

# Influence of regular exercise on gastric emptying in healthy men: a pilot study

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**Functional gastrointestinal disorders (FGIDs), including functional dyspepsia (FD), are common chronic disorders even in the younger population. Physical activity is advocated for patients with FGIDs, although the evidence is insufficient. We investigated the association between the intensity of regular exercise and gastric emptying to determine the effect of physical activity on dyspeptic symptoms. Thirty healthy individuals were selected and divided into three groups (low, moderate, and high) using the index of total exercise intensity in a week. Gastric emptying was evaluated by the <sup>13</sup>C-acetate breath test. Gastroesophageal reflux symptoms, dyspeptic symptoms, stool forms, scores of anxiety and depression, and scores of sleep quality were also compared. Baseline scores of gastroesophageal reflux symptoms, anxiety, depression, and sleep quality were not different among the three groups. Gastric emptying was significantly faster in low-intensity exercise group than the moderate-intensity exercise group. Although the presence of loose stool and alcohol consumption were also associated with the intensity of regular exercise, these variables were not confounders. In conclusion, the intensity of regular exercise was independently associated with gastric emptying in healthy individuals. These baseline data would be useful for consideration of an optimal exercise intervention for the treatment of FD.**

**Key Words:** exercise, gastric emptying, functional dyspepsia, irritable bowel syndrome, <sup>13</sup>C-acetate breath test

Functional gastrointestinal disorders (FGIDs), especially functional dyspepsia (FD) and irritable bowel syndrome (IBS), are common chronic disorders that impaired health-related quality of life. Physical activity is advocated for patients with IBS, although the evidence is insufficient. Physical activities have been reported to improve gas transit and abdominal distension in healthy subjects<sup>(1)</sup> and in patients with chronic constipation.<sup>(2)</sup> A small randomized controlled trial showed that increased physical activity significantly improves the symptoms of IBS.<sup>(3)</sup> On the other hand, the influences of physical activities on dyspeptic symptoms have not been elucidated.

Although the pathogenesis of FD is not completely understood, gastric dysmotilities, including abnormal (accelerated or delayed) gastric emptying and impaired gastric accommodation, should play some roles. Delayed gastric emptying is reported to be associated with nausea/emesis and postprandial fullness.<sup>(4)</sup> Accelerated gastric emptying also causes gastroparetic symptoms.<sup>(5,6)</sup> To estimate the effects of physical activity on dyspeptic symptoms, it would be worth assessing the association between gastric motility and regular physical activity. A meta-analysis of previous reports suggests that exercise intensity influences gastric emptying during and after acute exercise.<sup>(7)</sup> However, the influence of regular exercise habit on gastric emptying has not been

evaluated. Therefore, we investigated the association between the intensity of regular exercise and gastric emptying in healthy individuals.

## Materials and Methods

**Participants.** The protocol for this study was approved by the ethics committee of the Keio University School of Medicine (No. 20120251). Thirty healthy medical students were recruited at Keio University School of Medicine. They were classified into three groups, such as the low-intensity exercise group, moderate-intensity exercise group, and high-intensity exercise group, with each group containing 10 participants. Written consent was obtained from all participants. Liquid gastric emptying was measured using the <sup>13</sup>C-acetate breath test.<sup>(8)</sup> The intensity of exercise during the week before the test was assessed. In addition, questionnaires on age, height, weight, smoking and alcohol drinking habits, the Rome III criteria of FD<sup>(9)</sup> and IBS,<sup>(10)</sup> and the frequency of passing hard stool or loose stool were provided. Using the Bristol stool form scale,<sup>(10)</sup> the presence of hard stool was defined as hard or lumpy stools at least 25% of the time, while the presence of loose stool was defined as loose or watery stools at least 25% of the time. We also asked to answer the following well-validated self-report questionnaires: the Pittsburgh Sleep Quality Index (PSQI),<sup>(11)</sup> the Gastroesophageal Reflux Disease Questionnaire (GerdQ),<sup>(12,13)</sup> and the Hospital Anxiety and Depression Scale (HADS).<sup>(14)</sup>

**<sup>13</sup>C-acetate breath test.** Participants were asked to fast for 8 h before testing. A test diet consisting of <sup>13</sup>C-acetate (100 mg) mixed into a liquid diet (Racol<sup>®</sup>, Otsuka, Japan), providing 200 kcal/200 ml, was administered to the participants. They exhaled air into a breath sampling bag at 11 points: prior to diet (0 min) and after 5, 10, 15, 20, 30, 40, 50, 60, 75, and 90 min. The <sup>13</sup>CO<sub>2</sub> value (‰) in the breath was measured with an infrared spectrophotometer (POCone<sup>®</sup>, Ostuka, Japan). The peak time of <sup>13</sup>CO<sub>2</sub> excretion (T<sub>max</sub>) was measured. Gastric half-emptying time (T<sub>1/2</sub>) was estimated using exponential power model for curve fitting.

