J Korean Med Sci 2001; 16: 183-7
ISSN 1011-8934

Effect of Graded Running on Esophageal Motility and Gastroesophageal Reflux in Fed Volunteers

The effects of different grades of running on esophageal motility and gastroesophageal reflux in the fed state were evaluated. We studied healthy volunteers (male: 12, age: 27±5 yr) using ambulatory esophageal manometry, pH catheter and portable digital data recorder. Each exercise was performed 30 min after meal, with 20 min of rest between exercises. Subjects exercised on a treadmill at 40% and 70% maximal heart rate. The number of gastroesophageal reflux episodes, the duration of esophageal acid exposure and percent time pH below 4 were significantly (p<0.01) increased during exercise at 70% maximal heart rate. The frequency of contraction (contraction/min) (p<0.05), frequency of repetition (p<0.01), percent of simultaneous contraction (p<0.01), percent of above 100 mmHg amplitude (p<0.05), and frequency of 2-peak contraction (p<0.01) were significantly increased during exercise at 70% maximal heart rate. However, median amplitude and median duration showed no significant changes between each exercise session. Postprandial running exercises induce gastroesophageal reflux, which correlates with exercise intensity. These effects are mediated by disorganized esophageal motility.

Key Words: *Exercise; Gastroesophageal Reflux; Ambulatory Esophageal Manometry*

Suck Chei Choi, Kyoung Hoon Yoo, Tae Hyeon Kim, Sun Ho Kim*, Suck Jun Choi*, Yong-Ho Nah

Department of Gastroenterology, Wonkwang University School of Medicine, Wonkwang Health Science College*, Iksan, Korea

Received: 28 July 2000
Accepted: 6 November 2000

Address for correspondence
Yong-Ho Nah, M.D.
Department of Internal Medicine, Division of Gastroenterology, Wonkwang University Hospital, 344-2 Shinyong-dong, Iksan 570-180, Korea
Tel: +82.63-850-1067, Fax: +82.63-854-7675
E-mail: bohru@wmc.wonkwang.ac.kr

*This paper was supported by grants from the SUNGSAN Research Foundation in Wonkwang University (1999).

INTRODUCTION

In recent years, the public has become increasingly aware of the importance of regular aerobic exercise in promoting general health status. However exercise has been known to contribute to the development of heartburn, belching, regurgitation, and chest pain. These symptoms may manifest as esophageal dysfunction and gastroesophageal reflux (1-3). Exercise also has been believed to have an influence on the esophageal contraction and gastroesophageal reflux, which are used to determine the intensity and the degree of exercise in both trained athletes and nontrained subjects (4-5). Even though people practice moderate to severe exercise after eating in ordinary lives, the effects of graded running exercise on gastroesophageal reflux after eating has not yet been clearly demonstrated. The purpose of this investigation is to study the effect of graded running on esophageal motility and gastroesophageal reflux after eating in healthy volunteers.

MATERIALS AND METHODS

Subjects

Twelve male subjects (age: 27±5) participated in this study. Their life styles had been sedentary with daily routine activity at work as well as at home. They were all healthy nonsmokers without any gastrointestinal complaints. The Human Investigations Committee of Wonkwang University Hospital approved the protocol and each subject gave on informed consent.

Motility recording

Esophageal motility was measured by a thin (2.8 mm OD, 225 cm length) and flexible probe (Sentron, Netherlands) with three-pressure transducer spaced 5 cm apart. The probe was passed transnasally. The distal sensor was positioned at the upper margin of lower esophageal sphincter (LES), which was located beforehand by a

standard pull through technique. The probe was connected to a solid-state datalogger (Microdigitrapper 4Mb, Synetics Medical, Sweden). It was carried in a shoulder bag, allowing continuous recording while not interfering with the physical activity of the subjects. At the end of the study an analog recording was connected to a computer for the analysis of the data.

pH recording

Intraesophageal pH monitoring was used to evaluate the gastroesophageal reflux. A monocrystant antimony pH electrode (2.1 mm, OD, Synetics Medical) was calibrated with pH 1.0 and 7.0 buffers and then passed transnasally and positioned 5 cm above the upper margin of the LES with esophageal pressure transducer, which was determined manometrically. Then, an ambulatory recorder (Microdigitrapper 4Mb, Synetics Medical) was used to obtain a continuous pH monitoring.

