Original Article

Effect of different types of foods on gastric myoelectrical activity during simulated microgravity

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Abstract

Background and Aim: Gastric functions are altered in microgravity condition. Studies are rare on how does microgravity, or low gravity condition impairs gastric function on the intake of different types of food. Therefore, this study was taken up to investigate the effect of dry supine immersion (DSI), a well-known technique to simulate physiological effect of microgravity on the earth on gastric functions after intake of four different types of food.

Methods: Gastric electrical response of the stomach was recorded by electrogastrography (EGG) in 20 healthy males after intake of carbohydrate rich food (CHO), protein rich food (PR), mixed food (MI), and fat rich food (FR). Mean frequency (MF) of gastric electrical activity (GEA) and percentage of normogastria, bradygastria, tachygastria and arrhythmia from EGG wave were determined.

Results: MF of GEA reduced significantly from baseline supine to DSI after intake of CHO (3.55 vs. 3.19 cpm), PR (3.38 vs. 3.16 cpm), MI (3.53 vs. 3.09 cpm) and FR (3.01 vs. 2.57 cpm) foods. Normogastric wave pattern was reduced significantly during DSI from baseline supine after intake of CHO (81% vs. 72%), PR (80% vs. 73%), mixed (78.8% vs. 69.5%), and FR (70% vs. 61.5%) foods. Bradygastric and arrhythmic wave appeared during DSI.

Conclusion: This study showed that during DSI, MF of GEA, a surrogate measure of gastric motility, reduced significantly after intake of any type of food. Highest gastric slowdown being observed after consumption of FR food.

Key words: Electrogastrography, gastric electrical activity, simulated microgravity

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INTRODUCTION

The microgravity environment alters gastric function including gastric motility and gastric emptying rate.[1] The combined effects of fluid shifts, fluid loss, decreased fluid consumption, and postural changes in microgravity are reported to reduce splanchnic blood flow, decrease gastrointestinal (GI) motility, and thereby decrease absorption and availability of pharmaceutical countermeasures and nutrients.[2,3] Studies have demonstrated that adequate nutritional status is important for short duration space flight and also critical for maintaining crew health during long duration spaceflight.[4]

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Scientific study has reported that electrogastrography (EGG) amplitude and EGG responses were reduced after ingestion of solids and liquids in monkeys during space flight.[5] Most techniques such as scintigraphy, serosal electrodes, and intraluminal transducers which are used in clinical evaluation and diagnosis of GI disorders are impractical for use in space flight. EGG, is a noninvasive technique for recording gastric myoelectric activity using cutaneous electrodes. This may be a useful objective indicator of potential changes in postprandial gastric myoelectrical activity and can be used effectively during real or simulated space flight conditions. It has been reported that GI symptoms start within minutes to few hours after orbital insertion.[5] In earth-based microgravity simulation experiment, the gastric function of healthy volunteers has been evaluated during dry supine immersion (DSI) for 7 days.[6] Pei *et al*. has measured the EGG in healthy volunteers before and after a meal during

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21 days of head down tilt at −6° bed rest.[7] A significant increase in the mouth to cecum transit time has been demonstrated in ground simulations (10 days of −6° head-down bed resting)[8,9] and water immersion.[10]

No study to date is available where the effect of intake of different types of food on the gastric electrical response during exposure to short-term DSI has been examined. The aim of this study was to investigate the gastric electrical response in healthy Indian males after intake of carbohydrate rich food (CHO), protein rich food (PR), mixed food (MI) and fat rich food (FR) on exposure to 6 h of DSI, an analog to simulate the effects of microgravity on the earth, and compare it with baseline gastric electrical response recorded during supine posture after intake of test meal.

MATERIALS AND METHODS

A total of 20 healthy, adult Indian males in the age range of 24–31 years amongst trainees of the Institute were selected in this study using simple random sampling. A detailed clinical history of the participants was taken before selecting them in the study. A thorough clinical examination of the participants including ECG, resting blood pressure and heart rate, hematological, and biochemical investigation was carried out to rule out any disorders. Smokers, alcoholics, persons suffering from any GI ailments were excluded. The participants were briefed about the protocol of the study and possible consequences of DSI. Voluntary written informed consent was obtained from them. The ethical committee of the Institute approved the test protocol.

