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Role of Sham Feeding in Postprandial Changes of Gastric Myoelectrical Activity

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The aim of this study was to evaluate the role of sham feeding in postprandial changes of gastric myoelectrical activity. Eighteen asymptomatic healthy volunteers (10 men, 8 women; mean age: 31), with no history of gastrointestinal disease were studied. Gastric myoelectrical activity was recorded for 30 min at baseline, 30 min after sham feeding, and 1 hr after eating, using surface electrogastrography. The electrogastrogram (EGG) was analyzed by spectral analysis. It was found that the changes of postprandial EGG parameters were significantly correlated with those after sham feeding (EGG dominant power: $r = 0.6$, $P < 0.01$; dominant frequency: $r = 0.8$, $P < 0.001$; percentage of regular slow waves: $r = 0.7$, $P < 0.003$). We concluded that intrinsic gastric electrical activity can be altered by sham feeding and the cephalic phase of digestion plays an important role in the postprandial response of gastric myoelectrical activity.

KEY WORDS: electrogastrography; gastric motility; cephalic stimulation; sham feeding.

The effects of sham feeding on gastric secretory functions have been widely investigated. After the initial description of Pavlov, numerous studies have been reported (1–7). Compared with direct gastric stimulation, considerably less information is available on cephalic stimulation of gastrointestinal motility. Sham feeding was found to have little or no effect on gastric emptying of saline and homogenized food in humans (8). However, it has been found to be capable of converting the fasting pattern of gastric motility to the fed pattern. A delayed appearance of the subsequent phase III of the migrating motor complex after sham feeding and a prolonged recovery after eating were reported (9). A recent study (7) showed that parallel to secretion, antroduodenal motility was immediately enhanced after the start of sham feeding. The motility index and antroduodenal coordination were concomitantly enhanced by sham feeding. The magnitude of gastric motility induced by sham feeding was approximately 70% of the response to a standard 350-kcal solid meal used for postprandial motility studies (7).

Postprandial changes of gastric myoelectrical activity are routinely observed. We hypothesized that they are caused by the cephalic phase of digestion, gastric distension, and chemical reactions of food and digestive products with gastrointestinal mucosa causing the release of gastrointestinal hormones. While the effects of gastric distension and gastrointestinal hormones have been previously studied and confirmed, the aim of this study was to investigate the effect of the cephalic phase of digestion on postprandial gastric myoelectrical activity.

Stern *et al* (10) investigated the effect of sham feeding on gastric myoelectrical activity using electrogastrography. They reported an increase in the power of the gastric slow wave during sham feeding and a rapid return to baseline after sham feeding (10). However, it is unknown whether sham feeding will affect the frequency and regularity of the gastric slow wave and how long these effects may last.

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MATERIALS AND METHODS

Subjects

Eighteen healthy volunteers (10 men, 8 women; age: 24–65, mean: 31) participated in this study. None of the subjects had a history or symptoms of gastrointestinal disease and none took medication the week before or during the study. The research protocol was approved by the Institutional Review Board at the Baptist Medical Center of Oklahoma, and written consent was given by all subjects before the study.

Electrogastrogram

Gastric myoelectrical activity was measured in each subject using surface electrogastrography. Prior to the attachment of electrodes, the abdominal surface where electrodes were to be positioned was cleaned with sandy skin-prep jelly (Omni Prep, Weaver & Co., Aurora, Colorado) to reduce the impedance. Three silver–silver chloride ECG electrodes were placed, one at the midpoint between the xiphoid and the navel, one at 5 cm to the left and 5 cm above this point, the third electrode, used as a reference, was placed at the left costal margin horizontal to the first electrode. These electrodes were then connected to an ambulatory EGG recorder (Digitrapper EGG, Synectics Medical Inc. Irving, Texas) operated by a 9-V battery. The EGG signal was derived from the two epigastric electrodes and amplified with a low and high cutoff frequency of 1 and 18 cpm, respectively. The sampling frequency was 1 Hz.