**Evaluation of the intensity of regular exercise.** Exercise energy expenditure was estimated using standard metabolic equivalent values (METs).<sup>(15)</sup> Normal walking is equivalent to 3 METs. The index of total exercise intensity (Ex) was expressed by the following formula.

Amount of exercise (Ex) = Intensity of physical activities (METs) × Duration of exercise (h)

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**Statistical analysis.** The participants were divided into three groups based on the intensity of regular exercise. The differences of the characteristics among the three groups were compared using Pearson's chi-square test for categorical variables and Kruskal-Wallis test for continuous variables. The differences of the  $T_{\max}$  and  $T_{1/2}$  values between two groups were compared using Mann-Whitney  $U$  test. Statistical analyses were performed using IBM SPSS Statistics 22 (IBM Corporation, Armonk, NY). The data are expressed as means  $\pm$  SD. Two-sided  $p$  values  $<0.05$  were considered statistically significant.

## Results

Thirty participants were divided equally into three groups, such as the low-intensity exercise group ( $<21$  Ex/week), moderate-intensity exercise group (21–60 Ex/week), and high-intensity exercise group ( $>60$  Ex/week). According to the Japanese Official Physical Activity Guidelines for Health Promotion in 2013 published by the Ministry of Health, Labour and Welfare in Japan, at least 23 Ex/week of regular exercise was recommended for health promotion. Characteristics of participants in the three groups were shown in Table 1. The frequency of alcohol drinking was significantly higher in the high-intensity exercise group than in the other groups. One participant who met the Rome III criteria of FD was included in the high-intensity exercise group. One participant who met the Rome III criteria of diarrhea-type IBS was included in the low-intensity exercise group. Loose stool was more frequently observed in the low-intensity exercise group. Nobody met the criteria of the other types of IBS. The average scores of GerdQ, HADS, and PSQI were not different among the three groups.

The average  $T_{\max}$  levels were significantly higher in the moderate-intensity exercise group than in the low-intensity exercise group (Fig. 1). The average  $T_{1/2}$  levels were also the highest in the

moderate-intensity group. These results showed that gastric emptying was delayed in the moderate-intensity exercise group as compared with that in the low- or high-intensity group. Regarding the difference of alcohol consumption among the three groups, the association between  $T_{\max}$  or  $T_{1/2}$  and alcohol consumption was analyzed (Table 2). We confirmed that the difference of alcohol consumption did not affect  $T_{\max}$  or  $T_{1/2}$ . In addition,  $T_{\max}$  or  $T_{1/2}$  was not associated with the presence of loose stool (Table 3). These data showed that gastric emptying was independently associated with the intensity of regular exercise in healthy individuals.

## Discussion

The previous reports suggest that gastric emptying appears to be accelerated during low-intensity exercise, and delayed during high-intensity exercise.<sup>(7)</sup> The present study showed that the intensity of regular exercise also affects gastric emptying in resting conditions. Since there were no differences of age, gender, mental health conditions, and sleep quality among the three exercise-intensity groups, the intensity of regular exercise would be independently associated with gastric emptying.

