By E. Cheraskin, W. M. Ringsdorf Jr., F. H. Medford, and B. S. Hicks

Reprinted from
American Laboratory, August, 1975

Physical activity and carbohydrate metabolism

IT IS NOTEWORTHY that very little attention has been directed to the relationship of physical activity and carbohydrate metabolism.[1-11] The few published studies suggest that physical activity serves as a hypoglycemic agent in hyperglycemic subjects. This report is designed to reexamine carbohydrate metabolism in terms of reported physical activity. Specifically, an attempt will be made to analyze the classical 3-hr glucose tolerance pattern and the diurnal blood glucose pattern in subjects who report daily exercise vs individuals who report no daily exercise.

Methods

In 1965, a multiple testing health program for members of the health professions was inaugurated under the auspices of the Southern Academy of Clinical Nutrition. In 1969, the project was extended to include a group designated as the Southern California Academy of Nutritional Research, and a third group was organized under the aegis of the Ohio Academy of Clinical Nutrition. In 1971, a fourth segment was added under the direction of the Northeast Academy of Clinical Nutrition. Finally, in 1972, a fifth group was started under the guidance of the Northern California Academy of Nutritional Research.

Dr. Cheraskin is Professor and Chairman, Dr. Ringsdorf is Associate Professor, Ms. Medford is Research Assistant, and Mr. Hicks is Student Assistant, Department of Oral Medicine, University of Alabama in Birmingham.

Eight hundred thirty-two dental practitioners and their wives were evaluated in terms of exercise as reported in the Cornell Medical Index Questionnaire. The 3-hr glucose tolerance test was performed on 66 persons. This test begins with a blood glucose determination following a 12-hr fast. Immediately, the person swallows a load of 100 g of glucose. Determinations are again made 30 min., 1 hr, 2 hr, and 3 hr after this loading of blood glucose. In this study the 30-min blood sample was omitted. A diurnal blood glucose pattern was determined in 538 subjects by measuring blood glucose under natural conditions at 8:30 AM, 10:30 AM, 12:30 PM, 2:30 PM, and 4:30 PM.

Results

Experiment one:

Thirty-three subjects claiming no daily exercise were matched by age and sex with thirty-three subjects performing some form of exercise on a daily basis. The classical 3-hr glucose tolerance test was performed on each of the subjects. *Table 1* outlines the results. Three points are worthy of special mention. First of all, there are no statistically significant differences of the means between exercisers and non-exercisers at any of the temporal points. Second, the spread of values (variances) is greater at every temporal point in the no-exercise group vs the exercise group. Finally, the variances are only statistically significantly different under fasting conditions [t = 0.498, $P<0.050$].

Experiment two:

A group of 269 subjects claiming no exercise on a daily basis were paired by age and sex with a group of 269 subjects who reported daily exercise. The diurnal blood glucose levels were determined at 8:30 AM, 10:30 AM, 12:30 PM, 2:30 PM, and 4:30 PM under routine dietary

Table 1

Relationship of physical activity and the classical 3-hr glucose tolerance test in paired subjects, November 1973 (n=66)[a]

	No-exercise group	Exercise group	Significance of the differences of the means	variances
Fasting	80 ±10	78 ±7	t = 0.926, P >0.200	t=0.498, $P<0.050$[b]
1 hr	130 ±40	122 ±32	t = 0.857, P >0.200	t=0.661, P>0.100
2 hr	95 ±27	89 ±23	t = 0.970, P >0.200	t=0.708, P>0.100
3 hr	71 ±16	73 ±15	t = 0.547, P >0.500	t=0.853, P>0.250

[a] CMI Question 141: Do you find it impossible to take regular daily exercise?
[b] Statistically significant difference of the variance.

