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# Effects of meal volume and composition on gastric myoelectrical activity

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**Levanon, Daniela, Ming Zhang, William C. Orr, and J. D. Z. Chen.** Effects of meal volume and composition on gastric myoelectrical activity. *Am. J. Physiol. 274 (Gastrointest. Liver Physiol. 37): G430–G434, 1998.*—The absence of a standard meal in electrogastrography may limit its clinical significance. Different meals may fail to produce the expected postprandial motility pattern. The aim of this study was to investigate the effect of meal volume and composition on postprandial myoelectrical activity. Fourteen healthy subjects were given four meals that differed from a “reference meal” in one single parameter (volume, calorie, or fiber content). Gastric myoelectrical activity was measured using surface electrogastrography. Spectral and statistical analyses were performed to investigate the effect of food properties on electrogastrogram (EGG) parameters. It was found that the reference meal produced a postprandial increase in the dominant frequency ( $P < 0.007$ ), dominant power ( $P < 0.04$ ), and percentage of normal 2–4 cycle/min gastric slow waves ( $P > 0.05$ ). Similar changes were observed with the low-volume and high-fiber meals but not with the reduced-calorie meal. Fasting EGG parameters in all four sessions showed no significant difference. It was concluded that low-calorie meals do not result in expected postprandial physiological responses and thus are not appropriate for EGG tests. A volume reduction of down to one-half the volume of a regular meal does not affect postprandial changes of the EGG; thus a condensed test meal may be recommended for symptomatic patients.

electrogastrography; gastrointestinal motility; gastric emptying; stomach

THE ROLE OF THE MEAL is of great importance in assessing electrogastrography results, because it influences the gastric transit time by its content, volume, and physical properties (11, 12, 15). However, no single meal has been established as a standard for this purpose, and different investigators have used a variety of meals (10, 14, 23). Efforts have been made in standardizing other aspects of the electrogastrogram (EGG), mainly by elaborating methods of data acquisition and analysis. In the absence of a common denominator, the evaluation of EGG studies performed in different laboratories is difficult. The selection of an appropriate test meal poses a major challenge to the investigator who is guided by two different objectives as follows: a small and light meal that a symptomatic patient can tolerate, and a well-balanced, nutritious food to generate a postprandial motility pattern.

A few experiments have been performed to investigate the effect of meal constituents on gastric motor and myoelectrical activity. Different responses of gastric myoelectrical activity to liquid and solid meals were reported (5). The effect of meal temperature on gastric motility as well as on gastric myoelectrical

activity was studied, and an inhibitory effect was found in both extremes (26). Chen et al. (3, 6) investigated the effect of fat and milk on gastric myoelectrical activity using electrogastrography and found a decrease in postprandial power of the gastric slow wave. Although not specifically mentioned, most meals that have been studied differed substantially in their caloric contents and physical properties (10, 17) and were not practically suitable for laboratory testing.

The aim of this study was to investigate the effect of meal volume and composition on the postprandial pattern of the EGG using practical test meals.

## METHODS

**Subjects.** Fourteen healthy volunteers were recruited for the study. None had any gastrointestinal symptomatology, disease, or surgery. Average age was  $30.7 \pm 1.8$  yr, ranging from 22 to 41 yr of age (7 males and 7 females). All women were studied during the follicular phase of their menses to eliminate potential hormonal effects. No subjects were taking medications during the study period except two females who used contraceptives. The protocol was approved by the Institutional Review Board at Integris Baptist Medical Center, and a consent form was signed before each study.

Each subject was presented with four different meals in four randomized sessions and was required to fast for at least 6 h before the recording. An EGG was performed for 1 h before and 2 h after each test meal. Subjects were tested in a quiet room where they could watch television in a supine position. They were requested to minimize their movements, and talking or reading was not allowed.

