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Evaluation of a snack bar containing uncooked cornstarch in subjects with diabetes

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Abstract

The objective of this study was to determine the effect of a snack bar containing uncooked cornstarch, equivalent to 1 1/2 starch/bread exchanges (bar 1), compared to a control bar (bar 2), on the incidence of nocturnal and morning hypoglycemia in subjects with diabetes. Adolescent campers and counselors with diabetes ($n = 79$) were randomly assigned to Group A (5 nights of snack bar 1 as the evening snack, followed by 5 nights of snack bar 2) or Group B (5 nights of snack bar 2 as the evening snack, followed by 5 nights of snack bar 1). Midnight and morning finger stick blood glucose levels were compared to determine the incidence of hypoglycemia (< 60 mg/dl) and hyperglycemia (> 250 mg/dl), and events were analyzed for the total cohort, Group A, and Group B and by glycated hemoglobin quartile to determine the effect of each bar on glycemia. For subjects with diabetes there was a significant decrease in the number of hypoglycemic episodes with bar 1 compared to bar 2 at midnight (total cohort and Groups A and B) and in the morning (total cohort and Group A). There was a significant decrease in the number of subjects to ever experience hypoglycemia with snack bar 1 compared to snack bar 2, a significantly lower incidence of hyperglycemic episodes at midnight with snack bar 1, and no difference in the incidende of hypoglycemia by glycated hemoglobin quartile. These data suggest that the snack bar containing uncooked cornstarch can diminish night time and morning hypoglycemia in subjects with diabetes, without causing hyperglycemia. © 1997 Elsevier Science Ireland Ltd.

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1. Introduction

While there are apparent long-term benefits to improving glycemia in patients with type 1 diabetes, intensive management is associated with an

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appears to be the rate-limiting step for many subjects attempting to adhere to intensive management protocols [2]. In an attempt to develop strategies to diminish hypoglycemia in children and adolescents with type 1 diabetes, we began using uncooked cornstarch as a component of the evening snack in 1993. This was modeled after treatment strategies used in the glycogen storage diseases described by Chen, Cornblath and Sidbury, in 1984 [3].

Uncooked cornstarch is a complex carbohydrate composed of 27% of the linear chain dextrose polymer amylose, and 73% of the branched chain dextrose polymer amylopectin. Uncooked cornstarch is converted into maltose and other very small glucose polymers in the duodenum and upper jejunum by pancratic amylase. These compounds are then hydrolyzed into monosaccharides in the small intestine by intestinal epithelial enzymes and slowly absorbed into the portal circulation over at least a 4–6 h period [4].

Our initial pilot study involved 13 children and adolescents who adhered to an intensive management protocol. For a 2 week time period, each subject ingested either 5–7 g of uncooked cornstarch in milk as part of the evening snack, or an equivalent standard snack [5]. We saw a significant reduction in night time and fasting hypoglycemic episodes defined as a blood glucose level by finger stick < 60 mg/dl, with the cornstarch snack compared to the standard snack. At 02:00, there was a mean of 0.61 ± 0.87 hypoglycemic episodes for the entire group with the cornstarch snack, compared to 2.00 ± 2.12 events with the standard snack ($P < 0.025$). Similarly, at 07:00 h there was a mean of 0.69 ± 1.03 hypoglycemic events with the cornstarch snack, compared to 2.62 ± 2.25 with the standard snack ($P < 0.010$).

This observation was substantiated in 1994 by a 10 day randomized, blinded trial involving 51 subjects at the American Diabetes Association sponsored summer camp in Southern California [6]. A snack containing 5 g of uncooked cornstarch in milk or sugar-free pudding was compared to a standard snack of equal carbohydrate content. The average frequency of hypoglycemia at midnight was reduced from 12.2 to 2.2% ($P < 0.001$) and the average incidence of hypoglycemia in the morning was reduced from 9.5 to 4.5% ($P < 0.05$) with the cornstarch snack compared to the standard snack. Similarly, there was a reduction in the number of individual campers to ever experience a hypoglycemic event with the cornstarch snack compared to the standard snack at midnight (12 vs. 46%, $P < 0.001$) and in the morning (16 vs. 26%, $P = 0.327$).