Exercise testing with protocol

Each subject was fed with rice-rolls (8 pieces, 660 cal) and water before exercise, and was then seated on chairs for 30 min to obtain baseline information after being fitted with the ambulatory manometry and pH probes. Maximal heart rate (MHR) of the subjects was obtained while running on a treadmill (Marquette Case 15 Electronic INC) with increasing speed and elevation until reaching the calculated target heart rate. Each subject initially exercised for 30 min at walking, 30 min at 40% of maximal heart rate and 30 min at 70% of maximal heart rate. The exercise sessions were separated by 20 min rest periods (Fig. 1) Meanwhile, in order to preserve a constant volume of gastric content, meals (4 pieces, 330 cal) were provided at each resting period. All studies started with 30 min rest periods. The subjects assumed a sitting position during all rest periods.

Fig. 1. The experimental design (MHR, maximal heart rate).

Analysis

Esophageal manometry and pH records were analyzed by a computer software program (Polygram, Gastrosoft, Sweden), using the data obtained during the 30 min exercise session and were then compared with the data obtained 30 min rest period. The gastroesophageal reflux was considered present when pH dropped below 4. Results were expressed as means±SD. One-way ANOVA and $p<0.05$ were selected to make statistic comparisons between various sessions.

RESULTS

The subjects did not experience any gastrointestinal symptoms during the exercise sessions in the fed state. The mean amplitude of esophageal contraction at rest was 32.9±11.6 mmHg. There were no significant amplitude changes of esophageal contraction among three experimental conditions including walking with the mean of 41±19.1 mmHg, 40% MHR with the mean of 39.3 ±14.6, and 70% MHR with the mean of 41.3±17.7 mmHg. The median duration of esophageal contraction was not significantly different in all experimental groups with the average of 1.87±0.57 sec at base, 2.21±0.65 sec at walking, 2.02±0.73 sec at 40% MHR, and 1.9± 0.69 sec at 70% MHR. However, the frequency of contraction ($p<0.05$), frequency of repetition ($p<0.01$), percent of simultaneous contraction ($p<0.01$), percent of above 100 mmHg amplitude ($p<0.05$) and frequency of 2 peaks contraction ($p<0.01$) were significantly increased

Table 1. Effect of graded running on esophageal motility

	Rest	Walking	40% MHR	70% MHR
Median amplitude (mmHg)	32.9±11.6	41±19.1	39.3±14.6	41.3±17.7
Median duration (sec)	1.87±0.57	2.21±0.65	2.02±0.73	1.9±0.69
Contratcion/min	1.25±0.58	1.4±0.61	1.21±0.30	1.5±0.35*
Frequency of repetition	2.82±3.4	1.7±2.5	3.3±3.3	11.7±9.4*,†
% of peristaltic contration	78.2±17.5	77.8±20.1	80.9±11.9	79.5±12.0
% of simultaneous contraction	9.63±6.06	7.57±5.5	11.17±5.7*	21.1±10.3*,†
% of amplitude >20 mmHg	78.9±10.7	82.6±12.1	88.5±5.7	84.5±6.5*
% of amplitude >100 mmHg	0.87±1.42	4.7±4.81	3.28±3.92	6.3±7.9*
% of 2 peak	1.0±1.8	1.1±2.5	2.0±4	6.0±5.07*

Values are mean±SD

* $p<0.05$ compared with rest; † $p<0.05$ compared with 40% MHR

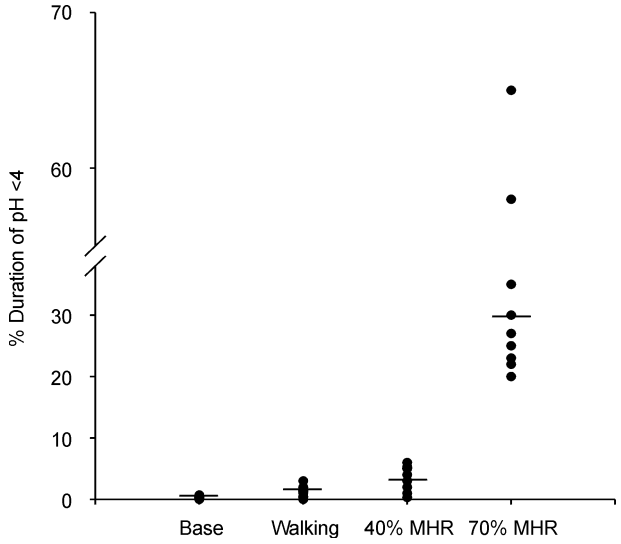

Fig. 2. Distribution of percent durations of pH <4 in each subject in each session. Horizontal lines represent the mean. The single asterisk indicates $p<0.05$ compared with base (MHR, maximal heart rate).