Experimental Procedure

All subjects were fasted for 6 hr or more before the study. First, a 30-min baseline recording of the EGG was performed and then the subject was asked to chew and expectorate a hot dog (fat: 25 g, carbohydrate: 21 g, protein: 12 g, 360 kcal, 63% of the calories from fat) without swallowing any food within 7 min. After sham feeding, another 30-min recording of the EGG was made, and then the subject ate another hot dog (exactly the same as the one used in sham feeding) within 7 min. The postprandial recording of the EGG was continuously made for an hour immediately after eating. Subjective responses to sham feeding of the hot dog were recorded. The study was performed in a quiet room with the subject lying quietly in a same supine position during the whole study period except for sham feeding and eating, during which the subject was sitting on the bed.

Data Analysis

Three periods of the EGG recordings in each subject were subjected to computerized analysis: period A: 30-min baseline; period B: 30 min after the termination of sham feeding EGG; period C: 60-min postprandial EGG. A number of EGG parameters during each recording period were computed using spectral analysis, including dominant frequency, dominant power, and the percentage of normal gastric slow waves.

EGG Dominant Frequency. The frequency at which the EGG power spectrum has a peak power in the range of 2–4 cpm was defined as the EGG dominant frequency. The dominant frequency of the EGG has been shown to be equal to the frequency of the gastric slow wave measured from the implanted serosal electrodes (11). It was computed using the smoothed power spectral analysis method (12). This method was used to produce an averaged power spectrum for the EGG during each of the recording periods.

EGG Dominant Power. The power at the dominant frequency in the power spectrum of the EGG was defined as EGG dominant power. Previous studies have shown that the relative change of the EGG dominant power reflects gastric contractility (13, 14). The EGG dominant power was calculated from the smoothed power spectrum. Decibel (dB) units were used to represent the power of the EGG. Assuming a sinusoidal signal with an amplitude of A, power P in dB is expressed as $P(\text{dB}) = 10 \times \log A^2$.

Percentage of Normal Slow Waves. The percentage of normal gastric slow waves was defined as the percentage of time during which normal 2- to 4-cpm slow waves were present over the entire observation period. It was computed using the adaptive running spectral analysis method (15). Each EGG recording was divided into blocks of 1 min without overlapping. The power spectrum of each 1-min EGG was calculated and examined to see if the peak power was within the range of 2–4 cpm. The 1-min EGG was called normal if the peak power was within the 2- to 4-cpm range. Otherwise, it was called dysrhythmia.

Statistical Analysis. Statistical analyses were performed to investigate the correlation of the change of each EGG parameter attributed to food ingestion and that due to sham feeding. The change due to food ingestion was assessed by comparing the postprandial EGG parameters with those of the baseline EGG. The effect of sham feeding was assessed by comparing the EGG parameters after sham feeding with those of the baseline EGG. Statistical analyses were also performed to assess the duration of the effect of sham feeding. The 30-min EGG recording after sham feeding was divided into six segments of 5 min each. EGG parameters during the first 5 min after sham feeding were compared with those during the last 5 min. All data were presented as mean ± SEM. $P < 0.05$ was considered to be significant.

RESULTS

Table 1 summarizes the EGG parameters including the dominant frequency, the dominant power, and the percentage of normal (2–4 cpm) slow waves obtained during the 30-min fasting period, the 30 min after sham feeding, and 1 hr after food ingestion.

Effects of Sham Feeding and Food Ingestion on Regularity of Gastric Slow Wave

A majority of the EGG recordings showed regular 2- to 4-cpm gastric slow waves (Figures 1 and 2). Individually, the regularity of the EGG, ie, the percentage of the 2- to 4-cpm waves, was effected by sham feeding as well as food ingestion. Sham feeding resulted in a decrease in the percentage of the 2- to 4-cpm slow waves in 12 subjects and an increase in