The study was a double-blinded randomized within the subject experimental study. The study protocol involved recording of gastric electrical activity (GEA) of individuals during DSI after intake of one of the four foods namely carbohydrate-rich vegetable “Pulao” (CHO - 80%, fat - 10%, and protein - 10%), PR peas “Pulao” (CHO - 60%, fat - 20% and protein - 20%), mixed balanced vegetable “Pulao” (CHO - 70%, fat - 20% and protein - 10%) and FR “Halwa” (CHO - 60%, fat - 30% and protein - 10%) in four different sessions. Each test session examined only one type of food. Food packets were obtained from the Defence Food Research laboratory (DFRL), Mysore, India. The volumes and composition of these four types of food were carefully designed by DFRL taking into account the preference, palatability and shelf life of the packets. The texture, fiber content and other physical properties of the food were kept constant across different food types in order to avoid subjects’ biasness. Each food packet contained 300 g of one of the food type. On the day of the experiment, the specific food packet was warmed in a microwave oven for 2 min at 150°C before offering it to the participant. Two sessions of the study were separated by a gap of 4 days. During each session, the volunteer underwent DSI for 6 h.

On the day of the experiment, the subject reported to the laboratory at 0830 h after 12 h overnight fast. For recording of EGG, three pre-gelled adhesive Ag/Agcl electrodes were placed on the skin surface along the external anatomical landmark of the greater curvature of the stomach. The abdominal skin surface where the electrodes were placed were placed was thoroughly cleaned to ensure good contact. Any hair on the skin overlying the stomach was shaved to improve the conduction. One electrode was placed at the midpoint on a line connecting the xiphoid and umbilicus. A second active electrode was placed 5 cm to the left of the first active electrode (up and 45°), at least 2 cm below the rib cage. A ground electrode was placed on the right costal margin along the right midclavicular line or right axillary line.

The baseline EGG data of the participant was recorded for 20 min in fasting state in supine posture using an EGG (Biopac Systems Inc., USA). After baseline recording, the subject consumed 150 g of one of the test meals along with 150 ml of water. EGG was then recorded during post meal supine for 30 min. The participant was then immersed in a dry floatation tank. After 4 h 30 min of flotation, the participant was given 150 g of remaining food. Postprandial EGG was recorded during floatation for 30 min.

DSI is one of the microgravity simulation technique used for evaluating the physiological effects of microgravity on the earth. Here, the participant floats in the water on a tarpaulin sheet within a large water tank and temperature of the water is maintained closer to mean skin temperature (34–35°C). Direct contact of the body with water was avoided by using a tarpaulin sheet thus preventing skin maceration due to prolonged exposure in water during DSI. Thermoneutral water floatation prevents peripheral vasculature to constrict or dilate, thus preventing any cardiovascular reflexes to be elicited due to central hypervolemia or hypovolemia.

The microgravity effect in DSI is simulated by a redistribution of body fluid from lower parts of the body to cephalic side due to assuming supine posture and creation of buoyancy force as a result of immersion in the water. In real microgravity condition, most of the physiological effects are attributed to this fluid shift.

After capturing EGG data, segments of the graph were selected based on the features of the graphs including the frequency, amplitude, and variations. After a careful removal of motion artefacts, selected segment of the graph was subjected to spectral analysis using Fast Fourier Transformation to derive various frequency domain parameters of the EGG. Acknowledge data analysis software of Biopac data acquisition system was used to derive the EGG data. Time domain parameters included measurement of the mean frequency (MF) and the delta frequency (DF) of GEA. The frequency bands were expressed in units of contractions per minute. The MF is the average of frequencies obtained for the duration of the EGG wave after administering any of the food types either at baseline resting supine or during DSI. The delta frequency was the averaged out rate of change of frequency of EGG over the entire period of recording under one condition. Frequency domain analysis measured the percentage of the normogastria (2.0–4.0 wave cpm), bradygastria (0.5–2.0 wave cpm), tachygastria (4.0–6.0 wave cpm) and arrhythmia.

Statistical analysis of data

Data were analyzed using statistical software Statistica 8.0 (Statsoft, Inc., USA). Data were first checked for normality by Shapiro–Wilks "W" statistic. Two factors repeated measure ANOVA was used to analyze the data. Two factors in the present study were types of foods and condition of testing. Types of foods had four levels: CHO, PR, MI, and FR. Condition of testing had two levels: Postprandial baseline supine and DSI. After significant outcome from ANOVA, the data were subjected to Tukey HSD test for *post-hoc* comparisons. P value < 0.01 was considered to be statistically significant.