Table 2
Relationship of physical activity and diurnal blood glucose in paired subjects, December 1973 (n=538)[a]

Time	No-exercise group	Exercise group	Significance of the differences of the means	Significance of the differences of the variances
8:30 AM	98 ±30	95 ±21	t = 1.143, P >0.100	t = 0.469, P <0.0005[b]
10:30 AM	98 ±25	95 ±14	t = 1.731, P >0.050	t = 0.321, P <0.0005[b]
12:30 PM	103 ±30	100 ±19	t = 0.881, P >0.200	t = 0.386, P <0.0005[b]
2:30 PM	105 ±30	102 ±19	t = 1.146, P >0.200	t = 0.412, P <0.0005[b]
4:30 PM	102 ±33	101 ±21	t = 0.402, P >0.500	t = 0.415, P <0.0005[b]

[a] CMI Question 141: Do you find it impossible to take regular daily exercise?
[b] Statistically significant difference of the variance.

conditions. Three points are clear. First, there are no statistically significant differences of the means at any of the temporal points. Second, the variance is greater in the no-exercise group vs the exercise group at every temporal point. Finally, there are statistically significant differences of the variance at every temporal point. This is seen in *Table 2.*

Discussion

Many years ago, Claude Bernard pointed out that life and death are functions of homeostasis, the steady state. Since then, he and others have shown that the internal chemical state of the body is indeed steady. Good health is characterized by only small variations, but disease is represented by wide fluctuations in body functions or in its internal molecular environment.

A graph of the concept of homeostasis is shown in *Figure 1.* For example, in a healthy subject the temperature varies minimally during the day, but in the sick person it may fluctuate widely. In the healthy person, the psychic state varies only slightly (from minimal elation to marginal depression); in the sick, it may vary in abrupt manic-depressive cycles. The patterns for blood pressure, peristalsis, and other clinical and biochemical signs vary in similar fashion.

Figure 2 represents an extension of Figure 1 over a period of years. In the very early stages of chronic disease, the amplitudes increase. With the passage of time, the large undulations become smaller and slowly rise toward a plateau, e.g., the course of hyperglycemia in diabetes mellitus and of hypertension in heart disease.

On this basis, it follows that relatively young persons usually show relatively small variations in clinical and biochemical signs. With advancing age, the fluctuations increase, and the base levels slowly rise, as indicated in *Figure 3.*

Figure 4 pictorially portrays the data earlier provided in Table 1. It is clear that the spread of values is greater in the no-exercise group. Thus, there is a greater incidence of both lower and higher glucose levels in this group. In other words, there is less homeostasis in the no-exercise group as judged from the classical glucose tolerance test.

Figure 5 graphically depicts the data earlier shown in Table 2 derived from diurnal blood glucose patterns. Here the evidence is even more sharply defined showing a greater incidence of both hyperglycemia and hypoglycemia in the no-exercise group.

Thus, exercise may be viewed as a resistance agent. When it is employed, disease is discouraged; when it is insufficient, homeostasis is disrupted and disease is encouraged.

A breakdown in glucose homeostasis results in an impaired tolerance to dietary sugars and an en-

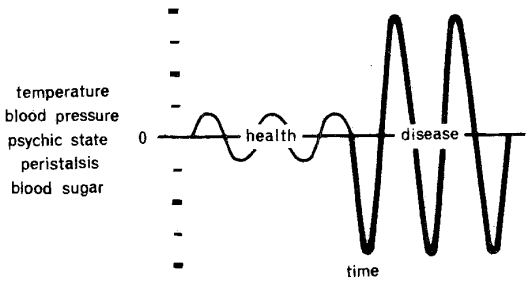


Figure 1 *In health, factors such as temperature, blood pressure, psychic state, peristalsis, or blood sugar concentration can be represented by small daily fluctuations. In disease, the amplitudes are much greater.*

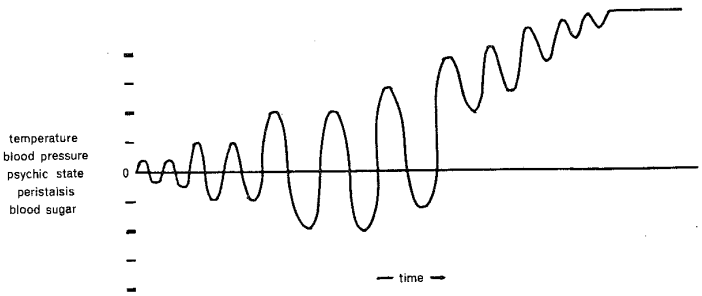


Figure 2 *This is an extension of Figure 1 over a period of years. In the early stages of chronic disease, the amplitudes increase. With additional time, the broad undulations become more narrow and the baseline slowly rises (or declines) to a plateau.*

