5	–	54.4 ± 8.9	–

Values represent the mean ± SEM. Data were analyzed using an ANOVA followed by a Tukey-Kramer post hoc test.
S, n = 10; A, n = 11; P, n = 10.
[a] Raisin AUC is less than glucose solution AUC for groups S (P = .001), A (P = .006), and P (P = .012).
[b] Raisin AUC is less than glucose solution AUC for groups S (P = .029), A (P < .001), and P (P = .014).
[c] Raisin AUC is significantly different between A and P groups (P = .008).
[d] Glucose solution AUC is significantly different between A and P groups (P = .002).

significantly different (P = .075). A similar trend was observed for serum insulin response to raisins in groups S and A; the response in S group was 90% higher than that in group A. Insulin index of raisins was not significantly different among groups (P = .72). The II of raisins were 47.3 ± 9.4, 51.9 ± 6.5, and 54.4 ± 8.9 for S, A, and P groups, respectively. However, the A group secreted 2- to 2.5-fold less insulin per gram of carbohydrate compared with the S and P groups, respectively (P < .05).

4. Discussion

The GI of raisins did not vary significantly among the different populations in our study, although the GI of raisins in athletes tended to be higher than that in sedentary people and prediabetic subjects. One possible explanation might be the presence of outliers in this group. However, upon examining the subject data for possible outliers in GI among the A group, we found no individual GI values that were greater than 2 SD above the mean for the group. Another possibility is that, because the GI is a ratio of the AUC values of the test and reference foods, the GI could be elevated by either a high AUC for the test food or a lower-than-expected AUC for the reference food. Because the A group had the lowest serum glucose AUC for the raisins among the 3 groups, the somewhat higher GI of raisins in the A group was associated with a less pronounced increase in serum glucose after the glucose solution. It is likely that increased insulin sensitivity in athletes results in faster glucose disposal from a glucose challenge than for sedentary people or prediabetic people [16-19]. In our study, athletes had 2- to 2.5-fold less insulin secretion for both the raisins and the glucose solution compared with sedentary and prediabetic people.

Two recent studies showed that the GI of breakfast cereals was dependent on the training status of subjects, with lower GI of cereals reported in trained subjects [9,10]. However, in our study, the GI of raisins was not significantly different among groups, although there was a somewhat higher GI value in the athletically trained subjects. The reason(s) for the discrepancy between our results and the results of Mettler et al [9,10] is not clear. One variation between the studies is that the cereals in their studies were fed with partially skimmed milk, bringing the protein content to 10 to 14 g and the fat content to 5 to 9 g. By contrast, the meals in our study were nearly 100% carbohydrate. Currently, it is unknown if macronutrients could have differential effects on glycemia in trained vs untrained persons. However, there is some evidence that dietary fiber and protein may lower glycemia more in persons with high vs low waist circumference and that fat reduces glycemia more in those with low vs high fasting plasma insulin [20].

Other methodological factors may have contributed as well. Mettler et al [9,10] used a portable blood glucose monitoring system as opposed to the YSI analyzer that was used in our study. The reliability of some of these portable systems for GI studies is questionable [21]. Considering that these portable systems use a very small volume of whole blood, subtle changes in the plasma vs red cell compartment have a greater opportunity to impact the glucose concentration compared with a serum analysis performed using the YSI system. As aerobic training is known to influence plasma volume, it is possible that there could be disproportionate errors for aerobic athletes vs nonathletes when using a portable glucose system with whole blood vs a YSI measurement using serum samples.

One important difference between our results and those of Mettler et al [9] is the higher glycemic AUC for the glucose solution in our population of sedentary adults (271 mmol·min·L^{-1}) vs theirs (208 mmol·min·L^{-1}). This is in contrast to the relatively similar glycemic AUC values for athletes in our study (217 mmol·min·L^{-1}) compared with theirs (202 mmol·min·L^{-1}) for the glucose solution. Some of the discrepancy in the sedentary values between these studies may be due to their reporting of whole blood glucose values vs serum glucose numbers in our study. As previously mentioned, this could lead to disproportionate errors for aerobic athletes vs sedentary individuals. Because the glycemic AUC number forms the denominator of the GI, a low glycemic AUC in the sedentary population, as observed by Mettler et al [9], sets the stage for their observation of a

higher GI in the sedentary population as compared with aerobic athletes. It should be noted that, in their second study of cereals [10], the mean whole blood glucose AUC in response to the same 50-g glucose solution as the first study (with the same glucose monitoring system) was approximately 175 mmol·min·L^{-1}. Pooling our results with those of Mettler et al [9,10], it is apparent that, even when studying healthy sedentary subjects of similar mean age (23-26 years) and BMI (21-23 kg/m^2), it is possible for the mean glycemic AUC to a 50-g glucose solution to vary from approximately 175 to 271 mmol·min·L^{-1}.

In conclusion, the current investigation demonstrated that the GI of raisins is low to moderate, despite their concentrated carbohydrate content. This property, in combination with other nutritional benefits, further boosts the case for raisins as a healthy snack food. In addition, the GI of raisins was not significantly different when measured in healthy sedentary individuals, athletes, and prediabetic persons. Our findings contradict other recent studies, indicating that further research is needed to evaluate the effect of training status on GI. Finally, our study confirms that endurance-trained athletes are able to normalize postprandial glycemia with lower insulin secretion compared with healthy sedentary adults.

Acknowledgment

This study was funded by the California Raisin Marketing Board. The authors thank Rochester Clinical Research for assistance with subject recruitment and Roxanne Nash for help with data collection.

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