TABLE 1. EGG PARAMETERS UNDER DIFFERENT CONDITIONS

	Fasting			*Sham feeding*			*Food ingestion*		
Subject	*Frequency*	*Power*	*2–4 cpm (%)*	*Frequency*	*Power*	*2–4 cpm (%)*	*Frequency*	*Power*	*2–4 cpm (%)*
1	3.04	31.2	73.0	3.16	33.4	79.0	3.05	52.3	67.8
2	2.70	28.7	67.0	2.93	25.2	51.4	3.05	23.1	60.8
3	2.81	29.8	76.7	2.93	30.7	67.3	2.81	25.6	30.2
4	3.05	26.7	46.7	2.46	31.5	66.7	2.93	37.1	96.0
5	2.79	36.3	96.0	2.70	32.5	66.7	2.81	34.3	63.1
6	2.93	33.4	82.8	3.05	23.1	67.9	3.05	32.3	98.1
7	2.34	29.1	69.3	2.81	26.1	68.8	2.70	25.2	72.1
8	2.70	31.5	86.4	2.81	27.8	92.3	2.81	30.9	89.2
9	2.81	29.2	93.2	3.05	26.9	69.2	3.28	25.3	70.5
10	2.81	22.9	83.0	2.81	25.1	76.2	2.93	31.3	88.0
11	2.58	30.2	90.0	2.81	29.4	71.3	2.93	35.8	87.0
12	2.70	31.1	95.0	2.57	38.6	92.4	2.81	30.9	88.8
13	2.93	37.4	100.0	2.70	34.5	100.0	2.70	39.7	93.0
14	2.81	20.4	73.0	3.16	23.7	54.0	2.11	35.3	58.0
15	3.28	27.3	96.0	3.28	28.0	82.5	3.63	24.5	70.0
16	2.81	24.5	94.0	2.93	25.3	94.0	2.93	27.2	94.0
17	3.05	26.2	88.0	2.93	26.5	70.5	2.46	25.8	76.0
18	3.28	30.7	97.0	3.28	28.9	100.0	3.28	27.7	98.0
Mean	2.86	29.2	83.7	2.91	28.7	76.1	2.90	31.4	77.8
SE	0.05	1.0	3.27	0.05	1.0	4.24	0.08	1.7	4.80

five subjects. Interestingly, the change noted with food ingestion was significantly correlated with that due to sham feeding ($r = 0.7, P < 0.003$). As shown in Figure 3, the change of the percentage of the 2- to 4-cpm waves due to food ingestion in each subject is plotted against that due to sham feeding. A linear correlation was observed between these two changes.

Effects of Sham Feeding and Food Ingestion on Dominant Frequency of EGG

While the regularity of the EGG reflects the percentage of time during which normal gastric slow waves (2–4 cpm) are present over a given time period, the dominant frequency indicates the mean frequency of the gastric slow wave over the given time period. The dominant frequency of the EGG in each recording period was within the range of 2–4 cpm. Most of the recordings had a dominant frequency very close to 3 cpm. Slight changes of the EGG dominant frequency were noted after sham feeding as well as after food ingestion in individual subjects. Similar to the changes of the percentage of the 2- to 4-cpm slow waves, the changes of the EGG dominant frequency due to food ingestion and sham feeding were also significantly correlated ($r = 0.8, P < 0.001$; Figure 4).

Effects of Sham Feeding and Food Ingestion on Dominant Power of EGG

Nine of the 18 subjects showed an increase in EGG dominant power after sham feeding, of which eight had a similar increase after food ingestion (see Figure 5 for an example). The other nine subjects had a

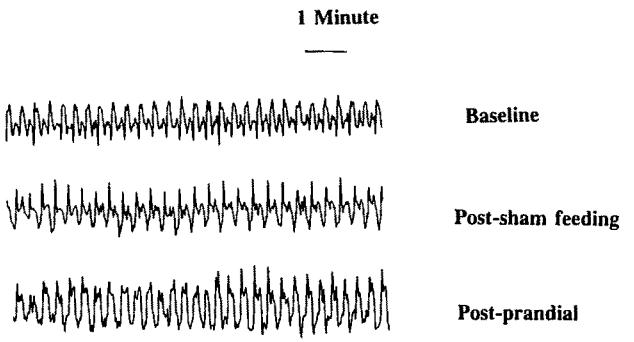

Fig 1. EGG recordings in a normal subject. Upper: portion of the baseline recording; middle: portion of the recording after sham feeding; bottom: portion of the recording after food ingestion. Regular 3-cpm waves are noted in all these recordings.

