EFFECTS OF DIFFERENT PRE-EVENT MEALS ON PERFORMANCE IN CYCLISTS

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Summary

Consuming carbohydrates too closely before participation in strenuous prolonged events is not generally recommended because some carbohydrates may cause large rises in blood insulin. This is not desirable before competition as the insulin can inhibit the release of free fatty acids, which contribute to the fuel during the event. However, different forms of carbohydrates are digested at different rates, providing varying rates of release of glucose into the blood, without necessarily stimulating insulin secretion (Crapo et al. 1976; Jenkins et al. 1981). We hypothesised that low glycemic index (GI) foods may be advantageous when eaten before prolonged strenuous exercise by providing a slow-release source of glucose to the blood without an accompanying insulin surge. Results suggest that a low GI pre-game meal may prolong endurance by inducing less post-prandial hyperglycemia and hyperinsulinemia, lower levels of plasma lactate before and during exercise, and by maintaining plasma glucose and free fatty acids at higher levels during critical periods of exercise.

I. INTRODUCTION

Our interest is in studying biochemical and physiological exercise responses in trained athletes after consumption of either a low or high glycemic index food. We hypothesized that a low glycemic index food may be an advantage when eaten before prolonged strenuous exercise by providing a slowly releasing source of blood glucose without an accompanying insulin surge (Thomas et al. 1988).

Foods such as legumes and pasta give a slow, sustained release of glucose to the blood (low glycemic index) with no sudden accompanying insulin surge, while foods such as potato, bread and many breakfast cereals give glycemic and insulin responses nearly as high as an equivalent amount of glucose (high glycemic index) (Jenkins et al. 1981).

The consumption of glucose in the hour before prolonged, strenuous exercise has been demonstrated as being disadvantageous, although there is conflicting evidence. Some studies have found increased use of muscle glycogen (Costill et al. 1977; Hargraves et al. 1985), a rapid rise in plasma insulin and shorter endurance times (Foster et al. 1979), when glucose is administered 15 to 60 minutes before exercise. However, other studies have found longer endurance times when glucose is given in the last few minutes before exercise (Lamb and Brodowicz 1986). Hence the position of glucose as a pre-exercise food is not clear and may be related to the timing before exercise or the form in which the glucose is administered.

Ingestion of staggered doses of glucose or glucose polymers during prolonged strenuous exercise has been shown to improve endurance. The longer times to exhaustion have been associated with higher concentrations of blood glucose and higher rates of carbohydrate oxidation towards the end of exercise (Coyle et al. 1986; Ivy et al. 1983; Lamb and Brodowicz 1986). Hence it is possible that a low glycemic index food which releases glucose slowly from the gut into the bloodstream may provide the same advantages as glucose given intermittently during exercise.

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II. EXPERIMENTAL METHODS

In a recent experiment (Thomas et al. 1991), we fed eight trained, fasted male cyclists equal carbohydrate portions of one of four test foods: lentils (low GI), potato (high GI), glucose, or water. The subjects were unaware of the hypothesis or of differences in GI between the foods. Prior to commencing the experimental trials, the volunteers underwent a maximal exercise test and a familiarisation trial.

One hour after ingestion, of the food, they pedalled to exhaustion on a cycle ergometer at 65-70 %VO_2max. Expired air samples were collected every 15 min and analysed for oxygen and carbon dioxide. Blood samples were taken at 15 min intervals throughout the experiment and analysed for plasma glucose, insulin, lactate and free fatty acids (FFA). Dehydration was minimised by encouraging the subject to drink 120 ml water after each blood sampling. The data from the four trials were compared using two way analysis of variance for repeated measures and Fisher's least significant differences ($P<0.05$). The Wilcoxon signed-rank test was used to assess statistical differences in plasma FFA levels and RER values.

III. RESULTS

Endurance time was 20 min longer after low GI than after high GI ($P<0.05$). The plasma glucose and insulin levels were lower after low GI than after high GI from 30 to 60 min after ingestion ($P<0.05$). Plasma free fatty acid levels were highest after water ($P<0.05$) followed by low GI and then glucose and high GI. From 45 to 60 min after ingestion, plasma lactate was higher in the high GI trial than in the low GI trial ($P<0.05$) and remained higher throughout the period of exercise. The rank order from lowest to highest for total carbohydrate oxidation during exercise was water, lentils, glucose and potato. There was no significant difference between the CHO trials in mean heart rates or %$V0_2$max.