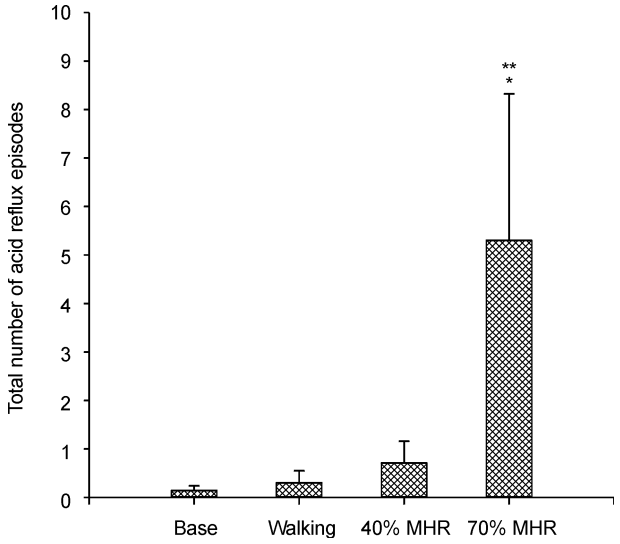

Fig. 3. The total number of acid reflux (pH <4) episodes for 12 subjects during each session. The single asterisk indicates $p<0.05$ compared with base. The double asterisk indicates $p<0.05$ compared with walking (MHR, maximal heart rate).

during exercise at 70% MHR (Table 1).

The distribution of percent durations of esophageal pH <4 in each subject was shown in Fig. 2. Mean percent duration was significantly ($p<0.01$) longer at 70% MHR exercise than at base (base; 0.16±0.28%, walking; 1.51 ±2.49%, 40% MHR; 3.34±3.49%, 70% MHR; 29.0± 26.1%). The total number of reflux episodes during each exercise increased with increasing the intensity of exercise and was significantly ($p<0.05$) increased at 70% MHR exercise compared with that at base and 40% MHR exercise (base; 0.14±0.10, walking; 0.3±0.25, 40% MHR; 0.71±0.45, 70% MHR; 5.3±3.02). These effects are illustrated in Fig. 3. As the exercise grade increased, the duration of the longest reflux episodes was increased and was significantly ($p<0.05$) longer at 70% MHR exercise than it was at base and at 40% MHR exercise (base; 0.04±0.02, walking; 0.23±0.14, 40% MHR; 0.47±0.25, 70% MHR; 3.11±1.78) in Fig. 4.

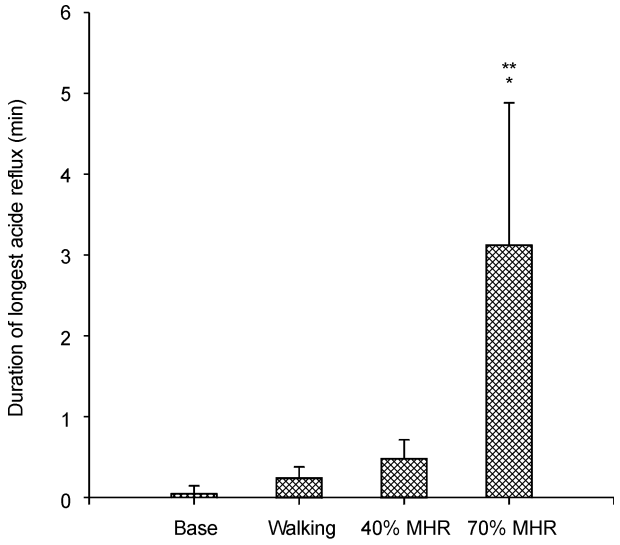

Fig. 4. The duration of longest acid reflux (pH <4) for 12 subjects during each session. The single asterisk indicates $p<0.05$ compared with base. The double asterisk indicates $p<0.05$ compared with walking (MHR, maximal heart rate).

DISCUSSION

Gastroesophageal reflux (GER) is commonly found in the general population, and has recently been demonstrated to occur more frequently during exercise than at rest. This fact is significant to the substantial number of athletes who complain of exertional upper gastrointestinal symptoms and exercise-induced chest pain. The symptoms could be cardiac but may be caused by gastrooesophageal reflux.