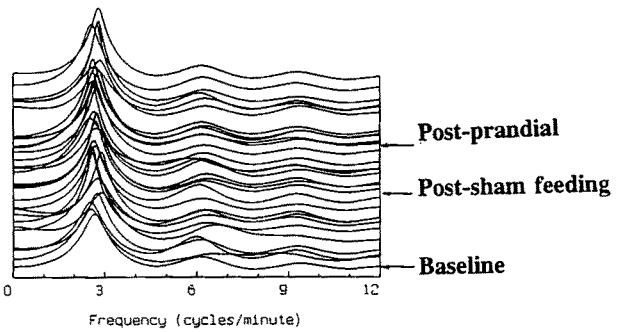

Fig 2. Running spectra of the EGG recordings shown in Figure 1. Each line reflects the spectrum of 1-min EGG data starting from the bottom. Spectral peaks at about 3 cpm indicate persistent gastric slow wave frequencies.

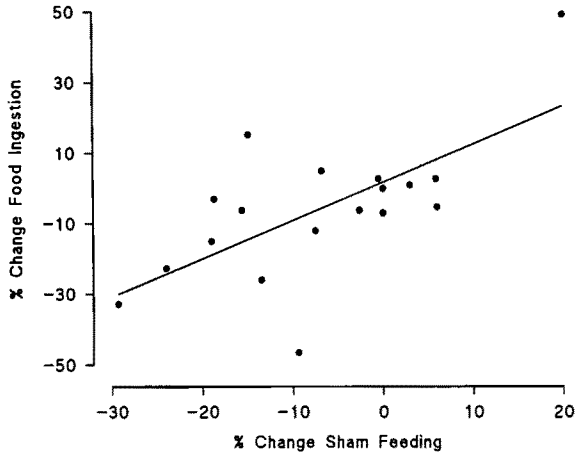

Fig 3. Correlation of the response of the EGG to food ingestion with that to sham feeding in the percentage of 2- to 4-cpm waves ($r = 0.7$, $P < 0.003$). x axis: the difference in percentage of the 2- to 4-cpm waves between the 30-min period after sham feeding and the 30-min baseline. y axis: the difference in percentage of the 2- to 4-cpm waves between the 60-min period after food ingestion and the 30-min baseline.

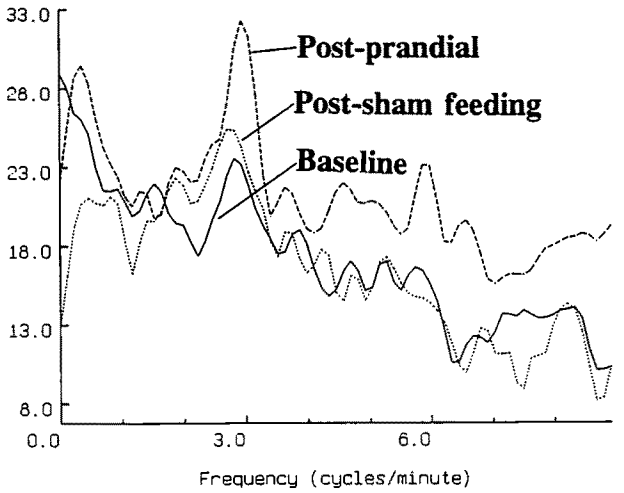

Fig 5. Power spectra (in dB) of the EGG recordings (30 min at baseline, 30 min after sham feeding and 60 min after food ingestion) in a normal subject, illustrating the change of the EGG dominant power (at 3 cpm) due to sham feeding and food ingestion. An increase in the dominant power is noted after sham feeding as well as after food ingestion in this subject.

decrease in EGG dominant power after sham feeding, and all of them had a similar decrease after food ingestion. The change of the EGG dominant power attributed to food ingestion was found to be significantly correlated with that due to sham feeding ($r = 0.6$, $P < 0.01$, Figure 6).

