

Exercise-induced vomiting

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Gastrointestinal (GI) symptoms are common complaints reported by sportsmen. The incidence of such problems visibly differs in various data sources, but it concerns at least 20% [1] of athletes, in some studies reaching even 70% [2]. The occurrence of GI disorders depends on age, sex, training history and physical performance [1]. It also noticeably differs in various sport disciplines. In general, the most strongly affected group is endurance athletes participating in strenuous long-lasting exercise [3]. One of the best investigated and described groups is marathon runners. Up to 83% of them complain of GI signs and link them directly with running [4]. However, other sportsmen also experience GI symptoms during their training and competitions.

Gastrointestinal complaints are usually divided into two groups according to the anatomical part of the GI tract which is affected. Upper gastrointestinal tract disabilities include nausea, vomiting, gastro-oesophageal reflux, heartburn and belching [5]. Those symptoms are generally common but more frequently concern cyclists in comparison to runners. Lower gastrointestinal tract symptoms, in contrast, are more often reported by runners [1] and comprise diarrhoea, intestinal cramping, gastrointestinal bleeding and flatulence [5–7].

Although the majority of athletes get used to exercise-related GI symptoms and do not consider them as related to a disease, some of them look for medical help. The diagnostic process is especially necessary when physical performance of sportsmen is worsened by the GI signs. Such states often require numerous tests, imaging investigations, or even invasive examinations. Even though in most of the cases the causes are (more or less physiological) functional disorders, GI symptoms can be provoked by a somatic disease which needs medical treatment.

The aim of this article is to describe a case of exercise-related nausea and vomiting reported by a professional athlete, followed by an investigation into possible causes of such a condition.

A 21-year-old male professional middle-distance runner was admitted to the hospital in order to diagnose exercise-induced vomiting. The symptoms occurred episodically after strenuous training or after competitions, 4–5 times a year on average. The sole accompanying symptom was nausea a few seconds before the vomiting occurred, without any other announcing signs and no following complaints. The patient reported that he consumed the last meal always at least 2 h prior to the exercise. The content of vomiting was liquid with slight addition of bile. The patient's history did not reveal any chronic diseases. There was no history of any surgery in the past. He also did not take any medications. Everyday training lasted usually between 1 h and 1.5 h. The physical examination revealed no abnormalities.

Laboratory tests including electrolytes, blood count and biochemical analyses were all within the normal range, except slightly elevated thyroid stimulating hormone (TSH) level, with normal thyroxine (T4) and triiodothyronine (T3) hormone concentrations (exact results are presented in Table I). No cause of reported symptoms was found in gastroscopy, ultrasound and upper gastrointestinal tract X-ray in Trendelenburg position. A stress exercise electrocardiography (ECG) test was carried out, but it was concluded with the achievement of maximal heart rate, revealing very good exercise tolerance, without provoking any gastrointestinal complaints. During the test ECG did not reveal any changes of ST segment, arrhythmia or atrioventricular block. Resting blood pressure was 130/70 mm Hg and at the end of the test it reached 190/80 mm Hg. A detailed nutrition interview did not reveal any eating disorders or food intolerance except for a relatively low fluid intake. Since a somatic disease had been excluded, we diagnosed a functional disorder. We considered gastric emptying delay caused by the mechanical effect of strenuous exercise intensified by dehydration. The patient was advised to increase fluid intake with caution concerning electrolyte supplementation, before

and during training, in order to avoid dehydration. After 3 months of observation he reported one episode of vomiting after strenuous training in high temperature but admitted to improper fluid intake that day.

Nausea and vomiting are frequent exercise-related GI complaints which might have various causes. They most commonly stem from a functional disorder and therefore might be considered physiological, but they may also, relatively rarely, be related to some specific somatic diseases. Physiological causes concern gastric emptying delay, splanchnic ischaemia, dehydration and, potentially, hyponatraemia. Somatic causes, on the other hand, accompany such diseases as acute renal failure, heat stroke, food-dependent exercise induced anaphylaxis, gallbladder adhesions, cholangitis or pancreatitis, pheochromocytoma, cardiac ischaemia, superior mesenteric and left portal vein septic thrombosis (Table II).

Our patient presented functional disturbances of the upper gastrointestinal tract, caused by the delay in gastric emptying. This disorder is provoked more often by high-intensity exercise, whereas low-intensity training can even accelerate gastric emptying [5, 8]. The negative effect on gastric emptying was observed by Leiper *et al.* in sportsmen during activity reaching 75% of their VO_2 max [9].

Apart from exercise intensity, another frequent cause of such disorders in athletes is dehydration [10]. As has been described, our patient presented mitigation of the symptoms after appropriate hydration before and during training. However, there is much controversy in recommendations concerning proper hydration during physical exercise, especially of high intensity [6]. Gastric emptying depends on carbohydrate concentration and combination. Jeukendrup *et al.* reported that it can be delayed by the use of hypertonic carbohydrate fluids [11]. On the other hand, in one study which compared the effect of hydration with tap water and 7% carbohydrate solution, it was proven that the latter caused faster gastric emptying [12]. Combination of multiple carbohydrates (glucose and fructose) can also help to achieve faster fluid delivery compared with a glucose only solution. Probably the most effective way of rehydration is the use of fluids with 8% carbohydrate content, as stated by Jeukendrup *et al.* [13].