However, uncooked cornstarch, when mixed in milk or pudding is inconvenient to prepare and not particularly palatable. Therefore, subjects with diabetes may not choose to use uncooked cornstarch, despite its potentital efficacy in reducing hypoglycemia. In an attempt to design a product that would contain uncooked cornstarch and be convenient and palatable, we developed a pleasant-tasting snack bar in collaboration with Baker Norton Pharmaceutical (Miami, FL) that contained 5 g of uncooked cornstarch combined with 17 g of other complex carbohydrate, 7 g of protein and 2.5 g of fat which is now produced under the trade name Zbar©. This snack bar, equivalent to 1 1/2 bread/starch exchanges and 120 cal., could serve as all or part of the evening snack and be easily ingested by subjects at risk for hypoglycemia. The present studies were done to compare the cornstarch snack bar to a control snack bar of equal carbohydrate, protein, fat and caloric content. This study was performed to determine the effect of the bars on midnight and morning blood glucose levels in subjects with diabetes.

2. Materials and methods

This study was conducted during the teen session at the American Diabetes Association sponsored Camp Chinnock, in Southern California, and was similar to the study performed the year prior using uncooked cornstarch in milk or sugar-free pudding, as previously described [6]. Seventy nine of a potential 115 campers and counselors entered this study after they were solicited with a letter describing the study protocol, and after they and/or their parents signed an informed consent. The subjects were 14–30 years of age, there were 33 males and 46 females, with a duration of

diabetes from 1.5 to 19 years. Half of the subjects were on two injections per day, while the remainder were on three or more, or used continuous subcutaneous insulin infusion. Glycated hemoglobin levels were reported on the camp form in 73 study subjects. Levels were analyzed by % above the upper limit of the reported assay norm, and divided into quartiles.

Thirty nine subjects were randomly assigned to receive bar 1 for 5 nights, followed by bar 2 for 5 nights (Group A), while 40 subjects were randomly assigned to receive the bars in the oposite order (Group B). Snack bars were eaten with 4 oz of milk as the evening snack if the blood glucose level was ≥ 120 mg/dl. In addition to the bars, if the blood glucose level was ≥ 80 and < 120 mg/dl, 1/2 starch and 1/2 protein exchanges were added; if the blood glucose was ≥ 50 and < 80 mg/dl, 1 fruit exchange was added to the 1/2 starch and 1/2 protein exchanges, and if the blood glucose level was < 50 mg/dl, 1 1/2 fruit exchanges were given in addition to the 1/2 starch and 1/2 protein exchanges. The campers, counselors, staff, dieticians, and physicians deciding the insulin dosages and treatments for hypoglycemia were blinded to the snack bar assignment. Only the research assistants knew which campers had consumed which bars, but they had no other role in diabetes management.

The goal of the medical management was to maintain the subjects' blood glucose levels in the targeted range of 70–150 mg/dl, avoiding extremes of glycemic excursion. On the first day of camp, the home insulin dosage was decreased by 15%. Thereafter, insulin dosage adjustment was done daily by the medical staff under the supervision of a pediatric endocrinologist according to an algorithm as previously published [7]. Participants ate three full meals and three snacks per day composed of 25% fat, 50% carbohydrate and 25% protein, and subjects were encouraged to consume their usual caloric intake. The evening snack was given between 21:00 and 21:30 h nightly. Carbohydrate intake after each meal was recorded by the staff dieticians as reported by campers. All subjects routinely tested their blood glucose levels with a glucose meter (One Touch, Lifescan, Milpitas, CA or Glucometer Elite, Miles, Elkhart, IN) five times per day: before breakfast, lunch, dinner, evening snack and between midnight and 01:00 h. Glucose meters were checked for accuracy with high and low standards daily by nursing staff. Subjects participated in the full range of camping activities without restrictions. Hypoglycemia was treated according to a standard protocol. If the blood glucose level was < 40 mg/dl, 1 1/2 fruit exchanges were given, if the blood glucose was ≥ 40 and < 70 mg/dl, 1 fruit exchange was given. If hypoglycemia occurred more than 1 h before the next meal, an extra starch and protein exchange were given.

