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Electrogastrographic biofeedback: a technique for enhancing normal gastric activity

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Abstract *Biofeedback has been used effectively for approximately 40 years as a technique to help individuals learn to control muscle activity, brain waves, certain autonomic nervous system responses such as heart rate and blood pressure, and, more recently, constipation and fecal and urinary incontinence. In the present study, biofeedback of electrogastrographic (EGG) activity was used to determine the extent to which healthy subjects could increase normal 3 cpm gastric myoelectric activity. Thirteen experimental participants were provided with biofeedback of their EGG activity on a computer screen, and instructed to try to make their own EGG signal match a simulated 3 cpm signal that was also present on the screen. Subjects were told to relax using various forms of imagery, and to heighten their awareness of their stomach activity. Thirteen control participants did not receive any biofeedback but were otherwise given the same instructions. Both groups showed an increase in 3 cpm activity while relaxing. However, over four trials separated by 2–7 days, experimental participants showed an increased percentage of 3 cpm activity during biofeedback sessions, while control participants showed a decrease in 3 cpm activity during the corresponding sessions. In conclusion, we have demonstrated that healthy subjects can increase their normal gastric 3 cpm activity with the use of EGG biofeedback.*

Keywords *biofeedback, electrogastrograms, gastric motility.*

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INTRODUCTION

Numerous studies[1] have demonstrated that normal gastric function is associated with rhythmic 3 cycle per min (cpm) gastric myoelectric activity, and that abnormal gastric function, which occurs during symptoms such as nausea, is associated with dysrhythmic gastric activity, either bradygastria or tachygastria. The purpose of this study was to determine the extent to which healthy subjects could enhance their 3 cpm electrogastrographic (EGG) activity by using relaxation and biofeedback. Biofeedback has been used effectively to treat certain types of constipation[2] and fecal[3] and urinary incontinence.[4]

There were two early attempts to use EGG biofeedback to train subjects to control their EGG activity.[5,6] Mixed results were obtained, but both studies were carried out at a time when EGG recording and analysis techniques were not well developed. Whitehead and Drescher,[7] using an invasive technique, tested the hypothesis that the ability to perceive visceral responses is a reliable predictor of the ability to control such responses, and they also examined the extent to which biofeedback enhanced the ability of subjects to control their gastric motility. They reported that the ability to perceive gastric contractions was unrelated to control of gastric motility, but that subjects who received biofeedback were able to increase normal gastric 3 cpm activity but not decrease motility on command. Subjects who did not receive biofeedback could not increase or decrease their gastric motility.

A more recent, non-invasive study[8] sought to determine whether biofeedback of autonomic responses would be an effective form of therapy for patients with mild to moderate delayed gastric emptying. The training involved biofeedback and imagery exercises eliciting relaxation and arousal. The results of the study revealed that 58% of the patients showed improvements in gastrointestinal symptoms following the biofeedback training sessions.

In the present study, subjects in the biofeedback group were not only presented with their own EGG as one real-time tracing on a computer screen, but they also saw simultaneously a computer-generated 3 cpm signal on a second tracing and were told to try to make their signal look like the computer-generated 3 cpm signal. The dependent measure of interest was the percentage of 3 cpm activity in the recorded EGG signal, because this is the measure that reflects normal healthy gastric functioning and decreases in conditions such as nausea as dysrhythmias develop. It was hypothesized that both the biofeedback group and the control (no-biofeedback) group would show an increase in 3 cpm from baseline to the period when they were relaxing, but only those subjects who received biofeedback of their EGG activity would show increasing amounts of normal 3 cpm activity from session to session.

METHODS

Participants

The Penn State Office of Research Protection approved the study. Twenty-six healthy college students, 10 male, aged 18–21, participated in the study. Prior to attending the first session, participants agreed to return for four sessions and to arrive at the laboratory for each session after having fasted for a minimum of 3 h.

Apparatus

Electrogastrographic activity was recorded using a model 2121 Fetrode® bioamplifier (UFI, Morro Bay, CA, USA). The signal was sent to a Model RS 3800 polygraph (Gould, Cleveland, OH, USA) for visual inspection of the record and to a computer for FFT analysis of the percentage of the total power (not time) that was in the normal 2.50–3.75 cpm frequency range (for a detailed description of this method of EGG analysis see Ref. 9). A UFI model 1504 simulator generated a 3 cpm wave that was employed during biofeedback trials. During biofeedback trials this signal was sent to a computer for participants to view on a monitor alongside their own EGG signal. In other words, the subject saw two wave forms, their EGG and a computer-generated 3 cpm signal, continuously scrolling from left to right on a 15-inch monitor. When the signals reached the right edge of the screen, and approximately 2 min of data were displayed, the signals would reappear starting on the left edge of the screen.

