The Effects of Carbohydrate Consumption on Stress Levels in Humans

Marli SHIMBO1, Chozo KUROIWA2 and Hidehiko YOKOGOSHI1,*

1School of Food and Nutritional Sciences, and COE Program in the 21st Century, The University of Shizuoka,
52-1, Yada, Shizuoka 422-8526, Japan
2Department of Early Childhood Education, Iida Women’s Junior College, 610 Matsuo-shirota, Iida,
Nagano 395-8567, Japan
(Received November 7, 2003)

Summary A significant increase in calculation ability was observed in the glucose, fructose and sucrose administration groups during both the first and second half of the Uchida Kraepelin test. There was no significant difference in alpha waves between carbohydrate groups (glucose, fructose and sucrose) and control groups at baseline. After a stress situation, there was a significant increase in alpha waves at 11–20 min (p<0.05) in glucose, 11–20 min (p<0.01) and 21–30 min (p<0.01) in fructose, and 0–10 min (p<0.05) in sucrose compared, with each control group. There was no significant difference in beta waves in any of the paired groups.

Key Words carbohydrate, stress, calculation ability, electroencephalographic (EEG)

Materials and Methods
All 11 volunteers were women aged between 18–20 y. The subjects were instructed to refrain from either eating or drinking, excluding water, for at least 2 h prior to commencement of the experiment. First, the subjects were seated and given time to acclimatize to the new environment, during this 10 min period, the subject’s EEG was measured continuously to establish a baseline for later comparison and analysis. The EEG was measured from the left frontal lobe with two electrodes using MinD Sensor II (Brain Function R&D Center, Tokyo, Japan). The room temperature was kept at a constant 25°C.

The 11 subjects repeated the testing procedure during separate sessions using one, two or three of the different carbohydrate solutions. All subjects acted as a control during one of the sessions.

Seven volunteers were given a glucose solution (50 g/100 mL soda water), 7 a fructose solution (50 g/100 mL soda water) and 6 a sucrose solution (50 g/100 mL soda water). As a control, soda water (100 mL) was given to each volunteer.

Second, after taking a carbohydrate solution, the Uchida-Kraepelin psychodiagnostic test was conducted to measure an individual’s ability to perform a stressful task. In this test, the subjects were asked to add a pair of numbers in series on a continuous line and write down the first digit from the sum of each pair, this was done continuously for 1 min. After the 1 min period had finished, the subjects were then asked to repeat the process on the next line. This was repeated for a total of 15 times. Once finished, the subjects were given a 5 min rest period and were then asked to repeat the entire process.

* Corresponding author.
Table 1. Results of Uchida-Kraepelin psychodiagnostic test.

| Group           | Control | Glucose | Control | Fructose | Control | Sucrose |
|-----------------|---------|---------|---------|----------|---------|---------|
| First half of test | 822±43.4 | 943±68.1* | 781±44.8 | 982±75.1* | 834±21.8 | 1.014±38.7* |
| Second half of test | 911±62.2 | 1.006±77.6* | 876±67.2 | 1.038±75.3* | 951±46.2 | 1.068±48.0* |

Values are means±SE.
All comparisons were made by Student’s paired t test.
* Significant difference (p<0.01).

Third, after the Uchida-Kraepelin psychodiagnostic testing was completed, the subject’s EEG was measured for 60 min. The alpha and beta wave measurements were compared between the carbohydrate and control groups at 10-min intervals for 60 min.

Statistical analysis of all data was obtained by Student’s paired t test using SPSS for Windows (version 11.5: SPSS Inc., Chicago, IL, USA).
This study was done in accordance with the code of ethics of the World Medical Association (Helsinki Declaration of 1964 as revised in 2000).

Results and Discussion

Table 1 shows the effects of carbohydrate administration on the total number of sums calculated. There was a significant higher number of total sums calculated in each of the three carbohydrate groups as compared to each groups control (Table 1).

Figure 1 shows the effects of carbohydrate administration on alpha wave frequency. There was no significant difference between carbohydrate and control groups at baseline.