Comparisons of the number of hypoglycemic events, defined as a blood glucose levels < 60 mg/dl, and the number of hyperglycemic events, defined as a blood glucose levels > 250 mg/dl, occurring at midnight and at 07:00 h, were made for the cornstarch bar nights vs. the control bar nights. In addition, comparisons were made for snack bar 1 and snack bar 2 for Group A and Group B. Statistical analysis to compare blood glucose levels was done with the Fisher's Exact test. McNemar's test was used to compare blood gluose levels for individual campers and χ^2 was used for glycated hemoglobin.

2.1. Snack bars

Both snack bar 1 and snack bar 2 were composed of soy protein isolate, peanut butter, water, polydextrose, peanuts, whey protein concentrate, natural flavors, sorbitol, lecithin and citric acid. As shown in Table 1, a single bar was 31 g or 1.1 oz. Each contained 120 calories, 23% from protein, 54% from carbohydrate, and 23% from fat.

Snack bar 1 contained 5 g of uncooked cornstarch and 17 g of complex carbohydrate in the form of polydextrose, in addition to 7 g of protein and 2.5 g of fat. Snack Bar 2 was composed of 22 g of complex carbohydrate in the form of polydextrose, in addition to 7 g of protein, and 2.5 g of fat.

Table 1
Composition of cornstarch bar—nutrition facts[a]

Amount per serving		Daily value based on 2000 calories (%)		DRV for 2000 calories
Calories	110			
Calories from fat	25			
Total fat (g)	2.5	4		65
Saturated fat (g)	0	0		20
Monounsaturated fat (g)	1			
Polyunsaturated fat (g)	1			
Cholesterol (mg)	0	0		300
Sodium (mg)	90	4		2400
Potassium (mg)	90	3		3500
Total carbohydrate (g)	22	7		300
Dietary fiber (g)	1	4		25
Sugars (g)	1			
Sugar alcohol (g)	8			
Other carbohydrate[b]				
Protein (g)	7			
Vitamin A	—	Folate (%)	2	
Vitamin C	—	Vitamin B12	—	
Calcium (%)	4	Biotin	—	
Iron (%)	4	Pantothenic	—	
Vitamin D	—	Phosphorous (%)	8	
Vitamin E	—	Iodine (%)	2	
Thiamin	—	Magnesium (%)	4	
Riboflavin (%)	2	Zinc (%)	2	
Niacin	—	Copper (%)	4	
Vitamin B6	—			

[a] Serving size 1 Bar (33 g/1.2 oz).
[b] Cornstarch 5 g.

2.2. Starch staining

Blinded samples of snack bar 1 and snack bar 2, in addition to uncooked rice as a control, were analyzed for the presence of unhydrolyzed starch. After mixing 200 mg of each bar or uncooked rice with 2 ml water, the sample was centrifuged at 1500 rpm for 20 min at 4°C. The supernatant was discarded and a drop of iodine was added to the samples to determine the presence of starch.

3. Results

There was a significant difference in the number of hypoglycemic events at midnight between snack bar 1 and snack bar 2 for the total cohort and for Groups A and B (Table 2). A similar result occurred in the morning for the total cohort and Group A; however, statistical significance was not reached for Group B. As shown in Table 3, there was a significant decrease in the number of hyperglycemic events for the total cohort at midnight when snack bar 1 was ingested compared to snack bar 2. There was a significant decrease in the number of subjects to ever experience a hypoglycemic event at both midnight and in the morning when snack bar 1 was taken compared to snack bar 2 (Table 4).

