High-carbohydrate diet for long distance runners—a practical view-point

M. Fogelholm, MSc(Nutr)¹, H. Tikkanen, MD², H. Näveri, MD, PhD³ and Professor M. Härkönen, MD, PhD²

¹Department of Nutrition, University of Helsinki, Viikki, SF-00710 Helsinki, Finland

²Department of Clinical Chemistry, University of Helsinki, Haartmaninkatu 4, SF-00250 Helsinki, Finland

³First Department of Medicine, University of Helsinki, Haartmaninkatu 4, SF-00250 Helsinki, Finland

The nutritional value of a high-carbohydrate diet was evaluated. Seven male marathon runners kept a food record diary for the three days preceeding two endurance races. They were instructed in how to compose a diet which contained about 9 g carbohydrate day⁻¹ kg body weight⁻¹. Sixty three per cent of the subjects' total energy intake was derived from carbohydrates. The dietary intake of vitamin C was six times the Recommended Daily Dietary Allowances (RDA). Intakes of thiamin, riboflavin, calcium, magnesium and iron were more than twofold, and niacin intake 1.4-fold compared to the allowances. The diet contained sufficient amounts of carbohydrate to refill and enlarge muscle glycogen stores. Moreover the nutritional value was high, and therefore this kind of a diet can be recommended to endurance athletes even on a daily basis.

Keywords: Endurance athletes, diet, carbohydrates, vitamins, minerals

Introduction

The time of onset of exhaustion during strenuous prolonged exercise is positively correlated with pre-exercise muscle glycogen concentration¹. Muscle glycogen stores can be enlarged by first depleting the stores and then reloading them by eating a high-carbohydrate diet and taking only light exercise. This procedure is called carbohydrate loading. Moreover, it seems that athletes may need a high-carbohydrate diet on a daily basis to ensure rapid recovery and glycogen resynthesis after long and intense training bouts².

Though the importance of dietary carbohydrates is well accepted, the glycogen loading procedure has also been criticized³. In addition, a high-carbohydrate diet may be deficient in some B-complex vitamins⁴, and thus not optimal as a day-to-day diet for an endurance athlete.

In this study we evaluated the nutritional value of a high-carbohydrate diet which was designed to contain enough carbohydrates for carbohydrate loading, as well as for rapid recovery from daily training.

Subjects and methods

Seven male marathon runners gave their oral consent. Their mean age was 31 years (range 24–39), height

1.78 m (1.75–1.82), and weight 65 kg (60–71). They run 100–160 km week. The subjects recorded their total food and fluid intake on the three days preceeding two endurance races. Thus, each subject recorded a total of six days. The subjects were given written instructions of the procedure, and a postal scale for weighing portions.

The subjects were instructed on how to choose food and drink in order to compose a high-carbohydrate diet which contained about 9 g carbohydrate kg body weight. The main food items used in the diet were whole grain bread, orange juice, hot or cold cereals (porridge, corn-flakes, etc.), fruit yoghurt, milk, bananas, and apples. The instructions were not strict, and the subjects could choose more or less according to their own preferences. The daily energy intake and consumption of meat and fish was not restricted, but the subjects were asked to avoid visible fat.

The nutrient content of the diet was calculated by a computer method of the Department of Nutrition, University of Helsinki⁵. The daily intakes were compared to the Recommended Daily Dietary Allowances (RDA) from 1980. All results are expressed as mean $\pm$ SEM. Statistical analysis was performed by Wilcoxon's Signed Ranks test⁶.