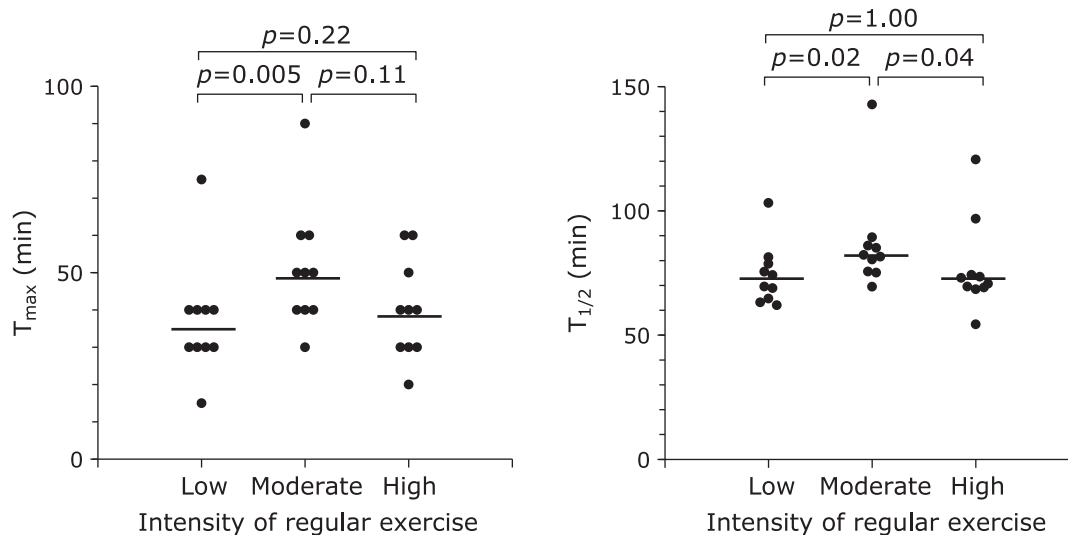
According to our results, gastric emptying was faster in the low-intensity exercise group than in the moderate-intensity exercise group. This suggests that dyspeptic symptoms, which would be caused by accelerated gastric emptying, might be improved by the intervention of moderate-intensity regular exercise. In the low-intensity group, loose stool was more frequently observed than in the other groups. It is well-known that accelerated gastric emptying often causes diarrhea.<sup>(16)</sup> Lawal *et al.*<sup>(17)</sup> reported that 70% of patients with accelerated gastric emptying had diarrhea. Therefore, a possible reason for the decreased frequency of loose stool in moderate-intensity exercise groups would be the improvement of accelerated gastric emptying.

According to the data of  $T_{1/2}$ , gastric emptying was also faster

**Table 1.** Differences of characteristics depending on the intensity of exercise

	Low ( $<21$ Ex/week) ( $n = 10$ )	Moderate (21–60 Ex/week) ( $n = 10$ )	High ( $>60$ Ex/week) ( $n = 10$ )	$p$ value
Age (y) (Mean $\pm$ SD)	20.9 $\pm$ 0.9	20.3 $\pm$ 2.2	20.3 $\pm$ 1.2	0.30 <sup>†</sup>
Current smoker	0 (0%)	0 (0%)	0 (0%)	0.35 <sup>†</sup>
Alcohol consumption				0.002 <sup>‡</sup>
none	2 (20%)	5 (50%)	3 (30%)	
less than 4 times a month	8 (80%)	0 (0%)	2 (20%)	
1–2 days a week	0 (0%)	3 (30%)	5 (50%)	
3–4 days a week	0 (0%)	2 (20%)	0 (0%)	
5–7 days a week	0 (0%)	0 (0%)	0 (0%)	
BMI (kg/m <sup>2</sup> ) (Mean $\pm$ SD)	20.6 $\pm$ 1.1	22.2 $\pm$ 2.1	22.0 $\pm$ 3.5	0.14 <sup>†</sup>
GerdQ (Mean $\pm$ SD)	6.3 $\pm$ 0.7	6.2 $\pm$ 0.6	6.1 $\pm$ 0.6	0.84 <sup>†</sup>
Functional dyspepsia	0 (0%)	0 (0%)	1 (10%)	0.36 <sup>†</sup>
Postprandial fullness	0 (0%)	0 (0%)	2 (20%)	0.12 <sup>†</sup>
Early satiation	0 (0%)	0 (0%)	0 (0%)	NA <sup>‡</sup>
Epigastric pain	0 (0%)	0 (0%)	0 (0%)	NA <sup>‡</sup>
Epigastric burning	1 (10%)	0 (0%)	0 (0%)	0.36 <sup>†</sup>
Irritable bowel syndrome	1 (10%)	0 (0%)	0 (0%)	0.36 <sup>†</sup>
Hard stool	0 (0%)	1 (10%)	1 (10%)	0.59 <sup>†</sup>
Loose stool	4 (40%)	0 (0%)	1 (10%)	0.04 <sup>†</sup>
HADS-A (Mean $\pm$ SD)	3.0 $\pm$ 2.4	5.1 $\pm$ 3.4	3.5 $\pm$ 3.3	0.28 <sup>†</sup>
HADS-D (Mean $\pm$ SD)	3.5 $\pm$ 2.8	4.6 $\pm$ 3.9	4.3 $\pm$ 3.0	0.80 <sup>†</sup>
PSQI (Mean $\pm$ SD)	4.5 $\pm$ 2.4	4.0 $\pm$ 2.1	4.7 $\pm$ 1.8	0.81 <sup>†</sup>