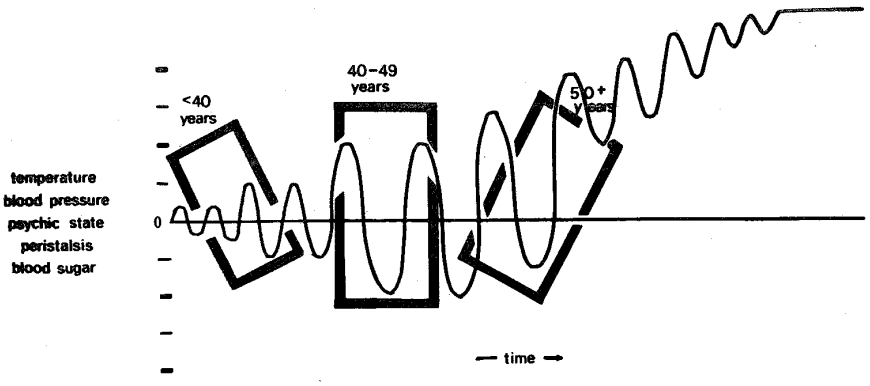
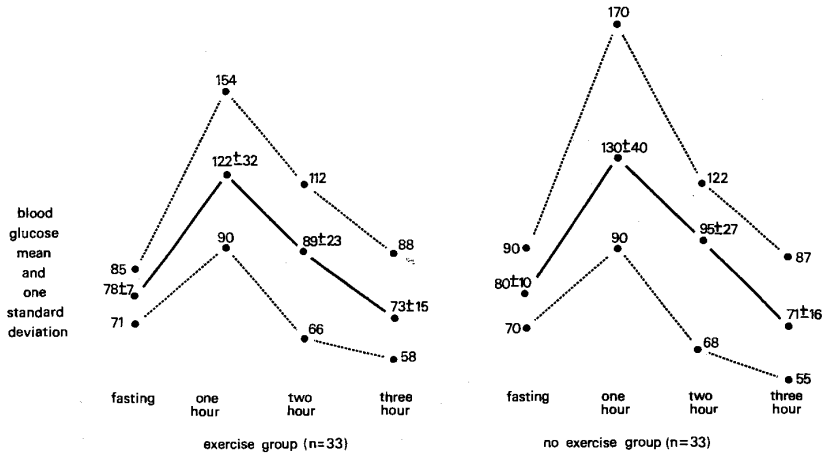


Figure 3 *This is a supplement to Figure 2 showing that, with aging, the amplitudes of fluctuation become larger and the mean scores slowly rise (or fall).*

hanced proneness to a variety of chronic disease symptoms and signs. This is not just a feature of diabetes mellitus and its precursor, hypoglycemia. For example, impaired glucose tolerance has been demonstrated in a host of other clinical conditions[1,2-1,6]: addiction, aging, alcoholism, arteriosclerosis and atherosclerosis, cancer, congenital malformations and anomalies, coronary heart disease, dizziness, dry and burning mouth, exhaustion-fatigue syndrome, eye disorders, gout, headache, hyperlipemias, hypertension, hyperthyroidism, infectious disorders, insomnia, liver disease, multiple sclerosis, obesity, osteoporosis, peptic ulcer, periodontal disease, pregnancy, psychologic disorders (neuroses and psychoses), pulmonary emphysema, renal failure, skin disorders, sterility, suppression of ovulation with oral contraceptives, and tic douloureux. In brief, the evidence suggests that every tissue, organ, and system which has been studied can be implicated.