**Test meals.** A balanced reference meal was designed by a dietitian and was composed of solid food (a turkey sandwich, potato chips, and a chocolate chip cookie) and half a cup of liquid (orange juice). Three other test meals were designed to be different from the reference meal in one single parameter [caloric intake (the reduced-calorie meal), fiber content (the high-fiber meal), and volume (the low-volume meal)]. All had the same weight and the same ratio of protein, fat, and carbohydrate (see Table 1). The reference meal was chosen to consist of basic constituents of “Western” cuisine that were familiar to the test subjects and would promote their appetite. The caloric intake was one of a medium size, the volume included solid food and half a cup of liquid, and the fiber content was matched to an average meal (e.g., not composed of legumes/cereals). Three other meals differed from the reference meal in one single parameter (see Table 1).

**EGG measurement.** Gastric myoelectrical activity was recorded noninvasively using the surface electrodes. This measurement (EGG) depicts a weighted summation of the electrical muscle activity of the stomach from different areas. Previous studies have shown that the EGG is an accurate measurement of the gastric slow wave and is associated with gastric motility (1, 4, 25).

Normal gastric slow wave frequency in humans is 3 (between 2 and 4) cycles/min (cpm), whereas pathological recordings may vary from 1 to 9 cpm. To encompass this wide range, a portable ambulatory device with a recording fre-

quency of 1–18 cpm was used to record gastric myoelectrical activity (Digitrapper EGG; Synectics Medical, Irving, TX).

The EGG recording was made from three electrodes placed on the abdomen after skin preparation. The positioning of the electrodes was based on a previous study in which the stomach was localized sonographically (9). The first electrode was placed above the antrum (located 1–3 cm right to the midpoint of a line connecting the xiphoid process and the umbilicus), the second 45 degrees, 5 cm above, and to the left of the first electrode, and the third (reference electrode) on the left flank beneath the rib cage.

Due to its low signal-to-noise ratio, EGG analysis is computerized. As mentioned earlier, the normal gastric frequency ranges between 2 and 4 cpm. Electrical activities generated by other organs have different frequencies and can be easily distinguished in the power spectrum. However, motion artifacts interfere with accurate analysis of the EGG. They were minimized during the study and deleted by visual inspection of the recording before computerized spectral analysis.

The following parameters were used in assessing the EGG recordings. "Dominant frequency" represents the frequency of the gastric slow waves. Normal values are considered to be 3 cpm (between 2 and 4). "Dominant power" is the power of the dominant frequency, which reflects amplitude and regularity of the stomach. "Percentage of 2–4 cpm waves" specifies the proportion of regular 2–4 cpm gastric slow waves; "percentage of dysrhythmias" represents the proportion of irregular gastric slow waves (see Fig. 1). It was further classified as bradygastria (dominant peak in the 0.5–2.0 cpm range), tachygastria (dominant peak in the 4.0–9.0 cpm range), and arrhythmia (no dominant peak observed in the 0.5–9.0 cpm range); "instability coefficient of the dominant frequency" reflects the variation of the dominant frequency on a minute-by-minute basis (8).

**Statistical analysis.** All data were expressed as means  $\pm$  SE, and  $P$  values  $<0.05$  were considered to be statistically significant. Student's  $t$ -test was performed to assess the general response to food (pre- and postprandially) and the response of the EGG to a specific meal (calorie, volume, or fiber) compared with the reference meal.

## RESULTS

**Baseline fasting data.** Regular slow waves were recorded in the EGG, and a typical fasting recording and its running spectra are shown in Fig. 1.

Baseline fasting EGG data were acquired from all individuals in all four sessions. No significant differences were noticed among the recordings in any of the EGG parameters (see Fig. 2). The average fasting dominant EGG frequency in the four sessions was  $2.89 \pm 0.05$  cpm (Fig. 2A), the average percentage of the 2–4 cpm waves was  $79.3 \pm 4.4\%$  (Fig. 2B), and the average instability coefficient of the dominant frequency was  $0.34 \pm 0.05$  (see Fig. 2C).

