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Exercise-related abdominal complaints in a large cohort of runners: a survey with a particular focus on nutrition

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ABSTRACT

Objectives Abdominal complaints (AC) during exercise are a common problem in runners. Nutrition is known to play a role in exercise-related AC, but information on the role of habitual dietary intake is limited. We assessed the prevalence of AC in a large cohort of runners, and investigated its association with potential risk factors, with a particular focus on nutritional factors in the habitual diet.

Methods A total of 1993 runners completed two online questionnaires: a general questionnaire on, among others, running habits and exercise-related AC and a Food Frequency Questionnaire. Runners with and without either upper AC (UAC) or lower AC (LAC) were compared regarding personal characteristics, running characteristics and habitual dietary intake.

Results 1139 runners (57%) reported AC during and/or up to 3 hours after running: 302 runners (15%) reported UAC, 1115 (56%) LAC and 278 (14%) both. In about one-third of runners with AC, these complaints negatively affected their running. Exercise-related AC were positively associated with female gender, younger age and more intense running. Most associations with nutritional factors were observed only for LAC in men, with a higher intake of energy, all macronutrients and grain products in men with LAC. In both men and women, a higher intake of tea and unhealthy choices were associated with AC.

Conclusion Exercise-related AC were quite prevalent, and in about one-third of the cases, AC impacted their running. Being female, having a younger age and running at higher intensity were positively associated with AC. Some aspects of the habitual diet were associated with AC. Most notable were positive associations for intake of fat, tea and unhealthy choices.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Exercise-related abdominal complaints (AC) are common in runners.
⇒ Intake of fibre, fat, protein and beverages with high osmolalities (>500 mOsm/L), especially shortly before or during exercise, is known to induce AC during and/or shortly after exercise. However, knowledge about the role of the habitual diet in exercise-related AC is limited.

WHAT THIS STUDY ADDS

⇒ The present study confirms the high prevalence of exercise-related AC in runners.
⇒ These exercise-related AC negatively affected running in about one-third of the runners.
⇒ Some nutrients and food groups in the habitual diet, for example, fat, tea and unhealthy food choices were associated with exercise-related AC.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Habitual dietary intake is associated with exercise-related AC. Still, more research on the impact of dietary habits on AC and its causality is warranted to develop dietary guidelines and advice to prevent or manage exercise-related AC.

INTRODUCTION

Exercise-related abdominal complaints (AC) are very common among athletes. Prevalence rates are highly different between studies because of different methodologies, the use of different definitions for exercise-related AC and the different types of events and athletes studied. AC are, in particular, highly prevalent among runners and more common and more severe with high exercise intensity compared with low exercise intensity and with long exercise duration compared with short exercise duration.[1] Prevalence rates of AC in distance runners range from 30% to 90% with the highest rates reported in ultramarathon runners,[1] most likely due to a very high running load, but also due to limited fluid and nutrient intake.[2] Exercise-related AC include among others nausea, vomiting, diarrhoea and abdominal pain. AC are considered the most common cause of underperformance in endurance events. Besides, AC can also impair subsequent postexercise recovery.[1]

The aetiology of exercise-related AC is multifactorial, with physiological, mechanical and/or nutritional causes.[1] The main physiological factors contributing to AC during exercise are gastrointestinal ischemia due to splanchnic hypoperfusion[3–5] and reduced overall gastrointestinal functional capacity due to increased sympathetic activation,[5] with increased gastrointestinal permeability and inflammation as a likely consequence.[5] Other physiological factors include alterations in motility, absorption and immune function.[1 6] Mechanical bouncing may explain the higher prevalence among runners compared with other athletes.[7] Nutritional factors are also known to induce AC during and/or after exercise. Studies have shown that intake of fibre, fat, protein and beverages with high osmolalities (>500 mOsm/L), especially shortly before or during exercise, is associated with multiple AC.[1 8] Fluid restriction during exercise and/or dehydration is known to increase gastrointestinal permeability,[9] and as such is also associated with AC. Interestingly, research on irritable bowel syndrome (IBS) reveals that regular or habitual dietary factors could trigger AC. Not only cereal-based foods, predominantly bread or its components,[10] but also greasy foods, onions, cabbage and spicy and fried foods are often mentioned.[11] However, the impact of regular or habitual dietary factors is not explored in running-related AC, in contrast to food intake shortly before or during exercise. Knowledge of the role of nutrition, and especially habitual dietary intake, in inducing exercise-related AC is relevant for developing nutritional guidelines and advice aimed at preventing or managing exercise-related AC.

Therefore, the aim of this study is to assess the prevalence of exercise-related AC in a large cohort of runners and to investigate its association with potential risk factors, with a particular focus on nutritional factors in the habitual diet.

METHODS

The Eat2Run study is an observational study with a cross-sectional design. Participants were runners who completed two online questionnaires: a general questionnaire and a Food Frequency Questionnaire (FFQ). The general questionnaire contained questions about general participants' characteristics, running habits, current and past injuries, the occurrence and perceived impact of AC and general health issues. The FFQ was used to assess habitual dietary intake.