Duration of Effect of Sham Feeding

To assess the duration of the effect of sham feeding on each of the EGG parameters, the 18 subjects were divided into two groups based on the change of a specific EGG parameter. The subjects who showed an increase in the specified parameter after sham feeding were classified as group A, while those who had a decrease in the same parameter were designated as group B. EGG parameters obtained from different time periods (first 5-min to the sixth 5-min periods) after sham feeding were analyzed and compared and were found to approach the baseline (a decrease in group A and an increase in group B). However, no significant differences were observed either in group

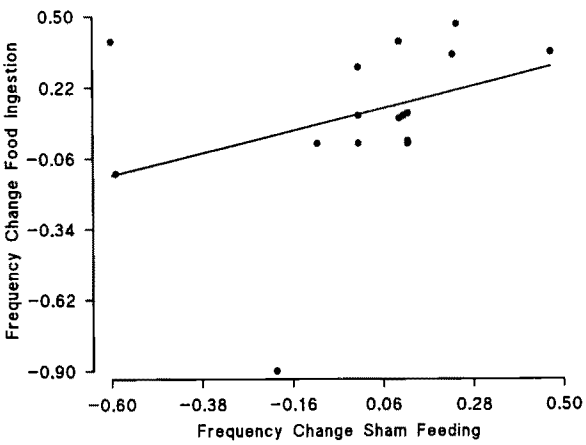

Fig 4. Correlation of the response of the EGG to food ingestion with that to sham feeding in the dominant frequency ($r = 0.8$, $P < 0.001$). x axis: the difference in EGG dominant frequency between the 30-min period after sham feeding and the 30-min baseline. y axis: the difference in EGG dominant frequency between the 60-min period after food ingestion and the 30-min baseline.

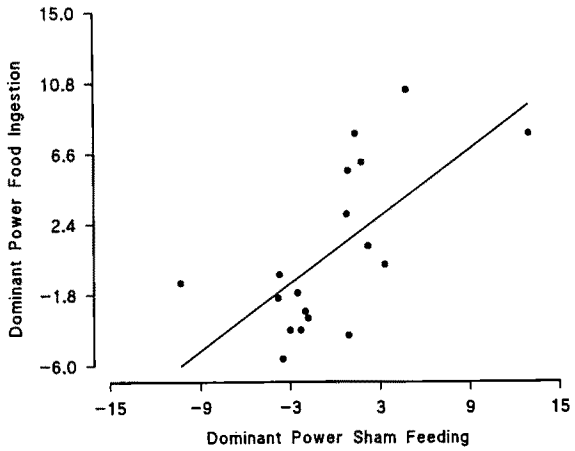

Fig 6. Correlation of the response of the EGG to food ingestion with that to sham feeding in the dominant power ($r = 0.6$, $P < 0.01$). x axis: the difference of the EGG dominant power between the 30-min period after sham feeding and the 30-min baseline. y axis: the difference of the EGG dominant power between the 60-min period after food ingestion and the 30-min baseline.

A or group B in the comparison of the EGG during the first versus the sixth interval after sham feeding with the EGG during the sixth 5-min period after sham feeding.

Subjective Response to Feeding

There was no clear correlation between the change of EGG dominant power and the subjective response to sham feeding. While 14 of the 18 subjects responded "fine" to sham feeding, 64% of them showed an increase in EGG dominant power and 36% had a decrease. Four subjects quoted "dislike," two showed an increase in the dominant power after sham feeding and the other two, a decrease.

DISCUSSION

Sham feeding and EGG were applied in this study to investigate the role of the cephalic phase of digestion in postprandial changes of gastric myoelectrical activity. The results indicate that the alteration in the EGG after food ingestion is significantly correlated with that after sham feeding, including the dominant frequency, dominant power, and percentage of the 2- to 4-cpm waves.

It is known that gastric acid secretion after eating is stimulated by three major physiological mechanisms: (1) stimulation secondary to anticipating, seeing, smelling, tasting, and chewing, collectively termed "cephalic stimulation"; (2) gastric distension, which stimulates cholinergic reflexes in the body and fundus of the stomach (16, 17); and (3) chemical reactions of food and digestive products with gastrointestinal mucosa, causing the release of gastrointestinal hormones such as gastrin (4, 18). Similar to gastric acid secretion, postprandial changes of gastric myoelectrical activity are routinely observed. What are the causes of the postprandial gastric myoelectrical activity change? We hypothesized that the same three major physiological mechanisms for the postprandial acid secretion might apply for the postprandial change of gastric myoelectrical activity, ie, cephalic stimulation, gastric distension, and gastrointestinal hormones.