**Postprandial response of the EGG to the reference meal.** Postprandial changes after the ingestion of the reference test meal were observed as follows: a significant increase in the dominant frequency (Fig. 3A) was noted postprandially and reached the value of  $3.17 \pm 0.07$  cpm ( $P < 0.007$ , compared with the fasting value), an increase of 8.6%. A postprandial increase of 2.52 dB ( $P < 0.05$ ) was documented in the dominant power (Fig. 3B), representing about a onefold increase in power (in

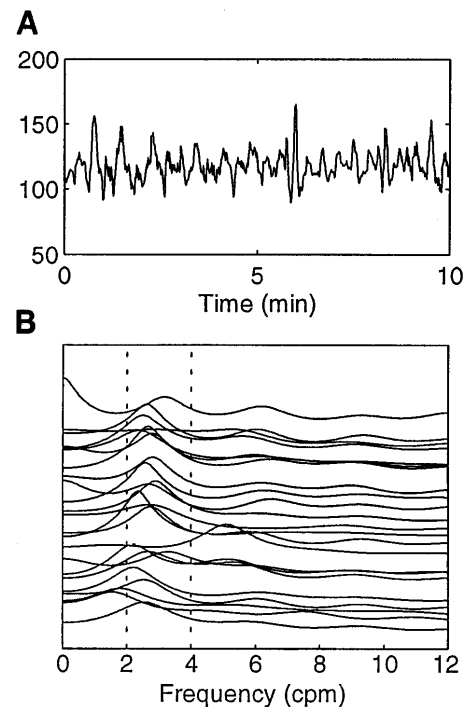


Fig. 1. Typical electrogastrographic baseline recording in one subject, obtained in the fasting state. *A*: 10-min electrogastrogram (EGG) recording. *B*: running power spectra computed according to the adaptive spectral analysis method. Each line represents the power spectrum of a 1-min EGG datum.

linear scale). The percentage of 2–4 cpm gastric slow waves (Fig. 3C) showed a noticeable increase, which was, however, not statistically significant. Most subjects showed a decrease in the percentage of dysrhythmia: bradygastria,  $7.9 \pm 2.5$  to  $5.4 \pm 1.4\%$ ; tachygastria,  $5.4 \pm 0.9$  to  $4.6 \pm 1.3\%$ ; and arrhythmia,  $7.1 \pm 2.3$  to  $4.5 \pm 1.2\%$ . However, none was found to be significant. The instability coefficient showed no postprandial change:  $0.28 \pm 0.05$  vs.  $0.27 \pm 0.02$  ( $P > 0.05$ ).

**Effects of caloric content.** In contrast to the reference meal, the reduced-calorie meal did not generate significant pre- to postprandial changes in the dominant frequency ( $2.95 \pm 0.05$  vs.  $2.95 \pm 0.09$  cpm,  $P > 0.9$ ) and in the dominant power ( $29.74 \pm 1.62$  vs.  $32.6 \pm 1.29$  dB,  $P > 0.9$ ).

The postprandial dominant frequency after the reduced-calorie meal ( $2.95 \pm 0.09$  cpm) was significantly lower than that after the reference meal ( $3.17 \pm 0.07$  cpm,  $P = 0.02$ ). Similarly, the postprandial increase in the dominant frequency was significantly less after the reduced-calorie meal than after the reference meal ( $0.001 \pm 0.08$  vs.  $0.24 \pm 0.07$  cpm,  $P = 0.02$ ).

All other EGG parameters, as in the reference meal data, showed no significant postprandial changes. The percentage of 2–4 cpm waves after the reduced-calorie meal was  $80.2 \pm 4.6\%$  ( $P = 0.9$  compared with the corresponding fasting value), and the total postprandial percentage of dysrhythmia was  $19.8 \pm 5.5\%$  ( $P > 0.05$  compared with the corresponding fasting value).