Study population

In July 2021, recruitment of runners started by requesting athletics clubs and running event organisations in the Netherlands and Belgium, among which the popular Dutch Seven Hills run in Nijmegen, to help with the recruitment by posting a news item in their newsletter or on their website. In the second stage, social media (Facebook, Twitter, LinkedIn) were also used for recruitment. Finally, in March 2022, participants of the 2022 edition of the well-known Rotterdam Marathon who indicated a willingness to participate in scientific studies were invited. When the recruitment period closed on 1 June 2022, 3643 runners had expressed interest for the study.

To be included in the present analyses, runners (1) had to be at least 18 years old, (2) had to run at least once a week in the past year, no matter the time or distance, or would usually run at least once a week if they had not been injured, (3) had to complete both the general questionnaire and the FFQ and (4) their reported habitual dietary intake in the FFQ had to be plausible (see below). Finally, 1993 runners could be included in the data analyses (see Results section).

Assessment of AC and their impact

The general questionnaire not only contained questions about general participants' characteristics and running habits but also included validated and/or previously used questionnaires about tendon injuries (which was the focus of a separate study[12]) and AC. The AC questions were selected from multiple questionnaires that were previously used, mainly in IBS patients.[13–15] After the initial development of the general questionnaire, it was critically reviewed by the research team and it was circulated among 50 volunteers to receive feedback on, among others, clarity and unambiguous formulation.

Regarding AC, the occurrence of specific symptoms during and/or shortly (ie, up to 3 hours) after running was asked, for nine symptoms independently: nausea/vomiting, reflux, side stitch, bloating, flatulence, urge to defecate, faecal incontinence, diarrhoea and constipation. Runners were instructed to indicate a complaint only if they experienced this as bothersome. No specific time frame was specified for the occurrence of AC, but the questions were formulated so that they would be a present issue when running.

Additionally, runners were asked to rate the severity of the nine symptoms. Each symptom could be scored on a scale from 0 (not bothersome) to 100 points (very bothersome), resulting in a maximum total score of 900 points. If runners indicated that a symptom occurred, but they did not fill in a score, this missing value was set to 0.

Finally, runners were asked about the perceived impact of AC and personal experiences with nutrition and AC.

For the analyses, the nine symptoms were divided into upper AC (UAC) (nausea/vomiting and reflux) and lower AC (LAC) (side stitch, bloating, flatulence, urge to defecate, faecal incontinence, diarrhoea and constipation). Runners with AC during and/or shortly after running were compared with runners without AC regarding personal characteristics, running characteristics and nutritional factors. This was done separately for UAC and LAC. Runners were placed in the group with UAC and/or LAC if the severity score during and/or shortly after running for one or more of the respective UAC and LAC symptoms was indicated to be above 0.

Assessment of dietary intake and diet quality

The FFQ was used to assess dietary intake over the past month. A comprehensive FFQ, validated for energy intake, macronutrients, dietary fibre and vitamins, was used to assess the frequency of consumption of 180 food items.[16 17] Portion sizes were estimated using natural portions (eg, one slice of bread) and commonly used household measures. From the FFQ data, the average daily intake of foods and food groups was calculated. Data on food consumption was also converted into average daily energy and nutrient intake using the Dutch food composition database of 2011.[18]

Runners reporting an implausible habitual dietary intake, that is, energy intake<800 and >4200 kcal for men and <500 and >3500 kcal for women,[19 20] were excluded from the analyses.

Statistical analyses

Continuous data were first checked for normality using a Kolmogorov-Smirnov test and visual inspection of Q–Q normality plots. After that, descriptive analyses were performed. Personal characteristics, running characteristics, prevalence and severity of AC and daily dietary intake were examined in the total population and per gender. Because continuous data were not normally distributed, these data are presented as median (25th–75th percentile); categorical variables are presented as n (%).

Differences between men and women were assessed using a Mann-Whitney U test for continuous variables and a Pearson χ^2 test for categorical variables. Gender-neutral runners and runners who did not fill in their gender were not compared with other groups because these groups were too small.

Next, runners with AC were compared with runners without AC. Differences between these two groups in personal characteristics, running characteristics and nutritional factors were assessed using a Mann-Whitney U test for continuous variables and a Pearson χ^2 test for categorical variables. Analyses were performed separately for UAC and LAC, and separately for men and women.

The results of all statistical tests were considered significant when the significance level was lower than 5%, that is, p<0.05. Statistical analyses were performed with SPSS software (V.25).

RESULTS

Study population

A total of 3643 runners expressed their interest for the study. From these, 2118 runners completed both questionnaires. Five runners were excluded because they were younger than 18 years or did not report their age. A total of 69 runners were excluded because they did not run, or would not have run if not injured, at least once a week in the past year. Finally, 51 runners were excluded because they reported implausible dietary intake. A total of 1993 runners (891 men, 1095 women, 5 gender neutral, 2 who did not fill in their gender) were included in the study.

The median (25th–75th percentile) age for the total population was 44 (34–54) years. Most runners (76%) considered their running level intermediate, and about half of the runners (49%) ran for at least 10 years. The median number of running sessions per week was 3 (2–4), and the median distance covered per week was 30 (20–42) km. A more detailed overview of personal and running characteristics is presented in online supplemental table 1.

