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Effect of Ingested Fluid Composition on Exercise-related Transient Abdominal Pain

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The present study investigated the effect of ingested fluid composition on the experience of exercise-related transient abdominal pain (ETAP). Forty subjects, susceptible to ETAP, completed 4 treadmill exercise trials: a no-fluid trial and flavored water (FW, no carbohydrate, osmolality = 48 mosmol/L, pH = 3.3), sports drink (SD, freshly mixed Gatorade®, 6% total carbohydrate, 295 mosmol/L, pH = 3.3), and reconstituted fruit juice (FJ, BERRI® orange, 10.4% total carbohydrate, 489 mosmol/L, pH = 3.2) trials. Measures of the experience of ETAP and gastrointestinal disturbances, particularly bloating, were quantified. The FJ was significantly ($p < .01$) more provocative of both ETAP and bloating than all other trials. There was no difference among the no-fluid, FW, and SD in the severity of ETAP experienced, although the difference between the no-fluid and SD approached significance at the .05 level ($p = .056$). There was a significant relationship between both the mean ($r = 0.40$, $p < .01$) and peak ($r = 0.44$, $p < .01$) levels of ETAP and bloating. When the level of bloating was controlled for, the FJ remained significantly ($p < .01$) more provocative of ETAP than the other conditions, with no difference between the FW and SD ($p = .37$). The results indicate that in order to avoid ETAP, susceptible individuals should refrain from consuming reconstituted fruit juices and beverages similarly high in carbohydrate content and osmolality, shortly before and during exercise. Further, the mechanism responsible for the heightened experience of ETAP in the FJ trial extends beyond a gastric mass explanation.

Key Words: stitch, side ache, hydration, gastrointestinal distress, bloating

Introduction

The importance of adequate hydration to maintain blood volume, thereby supporting metabolism and thermoregulation during exercise, is well established (1). Yet there is anecdotal evidence that some individuals may refrain from consuming

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adequate volumes of fluid both prior to and during activity for fear of experiencing abdominal discomfort. One symptom that is commonly associated with fluid consumption in an exercise context is exercise-related transient abdominal pain (ETAP), colloquially referred to as "stitch" or "side-ache" (5–7, 11, 13).

Noteworthy, the composition of ingested fluid, especially carbohydrate content and osmolality, may influence the experience of ETAP (6, 11, 13, 15). Rehrer et al. (15) reported that 80% of athletes who experienced ETAP during a half Iron Man triathalon had ingested a hypertonic beverage, although this observation only involved five cases of ETAP, and the beverage was strongly hypertonic (>800 mOsm · kg^{-1}). On a slightly larger scale, Plunkett and Hopkins (13) similarly found two hypertonic compounds, a decarbonated soft drink (420 mOsmol · L^{-1}) and a prepared solution of lactulose (440 mOsmol · L^{-1}), evoked greater symptoms of ETAP than water; hence, hypertonic beverages appear provocative of ETAP. Yet in an epidemiological study of 848 participants in a 14-km run, 229 episodes of ETAP were reported, but the composition of the pre-event meal or fluid consumed during the event had no bearing on the pain (4).

Plunkett and Hopkins (13) argued that hypertonic fluids are more provocative of ETAP than fluids of lower tonicity because they slow gastric emptying resulting in increased gastric mass. The authors were supportive of the commonly proposed aetiology for ETAP that asserts the pain is a response to tension on the visceral ligaments (17). However, in their study an isotonic sports drink (280 mOsmol · L^{-1}) evoked less symptoms of ETAP than water, suggesting that the mechanism of the pain may involve more than just gastric mass. Gastrointestinal distress such as belching, reflux, nausea, and a feeling of bloating vary with the composition of ingested fluids (11, 15), and there may be a relationship between the development of these symptoms and ETAP (10, 11). In the present study, we proposed that understanding the relationship between ETAP and these symptoms, particularly bloating as a gauge of gastric distension, may provide greater insights into the mechanism of ETAP.

The aim of this study was first to examine the influence of three commonly consumed beverage categories, varying in carbohydrate content and osmolality, on the incidence, time to onset, duration, and severity of ETAP when consumed in large volumes. Second, the relationship between ETAP and gastrointestinal distress, in particular bloating, was explored. In addition, due to the subjective nature of ETAP, the reliability of the pain was investigated. It was purposed that the findings of the study would allow recommendations to be made to individuals susceptible to ETAP regarding the least provocative fluid types to consume as well as provide further perspective regarding the aetiology of the pain.