RESULTS

Table 1 depicts comparison of postprandial EGG data for MF and delta frequency between baseline supine and DSI. Baseline supine EGG data were recorded for 30 min after consuming about 50% of the food and EGG data during DSI was captured for 30 min after consuming remaining 50% of the food after 4½ h of flotation. Thirty minutes of EGG data at baseline supine and DSI was analyzed for comparison. The reason for recording EGG after 4½ h of dry flotation was to examine the effect of simulated microgravity on gastric electrical response following the intake of different types of food. MF, as observed from the table, reduced significantly during DSI from baseline supine after intake of any types of food. When comparison was made between different food types, MF was recorded to be the lowest after intake of FR food both at baseline as well as during DSI. Delta frequency increased significantly during DSI from baseline state after intake of FR food only. The CHO, PR, and MI foods did not exhibit any difference in delta frequency between baseline and DSI condition.

The difference in the percentage distribution of gastric wave pattern following different food intake at baseline resting supine and during DSI has been shown in Table 2.

Figure 1a-d depicts, percentage distribution of gastric wave pattern at baseline supine and during DSI after intake of different types of food. It was observed from Figure 1a that normogastric wave reduced significantly during DSI from baseline supine after intake of any type of foods ($P < 0.001$). Percentage of normogastria was observed to be the lowest after consumption of FR food during DSI.

Figure 1b depicts the percentage distribution of bradygastric wave pattern after intake of different types of food at baseline supine state and during DSI. It was observed that the occurrence of the bradygastric wave was comparatively higher during flotation from resting state. FR food registered highest bradygastric wave during DSI as compared to three other types of food (all being significantly different at $P < 0.001$).

Figure 1c depicts the occurrence of the percentage distribution of tachygastric wave in GEA. It did not exhibit any significant difference among different food types during DSI. The occurrence of the tachygastric wave was found to be reduced significantly after intake of CHO and PR food during DSI when compared to the baseline state.

Figure 1d depicts the occurrence of the percentage distribution of arrhythmic wave in EGG. It was found to be significantly higher during DSI after intake of any type

Table 1: Effect of intake of different types of food on gastric electrical activity at baseline supine and DSI

Parameters	Mean±SD			
	CHO	PR	MI	FR
Mean frequency (cpm-cycles/min)				
Baseline	3.55±0.36	3.38±0.29$^{\#}$	3.53±0.39$^{\wedge}$	3.01±0.44$^{\#\#\#, \wedge\wedge\wedge, \$\$\$}$
DSI	3.19±0.26***	3.16±0.16***	3.09±0.35***	2.57±0.36$^{***, \#\#\#, \wedge\wedge\wedge, \$\$\$}$
Delta frequency (cpm-cycles/min)				
Baseline	0.41±0.13	0.45±0.16	0.51±0.20$^{\#}$	0.42±0.17$^{\$}$
DSI	0.45±0.17	0.41±0.13	0.47±0.16	0.47±0.22*

*Depicts comparison between baseline supine and DSI, ***P<0.01, $^{\#\wedge\$}$Comparison from CHO, PR and mixed food respectively, $^{\#}P$<0.05, $^{\#\#\#}P$<0.001, $^{\wedge}P$<0.01, $^{\wedge\wedge\wedge}P$<0.001, $^{\$}P$<0.05, $^{\$\$\$}P$<0.001. Baseline: Postmeal baseline supine, DSI: Dry supine immersion, CHO: Carbohydrate rich food, PR: Protein rich food, MI: Mixed balanced food, FR: Fat rich food, SD: Standard deviation

Table 2: Gastric wave pattern at resting supine and during DSI on intake of different types of food