The median energy intake in the total population was 2095 (1700–2538) kcal. Energy and macronutrient intake were higher in men than women. Regarding intake of food groups, men consumed more grain products, legumes, dairy, fats and oils, meat, sweetened beverages and fruit juices, alcohol and unhealthy choices (eg, cakes and cookies, sweets, snacks), while women consumed more vegetables, fruit and tea. A detailed overview of energy, macronutrient and food group intake is presented in online supplemental table 2.

Prevalence, severity and perceived impact of AC

Prevalence rates and severity of exercise-related AC and specific symptoms are presented in table 1. In total, 1139 runners (57%) reported having AC during and or shortly after running, and AC were significantly more often reported by women (67%) than by men (45%). A total of 302 runners (15%) reported UAC, 1115 (56%) reported LAC and 278 (14%) reported both. Reflux was the most common symptom of UAC (11%), and flatulence was the most common symptom of LAC (36%). Also, all individual symptoms were significantly more often reported by women than by men.

The median (25th–75th percentile) total score for the severity of AC was 75 (30–145). Generally, women perceived the symptoms as more severe than men, although not all differences between men and women reached significance.

Table 2 presents the perceived impact of AC and personal experiences with nutrition and AC. Between 23% and 35% of runners indicated that AC sometimes caused disruption, interruption or avoidance of running training; 4%–11% indicated that this occurred often or always. AC caused less often disruption, interruption or avoidance of running in competitions, although 5%–9% indicated that this occurred sometimes and 1%–3% indicated that this occurred often or always. Women more often reported these consequences of AC on running training and running in competitions than men.

The majority of runners with either UAC or LAC (67%–88%) reported that eating before or during exercise increases AC, and women more often reported this than men. Eating increased AC mostly by eating too much or shortly before running, but eating too little before running, eating during running and eating specific food products were also reported. Drinking before or during running was less often reported to increase AC than eating, although it was still quite common (25%–45%). This was also mostly due to drinking too much before running. Between 33% and 54% of runners reported taking measures to reduce AC. The most common measure was not eating (too much) just before running, followed by avoiding specific foods or drinks and defecating before running.

Factors associated with AC

Table 3 presents personal and running characteristics in runners with and without UAC or LAC. In both men and

Table 1 Prevalence and severity of abdominal complaints during and or up to 3 hours after running

	Total (n=1993)*	Men (n=891)	Women (n=1095)	P value men versus women†
Prevalence				
Any abdominal complaints	1139 (57)	398 (45)	738 (67)	**<0.001**
Any upper abdominal complaints	302 (15)	107 (12)	194 (18)	**<0.001**
Nausea/vomiting	149 (8)	31 (4)	118 (11)	**<0.001**
Reflux	209 (11)	87 (10)	121 (11)	**<0.001**
Any lower abdominal complaints	1115 (56)	383 (43)	729 (67)	**<0.001**
Side stitch	466 (23)	116 (13)	348 (32)	**<0.001**
Bloating	497 (25)	141 (16)	354 (32)	**<0.001**
Flatulence	726 (36)	272 (31)	453 (41)	**<0.001**
Urge to defecate	649 (33)	222 (25)	426 (39)	**<0.001**
Faecal incontinence	141 (7)	30 (3)	111 (10)	**<0.001**
Diarrhoea	368 (19)	114 (13)	254 (23)	**<0.001**
Constipation	157 (8)	22 (3)	135 (12)	**<0.001**
Severity score				
Nausea/vomiting	19 (3 – 42)	17 (2 – 48)	20 (4–42)	0.742
Reflux	18 (0 – 37)	15 (0–34)	20 (1 – 40)	0.419
Side stitch	29 (10–48)	20 (0 – 40)	30 (10 – 50)	**<0.001**
Bloating	13 (0 – 34)	15 (0–31)	11 (0–35)	0.923
Flatulence	25 (7–41)	25 (6–48)	25 (8–40)	0.774
Urge to defecate	40 (19–66)	30 (10–59)	45 (21–70)	**<0.001**
Faecal incontinence	28 (10–51)	15 (4–43)	30 (12–52)	**0.017**
Diarrhoea	21 (3–51)	12 (0–40)	30 (7–57)	**<0.001**
Constipation	3 (0–21)	0 (0–10)	5 (0–23)	**0.041**
Total score	75 (30–145)	58 (20–110)	90 (39–164)	**<0.001**

Data are presented as n (%) or median (25th–75th percentile).
*The total population includes five gender-neutral runners and two runners who did not fill in their gender.
†P values for differences in prevalence were obtained with a Pearson χ^2 test, and p values for differences in scores with a Mann-Whitney U test; statistical significance (p<0.05) is indicated in bold.

women, runners with both UAC and LAC were younger and trained at a higher intensity. In men only, runners with UAC were more competitive than runners without UAC. In women only, runners with UAC had a shorter running career than those without UAC, and runners with LAC had a lower body mass index and ran more kilometres a week than those without LAC.

