REVIEW ARTICLE

Exercise and the gastro-intestinal tract

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Abstract **Approximately 50% of athletes will develop gastro-intestinal symptoms at some stage in their careers. These range in severity from heartburn to gastro-intestinal bleeding. Fortunately symptoms are usually mild and inconvenient, but in certain individuals they can be incapacitating. It is important to exclude the more common gastro-intestinal conditions before diagnosing exercise-related syndromes. However, once such a diagnosis has been made, therapeutic options are limited.**

The physiological role of the gastro-intestinal tract in fluid and energy replacement is increasingly being recognised. Without adequate replacements, performance may be limited. The volume of fluid ingested during endurance events needs to be limited to actual requirements; 500 ml/h is the average. Greater volume intake may be associated with overhydration and hyponatraemia. Glucose supplementation is essential for adequate performance in events of 2 - 3 hours' duration or longer. Studies of hyperosmolar carbohydrate solutions and their influence on energy and fluid emptying from the stomach suggest that higher carbohydrate concentration solutions than those often used by athletes may be advantageous.

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Anyone who has had the pleasure of partaking in equestrian sports will know the effect of relatively mild exercise on the horse's gastro-intestinal system. In man, cardiovascular and respiratory limitations on performance and the value of cardiovascular training in improving performance in aerobic sports is well recognised. The role of the gastro-intestinal tract, both as a limiting and sustaining factor in aerobic exercises, is less well appreciated.

Gastro-intestinal symptoms

The spectrum of gastro-intestinal effects of exercise is wide (Table I), and ranges from the unlikely observation that swallowing decreases oxygen saturation in patients with chronic obstructive airways disease[1] and, by inference, in exercising athletes, to the more serious rectal bleeding that may be due to ischaemic bowel.[2]

The symptoms experienced by marathon runners are well known,[3] with over 50% of runners at some stage of their careers reporting an urge to defaecate and just under 50% actually passing stools at least once while running (Table II). Abdominal cramps and anorexia are

TABLE I.
Gastro-intestinal effects of exercise

Swallowing
Gastro-oesophageal reflux
Gastric emptying
Gastric acid secretion
Peptic ulcers
Gastro-intestinal blood supply
Intestinal motility
Pancreatic function
Colonic function

almost as common. The apparent high frequency of these symptoms does not necessarily reflect the experience of each runner at each race, as shown in a study where only 1 out of 86 patients actually complained of diarrhoea[2] (Table III). More serious, however, was the discovery of occult blood-positive stool in 13% of the patients in this latter study. This did not appear to be related to the amount of training the runners had undertaken or the duration of their running experience. If blood loss is so common, what is the cause of this dramatic symptom? A number of causes of occult blood in the faeces have been suggested, including traumatic damage caused by shaking of the bowel, a gastritis related to the stress of the exercise, and gut ischaemia. Splanchnic vessel constriction has been shown to occur in runners during intense exercise with visceral blood flow decreasing by 20 - 30% of resting values.[4] This decrease in blood flow appears to be related to exercise intensity and was unrelated to the fitness of the subjects. Although this would explain the positive occult blood tests in experienced as well as inexperienced athletes[2] it is unlikely that splanchnic ischaemia would cause mucosal ulceration and blood loss. The relationship between exercise and splanchnic ischaemia is complicated by the observation that stressed baboons who are exercised experience a greater decrease in splanchnic blood flow than normal baboons do when exercised.[5]

TABLE II.
Overall experience of gastro-intestinal symptoms in 119 marathon runners[3]

Feel need to defecate	54%
Pass stool	44%
Diarrhoea	26%
Anorexia after exercise	41%
Abdominal cramps	42%
Nausea	21%
Heartburn	11%

TABLE III.
History of gastro-intestinal symptoms in 63 marathon runners[2]

	Previous		Current	
	No.	%	No.	%
Macroscopic bleeding	2	3	0	0
Nausea/vomiting	12	20	7	12
Abdominal pain	16	27	3	5
Diarrhoea	25	42	1	2
Other	32	54	10	17