Methods and Procedures

Subjects

Forty subjects, 30 males and 10 females, who claimed to be susceptible to ETAP (age = 21.0 ± 0.5 yrs, height = 177.1 ± 1.4 cm, weight = 71.9 ± 1.9 kg) were recruited for the study. Subjects were sourced from previous epidemiological studies (5–7). All subjects were active and considered themselves to be in good physical condition. The study was approved by the Avondale College Human Research Ethics Committee. Informed written consent was obtained from each of the subjects prior to participation.

Laboratory Testing Protocol

Each subject performed four trials that involved running on a treadmill for 23 min at a velocity selected by the subject as their recreational running speed (average velocity = 10.3 ± 0.3 km · h^{-1}). On three occasions, the subjects consumed a fluid (fluid trials) shortly before and during exercise and, on one occasion, no-fluid was consumed but an otherwise identical testing protocol was followed. The order of the trials was arranged according to a Latin Square design. The four testing sessions were each separated by approximately 1 week in order to minimize the possibility of a carryover effect, and the time of day was consistent from one test to the next.

Before all testing sessions, the subjects were required to fast for a minimum of 5 hours leading up to the running test and, in most cases, the subjects performed an overnight fast. Two hours before the testing session, including the no-fluid trial, the subjects consumed 500 ml of plain water in an attempt to standardize their hydration status for the trials (1).

The three fluids ingested were a flavored water (FW, no carbohydrate, osmolality = 48 mosmol/L, pH = 3.3), a sports drink (SD, freshly mixed Gatorade®, 6% total carbohydrate, 295 mosmol/L, pH = 3.3), and a reconstituted fruit juice (FJ, BERRI®, Valencia Orange, 10.4% total carbohydrate, 489 mosmol/L, pH = 3.2). All fluids were served at 15 °C.

The volume of fluid consumed in the fluid trials was based on body mass. The timing and volume of fluid consumption for the fluid trials is illustrated in Figure 1. Twenty minutes prior to the treadmill exercise, the subjects consumed 6 ml/kg body mass of the fluid (mean = 431 ± 12 ml) and then a further 4 ml/kg (mean = 288 ± 8 ml) 10 min prior to the commencement of exercise. Immediately prior to exercise, the subjects then consumed 2 ml/kg body mass (mean = 144 ± 4 ml), and this volume was consumed every 4 min throughout the trial. In total, the subjects consumed 22 ml/kg body mass (mean = 1582 ± 42 ml) of fluid during the 43-min testing session.

Every 2nd minute from minute 1 of the treadmill running exercise, the subjects were asked to indicate any experience of ETAP or gastrointestinal discomfort. If present, the severity of ETAP was quantified using an 11-point numerical rating scale (3), which represented the transition from *no pain*, represented as 0, to *pain as bad as it could be*, denoted as a score of 10. This scale has been used in other ETAP studies (5, 7, 13).

The gastrointestinal symptoms assessed were belching, reflux, nausea, and any feeling of "heaviness" or "bloating" in the abdominal region. The experience of bloating was also quantified using an 11-point numerical rating scale in which 0 represented no symptoms, 1 indicated very mild symptoms, and 10 represented the point of unbearable discomfort. The experience of the other gastrointestinal symptoms was assessed on a dichotomous score of present or absent.

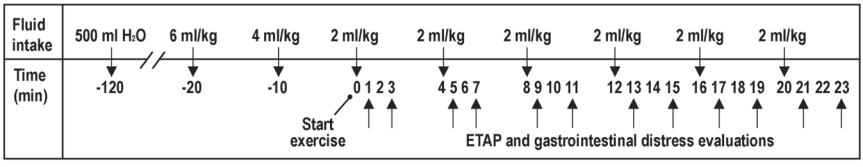


Figure 1 — The timing and volume of fluid consumed during the fluid trials and the timing of ETAP and gastrointestinal distress evaluations during all trials.

Importantly, the subjects were clearly informed prior to the testing session that they were not necessarily expected to experience any symptoms or discomfort. This point was stressed in order to discourage the subjects from inventing information.

