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Sham Feeding

Cephalic–Vagal Influences on Gastric Myoelectric Activity

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The effects of sham feeding on gastric motility of human subjects have not previously been studied. The amplitude of 3-cpm electrogastrogram (EGG) waves increases after the ingestion of food. We hypothesized that sham feeding would stimulate a similar, but briefer gastric myoelectric response. Healthy human subjects chewed and expectorated a hot dog on a roll and later ate a second hot dog. EGGs were continuously recorded before, during, and after sham feeding and eating. The results of experiment I (N = 27) showed that the hand-scored amplitude of the 3-cpm waves increased significantly (P < 0.01) during sham feeding. Two minutes after sham feeding, the mean amplitude of 3-cpm EGG waves returned to baseline level. The increase in EGG amplitude during eating was also significant (P < 0.01), and remained increased for approximately 30 min after ingestion. The procedure used in experiment II (N = 20) was similar to experiment I, but EGGs were computer analyzed and power, ie, spectral intensities, at 3 cpm were obtained. The increase in power at 3 cpm during sham feeding and during eating was significant (P < 0.05 and P < 0.02, respectively). Similar to experiment I, the duration of increase in power at 3 cpm was brief during sham feeding compared to the postprandial increase. Four vagotimized subjects failed to show an increase in power at 3 cpm in response to sham feeding. We conclude: (1) The cephalic–vagal stimulation of sham feeding increases briefly the amplitude and power of 3-cpm gastric myoelectric activity in healthy subjects but not vagotomized patients. (2) The increase in postprandial 3-cpm amplitude is prolonged, reflecting initial cephalic–vagal activity and subsequent gastric stimulation by luminal contents.

KEY WORDS: sham feeding; electogastrography; gastric myoelectric activity; gastric motility; cephalic reflexes.

The question investigated in the present study was whether gastric myoelectric activity shows a cephalic phase, ie, an anticipatory increase in gastric motor activity brought about by sensory contact with foodstuffs rather than by postingestional consequences of food. Cephalic reflexes were reviewed in a recent publication (1) and their role in digestion, absorption, and metabolism discussed, but no mention was made of gastric motor activity.

Two lines of evidence are germane to this investigation. The first are the anecdotal reports, such as that of Wolf and Wolff (2), that when food was discussed with fasted fistulated subjects, an increase in gastric motor activity could be observed. Secondly, there are the laboratory studies, which

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followed from the classic studies of Pavlov (3), and include hundreds of reports that have provided clear evidence for the existence of cephalic–vagal gastrointestinal secretory reflexes: salivary secretion, gastric secretion, and pancreatic secretions.

The cephalic phase of gastric secretion was first documented by Pavlov (3) using the technique of sham feeding with dogs. Sham-fed dogs secreted both acid and pepsinogen if their vagi were intact. It is generally agreed that the cephalic phase of gastric acid secretion, mediated by the vagus, is activated by the sight, smell, taste, and thought of appetizing food (4, 5). Richardson et al and Feldman et al have used a modified sham-feeding technique (chew and expectorate) to study the role of cephalic–vagal stimulation in the acid secretory response to eating in healthy human subjects (6), with and without atropine (7), and in diabetic patients (8). These authors concluded that for healthy subjects cephalic stimulation accounts for approximately one third of the acid secreted, and gastric distension prolongs the response to cephalic stimulation. Atropine inhibited the acid secretory response to sham feeding, and diabetic patients showed a reduced acid secretory response to sham feeding, suggesting vagal neuropathy.