Energy and macronutrient intake, as well as intake of foods categorised into food groups in runners with and without UAC or LAC, is presented in table 4. In general, similar differences in dietary intake between those with and without complaints were reported for UAC and LAC, but differences tended to be stronger in LAC due to a larger number of cases. Men with UAC had a higher intake of total fat, sweetened beverages and fruit juices, and unhealthy choices than men without UAC. Men with LAC had a higher intake of energy, total carbohydrates, total fat, total protein, fibre, whole grain and refined grain products, nuts, tea, and unhealthy choices, and a lower intake of fruit than men without LAC. Women with UAC had a lower intake of wholegrain products than those without UAC, while women with LAC had a higher intake of tea and unhealthy choices than those without LAC.

DISCUSSION

The aim of this study was to assess the prevalence of exercise-related AC in a large cohort of runners and to investigate its association with potential risk factors, particularly nutritional factors in the habitual diet. The majority of runners (57%) reported having AC during and/or up to 3 hours after running. LAC were more common (56%) than UAC (15%), and all symptoms occurred more often, and were perceived as more severe in women than men. In about one-third of these runners, AC negatively affected their running. In both men and women, younger age and a higher training intensity were associated with both UAC and LAC. Regarding habitual dietary intake, certain nutrients and food groups were associated with AC. However, associations were different

Table 2 Perceived impact of AC and personal experiences with nutrition and AC

	UAC			LAC		
	Men (n=107)	**Women (n=194)**	**P value***	**Men (n=383)**	**Women (n=729)**	**P value***
Do AC disrupt, interrupt or avoid running training?			**0.014**			**<0.001**
Never	36 (34)	34 (18)		125 (33)	147 (20)	
Seldom	41 (38)	76 (39)		147 (38)	263 (36)	
Sometimes	25 (23)	68 (35)		93 (24)	240 (33)	
Often	5 (5)	14 (7)		16 (4)	67 (9)	
Always	0 (0)	2 (1)		1 (0)	12 (2)	
Do AC disrupt, interrupt or avoid running in competitions?			0.362			**0.038**
Never	43 (40)	56 (29)		157 (41)	235 (32)	
Seldom	13 (12)	25 (13)		60 (16)	110 (15)	
Sometimes	9 (8)	17 (9)		19 (5)	52 (7)	
Often	3 (3)	6 (3)		3 (1)	14 (2)	
Always	0 (0)	0 (0)		1 (0)	3 (0)	
Does eating before or during running increase AC?			**0.017**			**<0.001**
Yes	80 (75)	170 (88)		256 (67)	566 (78)	
No	25 (23)	22 (11)		123 (32)	155 (21)	
How does eating before or during running increase AC?						
Eating too much before running	58 (54)	132 (68)	**0.017**	203 (53)	447 (61)	**0.008**
Eating too little before running	15 (14)	30 (16)	0.736	29 (8)	73 (10)	0.180
Eating shortly before running	52 (49)	124 (64)	**0.010**	179 (47)	391 (54)	**0.029**
Eating during running	22 (21)	38 (20)	0.840	48 (13)	98 (13)	0.669
Eating specific food products that cause me complaints	19 (18)	57 (29)	**0.026**	69 (18)	179 (25)	**0.013**
Does drinking before or during running increase AC?			0.147			**<0.001**
Yes	38 (36)	87 (45)		94 (25)	263 (36)	
No	69 (65)	105 (54)		288 (75)	458 (63)	
How does drinking before or during running increase AC?						
Drinking too much before running	23 (22)	62 (32)	0.054	62 (16)	188 (26)	**<0.001**
Drinking too little before running	16 (15)	29 (15)	0.999	23 (6)	65 (9)	0.087
Drinking during running	10 (9)	28 (14)	0.203	30 (8)	73 (10)	0.233
Drinking specific drinks that cause me complaints	9 (8)	20 (10)	0.593	25 (7)	55 (8)	0.533
Do you take measures to reduce AC?			**<0.001**			**<0.001**
Yes	35 (33)	105 (54)		134 (35)	345 (47)	
No	72 (67)	89 (46)		248 (65)	382 (52)	
Which measures do you take to reduce AC?						
Not eating (too much) just before running	25 (23)	87 (45)	**<0.001**	101 (26)	274 (38)	**<0.001**
Drinking well before and/or during running	14 (13)	36 (19)	0.222	54 (14)	105 (14)	0.891
Avoiding specific foods or drinks	22 (21)	65 (34)	**0.018**	66 (17)	201 (28)	**<0.001**
Defecating before running	18 (17)	59 (30)	**0.010**	100 (26)	210 (29)	0.341
Decreasing running intensity	15 (14)	36 (19)	0.315	48 (13)	110 (15)	0.246
Other	5 (5)	18 (9)	0.150	18 (5)	68 (9)	**0.006**

Data are presented as n (%).
*P values were obtained with a Pearson χ^2 test; statistical significance ($p<0.05$) is indicated in bold.
AC, abdominal complaints; LAC, lower abdominal complaints; UAC, upper abdominal complaints.