Reliability

To derive a measure of reliability, 23 randomly selected subjects performed a fifth trial in which the FJ was repeated. The subjects were not informed of the purpose of this trial or that the fluid consumed would be the same as one consumed on a previous occasion.

Statistical Analysis

The *SPSS* (v. 10) statistical analysis package was used to analyze the data. Descriptive statistics were used to present subject details as well as the general characteristics of ETAP and the gastrointestinal symptoms. Descriptive analyses involved determination of percentages and mean ± standard error of the mean, or 95% confidence intervals. Correlation analysis was employed to determine associations between characteristics of ETAP and bloating.

Differences between the fluids in terms of the mean and peak ETAP and bloating scores were assessed using repeated measures ANOVA with LSD post hoc analyses. Additionally, a MANOVA with LSD post hoc analysis was used to analyze the effect of the fluids on the experience of ETAP whilst controlling for the level of bloating as a time varying covariate. Type III sum of squares analysis was selected to produce a corrected model.

An intra-class correlation coefficient derived from the sum of squares was used as a measure of the reliability of the mean and peak ETAP severity scores, as well as the mean and peak bloating scores in the two FJ trials. A paired *t* test was also used to identify changes in the magnitude of the scores from the first to second FJ trials.

Results

All but 2 subjects completed the four trials for the full exercise duration. These two subjects terminated the FJ trial at 19 and 21 min due to extreme gastrointestinal discomfort.

Effect of Fluid Ingestion on ETAP

As shown in Table 1, the incidence of ETAP was significantly higher when fluid was consumed, with the incidence in the FJ trial being more than two times greater than when no-fluid was consumed. Nine subjects (23%) reported symptoms of ETAP during every trial, and only 2 subjects completed all 4 trials without experiencing ETAP.

Onset of ETAP

The mean times to onset of ETAP differed in the 4 trials, with mean values of 11.5 ± 1.3 min (no-fluid, $n = 16$), 11.5 ± 1.2 min (FW, $n = 28$), 9.4 ± 1.1 min (SD, $n = 28$), and 7.4 ± 0.8 min (FJ, $n = 33$). The number of subjects with ETAP at each 2-min interval

of the exercise test is shown in Figure 2. By the end of the first 9 min of the test, only 3 subjects had reported ETAP in the no-fluid trial, whereas 12 had experienced ETAP in the FW trial, 18 in the SD trial, and 26 in the FJ trial; thus, the time course of the development of ETAP was faster with fluid ingestion and varied with fluid composition. The onset of ETAP was faster in the SD compared to the FW trial, but the number of subjects who developed ETAP by the end of these trials was similar.

Table 1 Percentage of Subjects Reporting ETAP and the Gastrointestinal Symptoms During the Different Fluid Trials

Symptom	No fluid (n = 40)	FW (n = 40)	SD (n = 40)	FJ (n = 38)
ETAP	40	70^{α}	70^{α}	$83^{\alpha\beta\phi}$
Bloating	5	85^{α}	93^{α}	$98^{\alpha\beta}$
Belching	15	88^{α}	$98^{\alpha\beta}$	$95^{\alpha\beta}$
Reflux	5	45^{α}	55^{α}	$68^{\alpha\beta\phi}$
Nausea	8	13	13	$38^{\alpha\beta\phi}$

Note. α, β, and ϕ indicate significant difference ($p < .05$) from the no fluid, FW, and SD trials, respectively.

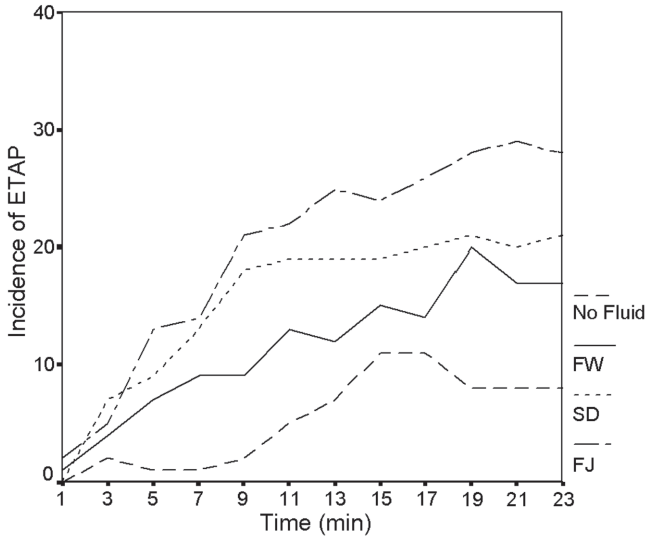


Figure 2 — Incidence if ETAP at each 2-min interval during the four fluid trials.