Whereas there are numerous sham feeding studies that have examined gastric acid secretion, it is difficult to find studies that have looked at the effects of sham feeding on gastric motor activity. In one older study (9), balloons were introduced into the stomachs of four fasted dogs through a gastric fistula to measure the motor effects of sham feeding. The authors summarized their findings with regard to antral motility as follows: "Antral tonus and wave amplitude usually decreased during sham feeding. Diminution in wave amplitude occurred in all instances when peristaltic activity preceded sham feeding." However, as has been pointed out (10, 11), the introduction of a balloon stimulates contractions of the stomach. Alvarez (10) has made the point that, "Contractions seen by users of balloons should not be spoken of as contractions of an empty stomach." The major procedural difference, then, between the early dog study cited here (9) and the present study is that the latter study is a noninvasive investigation of the effects of sham feeding on myoelectric activity, whereas the former was an invasive study of the effects of sham feeding on intraluminal pressures stimulated by placement of balloon catheters. Interestingly, the authors of the previous study (9) reported, "Sham feeding performed when the fundus was inactive usually resulted in an immediate increase in tone and an initiation or continuation of tonus waves." In a more recent study (12), the effects of modified sham feeding on liquid and solid gastric emptying in humans were studied. Sham feeding had no effect on the emptying of isotonic saline and only a minor effect on gastric emptying of a homogenized steak meal.

Electrogastrography is a superior method for studying sham feeding and eating behavior since it does not stimulate gastric activity, is noninvasive, and it is possible to obtain continuous recordings over a long period of time (13). The frequency of the EGG is identical to the frequency of gastric slow waves measured with mucosal (14–16) and serosal (17, 18) electrodes. Furthermore, the amplitude of the EGG after ingestion of meals is positively related to the contractile activity of the gastric antrum (16, 18, 19).

Several investigators (16, 18, 20) have demonstrated that postprandial EGG recordings reveal a two- to fourfold increase in the amplitude of the 3-cpm EGG. In the present study, we hypothesized that sham feeding of healthy, fasted subjects would stimulate gastric myoelectric activity and result in an increase in the amplitude of the 3-cpm EGG. The results of two similar experiments are presented. In the first experiment the amplitude of the EGG was hand scored, and in the second, computer-derived power of the EGG in the frequency range 2.5–3.5 cpm was obtained. Because of the unique nature of experiment I, it was deemed advisable to replicate the procedure after computer analysis of the EGG became available in our laboratory. In addition, EGG sham feeding data were obtained from four vagotomized patients.

MATERIAL AND METHODS

Experiment I

Volunteers. Twenty-seven college students, age range 17–22, 11 women and 16 men, participated in this experiment. No subject had a history of gastrointestinal disorders. Subjects fasted approximately 5 hr. The procedure used was approved by the Penn State Committee on Use of Human Subjects, and informed written consent was obtained from each subject.

Electrogastrographic Method. The EGG was recorded with cutaneous electrodes (TDE 20, Med Associates, East Fairfield, Vermont) from three abdominal sites configured in a shallow arc. The most proximal site was just below the subject's lower left rib margin 4.4 cm from midline and 8.9 cm above the umbilicus; the most distal

location was 3.1 cm above the umbilicus and 1.6 cm to the subject's right of midline. A common reference electrode was placed on the left arm. Electrodes were connected to a Beckman R611 recorder (Sensor Medics, Anaheim, California) with a time constant of 3 sec, high frequency cutoff of 0.08 Hz, and a paper speed of 1 mm/sec.

Sham Feeding and Eating Procedure. EGG recordings were obtained for six continuous periods as follows: before, during, and after sham feeding, and before, during, and after eating. Before and after periods were all 10 min, the mean time for sham feeding was 3.2 min, and the mean time for eating was 3.6 min. Prior to the sham feeding period, the subject was given a hot dog on a roll with mustard and/or ketchup and told to chew each bite six to seven times and then spit it into a plastic bag. Subjects were instructed to concentrate on not swallowing any food. The subject's general behavior and any evidence of swallowing was observed on a closed-circuit TV screen from another room. There was a 20-min break between the after-sham-feeding period and the before-eating period. Prior to the eating period, the subject was given a second hot dog and instructed to eat it and drink 8 oz of water.

Data Analysis. For each subject, the EGG channel showing the clearest 3-cpm tracing was used for data analysis. The amplitude of each wave was measured to the nearest millimeter and mean amplitudes obtained for each of the following six phases of the session: 3 min before sham feeding, during sham feeding, 3 min after sham feeding, 3 min before eating, during eating, 3 min postprandial. Differences between the means were tested for significance with *t* tests.