Bold values indicate significant differences ( $p < 0.05$ ); BMI, body mass index; GerdQ, gastroesophageal reflux disease questionnaire; HADS-A, hospital anxiety and depression scale-anxiety; HADS-D, hospital anxiety and depression scale-depression; PSQI, the Pittsburgh sleep quality index; NA, not analyzed; <sup>†</sup>Kruskal-Wallis test; <sup>‡</sup>Pearson's  $\chi^2$  test.



**Fig. 1.** Dot plots are shown to compare the gastric emptying among individuals with low, moderate, and high intensity of regular exercise ( $n = 10$  in each group). Gastric emptying was evaluated by the  $^{13}\text{C}$ -acetate breath test. The average levels of  $T_{\max}$  (left panel) and  $T_{1/2}$  (right panel) between two groups were compared using Mann-Whitney  $U$  test.

**Table 2.** Association between alcohol consumption and gastric emptying

Frequency of alcohol consumption	$T_{\max}$ (min)	$p$ value <sup>†</sup>	$T_{1/2}$ (min)	$p$ value <sup>†</sup>
None ( $n = 10$ )	$47.0 \pm 18.9$	0.17	$88.0 \pm 24.9$	0.44
<4 days/month ( $n = 10$ )	$36.0 \pm 16.3$		$73.6 \pm 13.3$	
1–2 days/week ( $n = 8$ )	$42.5 \pm 10.4$		$76.0 \pm 10.1$	
3–4 days/week ( $n = 2$ )	$55.0 \pm 7.1$		$77.8 \pm 3.8$	

<sup>†</sup>Kruskal-Wallis test.

**Table 3.** Association between the frequency of loose stool and gastric emptying

Loose stool	$T_{\max}$ (min)	$p$ value <sup>†</sup>	$T_{1/2}$ (min)	$p$ value <sup>†</sup>
Absent	$44.4 \pm 16.8$	0.14	$81.1 \pm 18.7$	0.14
Present	$34.0 \pm 5.4$		$70.3 \pm 6.7$	

<sup>†</sup>Mann-Whitney  $U$  test.

in the high-intensity exercise group than in the moderate-intensity exercise group. In endurance athletes, gastrointestinal symptoms such as nausea, vomiting, bloating, urge to defecate, and diarrhea, are well documented.<sup>(18,19)</sup> During high-intensity exercise, gastric emptying is thought to be delayed mainly through the over-activation of the sympathetic nervous system. On the other hand, exercise training may reduce resting blood pressure and decrease the activity of sympathetic nerves,<sup>(20)</sup> suggesting that high-intensity exercise may accelerate gastric emptying. Large fluctuations in gastric emptying during rest and high-intensity exercise might be a possible cause of dyspeptic symptoms in athletes.

A clear limitation of this pilot study is its small sample size. Multivariable analysis was unavailable due to the small sample size. Participants are all healthy young men, which limits generalizability. The other limitation is that we did not evaluate solid gastric emptying. Although both liquid and solid gastric emptying were shown to be associated with dyspeptic symptoms,<sup>(21)</sup> underlying mechanisms of impaired gastric emptying of solid and liquid meal would be different each other. Thus, further validation of our results is required in the general population as well as the population with dyspeptic symptoms.

In conclusion, the intensity of regular exercise was independently associated with gastric emptying. Gastric emptying was faster in the low- and high-intensity exercise groups than in the moderate-intensity exercise group. This suggests that accelerated gastric emptying might cause dyspeptic symptoms in individuals performing regular low or high-intensity exercise. The moderate-intensity exercise intervention might improve the dyspeptic symptoms caused by accelerated gastric emptying. Thus, the regular exercise intensity should be taken into account when considering the underlying mechanisms of dyspeptic symptoms. Further investigations are required to understand the association between regular exercise and gastric dysmotility.

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## Conflict of Interest

During the last 2 years, Author HS received scholarship funds for the research from Astellas Pharm Inc., Astra-Zeneca K.K., Otsuka Pharmaceutical Co., Ltd., Takeda Pharmaceutical Co., Ltd. and Zeria Pharmaceutical Co., Ltd., and received service honoraria from Astellas Pharm Inc., Astra-Zeneca K.K., Otsuka

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