Apart from the conditions presented by our patient, there are a number of other causes of GI symptoms in sportsmen. One of them is visceral ischaemia. Physical exercises provoke increased sympathoadrenal activity, leading to increased cardiac frequency and contraction force [14]. It also enhances blood flow in constricting muscles and skin, which grants better adaptation to increased muscle work and heat dissipation [2]. It is

Table I. Laboratory test results

Test/parameter	Result
Body mass index (BMI) [kg/m ²]	21.32
Blood pressure [mm Hg]	130/80
Sodium (Na) [mmol/l]	141
Potassium (K) [mmol/l]	4.17
Calcium (Ca) [mg/dl]	10.07
Magnesium (Mg) [mg/dl]	1.91
Creatinine [mg/dl]	0.79
Creatinine clearance [ml/min]	146.45
Fasting plasma glucose [mmol/l]	5.44
C-reactive protein (CRP) [mg/l]	1.90
Aspartate transaminase (SGOT) [U/l]	22
Alanine transaminase (SGPT) [U/l]	15
Thyroid-stimulating hormone (TSH) [μ U/ml]	4.58
Triiodothyronine (T3) [pmol/l]	5.11
Thyroxine (T4) [pmol/l]	15.7
White blood count (WBC) [$\times 10^3/\mu$ l]	9.50
Red blood count (RBC) [$\times 10^6/\mu$ l]	5.25
Haemoglobin (Hb) [g/dl]	15.9
Haematocrit (Ht) [%]	44.5
Mean corpuscular volume (MCV) [fl]	84.8
Thrombocytes (PLT) [$\times 10^3/\mu$ l]	151

Table II. Causes of nausea and vomiting during exercise

Frequent physiological causes	Rare somatic causes
Gastric emptying delay	Acute renal failure
Splanchnic ischaemia	Heat stroke
Dehydration	Food-dependent exercise-induced anaphylaxis
(Hyponatraemia)	Gallbladder adhesions
	Cholangitis/pancreatitis
	Pheochromocytoma
	Cardiac ischaemia
	Superior mesenteric and left portal vein septic thrombosis

all possible because of the simultaneous decrease in blood distribution in the splanchnic area, kidneys and non-contracting muscles [14]. The reduction of blood flow to central organs (intestines, liver) reaches almost 80% during exercise with intensity 70% of VO_2 max [6]. Qamar *et al.* observed superior mesenteric artery blood flow by using transcutaneous Doppler ultrasound af-

ter 15 min of exercise. They found a 43% decrease in the blood flow directly after physical activity [15]. According to van Wijck *et al.*, the decrease in splanchnic blood flow is most strongly pronounced during the first 10 min of exercise and the recovery of GI perfusion is most strongly marked during the first 10 min of rest [16]. Such physiological visceral hypoperfusion involves processes which may result in GI complaints. Van Wijck *et al.* reported the increase of intestinal injury markers during exercise-related GI hypoperfusion. Moreover, it correlated with transiently increased small intestinal permeability; however, it did not result in bacterial translocation [16]. This conclusion is in line with a study by Moore *et al.* which revealed no evidence that endotoxaemia could be the cause of GI symptoms in long distance cyclists after a 100-mile ride [17]. On the other hand, Brock-Utne *et al.* reported elevated plasma endotoxin concentrations in 81% of runners requiring medical help after running an 89.4 km ultramarathon. About 80% of them reported GI complaints including nausea and vomiting [18]. Apart from these discrepancies, the problem of endotoxaemia due to increased small intestinal permeability generally concerns sportsmen taking part in extremely long-lasting physical activity, rather than our patient, whose training sessions and competitions lasted usually about 1.5 h.

Both gastric emptying delay as well as visceral ischaemia are enhanced by dehydration. The hydration status is regulated by a few mechanisms. The two most important during rest and during low-intensity physical activity concern the sodium-plasma osmolality-plasma vasopressin hormonal system [19] and the renin-angiotensin II-aldosterone system [20]. The 2.3% decrease in body mass caused by the loss of fluids induces a hormonal response resulting in thirst stimulation during low-intensity activity [21]. In a study by Maresh *et al.* hypohydrated healthy volunteers drank more during low-intensity exercise in comparison to the euhydrated group. Their hydration status after physical activity was comparable [20]. However, high-intensity exercise (such as our patient's training) and emotional stress before sport competitions induce a catecholamine stimulus which suppresses thirst [2].