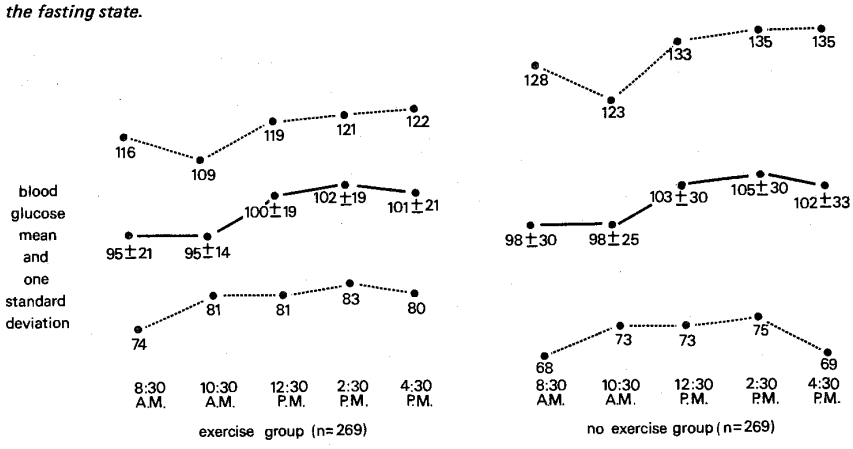
References

1. BERGSTROM, J. and HULTMAN, E., "Nutrition for maximal sports performance," *J.A.M.A. 221,* 999-1006, (1972).
2. BERGSTROM, J. and HULTMAN, E., "A study of the glycogen metabolism during exercise in man," *Scand. J. Clin. Lab. Invest.* 19, suppl. 94, 218-228 (1967).
3. GREEN, L. F. and THOMAS, V., "Some effects of glucose syrup ingestion during vigorous exercises of differing intensities and duration," *Proc. Nutr. Soc. 31,* 5A-6A (1972).
4. KLACHKO, D. M., LIE, T. H., CUNNINGHAM, E. J., CHASE, G. R.,



October 1973

Figure 4 *The classical 3-hr oral glucose tolerance pattern in paired subjects who perform daily exercise vs no daily exercise. The range of values is generally greater in the no-exercise group. Additionally, the spread of values is significantly greater in the no-exercise group in the fasting state.*



January 1974

Figure 5 *The diurnal glucose pattern in paired subjects who perform daily exercise vs no daily exercise. The range of values is clearly greater in the no-exercise group. Additionally, the spread of values is significantly greater in the no-exercise group at every temporal point.*

and BURNS, T. W., "Blood glucose levels during walking in normal and diabetic subjects," *Diabetes 21,* 89-100 (1972).

5. LIPMAN, R. L., RASKIN, P., LOVE, T., TRIEBWASSER, J., LECOCQ, F. R., and SCHNURE, J. J., "Glucose intolerance during decreased physical activity in man," *Diabetes 21,* 101-107 (1972).
6. MOLNAR, G. D., ACKERMAN, E., ROSEVEAR, J. W., GATEWOOD, L. C., and MOXNESS, K. E., "Continuous blood glucose analysis in ambulatory fed subjects. I: General methodology," *Mayo Clin. Proc. 43,* 833-851 (1968).
7. NIKKILA, B. A., TASKINEN, M. R., MIETTINEN, R. A., PELKONEN, R., and POPPINS, H., "Effect of muscular exercise on insulin secretion," *Diabetes 17,* 209-218 (1968).
8. PRUETT, E. D. R., "Glucose and insulin during prolonged work stress in men living on different diets," *J. Appl. Physiol. 28,* 199-208 (1970).
9. PRUETT, E. D. R. and OSEID, S., "Effect of exercise on glucose and insulin response to glucose infusion," *Scand. J. Clin. Lab. Invest. 26,* 277-285 (1970).
10. REICHARD, G. A., ISSEKUTZ, B., JR., KIMBEL, P., PUTNAM, R. C., HOCHELLA, N. J., and WEINHOUSE, S., "Blood glucose metabolism in man during muscular work," *J. Appl. Physiol. 16,* 1001-1005 (1961).
11. WAHREN, J., FELIG, P., AHLBORG, G., and JORFELDT, L., "Glucose metabolism during leg exercise in man," *J. Clin. Invest. 50,* 2715-2725 (1971).
12. CHERASKIN, E., RINGSDORF, W. M., JR., and CLARK, J. W., *Diet and Disease* (Rodale Books, Emmaus, Pa., 1968).
13. CLARK, J. W., CHERASKIN, E., and RINGSDORF, W. M., JR., *Diet and the Periodontal Patient* (Charles C. Thomas, Springfield, Ill., 1970).
14. CHERASKIN, E. and RINGSDORF, W. M., JR., *New Hope for Incurable Diseases* (Exposition Press, Inc., Jericho, N.Y., 1971).
15. CHERASKIN, E., RINGSDORF, W. M., JR., and BRECHER, A., *Psychodietetics: Food as the Key to Emotional Health* (Stein and Day, Briarcliff Manor, N.Y., 1974).
16. CHERASKIN, E. and RINGSDORF, W. M., JR., "Diabetic dilemma in dentistry," *Acta Diabetolog. Lat. 8,* 228-277 (1971).