Type of foods	Mean±SD			
	Normogastria	Bradygastria	Tachygastria	Arrhythmia
CHO				
Baseline	81.1±6.16	17.3±6.51	2.3±3.81	0.2±0.36
DSI	72.1±5.46***	25.1±5.65***	1.3±3.05*	1.5±0.81***
PR				
Baseline	80.2±5.64	17.1±6.09	2.4±3.39	0.3±0.44
DSI	73.3±5.66***	23.9±5.80***	1.3±1.96***	1.5±0.78***
MI				
Baseline	78.8±11.34	19.2±10.73	1.7±1.29	0.2±0.36
DSI	69.5±12.11***	27.4±11.27***	1.1±1.75	1.9±0.91***
FR				
Baseline	70.0±14.79	27.4±13.65	1.7±1.75	0.8±0.61
DSI	61.5±13.64***	35.4±13.28***	1.1±0.99	2.0±1.02***

Values are expressed in percentage. *Depicts comparison between baseline supine and DSI, *$P<0.05$, **$P<0.01$, ***$P<0.001$. Baseline: Postmeal baseline supine, DSI: Dry supine immersion, CHO: Carbohydrate rich food, PR: Protein rich food, MI: Mixed balanced food, FR: Fat rich food, SD: Standard deviation

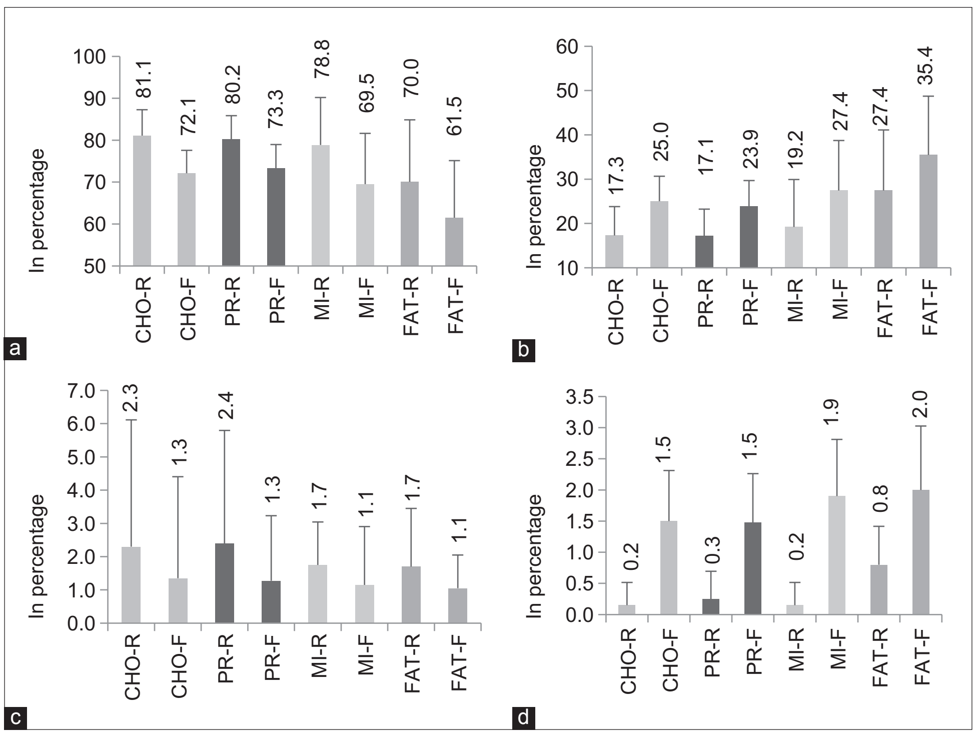

Figure 1: Percentage distribution of Gastric wave pattern following intake of different types of food at baseline resting supine and during dry supine immersion (a) normogastric wave (b) bradygastric wave (c) tachygastric wave (d) arrhythmic wave: For significance level, please refer to results section, CHO: Carbohydrate rich food, PR: Protein rich food, MI: Mixed food, FAT: Fat rich food, R: Baseline supine, F: Flotation

of foods as compared to the baseline state ($P < 0.001$). FR food though not significant showed the highest occurrence of an arrhythmic wave during DSI.

DISCUSSION

This study examined the electrical response of the stomach by noninvasive EGG during short term simulated microgravity condition after intake of different types of food. This study is the first of its kind where the gastric electrical response of different type of Indian foods has been examined during simulated microgravity condition. The literature suggests that GEA reduces after intake of fat food. This study showed that intake of FR food during simulated microgravity condition, further slows down GEA. Numerous studies have reported earlier that almost all astronauts experience motion sickness, nausea, vomiting, and other gastric ailments during first few hours to first 2–3 days of a space mission.[5] Foods which reduce gastric motility would perhaps be more detrimental for the astronaut as this can lead to gastric impairment and may compromise the nutritional requirement of the astronaut.