Duration of ETAP

The duration of ETAP varied among subjects and among trials. Combining all episodes of ETAP in all trials ($n = 105$), the pain relieved at some stage before the end of the 23-min test in 47% of cases ($n = 49$) but in some cases reappeared. In 70% of cases ($n = 74$), the subject completed the trial with the pain present. The mean duration of ETAP for those who experienced ETAP in each trial are presented in Table 2. There was no difference in the duration of ETAP between the no-fluid and FW trials, whereas the duration was significantly ($p < .05$) longer in the SD and FJ trials than in the no-fluid trial.

Severity of ETAP

The FJ was more provocative of ETAP than both the FW and SD (Table 2; Figures 2 and 3), resulting in a higher mean severity of ETAP ($p < .01$) throughout the trial. The same trend was observed for the peak severity of ETAP, with the FJ recording significantly higher values than the FW ($p < .001$) and SD ($p < .05$). Hence, the incidence and severity of ETAP was greatest when the FJ was consumed.

There was no difference in the mean ($p = .327$) or peak ($p = .280$) severity of ETAP between the no-fluid and FW trials (Table 2). Similarly, comparison of the SD with the no-fluid condition indicated no significant difference; however, the *p* values are noteworthy, as the difference in both the mean and peak severity of ETAP between these trials approached significance at the .05 level ($p = .056$ and .087, respectively). The mean and peak severity of ETAP experienced as a result of consuming the FJ was significantly ($p < .01$) greater than when no-fluid was ingested.

Effect of Fluid Ingestion and Composition on Gastrointestinal Disturbances

The levels of bloating rated by the subjects in response to consuming the different fluids, both in terms of the mean and peak level reported, are illustrated in Figure 4.

Table 2 Means and Standard Errors of ETAP and Bloating Measures

Variable	No fluid ($n = 40$)	FW ($n = 40$)	SD ($n = 40$)	FJ ($n = 38$)
ETAP duration (min)	6.8 ± 0.7	9.8 ± 1.2	13.2 ± 1.4$^{\alpha}$	14.4 ± 1.0$^{\alpha\beta}$
ETAP mean severity	0.4 ± 0.1	0.6 ± 0.1	0.8 ± 0.2	1.3 ± 0.2$^{\alpha\beta\phi}$
ETAP peak severity	1.2 ± 0.3	1.6 ± 0.2	1.9 ± 0.3	2.9 ± 0.3$^{\alpha\beta\phi}$
Bloating mean level	0.0 ± 0.0	1.6 ± 0.2$^{\alpha}$	1.8 ± 0.2$^{\alpha}$	2.8 ± 0.3$^{\alpha\beta\phi}$
Bloating peak level	0.1 ± 0.0	3.1 ± 0.3$^{\alpha}$	3.3 ± 0.3$^{\alpha}$	4.7 ± 0.4$^{\alpha\beta\phi}$

Note. α, β, and ϕ indicate significant difference ($p < .05$) from the no fluid, FW, and SD trials, respectively.

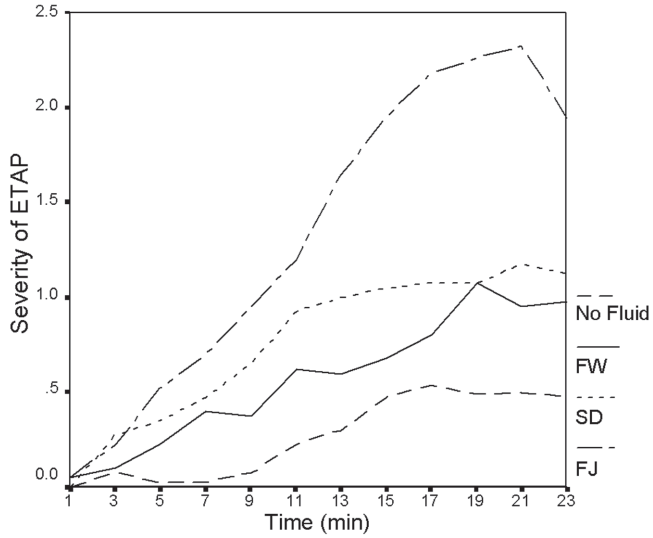


Figure 3 — The average severity of ETAP reported by the subjects for the different fluids over the duration of the trial.