Results and discussion

The energy consumption was 15.2 ± 0.8 MJ day⁻¹ (3620 ± 200 kcal day⁻¹). The carbohydrate intake was 599 ± 29 g day⁻¹, or correspondingly 63 per cent of the total daily energy intake. The range of six subjects was 545–786 g day⁻¹, but the remaining subject consumed on average only 388 g day⁻¹. According to Costill⁷ the rate of glycogen storage reaches a plateau when 500 g carbohydrates per day is consumed. This border may be an arbitrary due to the differing muscle masses among athletes, but it seems appropriate to conclude that the diet in our study was sufficient to ensure a rapid glycogen resynthesis in all but one of the subjects. Cereals, fruits, and orange juice were the main sources of carbohydrates for our subjects. Cereals especially contain a lot of complex carbohydrates which might make glycogen resynthesis more effective than mono- or disaccharides⁸.

The subjects' energy intake was higher during the second carbohydrate loading procedure (14.6 ± 0.8 vs.

Table 1. Energy and carbohydrate intake, training, and body weight of seven male marathon runners during two carbohydrate loading procedures. (Results are expressed as mean $\pm$ SEM)

	1st procedure		2nd procedure
Energy intake (MJ day ⁻¹)	14.6 $\pm$ 0.8	$p < 0.05^*$	15.7 $\pm$ 0.8
(kcal day ⁻¹)	3490 $\pm$ 180		3750 $\pm$ 200
Carbohydrate intake (g day ⁻¹)	590 $\pm$ 38	NS	609 $\pm$ 46
Training min day ^{-1**}	43 $\pm$ 9	NS	50 $\pm$ 3**
Body weight (kg)			
— before depletion	65 $\pm$ 2	NS	65 $\pm$ 2
— before loading	64 $\pm$ 2	NS	64 $\pm$ 2
— after loading	65 $\pm$ 2	NS	65 $\pm$ 2

*The significance of difference between the first and second procedure. NS = non-significant, i.e. $p > 0.05$.

**Moderate or easy running, pace approximately 7 min/mile, corresponding to an energy consumption of approximately 60 KJ/min or 15 kcal/min (McArdle et al. 1986)

15.7 $\pm$ 0.8 MJ day⁻¹, $p < 0.05$) (Table 1). However, there were no significant differences in the intake of carbohydrates. In spite of an apparently positive energy balance, the subjects' body weight changed only slightly.

The daily protein intake was 111 $\pm$ 7 g, which means a share of 12 per cent of the daily total energy intake. The proportion of protein was higher (about 14 per cent) in the diet of 20–39 year old Finnish men⁹. The protein intake in the diet was 1.7 $\pm$ 0.1 g kg⁻¹ body weight, which is at least adequate to meet all the demands of endurance athletes¹⁰. The fat content of the diet was low (100+14 g day⁻¹ or 24 per cent of the total energy intake).

The intake of the B-complex vitamins thiamin and riboflavin was more than twice the allowances (Figure 1). In addition, the intake of niacin was clearly sufficient. These vitamins are needed in energy meta-

Figure 1. Intake of thiamin, riboflavin, niacin, and vitamin-C from a high-carbohydrate diet consumed by seven endurance runners. Results are expressed by vertical bars comparing the intake to Recommended Daily Dietary Allowances of 1980, and numerically as mean $\pm$ SEM. **Figure 2.** Intake of calcium, magnesium, and iron from a high-carbohydrate diet consumed by seven endurance runners. Results are expressed by vertical bars comparing the intake to Recommended Daily Dietary Allowances of 1980, and numerically as mean $\pm$ SEM.

bolism, mainly in the glycolytic pathway as coenzymes or as structural parts of coenzymes^{10,11}. A body vitamin concentration high enough to ensure maximal activity of enzymes needed in energy metabolism has been shown to be necessary for maximal working capacity^{11,12}. Even if the requirements of some B-complex vitamins would increase in proportion to an increase in carbohydrate intake, the diet in our study would be sufficient.

The choice of cereal products affects the intake of most B-complex vitamins: the nutritional value of white bread is much lower compared to whole grain or brown bread. The intake of niacin can be raised to twice the RDA by consuming an extra serving of meat or fish daily, and reducing at the same time the consumption of food other than cereals. Even so the mean intake of carbohydrates would be close to 500 g day⁻¹.