After the stress situation, a significant increase was shown at 11–20 min (p<0.05) in glucose, 11–20 min (p<0.01) and 21–30 min (p<0.01) in fructose and 0–10 min (p<0.05) in sucrose, compared with each control (Fig. 1). There was no significant difference in beta waves in any of the carbohydrate or control paired groups (data not shown).

Previous studies suggest that glucose, fructose and sucrose administration increases the blood glucose levels and is associated an increase in cognitive performance and EEG slow wave activity (8–11).

The increase in blood glucose following the consumption of carbohydrates is associated with the release of insulin. Insulin causes the large neutral amino acids (LNAA) to be absorbed into the muscles, although tryptophan is bound to albumin in the blood. A meal comprising high quantities of carbohydrates thus increases the ratio of tryptophan to other LNAA in plasma. The tryptophan and other LNAA compete for the specific transporter molecules. A high-carbohydrate meal increases the tryptophan-to-LNAA ratio, which means more tryptophan is transported into the brain where it is metabolized into the neurotransmitter serotonin.

It is well established that as stress increases so does the brain’s consumption of serotonin (12, 13). Therefore, it is suggested that the improvement in calculation ability and the increase in alpha waves, occurring after carbohydrate intake during the stress situation, is due to an increase in serotonin and blood glucose levels.

In this study, blood glucose levels were not monitored during the examination and the sweetness (taste) of the carbohydrate samples varied. The effect, if any, of blood glucose levels and carbohydrate sweetness (taste) on ability and mood would require further examination.

Acknowledgments

This work was supported in part by a grant for scientific research from Shizuoka Prefecture, and a Grant-in-aid for Scientific Research from the Ministry of Education, Science, Culture, Sports and Technology of Japan.

REFERENCES

1) Adler N, Matthews K. 1994. Health psychology: why do
some people get sick and some stay well? *Annu Rev Psychol* **45**: 229–259.

2) Steptoe A. 1991. The links between stress and illness. *J Psychosom Res* **35**: 633–644.

3) Wurtman JJ, Brzezinski A, Wurtman RJ, Laferriere B. 1989. Effect of nutrient intake on premenstrual depression. *Am J Obstet Gynecol* **161**: 1228–1234.

4) Friedman D, Jaffe A. 1985. Influence of life-style on the premenstrual syndrome. Analysis of a questionnaire survey. *J Reprod Med* **30**: 715–719.

5) Benton D, Brett V, Brain PF. 1987. Glucose improves attention and reaction to frustration in children. *Biol Psychol* **24**: 95–100.

6) Benton D, Owens D. 1993. Is raised blood glucose associated with the relief of tension? *Psychosom Res* **37**: 723–735.

7) Markus CR, Panhuysen G, Jonkman LM, Bachman M. 1999. Carbohydrate intake improves cognitive performance of stress-prone individuals under controllable laboratory stress. *Br J Nutr* **82**: 457–467.

8) Scholey AB, Harper S, Kennedy DO. 2001. Cognitive demand and blood glucose. *Physiol Behav* **73**: 585–592.

9) Nuttall FQ, Khan MA, Gannon MC. 2000. Peripheral glucose appearance rate following fructose ingestion in normal subjects. *Metabolism* **49**: 1565–1571.

10) Benton D. 2002. Carbohydrate ingestion, blood glucose and mood. *Neurosci Biobehav Rev* **26**: 293–308.

11) Fishbein DH, Thatcher RW, Cantor DS. 1990. Ingestion of carbohydrates varying in complexity produce differential brain responses. *Clin Electroencephalogr* **21**: 5–11.

12) Joseph MH, Kennett GA. 1983. Stress-induced release of 5-HT in the hippocampus and its dependence on increased tryptophan availability: an in vivo electropharmacological study. *Brain Res* **270**: 251–257.

13) Vahabzadeh A, Fillenz M. 1994. Comparison of stress-induced changes in noradrenergic and serotonergic neurons in the rat hippocampus using microdialysis. *Eur J Neurosci* **6**: 1205–1212.