A permanent decrease in the mean LES pressure or transient relaxations of the LES can be lead to gastroesophageal reflux (13). Once reflux has occured, the clearance of the refluxate depends both on the esophageal motor response and the neutralization of acid by saliva (14). Although esophageal motility is believed to play an important role in prevention and clearance of gastroesophageal reflux in health and disease, in practice the interplay of motility of the esophagus and GER during exersice could, until now not be sufficiently determined.

We suggest that running immediately after eating induces gastroesophageal reflux in active healthy subjects as level of exercise intensity increases. This study showed that exercise after eating has a profound effect on gastroesophageal reflux episodes and esophageal motor activity in an exercise intensity dependent manner.

In previous studies, there has been an emphasis on the importance of the type of exercise in relation to gastroesophgeal reflux. Among them, running followed by weight exercises,has been regarded as the most likely cause of gastroesophageal reflux, especially in those in the fed state rather than those in the fasted state (6). Vigorous exercise such as running induced more gastroesophageal reflux than one with less body movement such as cycling (7). They proposed that the type of exercise was more important than its intensity with the respect to the degree of reflux induced. However, recent studies have placed an emphasis on the intensity instead of the types of exercise. In one study, a profound gastroesophageal reflux was reported at very high exercise intensity induced by a bike exercise, at 90% of VO_2 max (4).

In a previous fasting study, we found that running exercise had no effect on the relationship between the intensity of exercise and the induction of gastroesophageal reflux, including no differences at 50% and 70% maximal heart rates (8). However, it was found in this study that both the state of feeding and the intensity of exercise were crucial factors in inducing gastroesophageal reflux. We assume that gastric distension and increased abdominal pressure due to eating and increased exercise intensity may lead to an impairment of the antireflux barrier such as lower esophageal sphincter. In one study, it was shown that severe exercise produced a delayed gastric emptying induced by a dominant sympathetic effect (9), which was supposed to contribute to gastric distension.

It has been known that there is a positive correlation between LES pressure and the type of food. One study showed that individual meal component, such as fat, influences LES pressure, but it was not clear whether the postprandial increase of gastroesophageal reflux resulted from specific meal composition, meal volume, or both (10). We assumed that the food composition was one of the important factors affecting esophageal pH, which in turn influences gastroesophageal reflux. Therefore, we used carbohydrate food, rice rolls and water, which did not have any effect on esophageal pH instead of using foods, such as orange juice, corn flake, milk, and banana, that were used in other studies (6) and may effect the esophageal pH.

Even before the introduction of modern ambulatory manometrical device, there have been several studies showing a positive relationship between gastroesophageal reflux and exercise in the fed state. They reported that the reflux pattern was quantitatively greater in postprandially exercised subject than in fasting subject and that also the rate of transient LES relaxation was increased in the former (11, 12). The transient relaxation of the LES was suggested as an important mechanism in spontaneous episodes of gastroesophageal reflux in normal subjects as well as in patients (13). Also when LES and upper esophageal sphincter (UES) were measured before and after exercise, it was shown that LES pressure decreased during severe exercise without UES pressure change (1).

These studies were performed only with conventional esophageal manometry such as LES and UES pressure without other current esophageal manometry parameters such as frequency of contraction, frequency of repetition, percent of simultaneous contraction, percent of above 100 mmHg amplitude, frequency of 2-peak contraction, and pHmetry.

Using ambulatory manometry on exercise, which is similar to the one used in our study, one study reported that as intensity of exercise gradually increased there was a progressive decrease of duration, amplitude, and frequency of esophageal contraction and increase of gastroesophageal reflux (4, 5). This study showed similar results as ours that the number of gastroesophageal reflux episodes and the duration of esophageal acid exposure were significantly increased at a much higher degree of exercise on bicycle, 90% of VO_2 max, which is impractical to achieve for general population. However, our study was performed at much lower degree of exercise after eating on graded treadmill, below 70% MHR which was tolerable and practical to general population. Taken together, the data in our study indicated that intense exercise after eating significantly increased the frequency of peristaltic contraction and disorganized esophageal motility such as frequency of repetition, percent of simultaneous contraction, percent of above 100 mmHg amplitude, and frequency of 2-peak contraction as well as enhancement of gastroesophageal reflux. But the median duration and amplitude of esophageal contraction was not significantly different in all experimental conditions. The disorganized esophageal motility activity along with diminished deglutination response and drying of the mouth were common phenomena during intense exercise. These phenomena might be caused by a small amount of salivary bolus, which produced lower amplitude, and duration of contraction (15). In addition, there was esophageal ischemia possibly due to a significant decrease of visceral blood flow during exercise, which might be have resulted from the diversion of blood flow from the splanchnic viscera to the working muscle (16-18). Disorganized esophageal motility might be due, in part, to an increase in reflux-

induced secondary distal esophageal contractions. This concept is not supported by results of a study in which the esophageal motor response in a 2-min period after the onset of a reflux eposode was evaluated. Only in the supine period was a higher number of post-reflux contractions demonstrated, whereas in the upright period no significant differences were found (19).

