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

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The nutritional value of a high-carbohydrate diet was
evaluated. Seven male marathon runners kept a food record
diary for the three days preceding two endurance races.
They were instructed in how to compose a diet which con-
tained 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 Allow-
ances (RDA). Intakes of thiamin, riboflavin, calcium, mag-
nesium an diron 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 diet can be recommended
to endurance athletes even on a daily basis.

Keywords: Endurance athletes, diet, carbohydrates, vita-
mins, minerals

Introduction

The time of onset of exhaustion during strenuous pro-
longed exercise is positively correlated with pre-exer-
cise 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 criticized1. In addition, a high-carbohydrate
diet may be deficient in some B-complex vitamins2,
and thus not optimal as a day-to-day diet for an endur-
ance 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 preceed-
ing 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, ban-
as, 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 com-
pared to the Recommended Daily Dietary Allowances
(RDA) from 1980. All results are expressed as mean
±SEM. Statistical analysis was performed by Wilco-
son’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 con-
sumed on average only 388 g day−1. According to
Costill2 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. Cere-
als especially contain a lot of complex carbohydrates
which might make glycogen resynthesis more effec-
tive than mono- or disaccharides8.

The subjects’ energy intake was higher during the
second carbohydrate loading procedure (14.6±0.8 vs.
15.7±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±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 men⁷. The protein intake in the diet was 1.7±0.1 g kg⁻¹ body weight, which is at least adequate to meet all the demands of endurance athletes⁵⁰. 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 metabolism, mainly in the glycolytic pathway as coenzymes or as structural parts of coenzymes⁶⁰,⁶¹. 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 capacity¹¹,¹². 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.

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 ±SEM)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>1st procedure</th>
<th>2nd procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake (MJ day⁻¹)</td>
<td>14±0.8</td>
<td>15.7±0.8</td>
</tr>
<tr>
<td>(kcal day⁻¹)</td>
<td>3490±180</td>
<td>3750±200</td>
</tr>
<tr>
<td>Carbohydrate intake (g day⁻¹)</td>
<td>590±38</td>
<td>609±46</td>
</tr>
<tr>
<td>Training min day⁻¹**</td>
<td>43±9</td>
<td>50±3**</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>65±2</td>
<td>65±2</td>
</tr>
<tr>
<td>— before depletion</td>
<td>64±2</td>
<td>64±2</td>
</tr>
<tr>
<td>— before loading</td>
<td>65±2</td>
<td>65±2</td>
</tr>
</tbody>
</table>

*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)

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 ±SEM.

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 ±SEM.

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)

<table>
<thead>
<tr>
<th>Food/Fluid</th>
<th>Quantity</th>
</tr>
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<tbody>
<tr>
<td>Orange juice</td>
<td>1 litre</td>
</tr>
<tr>
<td>Skimmed milk</td>
<td>0.2 litre</td>
</tr>
<tr>
<td>Whole corn bread</td>
<td>10 slices</td>
</tr>
<tr>
<td>Cereals or müsli</td>
<td>1 serving (50 g)</td>
</tr>
<tr>
<td>Bananas</td>
<td>3</td>
</tr>
<tr>
<td>Apples</td>
<td>2</td>
</tr>
<tr>
<td>Potatoes or pasta</td>
<td>1 serving (200 g)</td>
</tr>
</tbody>
</table>

Acknowledgement
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References