Therefore, the foods prescribed for astronauts have to be gastric friendly and does not exacerbate the microgravity induced changes in gastric function.

EGG is a noninvasive technique to measure the myoelectrical activity of the stomach. An indirect assessment of gastric motility could be made by recording GEA. It has been reported in the literature that GEA is a determining factor of the maximum frequency and propagation of gastric contraction.[11] Various studies have reported that a correlation existed between EGG and gastric contractile activities.[12,13] In a clinical study, simultaneous recording of EGG and gastric manometry revealed an increased dominant power and reduced dominant frequency during motor activity of the stomach, as compared to motor quiescence.[12] EGG recording in patients with functional dyspepsia showed that gastric dysrhythmias detected in EGG wave were associated with gastric hypomotility or impaired gastric contractions recorded directly via internal serosal electrodes.[14] Notwithstanding the fact that contraction related spike activities cannot be recorded in the EGG, the relative increase in EGG dominant power had been repetitively and consistently shown to be associated with an increase in gastric contractile activity.

Postprandial EGG data at baseline supine and during DSI were recorded for 30 min in the present study. Many researchers have earlier recorded EGG for 30 min on the intake of the liquid caloric meal, solid meal, or water to examine the myoelectrical response of the stomach.[15-18] Researchers have also suggested that at any particular state, such as fasting, fed, baseline or after the intervention, ideally 30 min period is needed to ensure an accurate measure of the gastric slow wave.[19]

Changes in the digestive system similar to those observed in microgravity are simulated under the conditions of hypokinesia. It has been established that hypokinetic changes in the digestive system are more precisely reproduced under the conditions of head-down bed rest model.[20] Similar hypokinesia and hemodynamic effects of microgravity on the body are also reproduced by dry floatation technique.[20] Head-down bed rest (HDBR), as short as 4 h, is used as a simulation of microgravity exposure.[21,22]

The postprandial EGG was recorded during DSI after 4½ h of floatation. This time gap was intended for allowing translocation of body fluids toward the cephalic side, creating a physiological effect of microgravity. Literature suggests that HDBR for as short as 4 h has been used earlier by the researchers to simulate the effect microgravity on the cardiovascular system.[21] Second, emptying of the stomach in healthy individuals occur in about 4 h under normal conditions.[11] Mechanical effects of microgravity on the GI tract, perhaps in conjunction with other factors such as cephalic fluid shift, vestibular effect, hormonal changes, and other neural factors may retard the gastric emptying and intestinal transport time.

The present study revealed that MF was recorded to be the lowest at baseline state as well as during DSI after intake of FR food when compared to CHO, PR and MI foods. FR food caused slowing down of GEA to the maximum. The receptors located in the duodenal mucosa are sensitive to changes in lipid content, which when activated stimulates several neural and hormonal mechanisms. Fats release cholecystokinin which physiologically inhibits gastric emptying.[23,24] In addition, DSI causes the cephalic fluid shift, resulting in an increase in blood supply to inferior vena cava and creates a passive congestion in the venous system of the ventral cavity. Several studies have attributed this passive congestion in the venous system and are responsible for changes in the digestive system in microgravity.[20] Alteration of fluid distribution has also been directly held responsible for reduced GI motility by some researchers.[25,26] Evidence of slight hepatic and pancreatic enlargement has also been implicated for microgravity induced reduction in gastric motility.[27] They also opined that assuming upright posture is helpful in propelling food across GI tract.[27] It has also been reported that the transit time of food in the GI tract increases during real spaceflight.[28]

Parkman *et al*. in their study observed that MF of EGG wave at normal supine condition following consumption of a high protein diet (CHO - 46%, protein - 32% and fat - 22%) was 3.11 cpm.[29] MF recorded in the present study after intake of PR food at supine posture was 3.38 cpm and 3.16 cpm during DSI [Table 1]. The fat content of the PR food (20%) in this study was almost similar to the fat content of high protein diet used by Parkman *et al*. in their study; however, the protein content of the PR food (20%) was 12% lower than the test meal used by Parkman *et al*. The MF during DSI after CHO rich food (3.19 cpm) and MI food (3.09 cpm) was similar to the MF as obtained during DSI after PR food [Table 1]. The MF of EGG after FR food during DSI was significantly reduced as compared to three other type of foods [Table 1]. The results of the present study pointed towards the fact that if the fat content of the test meal remains within 20% of the total constituent of the diet, gastric slowdown during DSI does not occur to a greater extent. On the other hand, when fat content of the test diet was increased to 30% as in FR food, gastric slowdown during baseline resting supine and during DSI becomes very apparent and MF was recorded lowest as compared to other food types [Table 1].