**Effects of fiber.** The postprandial changes in the EGG parameters measured with the high-fiber test meal

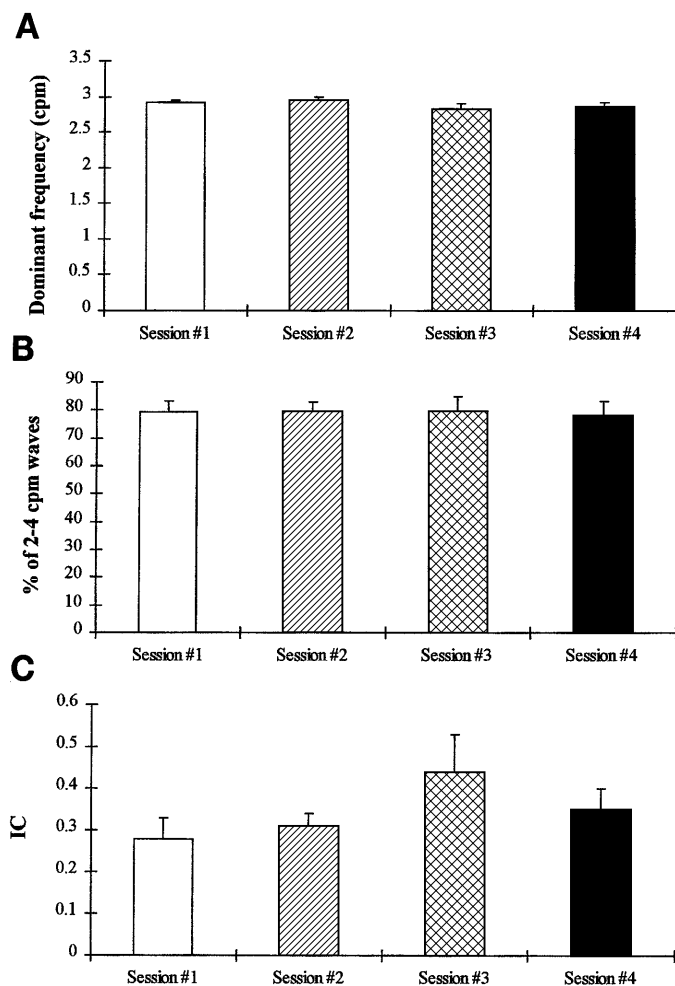


Fig. 2. Baseline fasting data in the four sessions. *A*: dominant frequency. *B*: percentage of 2–4 cycle/min (cpm) gastric slow waves. *C*: instability coefficient (IC).

were similar to the reference meal. The mean dominant frequency increased from  $2.83 \pm 0.07$  cpm in the fasting state to  $3.10 \pm 0.08$  cpm ( $P < 0.02$ ); the dominant power increased from  $29.84 \pm 1.61$  to  $33.29 \pm 1.26$  dB ( $P < 0.02$ ); the percentage of 2–4 cpm waves increased from  $79.9 \pm 5.0$  to  $86.9 \pm 2.5\%$  ( $P = 0.1$ ); and the total percentage of dysrhythmia decreased from  $20.0 \pm 6.33$  to  $13.0 \pm 3.4\%$  [ $P =$  not significant (NS)]. However, the postprandial decline in the instability coefficient reached statistical significance ( $0.44 \pm 0.09$  vs.  $0.24 \pm 0.03$ ,  $P < 0.05$ ). No significant difference was noted in any of the postprandial EGG parameters between the high-fiber and reference meals.

Table 1. Content of the different meals

Meal	Calories, kcal	Volume, ml		Fiber, g	Fat/Protein/Carbohydrate, %	Weight, g
		Liquid	Solid			
Reference	475	120+	372	2	17:21:61	170
Reduced calorie	170	120+	358	2	18:22:59	170
High fiber	461	120+	355	16	17:22:60	174
Low volume	469	60+	197	1	19:21:60	169