The intake of vitamin C was very high due to the great consumption of orange juice and fruits (Figure 1). The mineral intake was high as well (Figure 2). The main dietary sources of calcium were milk, yoghurt, and cheese, and for iron wholegrain bread and cereals.

Conclusion

This study has shown that a diet containing carbohydrates sufficient to enlarge and refill muscle glycogen stores could effectively be obtained using ordinary foodstuffs (Table 2). The diet on the whole is close to Scandinavian recommendations. We believe that by allowing a slightly higher fat intake (28–30 per cent of total energy intake) and correspondingly lower carbohydrate intake (58–60 per cent), this diet could be tolerated even on a long-term basis. The nutritional quality of the diet was very high, due to the inclusion of whole grain cereals. Thus, a diet containing approximately 500 g of carbohydrates day⁻¹ can be recommended for endurance athletes, even on a daily basis.

Table 2. Suggested base for a high-carbohydrate diet (approximately 400 g carbohydrates, 45 g protein and 10 g fat)

Food/Fluid	Quantity
Orange juice	1 litre
Skimmed milk	0.2 litre
Whole corn bread	10 slices
Cereals or müsli	1 serving (50 g)
Bananas	3
Apples	2
Potatoes or pasta	1 serving (200 g)

Acknowledgement

This study was supported by a grant from the Finnish Olympic Committee.

References

- 1 Saltin, B., Hermansen, L. 'Glycogen stores and prolonged severe exercise' In: Symposia of the Swedish Nutrition Foundation V: Nutrition and Physical Activity 32–46. Ed. G. Blix. Almquist and Wiksell, Stockholm, 1967
- 2 Costill, D.L., Flynn, M.G., Kirwan, J.P., Houmard, J.A., Mitchell, J.B., Thomas, R. and Park, S.H. Effects of repeated days of intensified training on muscle glycogen and swimming performance *Med Sci Sports Exerc* 1988, **20**, 249–254
- 3 Sharman, I.M. Glycogen loading: advantages but possible disadvantages *Br J Sports Med* 1981, **15**, 64–67
- 4 Jette, M., Pelletier, O., Parker, L. and Thoden, J. The nutritional and metabolic effects of a carbohydrate rich diet in a glycogen supercompensation training regimen *Am J Clin Nutr* 1978, **31**, 2140–2148
- 5 Ahlström, A., Räsänen, L. and Kuvaja, K. A method of data processing for food consumption surveys *Ann Acad Sci Fenn A IV* 1972, **194**, 1–8
- 6 Langley, R.L. 'Practical Statistics' 2nd ed, 179–182. Pan Books, London, 1979
- 7 Sherman, U.M. and Costill, D.L. (1984) *Author please supply details for this reference*
- 8 Costill, D.L., Sherman, W.M., Fink, W.J., Maresh, C., Witten, M. and Miller, J.M. The role of dietary carbohydrates in muscle glycogen resynthesis after strenuous running *Am J Clin Nutr* 1981, **34**, 1831–1836
- 9 Uusitalo, U., Pietinen, P. and Leino, U. Food and nutrient intake among adults in East and Southwest Finland—a dietary survey of the Finnmonica Project in 1982 Publications of the National Public Health Institute B1/1987
- 10 Haymes, E.M. 'Proteins, vitamins, and iron' In: *Ergogenic Aids in Sport* 27–55. Ed. M.H. Williams, Human Kinetic Publishers, Champaign, 1983
- 11 Beek, E.J. van, Dokkum, W. van, Schriver, J., Wesstra, J.A., Weerd, H. van der and Hermus, R.J.J. Effect of marginal vitamin intake on physical performance of man *Int J Sports Med* 1984, **5**, 28–31
- 12 Buzina, R., Grzic, Z., Jusic, M., Sapunar, J., Milanovic, N. and Brubacher, G. Nutritional status and physical working capacity *Hum Nutr Clin Nutr* 1982, **36C**, 429–238