Percentage distribution of gastric wave patterns in the EGG recording revealed that about 70–80% of entire EGG recording at resting supine and during DSI consisted primarily of normogastric wave following intake of CHO, PR and MI foods [Figure 1a]. However, FR foods caused a considerable reduction in a normogastric wave pattern with a concomitant increase in bradygastric and arrhythmic waves [Figure 1b and c]. Several studies have suggested that EGG recording in normal healthy adults primarily consisted of ≥70% of a normogastric wave.[30-33]

The results of the present study revealed that gastric electrical response during DSI reduced after intake of different types of food. The FR food caused maximum slowing down of gastric electrical response at baseline supine as well as during DSI.

Limitations of the study

The present study did not ascertain the quantity of redistribution of body fluid towards the cephalic side and ensuing effect of microgravity that had set in the participants during 6 h of DSI. Recording of gastric motor activity and gastric motility by direct gastric manometry, gastric emptying scintigraphy, ^{13}C breath tests, barostat and computed tomography could have given a detailed insight of the gastric response during simulated microgravity. Future studies are warranted to examine the gastric response to different foods differing in carbohydrate, protein and fat percentages during short and long-term microgravity simulation. This will help to understand the effect of microgravity exposure on gastric activity.

CONCLUSION

The present study suggests that administering FR food during DSI caused a significant reduction in electrical activity of the stomach, as assessed by a reduction in MF, reduction in normogastric wave, increase in bradygastric wave and appearance of arrhythmic wave.