Intestinal blood loss is one of the possible causes of 'runner's anaemia', but haematuria, haemolysis and reduced erythropoiesis analogous to a chronic disorder anaemia have also been implicated.[2]

Reflux symptoms were reported in 11% of marathon runners.[3] This contrasts with the 20% of patients with reflux who report that their symptoms become worse with exercise.[6] The reasons for this are not clear. Delayed gastric emptying associated with high fluid volume intakes and, in the case of cycling, a position designed to potentiate reflux, may all be important factors. The usual advice is to run on an empty stomach and observe routine anti-reflux measures.

Gastric emptying and exercise have been known to be related for many years. In 1833 William Beaumont commented that mild exercise hastened and severe exercise slowed gastric emptying.[7] This essentially summarises our knowledge to date.[8] Exercise does not appear to have a marked effect on gastric secretion. In a study of two groups of athletes who exercised for between 45 minutes and 75 minutes after taking a meal, there was no change in the acid secretion of the athletes compared with the controls.[9] This is in direct contrast to a study on dogs with Pavlovian pouches.[10] In these animals, gastric mucosal blood flow and acid secretion dropped quite markedly during exercise on a treadmill.

Pathological gastric conditions may be produced in animals by forced exercise. In a study where rats were exercised for three 45-minute periods with 15-minute rest periods in between, all of them developed gastric ulcers.[11] The relevance of this to humans is uncertain. There appears to be no data on the incidence of peptic ulceration in exercising athletes.

The effect of marathon running on bowel motility has also been difficult to understand. An initial increase in gastric motility appears to be followed by a reduction as the time and severity of the exercise increase.[8] An increased frequency of defaecation in marathon runners has been attributed to the possible effects of a high-fibre diet.[12] This change in fibre intake was also thought to account for the tendency of exercise to normalise bowel function, bringing those who were constipated or had diarrhoea back towards a normal stool.[13] These changes in bowel function might be due to shaking of the sigmoid colon with more frequent emptying of the bowel, rather than a true decrease in intestinal transit time. This observation has resulted in three patterns of bowel function being recognised: (*i*) an early bowel action when starting exercise; (*ii*) the diarrhoea that some athletes develop as they near exhaustion; and (*iii*) the type of diarrhoea that occurs in athletes who have collapsed.[14]

Pancreatic function has not been studied closely, but it would appear that exercise decreases pancreatic output in response to food and stimulatory hormones.[10] Endocrine pancreatic function is also affected by exercise; insulin secretion decreases in response to a falling blood glucose concentration associated with increased effort. As might be expected, glucagon concentrations conversely increase. Serum gastrin, motilin and vasoactive intestinal polypeptide (VIP) concentrations have also been shown to increase with exercise.[12] The physiological role of these changes is not yet clear.

Finally, there appears to be a correlation between the amount of exercise taken and colonic cancer. In a study comparing sedentary workers with those with active physical employment, it was found that those who had worked at a desk for over 20 years had twice the incidence of colonic cancers compared with physically active workers.[15]

In the management of patients complaining of gastro-intestinal symptoms caused by exercise, it is prudent to remember that conventional diagnoses are more likely to be correct than esoteric conditions associated with exercise. Symptoms of the irritable bowel syndrome often appear during exercise. In fact the physiological changes discussed above may exacerbate an underlying irritable bowel problem. Some unfortunate athletes may be forced to give up their sport because of uncontrollable symptoms during exercise.

Carbohydrate intolerances may account for some of the symptoms athletes experience. A reduced milk intake may bring about a dramatic improvement in some athletes with presumed lactose intolerance. Starch intolerances responsible for the 'splenic syndrome' may respond to reduced carbohydrate intake before exercise, but generally the results of such dietary manipulations are not rewarding.