Experiment II

Volunteers. The subjects were 20 healthy college students, 8 female and 12 male, ages 18–22. None had a history of gastrointestinal disorders, and all gave written consent prior to their participation. Subjects were fasted a minimum of 4 hr prior to the study.

Electrogastrographic Method. The same methodology for recording the EGG was used as described for experiment I. For this experiment, however, the EGG was simultaneously recorded on the Beckman polygraph and on a Honeywell 5600 FM tape recorder (Honeywell, Denver, Colorado). The EGG signal was later digitized at a rate of 1 Hz by a DEC PDP 11/34 computer (Digital Equipment Corp., Maynard, Massachusetts). The digitized signal was transmitted to an IBM 370/3381 (IBM, White Plains, New York) for spectral analysis.

Sham Feeding and Eating Procedures. The procedure was similar to that used in experiment I. However, the EGG recordings were combined as follows: baseline, sham feed and post-sham, and eating and postprandial. Again there was a 20-min break between the end of the sham feeding period and the start of the eating period. In addition, following the session, subjects were asked to rate their subjective feelings during sham feeding on a scale of 1 to 5 with "1" being disgusting, "3" neutral, and "5" being enjoyable.

Spectral Analysis. The time series obtained by digitizing the EGG signal was parsed into 256-sec epochs for spectral analysis. These 256-sec epochs were overlapped by 75%. Thus the first epoch consisted of the first 256 sec of data, while the second included seconds 65–320, and the third, seconds 129–384, and so forth. Thus each overlapping epoch included 64 sec of new information.

These overlapping epochs were spectral analyzed using the BMDP statistical program PIT (21). Examples of these spectral analyses are shown below via pseudo-three-dimensional plots. Frequency (0–15 cpm) is plotted on the horizontal axis, time (in 64-sec intervals) on the vertical axis, and power or spectral intensity (in microvolts squared per Hertz) on the axis that appears to rise from the surface of the paper.

Statistical Analysis. The spectral intensity or power estimates from the frequency band 2.5–3.5 cpm were averaged and submitted to a repeated measures analysis of variance. These averages were log transformed to meet better the assumptions of analysis of variance. Only the first six overlapping 256-sec epochs of the baseline, sham feeding, and eating periods were included, because this was the most data available for all subjects due to the variable duration of sham feeding and eating. These spectral intensity values were submitted to an analysis of variance with two repeated measures factors: period (baseline, sham feeding and post-sham, and eating and postprandial) and epoch (six epochs for each period).

Experiment III

Volunteers. The subjects were four healthy adults, two males and two females, with a mean age of 51. All had had truncal vagotomies and Billroth II surgery at least five years prior to this experiment and had no gastrointestinal symptoms at the time of testing. They gave written consent prior to their participation and were fasted a minimum of 4 hr.

Electrogastrographic Method. The same methodology for recording the EGG was used as described above for experiment II.

Sham Feeding and Eating Procedures. The procedure was the same as that used in experiment II except that the subjects sham fed and ate 3½ oz of cheese pizza rather than hot dogs. (When initially contacted and asked if a hot dog would be a highly desired food, the subjects said that they would prefer pizza.)

Data Analysis. The EGGs were spectral analyzed following the same procedure that was used in experiment II. Since there were only four subjects, rather than statistical tests, each spectral plot was visually inspected for peaks of power and changes over time.

RESULTS

Experiment I

Group mean and SEM for 3-cpm EGG amplitudes for the six phases of the session are shown in Figure 1 for all 27 subjects. The increase in EGG amplitude from before sham feeding to during sham feeding was significant (18.9 mm to 30.3 mm, $P < 0.01$). However, by 3 min after sham feeding the mean

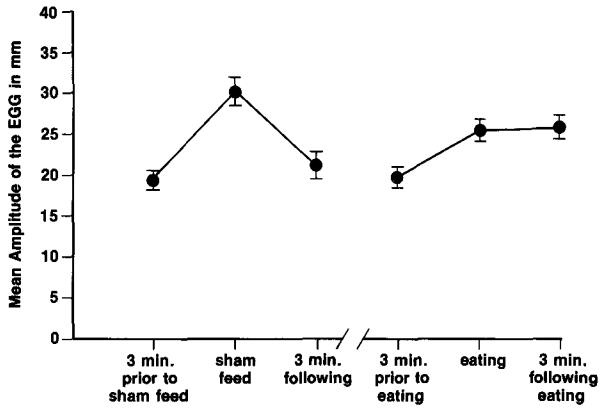

Fig 1. Group mean EGG results for 27 subjects used in experiment I. As can be seen, sham feeding produced a brief increase in the amplitude of the 3-cpm EGG which returned to pre-sham-feeding level within 3 min. Eating produced a similar increase in EGG amplitude that was sustained for at least 3 min.

