Intestinal absorption at high altitude

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Summary: Three tests of small intestinal function were performed at 3100 m and 4846 m to seek evidence of malabsorption of high altitude. Xylose tolerance did not change in 11 subjects but, in three who ascended to 5600 m, one-hour xylose levels were significantly lower. The results of an oxalate loading test did not suggest significant fat malabsorption. A direct fat absorption test using chylomicron levels after ingestion of 100 g fat showed significantly increased levels at high altitude. We conclude that there is no evidence of malabsorption up to 4846 m.

Introduction

Weight loss at high altitude is well documented. Dietary intake of carbohydrate, protein and fat is often reduced.¹ Daily calorie intake on the Amree expedition showed a 25% reduction at 6300 m, when compared with sea level. However, weight loss did not appear to be explained by reduced dietary intake or increased energy expenditure alone and a further factor might be intestinal malabsorption secondary to hypoxia. There are few studies of gut function at high altitude, although there is some anecdotal evidence to suggest that malabsorption does occur. Xylose absorption was studied during the Amree expedition when it was found that six of seven members showed a significant reduction.

We have performed three tests of intestinal absorption during ascent to high altitude; namely xylose absorption, an oxalate load test and a measurement of chylomicrons after food.

Subjects and methods

Nine to fourteen normal subjects were studied during a walking ascent over 11 days to high altitude.² Subjects had been allocated randomly to placebo or acetazolamide 500 mg/day as indicated in the figures.

Tests of absorption were performed at 3100 m and at 4846 m. These tests consisted of: (i) a one-hour plasma xylose estimation after an oral load. (The lower limit of normal is 0.64 mmol/l.) (ii) Chylomicrons in plasma after ingestion of 100 g fat. (iii) An oxalate loading test over 48 hours measuring oxalate excretion in urine. Oxaluria greater than

0.44 mmol/24 hours correlates with fat malabsorption.³

After an overnight fast, blood was taken for baseline xylose and chylomicron levels. Subjects were given 5 g of xylose dissolved in 150 ml of water, and blood taken at 1 hour for plasma xylose. Subjects then ate one and a half Yorkie Bars (100 g of fat) and blood was taken for chylomicron levels one hour later. Plasma was stored with sodium azide and analysed on return to Birmingham.

The oxalate loading test was performed on the following two days. All subjects were given 600 mg of sodium oxalate daily, taken with meals, for two days. During the second day a 24 hour urine collection was made, the volume noted and a 20 ml aliquot stored with sodium azide. There were no dietary restrictions during the test. All specimens were stored at ambient temperature until assayed in Birmingham 4–6 weeks later. Oxalate concentrations were assayed using a standard kit (Sigma). Where possible, the excretion rates per 24 hours and oxalate:creatinine ratios were obtained.

Chylomicrons were estimated using a nephelometer.⁴ Statistical analyses were performed using paired *t* tests. Not all samples collected arrived intact and therefore sample numbers vary for each test.

Results

Xylose absorption

Fourteen subjects had paired samples suitable for analysis. At 3100 m all plasma levels were within the normal range. At 4846 m all but three subjects had xylose levels within the normal range and unchanged from the levels observed at 3100 m. The three other subjects had markedly reduced 1-hour xylose levels (Figure 1).

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Figure 1 Xylose absorption. Normal range shaded. Open circles – tests performed after ascent to 5600 m.

Figure 2 Chylomicron level. ○—○, Placebo; ●—●, acetazolamide.

Figure 3 Oxalate excretion expressed as mmol/24 hours. ○—○, Placebo; ●—●, acetazolamide.

Fat absorption

Twelve samples were suitable for the chylomicron assay (Figure 2). All but three showed an increased level at the higher altitude ($P < 0.05$). There was a marked rise in four subjects in the acetazolamide group but much smaller changes in all the other subjects.

Only nine pairs of results were available for evaluation of oxalate excretion. This showed marked variation at 3100 m with seven out of nine subjects excreting levels of more than 0.44 mmol/24 hours (Figure 3). Oxalate excretion fell significantly at the higher altitude ($P < 0.05$) where only four out of nine subjects excreted more than 0.44 mmol/24 hours. In only one subject did oxalate excretion rise at 4846 m. In fourteen pairs of samples it was possible to relate oxalate excretion to creatinine excretion (Figure 4). Nine subjects had a rise in oxalate : creatinine ratio at altitude, in four the ratio fell and in one the ratio stayed constant. These differences were not significant.

Discussion

The most sensitive test for determining malabsorption is undoubtedly the presence of steatorrhoea. For practical reasons, it was thought that this method of testing could not be employed during a one month expedition. Alternative tests of small bowel absorptive capacity are not as sensitive or specific. For this

Figure 4 Urine oxalate/creatinine ratio. ○—○, Placebo; ●—●, acetazolamide.

reason, it was decided to utilize three methods which test different aspects of intestinal function.

The 1-hour blood xylose test as originally described has good sensitivity correlating well with the degree of steatorrhoea.⁵ We did not find any abnormal results at 3100 m. The only abnormal results at high altitude were in three subjects at 4846 m. Interestingly, these subjects had ascended to 5600 m the previous day. This may indicate that there is a critical threshold above which significant malabsorption may occur,

and this threshold would appear to be between 4846 m and 5600 m. An alternative explanation is that the xylose absorption test is affected by strenuous physical exertion. However, xylose is an inert non-utilizable sugar not normally found in plasma and it is thought unlikely that this sugar would be metabolized even in severe carbohydrate depletion.

The fat-absorption test using chylomicron assay did not show any evidence of malabsorption at high altitude. Indeed, there was an increase in chylomicrons in all but three of the subjects implying enhanced absorption or decreased clearance. There was a wide variation in results at high altitude but numbers were too small to show statistical significance.

The oxalate excretion test is said to show good correlation with steatorrhoea in a number of malabsorption states³ although the test has been criticized as having poor discriminating ability with large overlap between patients with steatorrhoea and healthy controls.⁶ In our studies, seven of nine subjects had oxalate excretion in the 'abnormal' range at 3100 m. None of these subjects had diarrhoea and it seems unlikely that this 'abnormal' oxalate excretion reflected steatorrhoea at this altitude. This view is further supported by the observation that oxalate excretion fell in all but one subject at the higher altitude. This subject had no other test which indicated malabsorption at 4846 m. Our results do not confirm the observation that urinary oxalate excretion of greater than 0.44 mmol/24 hours are likely to indicate malabsorption; in fact, there appears to be a paradoxical fall in oxalate excretion at altitude.

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