Table 3 Personal and running characteristics in runners with and without abdominal complaints during and/or up to 3 hours after running

	No UAC	UAC	P value*	No LAC	LAC	P value*
Men (n=891)	**n=784**	**n=107**		**n=508**	**n=383**	
Age, years	48 (38–57)	44 (32–56)	**0.015**	50 (39–58)	44 (35–55)	**<0.001**
Height, m	1.82 (1.78–1.87)	1.83 (1.78–1.87)	0.701	1.82 (1.78–1.87)	1.82 (1.78–1.87)	0.976
Weight, kg	76 (71–82)	75 (70–82)	0.581	76 (71–82)	75 (70–81)	0.129
BMI, kg/m^2	22.8 (21.5–24.5)	22.8 (21.4–23.8)	0.423	22.9 (21.6–24.5)	22.7 (21.4–24.1)	0.075
Running level			**<0.001**			0.126
Beginner	13 (2)	3 (3)		9 (2)	7 (2)	
Intermediate, not competitive	552 (70)	66 (62)		366 (72)	252 (66)	
Competitive (in age group)	216 (28)	34 (32)		131 (26)	119 (31)	
(Semi)professional	3 (0)	4 (4)		2 (0)	5 (1)	
Running years			0.075			0.122
<1 year	10 (1)	2 (2)		3 (1)	9 (2)	
1–2 years	52 (7)	10 (9)		32 (6)	30 (8)	
3–5 years	136 (17)	17 (16)		80 (16)	73 (19)	
6–9 years	159 (20)	21 (20)		104 (21)	76 (20)	
≥10 years	426 (54)	55 (51)		287 (57)	194 (51)	
Running, km/week	35 (25–50)	33 (24–50)	0.871	35 (24–50)	35 (25–50)	0.523
Longest distance per week (km)	16 (12–21)	16 (12–25)	0.596	15 (12–21)	16 (12–21)	0.063
Intensity most intensive training			**0.040**			**<0.001**
Moderately intensive	179 (23)	18 (17)		137 (27)	60 (16)	
Intensive	394 (50)	48 (45)		251 (49)	191 (50)	
Very intensive	211 (27)	41 (38)		120 (24)	132 (35)	
Warming up (yes)	492 (63)	77 (72)	0.17	313 (62)	256 (67)	0.200
Other sports besides running in the past year (yes)	407 (52)	52 (49)	0.697	250 (49)	209 (55)	0.147
Women (n=1095)	**n=901**	**n=194**		**n=366**	**n=729**	
Age, years	44 (33–52)	38 (28–48)	**<0.001**	46 (37–54)	41 (30–51)	**<0.001**
Height, m	1.70 (1.65–1.75)	1.70 (1.65–1.74)	0.468	1.70 (1.65 – 1.75)	1.70 (1.65 – 1.74)	0.842
Weight, kg	63 (58–69)	63 (58 – 68)	0.341	64 (59 – 70)	62 (58–68)	**0.012**
BMI, kg/m^2	21.6 (20.3 – 23.3)	21.7 (20.2 – 23.4)	0.716	22.0 (20.4–23.6)	21.5 (20.2 – 23.3)	**0.033**
Running level			0.521			0.184
Beginner	28 (3)	9 (5)		13 (4)	24 (3)	
Intermediate, not competitive	734 (82)	156 (80)		306 (84)	584 (80)	
Competitive (in age group)	135 (15)	27 (14)		47 (13)	115 (16)	
(Semi)professional	4 (0)	2 (1)		0 (0)	6 (1)	
Running years			**0.018**			0.077
<1 year	22 (2)	7 (4)		11 (3)	18 (3)	
1–2 years	66 (7)	27 (14)		22 (6)	71 (10)	
3–5 years	193 (21)	46 (24)		71 (19)	168 (23)	
6–9 years	203 (23)	35 (18)		79 (22)	159 (22)	
≥10 years	417 (46)	79 (41)		183 (50)	313 (43)	
Running, km/week	25 (17–40)	27 (15–40)	0.366	25 (16–35)	25 (18–40)	**0.013**
Longest distance per week (km)	12 (10–16)	14 (10–18)	0.316	12 (10–16)	13 (10–18	0.126
Intensity most intensive training			**0.022**			**0.022**
Moderately intensive	255 (28)	38 (20)		117 (32)	179 (24)	
Intensive	469 (52)	106 (55)		179 (49)	396 (54)	
Very intensive	177 (20)	50 (26)		70 (19)	157 (22)	
Warming up (yes)	571 (63)	122 (63)	0.098	230 (63)	463 (64)	0.755
Other sports besides running in the past year (yes)	613 (68)	125 (64)	0.332	243 (66)	495 (68)	0.616

Data are presented as median (25th–75th percentile) for continuous variables and n (%) for categorical variables.
*P values were obtained with a Mann-Whitney U test for continuous variables and a Pearson χ^2 test for categorical variables; statistical significance (p<0.05) is indicated in bold.
BMI, body mass index; LAC, lower abdominal complaints; UAC, upper abdominal complaints.