Physiology

While the practising physician may most often be consulted about pathological symptoms associated with exercise, the gastro-intestinal tract is essential for the provision of fluid, electrolytes and energy for the performance of strenuous prolonged exercise. Runners without supplementary energy supplies running at 70% VO_{2max} on a treadmill experienced a steady decrease in blood glucose concentration over 3 hours, after which time they could exercise no further. The same volunteers, given supplementary carbohydrates, performed the same exercise for an extra 30 minutes and finished the study with near-normal blood glucose concentrations.[16] This relationship of serum glucose concentration to exercise performance was again shown in a study where runners with a starting blood glucose concentration of 5,0 mmol/l experienced a progressive fall in blood glucose level to 3,1 mmol/l after 170 minutes of exercise, as opposed to volunteers given supplementary carbohydrate (glucose polymer) during exercise. These, in fact, had elevated blood glucose concentrations for the duration of the exercise.[17] The practice of taking extra carbohydrate during exercise to get a boost has some support in that serum glucose levels return to normal within 15 minutes of such supplementation.[18]

Fluid balance is as important as nutrient provision in prolonged exercise. During an hour of marathon running, approximately 60 mmol sodium and 5 mmol potassium are lost in 1 litre of sweat. This is partly compensated for by the 500 ml of fluid produced by metabolism; this leaves an extra 500 ml to be taken by the athlete each hour to maintain fluid balance. The rate of gastric emptying plays a central role. Factors that affect this include food particle size, osmolality, energy concentration, intensity of the exercise and the volume of gastric contents. In a study in dogs that compared the gastric emptying of fluid, liver chunks and 7 mm polystyrene spheres respectively, the liver chunks were shown to be emptied over a 4-hour period. The polystyrene spheres remained in the stomach throughout the study period.[19] This might have been expected as gastric emptying generally retains particles larger than 2 mm. Solid food ingested during exercise is therefore liable to remain in the stomach for some time. The overall effect of osmolality on gastric emptying is not yet clear. Increasing carbohydrate concentrations in the ingested fluid lead to slower gastric emptying of the volume ingested, although the amount of carbohydrate emptied is increased.[20] This delay has led to the use of glucose polymers to increase gastric emptying by lowering the osmolality. Recent evidence has suggested that carbohydrate polymers and starches may in fact be hydrolysed before reaching osmoreceptors in the small bowel. This results in a secondary inhibition of gastric emptying after initial rapid emptying. In this regard, starch may increase osmolality less than the soluble glucose polymers.[21] Equally important is that increased gastric volume can largely compensate for the decrease in gastric emptying associated with high-osmolality fluids.[20] In theory this would mean that an athlete is able to take large volumes of a hyperosmolar solution with the sure knowledge that adequate emptying and absorption of the carbohydrate will take place. The price may be abdominal discomfort and bloating. It may therefore be prudent to advise marathon runners to take a carbohydrate concentration of 15% freely in the first 2 hours to build up a residual gastric volume that will increase gastric emptying in spite of the high caloric concentration. The benefits of increased volume intake have been shown where increasing volumes ingested resulted in decreased weight loss during exercise.[22] However, it must be mentioned that there is a real danger of hyponatraemia in some athletes at the end of prolonged marathon races. It seems reasonable to recommend the ingestion of 500 ml of fluid every hour after the commencement of prolonged exercise. The dangers of taking large volumes of hypotonic solutions have been well described.[23] Athletes who collapsed during marathons with hyponatraemia were generally found to have ingested large volumes of the order of 1,1 l/h. They therefore seemed to be suffering from self-induced dilutional hyponatraemia.[23]

Amino acid and vitamin supplements have recently become popular with marathon runners. At present there is little evidence that these substances either improve performance or build stamina.

In summary, during exercise the gastro-intestinal tract can be responsible for incapacitating symptoms similar in nature to the irritable bowel syndrome. It does, however, play an essential role in providing adequate fluid, electrolytes and energy to athletes competing in prolonged events. New insights into gastrointestinal physiology and its supportive role in maintaining body homeostasis in the exercising athlete will provide the basis for improved performance during endurance events.

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