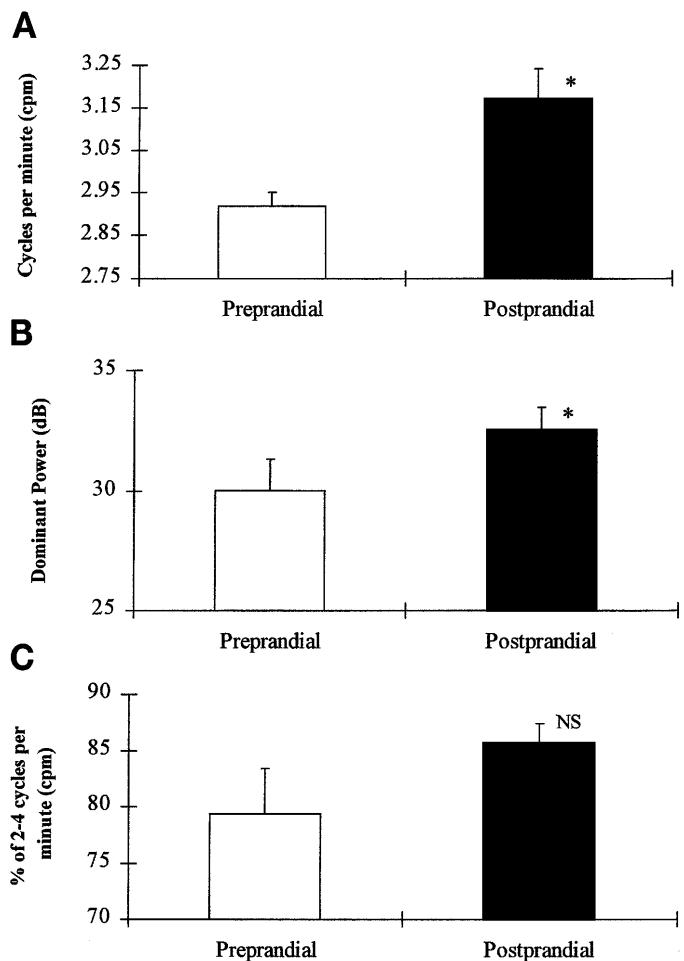


Fig. 3. Postprandial response in the EGG parameters to the reference meal. *A*: dominant frequency. *B*: dominant power. *C*: percentage of the 2–4 cpm gastric slow waves. \* $P < 0.05$ .

**Effects of volume.** All EGG parameters with the low-volume meal showed postprandial changes similar to those of the reference meal. The mean postprandial dominant frequency increased from  $2.86 \pm 0.05$  to  $3.04 \pm 0.05$  cpm ( $P = 0.02$ ); the power increased from  $29.96 \pm 1.46$  to  $32.99 \pm 1.11$  dB ( $P = 0.03$ ); the percentage of 2–4 cpm waves increased from  $78.3 \pm 5.1$  to  $86.1 \pm 2.7\%$  ( $P = 0.08$ ); and the total percentage of dysrhythmia declined from  $21.3 \pm 6.2$  to  $16.5 \pm 4.7\%$  ( $P =$  NS). The instability coefficient declined from  $0.35 \pm 0.05$  to  $0.30 \pm 0.04$  ( $P =$  NS). No significant difference was found in any of the EGG parameters after the low-volume meal compared with that after the reference meal.

**Summary of postprandial changes.** Table 2 summarizes the postprandial changes of the EGG parameters after the four different meals. It is seen that the high-fiber meal is the most potent in inducing postprandial responses. In addition to significant postprandial changes in dominant frequency and power, it resulted in a significant change in the instability coefficient as well. The reduced-calorie meal did not generate any significant postprandial changes in any of the EGG parameters. To understand whether this was attrib-

Table 2. Mean postprandial changes of the EGG parameters after the 4 test meals in the 14 subjects

Meal	$\Delta F$ (cpm)	<i>P</i>	$\Delta P$ (d)	<i>P</i>	$\Delta\%$ 2–4 cpm	<i>P</i>	$\Delta IC$	<i>P</i>
Reference	0.25	<0.007	2.52	<0.04	6.3	NS	-0.01	NS
High fiber	0.27	<0.02	3.45	<0.04	7.0	NS	-0.20	<0.05
Low volume	0.17	<0.03	3.03	<0.04	7.8	NS	-0.05	NS
Reduced calorie	0.00	NS	2.90	NS	0.5	NS	-0.02	NS

$\Delta F$ , postprandial change in dominant frequency;  $\Delta P$ , postprandial change in dominant power;  $\Delta\%$  of 2–4 cpm, postprandial change of % of 2–4 cycle/min (cpm) waves;  $\Delta IC$ , postprandial change of instability coefficient; NS, not significant. *P* values were in comparison with the fasting data.