In conclusion, although enhancement of gastroesophageal reflux during exercise can be influenced by various factors including gastric distension, and increased abdominal pressure, disorganized esophageal motility may be a major factor. The results also indicate that moderate exercise intensity may not have an effect on esophageal motility leading to gastroesophageal reflux.

REFERENCES

1. Peters O, Peters P, Clarys JP, De Meirleir K, Davis G. *Esophageal motility and exercise. Gastroenterology 1988; 94: A35.*
2. Moses FM. *The effect of exercise on the gastrointestinal tract. Sports Med 1990; 9: 159-72.*
3. Sullivan SN. *The effect of running on the gastrointestinal tract. J Clin Gastroenterol 1984; 6: 461-5.*
4. Soffer EE, Wilson J, Duethman G, Launspach J, Adrian TE. *Effect of graded exercise on esophgeal motility and gastroesophgeal reflux in nontrained subjects. Dig Dis Sci 1994; 39: 193-8.*
5. Soffer EE, Merchant RK, Duethman G, Launspach J, Gisolfi C, Adrian TE. *Effect of graded exercise on esophageal motility and gastroesophageal reflux in trained athletes. Dig Dis Sci 1993; 38: 220-4.*
6. Clark CS, Kraus BB, Sinclair J, Castell DO. *Gastroesophageal reflux induced by exercise in healthy volunteers. JAMA 1989; 261: 3599-601.*
7. Johnston P, O'Connor B, Lennon JR, Crowe J. *A comparative evaluation of bicycle exercise testing versus endoscopy plus 24 hour oesophageal pH monitoring in the diagnosis of gastro-oesophageal reflux. Gastroenterology 1987; 92: A1457.*
8. Choi SC, Nah YH, Choi SJ. *Effect of running on esophageal motility and gastroesophageal reflux. Korean J Med 1997; 53: 527-33.*
9. Hellanbrandt FA, Tepper RH. *Studies on the influence of exercise on the digestive work of the stomach. Its effect on emptying time. Am J Physiol 1934; 107: 355-63.*
10. Nebel OT, Castell DO. *Lower esophageal sphincter pressure changes after food ingestion. Gastroenterology 1972; 63: 778-83.*
11. Holloway RH, Hongo M, Berger K, McCallum RW. *Gastric distension: a mechanism for postprandial gastroesophageal reflux. Gastroenterology 1985; 89: 779-84.*
12. Dent J, Dodds WJ, Friedman RH, Sekiguchi T, Hogan WJ, Arndorfer RC, Petrie DJ. *Mechanism of gastroesophageal reflux in recumbent asymptomatic human subjects. J Clin Invest 1980; 65: 256-67.*
13. Dent J, Dodds WJ, Hogan WJ, Toouli J. *Factors that influence induction of gastroesophageal reflux in normal human subjects. Dig Dis Sci 1988; 33: 270-5.*
14. Helm JF, Dodds WJ, Pelc LR, Palmer DW, Hogan WJ, Teeter BC. *Effect of esophageal emptying and saliva on clearance of acid from the esophagus. N Engl J Med 1984; 310: 284-8.*
15. Hollis JB, Castell DO. *Effect of dry swallows and wet swallows of different volumes on esophageal peristalsis. J Appl Physiol 1975; 38: 1161-4.*
16. Clausen JP. *Effect of physical training on cardiovascular adjustment to exercise in man. Physiol Rev 1977; 57: 779-815.*
17. Qumar MI, Read AE. *Effects of exercise on mesenteric blood flow in man. Gut 1987; 28: 583-7.*
18. Rowell LB. *Human cardiovascular adjustments to exercise and thermal stress. Physiol Rev 1974; 54: 75-159.*
19. Timmer R, Breumelhof R, Nadorp JH, Smout AJ. *Oesophageal motor response to reflux is not impaired in reflux oesophagitis. Gut 1993; 34: 317-20.*