(a) Plasma glucose

After potato and glucose ingestion, plasma glucose levels rose rapidly reaching a peak at 30-45 min (8.5 ± 0.4 and 8.3 ± 0.6 mmol/L respectively) followed by a sharp decline 15 min into exercise (4.6 ± 0.4 and 4.3 ± 0.4 mmol/L respectively). After lentils ingestion, plasma glucose rose and fell more gradually. At 135 min (75 min exercise), lentils and potato gave higher values than water and glucose (5.8 ± 0.5 and 5.9 ± 0.5 mmol/L v. 4.8 ± 0.3 and 4.8 ± 0.4 mmol/L respectively, $P<0.05$). At 150 min (90 min exercise), plasma glucose levels for water and oral glucose had decreased (4.7 ± 0.3 and 4.3 ± 0.2 mmol/L), while the concentration in the lentils and potato trials was still being maintained (5.5 ± 0.6 and 5.2 ± 0.2 mmol/L).

(b) Insulin

After potato and glucose, plasma insulin levels rose rapidly, reaching a peak at 45 min (57.6 ± 18.3 and 53.1 ± 9.3 mIU/L respectively). After lentils, there was a smaller rise in plasma insulin (32.0 ± 6.4 mIU/L) which plateaued at levels half those reached in the glucose and potato trials.

(c) Plasma free fatty acids

During exercise, the plasma FFA concentration in the lentils trial was higher than in the potato or glucose trials (Wilcoxon $P<0.05$). The levels of plasma FFA in the potato trial were not different to those in the glucose trial. Plasma FFA levels after water remained higher than after the other test foods ($P<0.05$) at all time points except at 75 min.

(d) Plasma lactate

Plasma lactate levels tended to be higher after glucose and potato ingestion both before and during exercise, than after lentils or water ingestion. From 45 to 60 min after ingestion of potato and glucose, plasma lactate levels had risen significantly higher than after lentils or water ingestion ($P<0.05$). Hence exercise in the potato and glucose trials commenced with higher levels of plasma lactate (2.1 ± 0.4 and 2.0 ± 0.3 mmol/L respectively) than in the lentils or water trials (1.2 ± 0.1 and 1.4 ± 0.2 mmol/L respectively, $P<0.05$). Throughout the period of cycling, plasma lactate levels were higher in the potato trial than in the lentils trial ($P<0.05$ at 15 min and 45 min of exercise).

(e) Endurance

Endurance time in the lentils trial (117 ± 11 min) was significantly longer than in the potato (97 ± 11 min, $p<0.05$), glucose (108 ± 10 min) and water (100 ± 11 min) trials. The glucose, potato and water trials were not significantly different from each other.

(f) RER and carbohydrate oxidation

The respiratory exchange ratios (RER) increased at the beginning of exercise and then gradually decreased. The rank order of the foods remained the same throughout, with the potato and glucose trials producing the highest RER values, followed by lentils and then water. The same rank order was apparent in the RER values 15 min before exercise commenced. The differences between potato and glucose were not statistically different but both were different to the other foods. CHO oxidation during exercise (60-150 min) was highest in the glucose (191.9 ± 8.4 g CHO) and potato (183.4 ± 13.1 g) trials, followed by the lentils trial (176.6 ± 6.7 g) and then water (166.5 ± 9.7 g). CHO oxidation in both the lentils and water trials during the first 90 min of exercise was significantly lower than in the glucose trial.

IV. DISCUSSION

Our experimental data has provided support for the hypothesis that a low glycemic index food may contribute an advantage when eaten before prolonged strenuous exercise by providing a slow release source of glucose to the blood without an accompanying insulin surge. The low GI meal of lentils prolonged endurance at 67% VO_2max by 20 minutes compared to the high GI meal of potato. Lentils produced less hyperglycemia and less hyperinsulinemia before exercise but maintained plasma glucose and resulted in higher levels of FFA levels during exercise. Relative to potato, the lentils meal was also associated with lower levels of plasma lactate both before and during exercise. The average RER value during the first 90 min of exercise was lower in the low GI trial than in the high GI potato and glucose trials, indicating that less glucose was being oxidised. Since muscle glycogen is the preferred CHO fuel at the onset of exercise, this suggests that glycogen stores were being depleted at a slower rate after consumption of a low GI food (Bergstrom and Hultman 1967; Hickson et al. 1977). If less CHO is being used at the onset of exercise and there is greater reliance on FFA, muscle glycogen may be conserved.

At no timepoint was the potato trial significantly different to the glucose trial with respect to plasma glucose, insulin, FFA and lactate, RER values or CHO oxidation levels. Hence a high GI starchy food such as potato produced similar metabolic effects to a glucose solution.