amplitude of the EGG had fallen to 22.7 mm, not significantly different from before sham feeding. The increase in EGG amplitude from before eating to during eating was significant (18.6 mm to 26.6 mm, $P < 0.01$). The EGG amplitude continued to increase to a mean of 27.7 mm during the 3 min following ingestion of the hot dog and bun. Visual inspection of the EGG records showed that for most subjects the postprandial increase in amplitude was still evident after 30 min.

To obtain a more complete understanding of the decrease in EGG amplitude immediately following sham feeding, this period was divided into three 1-min intervals. The mean EGG amplitudes for the three intervals were 28.1 mm, 21.0 mm, and 20.4 mm. Of these three intervals, only the first differs significantly from the period before sham feeding. In other words, within 2 min of the termination of sham feeding, the mean EGG amplitude had returned to pre-sham-feeding level. In contrast to this rapid decline in EGG amplitude following sham feed, the mean EGG amplitudes for the three 1-min intervals following eating were 31.7 mm, 29.9 mm, and 24.4 mm. All of these values were significantly different ($P < 0.01$) from the EGG amplitude recorded before eating.

Experiment II

Seventeen subjects reported that sham feeding was a neutral experience by giving ratings of 2, 3, or 4. Two subjects reported that it was disgusting, and one indicated that it was enjoyable. Figure 2 shows a running spectral plot of subject 4, who reported that sham feeding was a neutral experience. Note

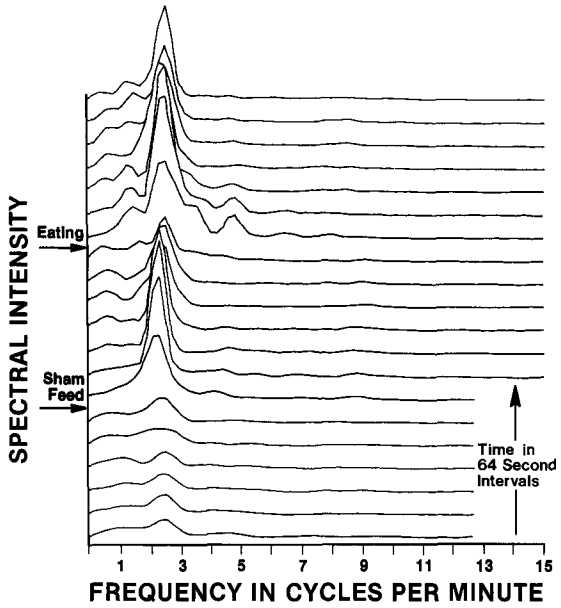

Fig 2. Running spectral analysis of the EGG of subject 4 who reported that the experience of sham feeding was neutral. Note the low level of activity at approximately 2.5 cpm before sham feeding and the increase in power during sham feeding and during eating.

that prior to sham feeding the subject showed relatively low power at approximately 2.5 cpm. During sham feeding the power at 2.5 cpm increased and then steadily decreased. On the other hand, the large postprandial increases in power at 2.5 cpm continued until the end of the recording.