Unremarkably, the consumption of any fluid increased gastrointestinal distress, with the no-fluid condition recording lower ($p < .01$) values for the mean and peak levels of bloating than all other trials (Table 2). There was no difference between the FW or SD in the mean ($p = .43$) or peak level ($p = .49$) of bloating. However, the mean and peak level of bloating experienced in response to consuming the FJ were significantly higher ($p < .01$) than the other beverages (Table 2).

The incidence of the other gastrointestinal symptoms is presented in Table 1. Ingestion of fluid, regardless of composition, increased the incidence of belching and reflux, although the FJ was most provocative of these symptoms. The no-fluid trial resulted in the fewest symptoms. In contrast, the incidence of nausea was not different when the FW, SD, or no-fluid was consumed but was much greater in the FJ trial.

Relationship Between ETAP and Bloating

The influence of the different fluids on both the severity of ETAP and the level of bloating exhibited similar trends (Figures 3 and 4). Accordingly, there was a relationship between the mean ETAP severity and mean level of bloating ($r = 0.402$, $p < .01$) as well as the peak ETAP severity and peak level of bloating ($r = 0.442$, $p < .01$).

Despite the relationship between ETAP severity and level of bloating, when a controlled model was applied, the influence of fluid composition on the severity of ETAP independent of bloating remained significant at the .01 level. The corrected model post hoc analysis indicated an identical trend in the manifestation of ETAP between the trials to that recorded when the level of bloating was not controlled for.

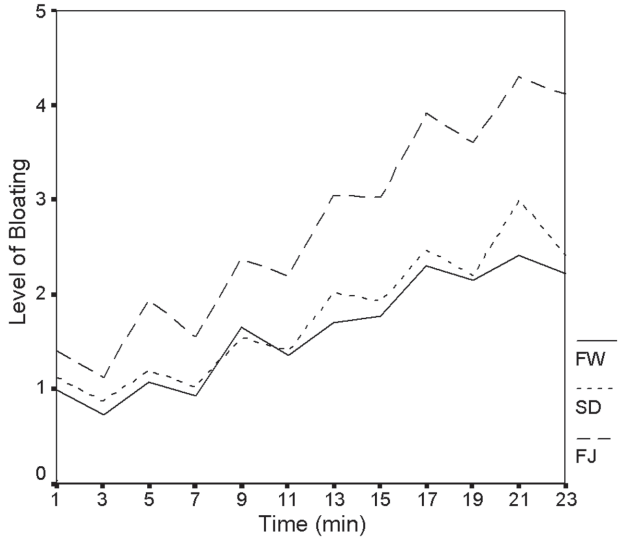


Figure 4 — The average level of bloating reported by the subjects for the different fluids over the duration of the trial.

For example, there was no difference between the FW and SD (p = .372). These beverages were not more provocative of ETAP than the no-fluid trial; however, the SD did once again approach significance at the .05 level (p = .076). Finally, the FJ was significantly (p = .01) more provocative of ETAP than all other trials.

Reliability

In each of the reliability trials, 20 of the 23 subjects (87%) reported ETAP. The 3 subjects who did not report the pain were different in the two trials. Consequently, 74% of the subjects experienced ETAP in both trials, whereas 26% experienced ETAP in only one of the trials.

Intra-class correlation analysis indicated that the mean severity of ETAP reported in the two reliability trials was significantly related (r = 0.66, p < .01); however, the peak severity was not well-correlated (r = 0.41). The mean time to onset of ETAP for the reliability trials, disregarding those subjects who did not develop the pain, were 8.5 ± 1.3 min and 8.8 ± 1.2 min, respectively (r = 0.36, p = .15), and subsequently the duration of ETAP in the two trials was correlated (r = 0.56, p < .01).