(a) Gastric emptying

Faster gastric emptying partially contributes to the higher glycemic response after potato than that after legumes, since gastric emptying has been shown to be faster after potato (Mitchell et al. 1988). However the rate of digestion of the starch in the small intestine, which is slower after legumes than after potato, is a far more important factor in the glycemic response (Crapo et al. 1976; Jansson and Kaijser 1982).

(b) Muscle glycogen stores

The subjects followed a standard food and exercise regimen prior to each experiment so as to commence with similar glycogen stores, since the level of muscle glycogen stored in the active muscles is a major factor in determining sub-maximal times to exhaustion (Bergstrom and Hultman 1967). As the volunteers continued to train during this period, their initial glycogen levels were not maximal and their times to exhaustion are not comparable to those possible had they rested or CHO loaded on the days prior to the trials.

(c) Hepatic glycogen

It has been shown that infusion of glucose during exercise can inhibit the release of hepatic glycogen and that exercise-induced hepatic glucose output is precisely sensitive to the rate of systemic glucose supply (Felig and Wahren 1979, Jenkins et al. 1985). Thus a low GI food, by maintaining plasma glucose concentrations, may help to conserve hepatic glycogen stores.

(d) Blood lactate

The results show that blood lactate levels during exercise may be influenced by the glycemic index of the pre-game carbohydrate food. The high GI foods caused an increase in the plasma concentration of lactate, presumably a result of increased glycolysis in tissues such as muscle. The observation that plasma lactate levels in the potato and glucose trials were already elevated in the 15 min prior to exercise suggests that glycolysis had already increased significantly even before the onset of exercise, stimulated by the surge in plasma glucose and insulin. Whereas other investigators have found that a pre-exercise diet high in CHO for five days increases plasma lactate levels during prolonged submaximal exercise (Ivy et al. 1983), our study has shown that the GI of a single pre-game meal may cause variation in plasma lactate.

(e) Plasma glucose and insulin

High plasma glucose and insulin responses following the consumption of glucose within 45 min before exercise have been associated with reduced endurance (Felig and Wahren 1979). The raised levels of insulin enhance glucose uptake into muscle and fat cells, and stimulate the activity of phosphofructokinase, a regulatory enzyme in glycolysis. Hence, in the potato and glucose trials, increased cellular glycolysis may already be well-established by the time exercise commences - explaining the significantly larger plasma lactate production from 45-60 min. Glycogen utilisation is greater during exercise after ingestion of glucose than after water (Costill et al. 1977). Since the potato trial gave similar metabolic responses to the glucose trial in our study, it seems reasonable to conclude that muscle glycogen usage would have been similarly increased.

(f) Free fatty acids

The minimal insulin response to lentils was associated with a significantly higher concentration of FFA during the first 60 min of exercise compared to the potato or glucose trials. FFA can be employed as energy substrates in direct proportion to their concentration in blood (Havel et al. 1967), and an increase in plasma FFA levels has been shown to result in a slower rate of muscle glycogen use during exercise in humans (Costill et al. 1977) and in rats (Hickson et al. 1977). Plasma FFA were lower in the potato and glucose trials and this may have increased the reliance on muscle glycogen. In the water and lentils trials, the higher concentration of plasma FFA may have spared CHO stores, with the lentils having the additional advantage of providing higher levels of plasma glucose.

(g) RER and CHO oxidation

We demonstrated that the GI of a single meal consumed one hour before exercise influences the RER during the following exercise. Hence, a high GI food causes higher rates of CHO oxidation during the first 90 min of exercise than does a low GI food. Since muscle glycogen is the principal source of CHO in the early stages of exercise (Bergstrom and Hultman 1967), this may be the fuel source that was being more rapidly depleted in the two high GI food trials (potato and glucose). This study has found that the GI of the CHO fed in a single pre-game meal caused a difference in CHO oxidation during the ensuing exercise. The RER was lowest during exercise in the water trial, indicating that more FFA were used as fuel from the onset of exercise.

V. CONCLUSION

The results suggest that the low GI meal of lentils ingested one hour before prolonged strenuous exercise, was able to provide an advantage over the high GI meal of potato. The mechanism may be related to the ability of the lentils meal to maintain higher levels of plasma glucose and free fatty acids at critical times during exercise without stimulation of insulin release in the period before exercise. Lentils also induced lower levels of plasma lactate both before and during exercise, and lower RER values and lower total CHO oxidation during the first 90 min of exercise when muscle glycogen is the major CHO fuel (Bergstrom and Hultman 1967). This suggests that a low GI meal is associated with lower levels of glycolysis and greater sparing of glycogen. We are conducting other studies to further clarify the contribution of the glycemic index of the pre-game meal and to rule out the potential bias introduced by the use of 'real' foods.

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