There was no association between the incidence of hypoglycemia and glycated hemoglobin level. With snack bar 1, the incidence of hypoglycemia was 7.9% in the subjects with glycated hemoglobin in the first quartile, 2.1% in the second quartile, 3.3% in the third quartile, and 0% in the fourth quartile. With snack bar 2, the incidence of hypoglycemia by quartile was 19.3, 17.0, 12.3 and 13.5%, respectively. The incidence of

Table 2
Number (%) of hypoglycemic events

Bar	Midnight*			Morning**		
	Group A	Group B	Total bar	Group A	Group B	Total bar
1	7/194 (3.6%)	6/199 (3.0%)	13/393 (3.3%)	2/195 (1.0%)	6/199 (3.0%)	8/394 (2.0%)
2	19/189 (10.1%)	40/198 (20.2%)	59/387 (15.3%)	15/191 (7.9%)	15/199 (7.5%)	30/390 (7.7%)

* Group A, $P = 0.014$; group B, $P < 0.001$; and total $P < 0.001$.
** Group A, $P = 0.001$; group B, $P = 0.072$; and total $P = 0.001$.

hypoglycemia was independent of the preceding glycated hemoglobin level when the subjects ingested bar 1 (P = NS), however, there was a significant decrease in hypoglycemia for each glycated hemoglobin level with snack bar 1 compared to snack bar 2 ($P < 0.001$). There was no difference in the mean daily dose of insulin used by subjects while ingesting snack bar 1 compared to snack bar 2 (mean paired difference was 0.10 ± 6.73 units/day, $P = 0.894$). However, there was an increase in insulin dosage during the last part of the camp session compared to the first part of camp. This difference was seen in both groups (mean difference of 2.93 units, range 23.8–9.9, more insulin in the last 5 days of camp compared to the first 5 days of camp, $P = 0.0001$). There was no difference in the mean carbohydrate intake (by bread/starch exchanges) at dinner for the subjects when ingesting snack bar 1 vs. snack bar 2 (mean paired difference −00.08 carbohydrate exchanges, $P = 0.71$).

3.1. Starch staining

The results of iodine staining showed the presence of starch in the uncooked rice and snack bar 1 of equivalent intensity; there was no starch detected in snack bar 2.

4. Conclusion

Our data suggests that in subjects with diabetes the cornstarch bar can diminish the incidence of hypoglycemia and reduce the number of subjects experiencing hypoglycemia at midnight, 3–4 h after ingestion, and in the morning, 9–10 h after ingestion. This decrease in hypoglycemia was not accompanied by a concurrent increase in hyperglycemia at these time periods. The improvement in glycemia appears to be due to the difference in the composition of the snack bars themselves, and not due to anything else that could have affected blood glucose control during this study, such as the carbohydrate intake at dinner or the overall insulin dosages administered.

There was a significant difference in insulin dosage between the first and the last part of the camp session for both Group A and B. This was most likely due to the fact that, at the beginning of camp, insulin dosages were routinely decreased in all campers, a camp policy based on prior experience that has been in place for over 2 decades. However, as the camp session progressed, insulin dosage increased back to precamp levels. There was no difference in total insulin dosage for subjects on snack bar 1 or snack bar 2, perhaps due to the short time-frame of this study, combined with the routine change in dosage on entry to camp. Therefore, the long-term effect of the ingestion of cornstarch bars on insulin requirements cannot be inferred from this study.