Table 4 Daily habitual dietary intake in runners with and without abdominal complaints during and/or up to 3 hours after running

	No UAC	UAC	P value*	No LAC	LAC	P value*
Men (n=891)	**n=784**	**n=107**		**n=508**	**n=383**	
Energy (kcal)	2350 (1933–2805)	2444 (2133–2817)	0.063	2306 (1870–2760)	2446 (2049–2885)	**<0.001**
Total carbohydrates (g)	258 (209–314)	264 (213–314)	0.286	252 (202–302)	268 (224–322)	**<0.001**
Total fat (g)	91 (72–114)	101 (85–116)	**0.010**	90 (70–112)	97 (77–118)	**<0.001**
Total protein (g)	86 (72–102)	89 (74–103)	0.234	83 (70–101)	89 (75–105)	**0.001**
Alcohol (g)	6 (2 – 13)	8 (2 – 15)	0.141	6 (2 – 14)	5 (1 – 12)	**0.036**
Fibre (g)	28 (23–36)	29 (23–35)	0.820	27 (22–35)	30 (24–36)	**<0.001**
Vegetables (g)	135 (79–214)	149 (88–210)	0.600	131 (77–202)	149 (83–231)	0.080
Fruit (g)	209 (102–256)	174 (91–252)	0.127	219 (105–259)	193 (96–245)	**0.043**
Total grain products	252 (184–330)	250 (170–322)	0.521	244 (177–310)	267 (195–351)	**<0.001**
Whole grain products (g)	140 (90–194)	133 (74–198)	0.580	131 (86–188)	146 (96–202)	**0.027**
Refined grain products (g)	108 (70–148)	110 (73–147)	0.927	104 (67–142)	114 (76–162)	**0.007**
Legumes (g)	17 (6–43)	17 (5–34)	0.316	17 (5–43)	18 (7–35)	0.226
Nuts (g)	13 (4–27)	11 (6–27)	0.938	12 (4–26)	13 (6–28)	**0.032**
Dairy (g)	258 (130–429)	256 (116–442)	0.896	254 (132–411)	268 (126–459)	0.310
Fish (g)	15 (7–17)	11 (4–17)	0.070	15 (5–17)	12 (5–17)	0.410
Tea (g)	96 (0–337)	130 (10–340)	0.109	80 (0–337)	121 (7–340)	**0.015**
Fats and oils (g)	23 (11–35)	20 (12–34)	0.809	22 (10–35)	23 (12–38)	0.167
Meat (g)	66 (32–105)	77 (43–111)	0.088	67 (32–105)	66 (33–106)	0.793
Red meat (g)	37 (15–60)	43 (19–63)	0.213	37 (17–61)	37 (15–59)	0.655
Processed meat (g)	24 (9–44)	30 (11–53)	0.075	24 (9–44)	25 (10–47)	0.573
Sweetened beverages and fruit juices (g)	52 (14–152)	116 (18–223)	**0.001**	52 (11–157)	64 (17–171)	0.083
Alcoholic drinks (g)	110 (35–225)	143 (44–248)	0.108	125 (38–239)	98 (34–219)	0.069
Unhealthy choices (g)	147 (106–205)	172 (126–210)	**0.005**	144 (99–202)	160 (120–211)	**0.001**
Women (n=1095)	**n=901**	**n=194**		**n=366**	**n=729**	
Energy (kcal)	1901 (1582–2266)	1841 (1564–2295)	0.441	1861 (1540–2234)	1905 (1592–2295)	0.086
Total carbohydrates (g)	211 (170–251)	202 (163–251)	0.307	204 (168–246)	211 (170–254)	0.090
Total fat (g)	75 (59–93)	76 (58–94)	0.963	75 (57–91)	77 (59–94)	0.087
Total protein (g)	71 (58–84)	67 (53–84)	0.104	69 (56–82)	70 (57–85)	0.117
Alcohol (g)	3 (1 – 8)	2 (0–8)	0.260	3 (1–9)	3 (1–8)	0.291
Fibre (g)	24 (20–30)	23 (18–30)	0.242	24 (19–29)	24 (19–31)	0.153
Vegetables (g)	185 (117–270)	201 (124–293)	0.165	181 (118–267)	192 (116–276)	0.501
Fruit (g)	224 (130–256)	219 (112–255)	0.210	223 (122–246)	224 (130–282)	0.149
Total grain products	173 (118–238)	158 (101–226)	0.076	171 (119–236)	171 (113–233)	0.648
Whole grain products (g)	86 (43–124)	70 (38–120)	**0.035**	88 (43–123)	80 (41–123)	0.430
Refined grain products (g)	84 (54–118)	75 (45–116)	0.174	84 (53–118)	81 (51–116)	0.778
Legumes (g)	17 (5–35)	17 (5–35)	0.950	17 (5–35)	17 (5–35)	0.322
Nuts (g)	12 (4–24)	11 (3–24)	0.672	12 (4–24)	12 (4–24)	0.875
Dairy (g)	193 (103–334)	174 (51–312)	0.067	200 (102–340)	180 (89–328)	0.298
Fish (g)	12 (4–17)	12 (5–17)	0.420	15 (5–17)	11 (4–17)	0.635
Tea (g)	291 (72–510)	337 (49–510)	0.699	257 (33–453)	305 (87–513)	**0.020**
Fats and oils (g)	14 (7–23)	13 (7–24)	0.677	14 (7–24)	14 (7–23)	0.768
Meat (g)	45 (7–82)	39 (12–81)	0.734	46 (11–84)	42 (6–80)	0.200
Red meat (g)	27 (4–52)	21 (7–54)	0.565	28 (7–55)	24 (4–50)	0.118
Processed meat (g)	13 (1–29)	12 (2–27)	0.974	13 (2–27)	13 (1–29)	0.513