The group mean power at 3 cpm during baseline, during sham feeding and post-sham, and during eating and postprandial—for the 17 subjects who reported that sham feeding was a neutral experience—is shown in Figure 3. Each data point is a sliding average, eg, the first point is the log mean spectral intensity in the frequency band 2.5–3.5 cpm for minutes 1–4 of EGG data, the second data point is the average power for minutes 2–5, etc. (In actuality, rather than minutes, the data were analyzed in 64-sec periods.) The increase in power at 3 cpm during sham feeding was significant compared to the baseline ($F = 4.44$, $P < 0.05$). The increase in power at 3 cpm during eating also was significant ($F = 6.36$, $P < 0.02$). The difference between the spectral intensity levels during sham feeding and during eating was not significant. Similar to experiment I, the duration of increased power at 3 cpm during sham feeding was brief. The last three data points shown during the sham feeding and post-sham period were not significantly different from the baseline level. On the other hand, the last three

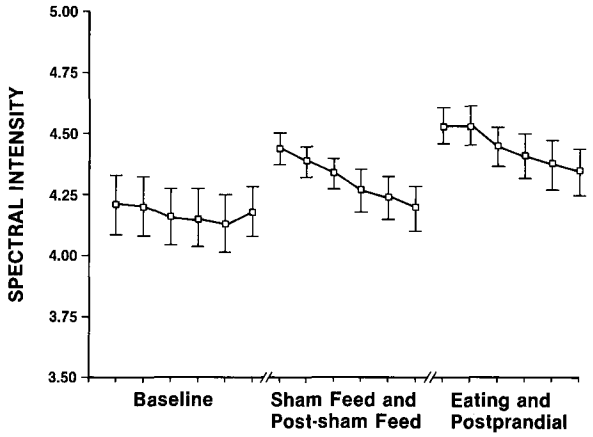

Fig 3. Group mean EGG results from experiment II for the 17 subjects who reported that the sham feeding experience was neutral. Each data point is a 4-min sliding average with 75% overlap of the spectral intensity in the EGG signal at 2.5–3.5 cpm. Note the similar increase in power during sham feeding and eating, the rapid return to baseline following sham feeding, and the more prolonged recovery following eating.

data points shown during the eating period and postprandially are significantly greater than the baseline level, demonstrating the relatively prolonged effect of eating on EGG power at 3 cpm.

Figure 4 shows the running spectral plot of subject 11, who reported that the experience of sham feeding was disgusting. Prior to sham feeding, the subject showed normal baseline activity at approximately 2.8 cpm. However, note that for this subject, rather than there being an increase in power during sham feeding, there was a decrease. After eating the hot dog, the subject did show a normal increase in power at 3 cpm. The other subject who reported that sham feeding was a disgusting experience also showed no increase in 3-cpm EGG activity during the sham feeding period.

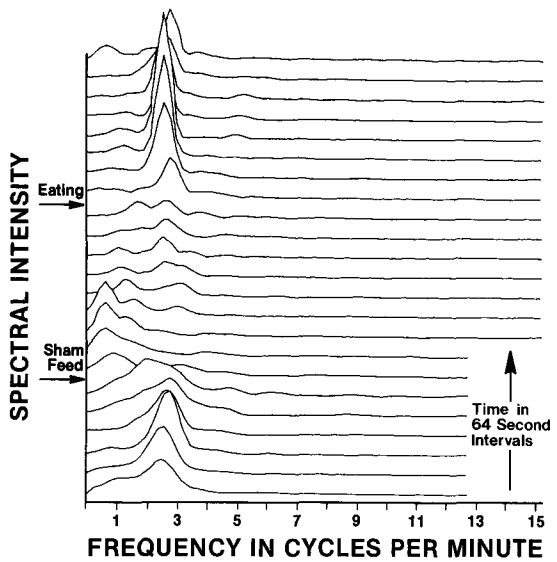

Fig 4. Running spectral analysis of the EGG from subject 11 who reported that the experience of sham feeding was disgusting. This subject showed power at approximately 2.8 cpm before sham feeding and a decrease during sham feed. The subject showed the typical increase in power during eating.

Experiment III

The results of sham feeding and eating for the vagotomized subjects are summarized in Table 1. During baseline, the peak of power was between 8.5–10 cpm for these subjects rather than at 3 cpm. During and immediately after sham feeding, there was no change in the EGG of these subjects with the exception of one who showed some activity between 6 and 7 cpm. The EGG response to eating was the appearance of relatively low-intensity activity between 2.0 and 2.5 cpm. None of these subjects showed a peak in their spectral plots at 3 cpm.