Both the mean and peak levels of bloating reported between the two FJ trials were significantly (p < .01) related (r = 0.62 and 0.75, respectively). In Table 3, the results of paired t test analyses are presented, and it can be seen that there was a trend for the measures of both ETAP and bloating to decrease in the second reliability trial. This trend for a decrease in the mean (1.7 ± 0.2 vs. 1.3 ± 0.2, p = .10) and peak (3.7 ± 0.4 vs. 3.2 ± 0.4) severity of ETAP from the first to second reliability trial was also observed when the analyses only included the 17 subjects who reported ETAP in both reliability trials.

Table 3 Comparison of the Average ETAP and Bloating Scores Between the Two FJ Reliability Trials

Variable	FJ Trial 1 (n = 23)	FJ Trial 2 (n = 23)	p value
Mean ETAP severity	1.3 ± 0.2	1.1 ± 0.2	.015
Peak ETAP severity	3.0 ± 0.4	2.8 ± 0.4	.232
Duration of ETAP (min)	11.5 ± 1.5	11.9 ± 1.4	.780
Mean bloating score	2.7 ± 0.3	2.4 ± 0.3	.032
Peak bloating score	4.7 ± 0.4	4.4 ± 0.4	.002

Discussion

This project is the largest experimental study on ETAP to date, and the results testify to the influence of consuming fluid at a high rate and beverages of a high carbohydrate content, and of osmolality on the experience of ETAP during running. The results are also informative from an aetiological perspective.

Effect of Fluid Consumption on ETAP

It is not surprising that the consumption of fluids increased the incidence of ETAP and the various gastrointestinal symptoms during running. We have previously reported that 38% of ETAP sufferers have noted the pain to be provoked by drinking prior to exercise (5). In another epidemiological study, almost half of the participants surveyed who experienced ETAP during a community fun run claimed that the pain manifest shortly after a drink station (6). Notwithstanding, ETAP can clearly be experienced in the absence of fluid ingestion (Figures 2 and 3), although the results of the present study testify to its provocative nature.

It must be recognized that the rate of fluid ingestion used in the study protocol was beyond that which occurs in a typical exercise situation. The average rate of fluid consumption by the subjects equated to 2373 ml · h^{-1}, which greatly exceeds the American College of Sports Medicine recommendations of 600 to 1000 ml · h^{-1} (1). The high rate of ingestion allowed significant manifestations of ETAP to be observed in a relatively short exercise period, hence avoiding dehydration, which has also been documented as influential on ETAP (14). It is interesting that symptoms of ETAP were reported shortly into the exercise period (1–3 min) by which time subjects had consumed 12 ml · kg^{-1} (mean volume = 863 ml) over a 20-min period. Hence, it would seem that this initial bolus is enough to evoke discomfort. Indeed, due to the excessive rate of fluid ingestion, the symptoms of ETAP observed in the present study would likely be an exaggeration of those expected if the ACSM guidelines were adhered to. During a 67-km ultra-marathon in which participants consumed an average of 350–400 ml · h^{-1}, which falls below the ACSM guidelines, Rehrer et al. (16) observed no correlation between the amount of fluid intake and gastrointestinal distress. Further research is required to ascertain the extent of ETAP and other abdominal complaints when the guidelines are followed.

Influence of Fluid Composition on ETAP

The results of the present study support the findings of Plunkett and Hopkins (13) that high carbohydrate content, hypertonic beverages are more provocative of ETAP than solutions of lower carbohydrate concentration and osmolality. Accordingly, individuals susceptible to ETAP should avoid such beverages before and during exercise as a prevention strategy. The studies differ, however, in their observed influence of hypotonic and isotonic fluids on ETAP. Plunkett and Hopkins (13) reported that an isotonic sports drink evoked less symptoms of ETAP than water, whereas the present study indicated a trend towards the opposite being the case. The rationale for the disparity is unclear, although it is acknowledged that the hypotonic solution used in the present study was not water.

One explanation for the pronounced effect of the FJ on ETAP above that of the other fluids could be, as argued by Plunkett and Hopkins (13), that the composition of the beverage slowed gastric emptying, leading to an increase gastric mass and greater tension on the supportive visceral ligaments. It is well documented that gastric emptying is affected by numerous factors, including caloric density, volume consumed, mode and intensity of exercise, acidity, osmolality, and beverage temperature (2, 8–10). While several of these factors were controlled in the present study, the higher osmolality, marginally lower pH, and especially the higher carbohydrate content of the FJ as compared to the other fluids—would be expected to relatively impede gastric emptying. The observation that the severity of bloating was highest in the FJ trial would further lend support to the proposition that, while not measured directly, this fluid slowed gastric emptying more than the FW and SD.