Continued

Table 4 Continued

	No UAC	UAC	P value*	No LAC	LAC	P value*
Sweetened beverages and fruit juices (g)	25 (2–78)	25 (2–79)	0.535	22 (0–72)	25 (5–81)	0.092
Alcoholic drinks (g)	46 (11–115)	34 (5–109)	0.186	53 (11–122)	39 (10–110)	0.157
Unhealthy choices (g)	115 (78–165)	119 (84–168)	0.371	108 (76–156)	122 (82–171)	**0.002**

Data are presented as median (25th–75th percentile).
*P values were obtained with a Mann-Whitney U test; statistical significance (p<0.05) is indicated in bold.
LAC, lower abdominal complaints; UAC, upper abdominal complaints.

for UAC and LAC, and for men and women. Most associations were observed for LAC in men. Differences between runners with and without AC that were most consistently present were a higher intake of fat, tea and unhealthy choices for runners with AC.

The high prevalence rate of AC in the current study confirms earlier observations, although prevalence rates of AC are highly different between studies because of different methodologies, the use of different definitions for exercise-related AC and the different types of events and athletes studied. In earlier studies among distance runners, prevalence rates of 30%–90% have been reported.[1] The higher prevalence among women than men is also in line with earlier observations,[21–24] as well as the higher prevalence of LAC than UAC.[24] The higher prevalence in women could be explained by ovarian hormones known to modulate gastrointestinal function.[25] The higher prevalence of LAC compared with UAC could be explained by the mechanical bouncing during running, which affect the lower gastrointestinal tract more than the upper gastrointestinal tract.

Quite a few studies on the prevalence of AC have been published. However, the perceived impact of AC is less often reported. In this study, we also evaluated this impact as well as personal experiences with nutrition and AC. About one-third of runners with AC indicated that these complaints sometimes or often/always negatively affected their running training or running in competitions. Although this is a subjective finding, this indicates that AC have a substantial impact on running. Most runners recognised that nutrition could provoke the occurrence of AC. An observation that shares some similarities with dietary triggers reported by IBS patients.[10] Eating before or during exercise was often reported to increase AC; drinking before or during exercise was less often reported to be related. Around 40% of the runners reported taking measures to reduce AC, for example, not eating (too much) just before running, avoiding specific foods or drinks and defecating before running. However, no clear dominant measure was reported and this seems to be very personal. Note that we only asked runners with AC whether they take measures to reduce AC. It could be that runners without AC take measures as well, which can totally prevent AC, and that prevalence rates of AC would be higher and AC would be experienced as more severe if runners do not take measures at all.

An important aim of this study was to investigate the association of AC with potential risk factors, with a particular focus on nutritional factors in the habitual diet. We observed positive associations between AC and training intensity and the running distance covered per week (the latter in women with LAC only), which seems likely to be explained by the higher running load and increased exercise stress. Exercise stress is both via circulatory-gastrointestinal and neuroendocrine-gastrointestinal changes linked to AC.[5] The redistribution of blood flow to working muscles and the peripheral circulation reduces splanchnic perfusion and can induce local ischaemia affecting the integrity of the gastrointestinal tract, while an increased sympathetic activation during exercise reduces overall gastrointestinal functional capacity.[5]

Furthermore, we observed negative associations between AC and age and running career (the latter in women with UAC only). Fewer AC in older runners could be explained by physical conditioning to withstand the effects of exercise on the gastrointestinal tract,[26] or simply said they could have learnt to deal with AC. At the same time, runners who experience AC when they start to run could have quit running before they were able to build up a long running career, explaining the negative association with running years.

Specific nutrients, foods or drinks are known to induce AC when consumed shortly before or during exercise, such as fibre, fat, protein and beverages with high osmolalities.[1 8] We, however, investigated the association of AC with the habitual diet, and not the effect of specific foods consumed before or during running. We observed a few associations between AC and the intake of certain nutrients and food groups. More associations, or differences in intake between runners with and without AC, were observed for LAC compared with UAC, particularly in males. This could be related to the fact that LAC were much more prevalent than UAC, but also to the fact that the habitual diet has likely more impact on (bouncing induced) LAC such as bloating, flatulence, urge to defecate and diarrhoea than typical UAC such as nausea/vomiting and reflux. Remarkably, more associations were observed for men, while complaints were more prevalent and perceived as more severe in women. Typically, men with LAC had a higher intake of energy and all macronutrients, including fibre and food groups such as grain products, nuts, tea and unhealthy choices, while fruit intake was lower than in men without LAC. These higher intakes could be a reflection of a generally larger food consumption, as overall energy intake was also significantly higher. However, body weight was not different between men with and without LAC, but men with LAC were younger and ran at a higher intensity than men without LAC and may therefore have a higher energy expenditure, and hence a higher energy intake to obtain a good energy balance. Food consumption was also higher in men compared with women. So it could be speculated that the amount of food consumed could explain some of our observed associations.