uted to fast emptying of the stomach, the 2-h postprandial value was divided into two 1-h intervals and reanalyzed. No statistical difference was found in the EGG parameters during the first and second postprandial hours (dominant frequency:  $2.92 \pm 0.38$  vs.  $2.97 \pm 0.25$  cpm,  $P > 0.05$ ; dominant power:  $31.68 \pm 5.72$  vs.  $30.90 \pm 4.79$  dB,  $P > 0.05$ ). Similarly, no significant difference was noted in any of the EGG parameters between the first postprandial hour and the fasting state.

## DISCUSSION

The importance of the test meal in EGG studies and the lack of an acceptable “standard meal” have encouraged us to look into specific postprandial responses associated with meal volume and composition.

In evaluating the reproducibility of the fasting data, according to the study protocol, we had the opportunity to study each volunteer four times and to compare the fasting EGG in the four different sessions. No significant difference was noted under the baseline condition in any of the EGG parameters analyzed. The EGG in the fasting state was found to be highly reproducible. These observations were in agreement with findings by other investigators (22).

The reference meal contained a small to moderate amount of calories and a small amount of fiber. As shown by our results, this meal produced the predicted (7), statistically significant, postprandial changes in the dominant frequency and power and a noticeable but not statistically significant increase in the percentage of 2–4 cpm waves and a parallel decrease in all types of dysrhythmia, as well as in IC. The reference meal is an appropriate test meal for the study of the postprandial response of the EGG.

*Caloric value.* The low-calorie meal was designed to have the same composition but about one-third the caloric value of the reference meal. Caloric content of the meal is one of the factors controlling gastric emptying rate (16, 27). DeWever et al. (13) found that prolongation of the fed motor state is proportional to the number of calories ingested. We found that a substantial cut in the caloric intake had a strong impact on the postprandial EGG. This was reflected by the absence of the expected postprandial change in all of the EGG parameters. Although it may be well tolerated by patients, reduced-calorie meals fail to generate the expected postprandial changes and thus are not appropriate for use as test meals.

*Fiber content.* The action of dietary fiber content on the stomach depends on the chemical structure and the physical properties of the type chosen. Nondigestible solids containing large particles, such as fibers, are retained for a longer period of time by the stomach and are later delivered to the duodenum. Controversial evidence demonstrates a delayed, unchanged, or accelerated rate of gastric emptying after ingesting dietary fibers, especially soluble fibers (20). Insoluble fibers have less water-holding capacity in the stomach and have less effects on the gut (its major effect is considered in the colon and cecum). The high-fiber meal that we used differed from the reference meal in that the fiber content was eight times higher in order to create a notable difference. Bound by our rules (controlling the weight and ingredient ratio), we used insoluble fibers, since the soluble fiber would have changed the proportions and would have contributed greatly in increasing the weight and the volume of the meal.

Under the conditions stated above (fiber type, liquid quantity), we found a postprandial pattern very similar to the reference meal. Although not significant statistically, the highest increase in the dominant power was observed after this meal when compared with any of the other meals. Antral contractions were found to increase substantially with particulate nutrients (19–21).

*Volume effect.* The accommodation reflex allows different volumes to enter the stomach without a major rise in pressure (by a progressive relaxation of the stomach walls). Most of it is done by the fundus, which functions as a reservoir pouch. Some of the previous investigators suggested that the power increase of the EGG after a meal was attributed to gastric distension (the recording was made closer to the origin of the signal as the stomach is brought closer to the surface (2). Recent studies, however, seemed to indicate that a higher postprandial EGG power was associated with increased contractility of the stomach after the meal. These observations were obtained from sonographic measurements, manometry, and simultaneous serosal and surface recordings (9, 18, 24). This may explain why the reduced-volume meal produced similar postprandial changes as the reference meal.

We conclude that a low-calorie meal is not able to produce expected postprandial physiological responses and thus is not an appropriate test meal for the study of the postprandial response of gastric myoelectrical activity, whereas a low-volume meal may be recommended for symptomatic patients.

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