While the effects of gastric distension and gastrointestinal hormones have been previously studied and confirmed, this study demonstrates the effect of cephalic stimulation on postprandial gastric myoelectrical activity. It is shown that the change of every EGG parameter after food ingestion is significantly correlated with that after sham feeding. The correlation of the response of the EGG to sham feeding with that to food ingestion seems to indicate that sham feeding may be capable of converting the fasting pattern of gastric myoelectrical activity into a pattern similar to the postprandial pattern. This is consistent with previous studies on the effect of sham feeding on gastric motility (7, 9). Sham feeding was found to immediately interrupt the gastric migrating motor complex and introduce a gastric motor pattern that is similar to postprandial pattern. The magnitude of antral motility after sham feeding approximated 70% of the response to a standard 350-kcal solid meal used for the postprandial motility study (7).

Stern *et al* have previously investigated the effect of sham feeding on gastric myoelectrical activity (10). They reported a significant increase in the amplitude of the 3-cpm activity recorded in the EGG during sham feeding, which rapidly returned to baseline after sham feeding. The novel approach of this current study was to investigate the role of the cephalic phase of digestion in postprandial changes of gastric myoelectrical activity by studying the correlation of the change of the EGG parameter due to sham feeding with that due to food ingestion. In addition to the amplitude of the 3-cpm activity, which was the only parameter investigated in the previous study, the dominant frequency and the percentage of the 2- to 4-cpm activity in the EGG were also analyzed in this current study. These three parameters give more complete information about gastric myoelectrical activity (19).

Different results were reported on the duration of the effect of sham feeding and are difficult to compare because of the different mode of sham feeding and duration of follow-up. Generally responses were maintained for short periods after termination of sham feeding (10). In our study, cephalic responses lasted for 30 min after termination of sham feeding, which is close to the finding by Katschinski *et al* (7) but much longer than that reported by Stern *et al.*

Both excitatory and inhibitory effects of sham feeding on gastric myoelectrical activity were observed in this study. The EGG in about half of the subjects showed an increase in the dominant power after sham feeding, whereas the EGG in the other half showed a decrease in the dominant power. Most of the previous studies reported excitatory effects of sham feeding on gastric acid secretion, gastric motility, and gastric myoelectrical activity. Some studies (21, 22) also indicated that sham feeding did not produce an increase in gastric acid secretion and amplitude of 3-cpm activity in EGG if the food that was chewed was not appetizing. Inhibitory effects were found in more subjects in this study than in the previous stud-

ies. However, the correlation between the change of EGG dominant power after sham feeding and the subjective response was not found to be statistically significant. Interestingly and most importantly, the response of the EGG to sham feeding, whether excitatory or inhibitory, was highly correlated with the response to food ingestion.

The postprandial decrease in EGG dominant power may be attributed to the high fat content in the test meal. A solid test meal usually increases gastric motility and myoelectrical activity in normal subjects (22–24). However, a test meal of fat may have more of an inhibitory effect (25, 29). Kelly and Code (28) found that intragastric instillation of fat decreases the incidence of spike activities in the stomach measured using serosal electrodes. Fat preload before a regular test meal was reported to decrease postprandial gastric motor activity (26) as well as the dominant power of the EGG (29). The fat content in the stomach may have an inhibitory effect, whereas other nonfat contents in the stomach may have an excitatory effect. In addition, an inhibitory biofeedback effect on gastric motility and myoelectrical activity will be superimposed when fat content is emptied into the small intestine. A combination of these effects may have led to the decrease of postprandial EGG power in some subjects and the increase in other subjects.

In conclusion, intrinsic gastric myoelectrical activity can be altered by sham feeding and the cephalic phase of digestion plays an important role in the postprandial response of gastric myoelectrical activity.

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