A few differences in intake between runners with and without AC were more consistently present, thus in men as well as in women, and/or for AUC as well as for LAC. This was the case for a higher intake of fat, tea and unhealthy choices in runners with AC than in those without AC. The higher fat intake and higher intake of unhealthy choices, which includes for example cakes, cookies, sweets and snacks, and also the reported lower fruit intake in men with LAC, could be a reflection of a slightly lower overall diet quality. A low diet quality could be linked to a higher occurrence of complaints such as reflux, bloating and flatulence. This observation is also seen in patients with AC in rest, such as those with IBS.[27] However, IBS symptoms are generally accompanied with a low intake of fibre and grain products, which was not the case in our population. Finally, tea consumption was higher in runners with LAC. Tea consumption is said to be laxative, at least for some kinds of tea, and higher tea consumption has been linked to symptoms of IBS.[28]

In general, the habitual diet can have an impact on gastrointestinal physiology. For example, dietary factors can delay gastric emptying (eg, fat) and either increase or decrease gut transit time (eg, fibre, laxatives), which could impact the experience of AC during exercise, particularly when food is consumed relatively close to exercise. In addition, diet is known to alter gut microbiota composition (eg, fibre, unhealthy foods), which can be beneficial but may also induce AC. Finally, increased fermentation on consumption of specific foods could potentially also induce AC during running.

Potential practical implications

Although we observed some associations with habitual dietary intake, the nature and design of our study limit drawing conclusion about causality and formulation of practical recommendations. We can imagine that in runners sensitive to dietary triggers, to some extent similar to what is seen in IBS patients, specific dietary strategies such as, for example, following a diet low in fermentable oligosaccharides, disaccharides, monosaccharides and polyols,[29] could be of value. But this warrants further research on the impact of dietary habits on AC to develop dietary guidelines and advice aimed at preventing or managing exercise-related AC. In addition, avoiding specific foods or too much food intake closely before running, proper hydration before and during running, and defecating before running are smart strategies to reduce exercise-related AC and were indeed reported as measures to deal with AC in our study population.

Strengths and limitations

Our study consisted of a fairly large population of 1993 runners, covering a broad range in age, running load and running level. Although the running characteristics (mostly intermediate level, running on average three times a week covering 30 km, a long running career) indicate a more committed recreational running population, which likely reflects our recruitment strategy via running events. As AC are related to factors such as running load and running career, this could explain differences in prevalence rates with other study populations,[1] either lower or higher. A clear strength of our study is the availability of comprehensive dietary intake data of the habitual diet.

Due to the nature of the study, a limitation is the self-reporting method of data collection. Assessment of dietary intake using an FFQ is prone to several types of error such as recall bias or the tendency to provide socially desirable answers.[30] Also, an FFQ is not the best method to assess absolute dietary intake. Moreover, nutrient intake from supplements could not be assessed. However, an FFQ is a reliable method to rank participants to their intake levels,[16 17] and in epidemiologic studies on associations of average daily dietary intake with diseases or complaints, such as exercise-related AC, the ranking of participants according to their intake levels is more relevant than absolute levels of intake. Indeed, our study identified some associations between AC and nutritional factors, such as fat intake and consumption of tea and unhealthy choices. Finally, one should be aware that data collection took place during the COVID-19 pandemic, and studies have shown that the lockdown due to this pandemic resulted in changes in dietary intake and physical activity in many people,[31 32] which could have influenced our results.

CONCLUSION

In this population of runners, exercise-related AC were quite prevalent. The majority of runners (57%) reported having AC during and/or shortly after running, and in about one-third of these runners AC negatively affected their running. LAC were more common (56%) than UAC (15%), and all symptoms occurred more often in women than men. Younger age and higher training intensity were associated with AC, as well as intake of certain nutrients and food groups in the habitual diet, of which a higher intake of fat, tea and unhealthy choices were most notable. In men only, LAC were associated with a higher intake of energy and food consumption, including a higher intake of grain products, but with lower fruit consumption. These results warrant further research on the impact of dietary habits on AC to develop dietary guidelines aimed at preventing or managing exercise-related AC.

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Contributors All authors were involved in the design of the study. AMB analysed the data and prepared tables and figures. AMB, BJMW and MM interpreted the results. AMB drafted the manuscript. RT, JZ, BJMW and MM critically reviewed it. All authors have read and approved the final manuscript. MM is the study guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. The Medical Ethical Review Commission from Wageningen University & Research assessed the study protocol and concluded that it did not fall within the scope of the Dutch Medical Research Involving Human Subjects Act (WMO), and formal medical ethical approval was not required. This study was, however, conducted following the ethical principles contained in the current revision of the Declaration of Helsinki. Participants gave informed consent to participate in the study before taking part.

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