The overall incidence of hypoglycemia and the number of subjects experiencing hypoglycemia with snack bar 2 were similar to that observed during our previous study when campers ingested a standard snack without cornstarch [7]. In both instances, approximately half of the campers had at least one hypoglycemic episode at midnight, and approximately one-quarter had at least one episode in the morning, with hypoglycemia occurring equally in subjects in all glycated hemoglobin quartiles. Since the cornstarch snack bars benefited subjects regardless of their antecedent

Table 3
Number (%) of hyperglycemic events

Bar	Midnight*			Morning**		
	Group A	Group B	Total bar	Group A	Group B	Total bar
1	12/194 (6.2%)	13/199 (6.5%)	25/393 (6.4%)	7/195 (3.6%)	13/199 (6.5%)	20/394 (5.1%)
2	20/189 (10.6%)	23/198 (11.6%)	43/387 (11.1%)	14/19 (7.3%)	18/199 (9.1%)	32/390 (8.2%)

* Group A, $P = 0.141$; group B, $P < 0.083$; and total $P = 0.022$.
** Group A, $P = 0.120$; group B, $P = 0.455$; and total $P = 0.086$.

glycemic control, this dietary adjunct might be efficacious not only in those subjects already practicing or wishing to instiute intensive diabetes management, but also in those less than optimally managed patients who are still at risk for hypoglycemia.

There appears to be an enhancement of the prolonged glycemic effect of cornstarch as a result of mixing it with other complex carbohydrate, fat which could delay gastric empyting, and protein which could provide subtrate for gluconeogenesis. In 1993, Ververs [8] showed that uncooked cornstarch in water, compared to a standard snack of equal carbohydrate content, decreased hypoglycemia at night in patients with diabetes, although this difference was not statistically significant. This may have been due to the fact that the entire snack was given as cornstarch without the addition of other disaccharides, fat or protein. To test this hypothesis, our original studies [4,5] added the cornstarch to an evening snack that contained milk and equalled a bread/starch exchange. The findings of these studies were used to develop the present snack bar that is equivalent to 1 1/2 starch/bread exchanges and can be ingested with milk as part or all of the evening snack in subjects with diabetes.

Table 4
Number (%) of campers to ever experience hypoglycemia

Bar	Midnight*	Morning**
1	12/79 (15.19%)	7/79 (8.9%)
2	41/79 (51.9%)	23/79 (29.1%)

* $P < 0.001$ and ** $P = 0.002$.

It appears that this snack bar containing cornstarch is a simple and inexpensive dietary intervention. This convenient and palatable medical food should become an adjunct to the overall diabetes regimen to diminish nocturnal and morning hypoglycemia in type 1 patients.

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References

[1] The Diabetes Control and Complication Trial Research Group (1993) The effect of intensive diabetes management on the development and progression of long-term complication in insulin dependent diabetes mellitus. The diabetes complication and control trial. N. Engl. J. Med. 329, 977–987.
[2] Cryer, P.E. (1994) Hypoglycemia: The limiting factor in the Management of IDDM. Diabetes 43, 1378–1386.
[3] Chen, Y-T., Cornblath, M. and Sidbury, J.B. (1984) Cornstarch therapy in type 1 glycogen-storage disease. N. Engl. J. Med. 310, 1721–1725.
[4] Lozano, R., Chalew, S.A. and Kowarski, A.A. (1990) Cornstarch ingestion after oral glucose loading: Effect on glucose concentrations, hormone response, and symptoms in patients with postprandial hypoglycemic syndrome. Am. J. Clin. Nutr. 52, 667–670.

[5] Kaufman, F.R. and Devgan, S. (1996) Use of uncooked cornstarch to avert nocturnal hypoglycemia in children and adolescents with type 1 diabetes. J. Diabetes Complications 10, 84–87.
[6] Kaufman, F.R., Halvorson, M. and Kaufman, N.D. (1995) A randomized, blinded trial of uncooked cornstarch to diminish nocturnal hypoglycemia at diabetes camp. Diabetes Res. Clin. Pract. 30, 205–209.
[7] Kaufman, F.R. (1994) Outpatient management of children and adolescents with IDDM. Clin. Diabetes 12, 146–150.
[8] Ververs, M.T.C., Rouwe, C. and Smit, G.P.A. (1993) Complex carbohydrates in the prevention of nocturnal hypoglycemia in diabetic children. Eur. J. Clin. Nutr. 47, 268–273.