In contrast, inappropriately high fluid intake during physical activity might also cause gastrointestinal as well as neurological complications. One of the potentially serious causes of nausea and vomiting during or after sport activity is exercise-induced hyponatraemia, first described by Noakes *et al.* in 1985 [22]. This electrolyte imbalance is caused by massive sodium losses during sweating followed by excessive, low-sodium fluid intake [23]. The definition of hyponatraemia is serum sodium level below 135 mEq/l, but it usually remains asymp-

tomatic until the concentration is lower than 125 mEq/l [24]. This medical state is relatively frequent in participants of long lasting endurance sport competitions such as marathon runs or triathlons. The prevalence of exercise-induced hyponatraemia is between 12.5% (Kipps *et al.* study after the 2003 London Marathon [25]) and even 29% (after the Hawaiian Ironman triathlon competition according to Speedy *et al.* [26]). The risk of developing exercise-induced hyponatraemia is proportional to the time span of activity and total amount of fluid ingested during competition [27]. The possible pathophysiological basis of exercise-induced hyponatraemia is excessive vasopressin secretion similar to the syndrome of inappropriate anti-diuretic hormone secretion (SIADH) [28]. In a study by Hew-Butler *et al.*, vasopressin concentration was elevated in sportsmen after running a 56-km ultramarathon [29]. Siegel *et al.* in their study described the mechanism of non-osmotic secretion of anti-diuretic hormone stimulated by the muscle-derived interleukin-6 in marathon runners [30]. However, the occurrence of exercise-induced hyponatraemia is not limited to strenuous exercise and endurance sports competitions. There are cases of serious hyponatraemia (reported for example by Zelingher *et al.* and William *et al.*) complicating moderate exercise performed by amateurs [31, 32]. Anastasiou *et al.* in their study focused on the role of sodium replacement with fluids consumed during exercise. They revealed that sodium intake in carbohydrate-electrolyte drinks can prevent sodium losses [33].

Although somatic causes of exercise-related GI complaints are rather rare, they might also be responsible for such symptoms as nausea and vomiting in sportsmen. For instance, nausea and vomiting after exercise can be the first symptoms of acute renal failure. The presence of accompanying loin pain is often reported. The group endangered the most are untrained individuals engaged in intensive strenuous exercise; however, there are cases reported in professional athletes [34]. The pathophysiological basis of this state is acute tubular necrosis, but the reported causes vary. Rhabdomyolysis occurs when myoglobin is released due to massive muscle damage which is the result of strenuous exercise or injury during training. This process might be intensified by accompanying infection [35]. Myoglobin in high concentrations is toxic for kidneys and might lead to tubular necrosis. Another cause of exercise-induced acute renal failure can be idiopathic renal hypouricaemia. It is a genetic disorder causing augmented renal urate excretion, which results in a uric acid serum concentration below 1 mg/dl [36, 37]. Such cases were reported for example in Japan by Kikuchi *et al.* [38] and Korea by Kim *et al.* [36].

Nicholson *et al.* in their study observed a few cases of heat stroke. This severe medical complication occurs usually after exercising in a hot environment without proper fluid intake. The symptoms consist of severe disturbance of the central nervous system (including nausea and vomiting), hyperpyrexia, and hot dry skin [39].

Nausea and vomiting accompanied by urticaria, bronchospasm and laryngospasm are the symptoms of anaphylaxis provoked by food allergy [40]. There is a specific type of allergy in which the allergic reaction takes place only when the intake of specific food is followed by physical exercise. Food-dependent exercise-induced anaphylaxis is caused by the increase of intestinal permeability which facilitates allergen absorption. This medical problem might be very hard to identify – the diagnosis is often possible only after further episodes of anaphylaxis and accurate dietary interview, as allergen consumption or physical exercise alone does not provoke anaphylaxis [6].

There are also some studies reporting rare cases of GI symptoms provoked by physical exercise where the causes are somatic internal or surgical diseases. Dimeo *et al.* described a case of a long distance runner suffering from GI symptoms during exertion. The causes were supernumerary ligaments connecting the colon, abdominal wall, and gallbladder. Cholecystectomy and resection of adhesions resulted in cessation of the symptoms [41]. Touzios *et al.* observed patients after hepatico – or pancreateojejunostomies who developed cholangitis or pancreatitis after strenuous exercise. They identified exercise-induced increase of intra-abdominal pressure as a cause of the disturbances and recommended avoiding heavy exercise. It protected the patients from recurrence of the disease [42]. In the D'Antono *et al.* study, nausea and vomiting in addition to chest pain during exercise were positive predictors of acute cardiac ischaemia in women and men. The mean age of the study group was 58 years [43]. According to King *et al.*, nausea and vomiting should also be considered as symptoms of pheochromocytoma. Nine patients (4.4% of the study group) reported exercise-related nausea and vomiting as the first signs of pheochromocytoma and they observed cessation of symptoms after removal of the tumour [44]. Walsh *et al.* reported a case of superior mesenteric and left portal vein septic thrombosis in a backpacker after a long hike. The patient's symptoms were unspecific – nausea, vomiting, abdominal pain and fever [45].

Nausea and vomiting are relatively frequent GI symptoms in athletes, especially those performing endurance sport disciplines. In the majority of the cases they are particular physiological reactions to strenuous exercise and might be alleviated by proper hydration.

However, there are cases of persistent nausea and vomiting caused by somatic diseases which sometimes demand expanded diagnostics and treatment.

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