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REFERENCES

1. Amidon GL, DeBrincat GA, Najib N. Effects of gravity on gastric emptying, intestinal transit, and drug absorption. J Clin Pharmacol 1991;31:968-73.
2. Roda A, Mirasoli M, Guardigli M, Simoni P, Festi D, Afonin B, *et al*. Non-invasive panel tests for gastrointestinal motility monitoring within the MARS-500 Project. World J Gastroenterol 2013;19:2208-16.
3. Cintron NM, Putcha L, Vanderploeg JM. In-flight pharmacokinetics of acetaminophen in saliva. Houston: National Aeronautics and Space Administration; NASA Technical Memorandum No: 58280; 1987. p. 19-23.
4. Smith SM, Zwart SR. Nutritional biochemistry of spaceflight. Adv Clin Chem 2008;46:87-130.
5. Harm DL, Sandoz GR, Stern RM. Changes in gastric myoelectric activity during space flight. Dig Dis Sci 2002;47:1737-45.
6. Afonin BV, Sedova EA. Digestive system functioning during simulation of the microgravity effects on humans by immersion. Aviakosm Ekolog Med 2009;43:48-52.
7. Pei J, Chang L, Liu Z, Zhang J, Wang C, Song K. Observation of EGG parameters during -6 degrees head-down bedrest for 21 days. Space Med Med Eng (Beijing) 1997;10:413-6.
8. Lane HW, LeBlanc AD, Putcha L, Whitson PA. Nutrition and human physiological adaptations to space flight. Am J Clin Nutr 1993;58:583-8.
9. Afonin BV, Goncharova NP. Secretory activity of the stomach during modeling of enhanced filling of abdominal veins. Hum Physiol 2011;37:832-5.
10. Afonin BV, Sedova EA, Goncharova NP, Solov'eva AA. Investigation of the evacuatory function of the gastrointestinal tract in 5-day dry immersion. Aviakosm Ekolog Med 2011;45:52-7.
11. Yin J, Chen JD. Electrogastrography: Methodology, validation and applications. J Neurogastroenterol Motil 2013;19:5-17.
12. Chen JD, Richards RD, McCallum RW. Identification of gastric contractions from the cutaneous electrogastrogram. Am J Gastroenterol 1994;89:79-85.
13. Geldof H, van der Schee EJ, Grashuis JL. Electrogastrographic characteristics of interdigestive migrating complex in humans. Am J Physiol 1986;250:G165-71.
14. Chen JD, Pan J, McCallum RW. Clinical significance of gastric myoelectrical dysrhythmias. Dig Dis 1995;13:275-90.
15. Sanaka MR, Xing J, Thota PN, Sofer EE. Can EGG recording duration be reduced after a liquid meal or a waterload test? Neurogastroenterol Motil 2002;14:308-9.
16. Jonderko K, Arsan K, Fajerowska BB. Meal temperature affects both the gastric pacesetter activity and gastric emptying in humans. Neurogastroenterol Motil 2002;14:308.
17. Jonderko K, Kotula I, Waluga M, Jonderko AK. Effect of doxepine on gastric myoelectrical activity and gastric emptying in humans. Neurogastroenterol Motil 2002;14:308.
18. Lin Z, Denton S, Durham S, Sarosiek I. Metamucil improves gastric myoelectrical activity and symptoms in patients with irritable bowel syndrome. Neurogastroenterol Motil 2002;14:310.
19. Levanon D, Zhang M, Chen JD. Efficiency and efficacy of the electrogastrogram. Dig Dis Sci 1998;43:1023-30.
20. Afonin BV, Sedova EA. Digestive system functioning during simulation of microgravity effects on humans by means of immersion. Hum Physiol 2012;38:776-80.
21. Edgell H, Grinberg A, Gagné N, Beavers KR, Hughson RL. Cardiovascular responses to lower body negative pressure before and after 4 h of head-down bed rest and seated control in men and women. J Appl Physiol 2012;113:1604-12.
22. Fischer D, Arbeille P, Shoemaker JK, O'Leary DD, Hughson RL. Altered hormonal regulation and blood flow distribution with cardiovascular deconditioning after short-duration head down bed rest. J Appl Physiol 2007;103:2018-25.
23. Barrett KE, Barman SE, Boitano S, Brooks HL. Gastrointestinal Physiology. In: Ganong's Review of Medical Physiology. 24th ed. San Francisco: Tata McGraw-Hill Publishing Company; 2012. p. 399-416.
24. Johnson LR. Motility. In: Essential Medical Physiology. 3rd ed. California: Elsevier Academic Press; 2003. p. 479-96.
25. Nimmo WS, Prescott LF. The influence of posture on

paracetamol absorption. Br J Clin Pharmacol 1978;5:348-9.
26. Thomas JE. Mechanics and regulation of gastric emptying. Physiol Rev 1957;37:453-74.
27. Baker ES, Barratt MR, Wear ML. Human responses to space flight. In: Barratt MR, Pool SL, editors. Principles of Clinical Medicine for Space Flight. New York: Springer; 2008. p. 27-57.
28. Lane HW, Whitson PA, Putcha L, Baker E, Smith SM, Stewart K, *et al*. Regulatory physiology: Gastrointestinal function during extended duration space flight. In: Sawin CF, Taylor GR, Smith WL, editors. Extended Duration Orbiter Medical Project Final Report. Houston, TX: National Aeronautics and Space Administration, SP-1999-534; 1999. p. 2.4-2.6.
29. Parkman HP, Hasler WL, Barnett JL, Eaker EY; American Motility Society Clinical GI Motility Testing Task Force. Electrogastrography: A document prepared by the gastric section of the American Motility Society Clinical GI Motility Testing Task Force. Neurogastroenterol Motil 2003;15:89-102.
30. Chen J, McCallum RW. Gastric slow wave abnormalities in patients with gastroparesis. Am J Gastroenterol 1992;87:477-82.
31. Pfaffenbach B, Adamek RJ, Kuhn K, Wegener M. Electrogastrography in healthy subjects: Evaluation of normal values, influence of age and gender. Dig Dis Sci 1995;40:1445-50.
32. Parkman HP, Harris AD, Miller MA, Fisher RS. Influence of age, gender, and menstrual cycle on the normal electrogastrogram. Am J Gastroenterol 1996;91:127-33.
33. Rossi Z, Forlini G, Fenderico P, Cipolla R, Nasoni S. Electrogastrography. Eur Rev Med Pharmacol Sci 2005;95 Suppl 1:29-35.

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