One point to qualify is that while bloating was related to ETAP, the mechanism of provocation might not necessarily be a result of an increased gastric mass but gastric distension. Gastric distension could occur as a result of gas production, which would not necessarily contribute to gastric mass. The FJ did not result in more belching than the other fluids in the present study, but Peters et al. (11) found a relationship between ETAP and belching in a project that explored the relationship between various gastrointestinal complaints during running and cycling. We have previously proposed that distension of any viscera may increase pressure on the parietal peritoneum, giving rise to symptoms of ETAP (5).

The finding that the experience of ETAP is influenced by the composition of the ingested fluid independent of the level of bloating may suggest that the stimulus for ETAP extends beyond a purely mechanical one. Essentially, it would seem that the FJ provoked ETAP for reasons other than just its effect on gastric mass or distension. Indeed, the fact that ETAP was observed during the no-fluid condition in the absence of bloating further testifies that, while bloating may contribute to the pain, it does not entirely explain its manifestation. Mechanisms contributing to ETAP other than mechanical trauma are speculative; however, Peters et al. (12) reviewed several potential explanations of gastrointestinal distress encountered during exercise, including the well documented decrease in splanchnic blood flow, neuroendocrine changes, and changes in gastrointestinal motility. In turn, they proposed that these challenges to the gastrointestinal tract might lead to secondary effects such as increased intestinal permeability, malabsorption, and even endotoxaemia.

More than likely, as evidenced by the results of the separate regression analyses in which the level of bloating was and was not controlled for, a combination of

the explanations alluded to above contributed to the heightened experience of ETAP in the FJ trial.

Reliability

In the only other study to consider the reliability of ETAP, Plunkett and Hopkins (13) reported poor between-days correlation coefficients in the range of 0.08 to 0.18. However, their study involved only 10 subjects, and they acknowledged that a greater sample size would improve the power of the study, possibly explaining the substantially higher reliability scores recorded in the present study. We felt that the reliability of both ETAP and bloating observed in the present study was acceptable but acknowledge the importance of controlling for potentially confounding variables when studying these conditions. These factors include the subjects being in a fasted but euhydrated state as well as consistency of ambient conditions. While the testing situation was somewhat clinical and not typical of the unstable conditions encountered during recreational or competitive exercise sessions, it is encouraging that, from a research perspective, trials can be conducted under such controlled conditions with moderate reliability. Yet, clearly any studies on ETAP that aim to assess the effectiveness of different intervention strategies or provoking factors need to adopt a repeated-measures design.

The trend for the mean severity of ETAP as well as the mean and peak level of bloating to decrease in the second FJ trial is noteworthy. The second reliability trial was performed after all other trials had been completed but, according to the Latin Squares design, the first trial used in the reliability analysis may have occurred at any point during the testing sequence. Hence, some of the subjects completed three testing sessions between the reliability trials. It could therefore be argued that the subjects demonstrated a learning effect throughout the study in which they could better cope with the volumes of fluid consumed during the exercise. The application of this observation is that individuals who have difficulty consuming fluid in association with exercise may be able to learn the skill. Indeed, the trainability of tolerating fluid consumed during exercise is worthy of further investigation.

Conclusions and Practical Applications

1. Ingestion of large volumes of fluid (1144–2420 ml) before and during a 24-min run appears to increase the incidence and severity of ETAP and other gastrointestinal symptoms in individuals susceptible to these complaints.
2. The reconstituted fruit juice was more provocative of ETAP than the flavored water and sports drink. This beverage differed from the others in terms of a higher osmolality and carbohydrate content, and slightly lower pH. From our results and those reported by Plunkett and Hopkins (13), it seems that a prevention strategy for individuals susceptible to ETAP is to avoid reconstituted fruit juices and beverages similarly high in carbohydrate content and osmolality, prior to and during exercise.
3. When the same beverage was ingested on two separate occasions, ETAP and bloating were lower on the second occasion. Therefore, individuals susceptible to ETAP may expect to reduce these complaints associated with drinking by practicing fluid ingestion during exercise.

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