DISCUSSION

The results of these experiments demonstrate that sham feeding significantly increased the amplitude or power of 3-cpm gastric myoelectric activity in healthy human subjects. The increase in gastric myoelectric activity, measured as an increase in the amplitude or power of the EGG, was similar to the increase in EGG amplitude elicited by actually eating a meal. However, sham feeding resulted in a very brief increase (1–2 min) in the amplitude of the EGG signal, whereas following eating, the increase in the amplitude of the EGG persisted for the duration of recording, a minimum of 10 min. The brief myoelectric response to sham feeding probably reflects the duration of cephalic–vagal activity. The postprandial EGG response is prolonged because it reflects both cephalic–vagal stimulation and gastric stimulation provoked by the luminal contents of the meal and perhaps neuroendocrine activity.

Sham feeding failed to elicit any 3-cpm activity in vagotomy patients. The lack of any change in the EGG of vagotomized subjects during sham feeding supports our assumption that the sham-feed response is vagally mediated. The dominant EGG frequency for all of these subjects during baseline was 8.5–10.0 cpm, probably jejunal in origin (22). Thus, it is possible that the vagotomized subjects failed to show a sham-feed response because a

TABLE 1. SUMMARY OF THE EFFECTS OF SHAM FEEDING AND EATING ON THE EGG RECORDINGS FROM FOUR PATIENTS WITH TRUNCAL VAGOTOMY AND BILLROTH II

Subject	*Baseline*	*Sham Feeding*	*Eating*
AH	9.0 cpm and very low amplitude 2.0 cpm	No change in EGG	3 min after eating showed increase in amplitude of 2.0 cpm
JJ	10.0 cpm	10.0 cpm and 6.0–7.0 cpm	2.0 cpm appeared before subject finished eating and continued postprandially
DP	8.5 cpm and 1.0 cpm	No change in EGG	10.0 cpm and some very low amplitude 2.5 cpm appeared 10 min after eating
PF	10.0 cpm	No change in EGG	Low amplitude 2.0 cpm appeared 8 min postprandially

vagotomy and antral resection had disrupted slow-wave activity. However, it should be noted that after eating all of the subjects showed an increase in EGG activity but at an atypical bradygastric frequency of 2.0–2.5 cpm.

In functional terms, the cephalic–vagal gastric myoelectric responses observed in this study may prime or ready the distal stomach to mix the luminal contents. Such activity may compliment vagal-mediated receptive relaxation of the gastric fundus. Another author (23) used the term "preregulation" to describe "early systemic" reflexes. Other functional terms that have been used to describe cephalic responses are "preparative metabolic reflexes" (24) and "prefeeding reactions" (25). Powley (26) has suggested that cephalic responses in anticipation of eating typically act as feed forward mechanisms, producing greater activity and release than is obtained when food is directly introduced into the stomach.

As mentioned above, the results of an earlier study showed that sham feeding had no effect on gastric emptying of a liquid and only minimal effect on gastric emptying of a solid (12). These results do not contradict the results of the present study because of procedural differences. In the former study, sham feeding was performed simultaneously with the infusion of a test meal directly into the stomach, and gastric emptying was the response measure. In the present study, fasted subjects were simply sham fed and gastric myoelectric activity was the measure of interest. The 3 min of sham feeding produced a 1- to 2-min increase in gastric myoelectric activity, a response that would not be expected to affect gastric emptying.

Two subjects reported that the experience of chewing and repeatedly spitting a hot dog into a bag was disgusting. Neither subject showed the increase in amplitude or power at 3 cpm during sham feeding that was found in the other subjects. There have been previous reports in the literature (27, 28) that indicate that sham feeding does not produce an increase in gastric acid secretion if the food that is chewed is not appetizing.

In conclusion, sham feeding increases EGG amplitude and power at 3 cpm in healthy subjects. The EGG response to sham feeding is a noninvasive method for studying the relationships between cephalic–vagal and gastric myoelectric activity in healthy subjects. The subject's emotional response to the sham feeding procedure may affect gastric myoelectric responses. Sham-feeding-induced EGG responses may also provide insights into cephalic–vagal abnormalities in patients with a variety of gastrointestinal disorders.

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