Procedure

Participants were brought into a small room containing a soft reclining chair that faced a computer monitor and electrodes were applied for EGG recording (see Ref. 9 for details of the EGG recording procedure). The participants were told that before the details of the investigation would be explained, they would simply rest in the chair for 6 min, during which time baseline data of EGG activity were recorded. All participants in both groups were also instructed to minimize movement, keep their respiration constant, and avoid voluntarily contracting abdominal skeletal muscles. An experimenter observed the subjects via a closed circuit TV at all times. Neither the biofeedback nor control participants viewed anything on the computer monitor during the baseline period.

Control group After collection of baseline data, the nature of the study was explained to each participant. In brief, subjects in the control group were told that we were interested in the extent to which people could alter their stomach activity using mental effort. It was explained that normal stomach activity is three contractions per minute, and that their job would be to try to increase the amount of this normal activity by relaxing and thinking of pleasant things such as lying on a beach on a beautiful day, or eating a favourite food. Participants were also told to imagine their stomach contracting three times per minute, much like a balloon inflating and deflating three times per minute.

Following these instructions to the participant, he or she was left alone for 10 min, during which time the experimenter checked out the apparatus and printed out the subject's EGG on a polygraph in a separate room. (Data from this first 10 min time period were not included in the analysis of this study because during this time subjects often asked for clarification about what they were to do, moved, and varied in the exact time it took them to settle down and begin the session.) After 10 min, each participant was asked how he or she felt they were doing, how relaxed they were, and what types of imagery they thought may have helped them to increase regular 3 cpm activity. The second 10 min time period was run in a manner identical to the previous time period. At the conclusion of the third time period, the electrodes were removed from the participant, and the trial ended. Three subsequent sessions, or trials, were conducted using the same protocol as the first, except that the participants had fewer questions and, therefore, the explanation of the study was not as lengthy, but all subjects were reminded of possible modes of imagery

and relaxation. This minor modification of the procedure for sessions 2–4 was identical for subjects in both groups. All follow-up sessions were run between 2 and 7 days following the previous session.

Biofeedback group Baseline EGG activity was collected from biofeedback participants in the same way as it was collected from control participants. Each individual was then informed of the nature and details of the study and instructed to employ imagery and relaxation techniques, just as the control participants were. However, they were also told that during the second 10 min time period they would see their own stomach activity on the monitor in front of them. They were told to watch this and to try to alter their output to match the simulated 3 cpm wave that was displayed above their EGG activity. After the second 10 min time period, the biofeedback participants were asked how they felt they did and which mental images tended to elicit more regular 3 cpm activity. The biofeedback monitor was turned off for the third 10 min time period, and the participants were asked to continue to employ imagery and relaxation techniques while maximizing their awareness of stomach activity. At the conclusion of the third time period, the electrodes were removed from the participant and the session ended. The three subsequent trials were the same as the first, except that the explanation of the study was not as detailed. Subjects were reminded of possible modes of imagery and relaxation, and follow-up sessions were run between 2 and 7 days following the previous session.

Quantification of data

Data were collected and compiled using EGGSAS-4®, version 2.1 (3 CPM; Crystal Bay, NV, USA) Any segments of the recorded signals that had artefacts were identified visually from the polygraph record and were not included in the analysis. For example, if a subject tried to alter his/her EGG by contracting and relaxing his/her abdominal wall musculature, the EGG tracing would appear off scale and that portion of the EGG record was not analysed. EGGSAS-4 provided the percentage of total power (not time) in the normal 3 cpm range for each of the three time periods analysed – 6 min baseline, second 10 min (the period when one group received biofeedback), and third 10 min. Means of all measurements were calculated after data points that varied more than two standard deviations from the mean were excluded as outliers. Mean percentages of 3 cpm activity during the three time periods were calculated for each of the four sessions, separately. Finally, a repeated measures analysis of variance (ANOVA) was performed in order to determine whether there was a significant trend over trials for each time period. When significant differences were found, follow-up analyses were run to determine where such differences occurred.

RESULTS

Nearly all subjects were able to increase their 3 cpm activity from baseline to the second time period, the period during which both groups tried to increase their 3 cpm activity, although only the experimental group received biofeedback.

Figure 1 shows the mean percentage 3 cpm EGG activity for both groups during the second period over the four trials. As can be clearly seen, there was an interaction; the level of 3 cpm activity decreased for the control group and increased for the biofeedback group [F (3, 60) = 2.84, $P < .05$]. Analysis of the between group differences for each trial revealed that there was not a significant difference for the first two trials, but the difference was significant at the 0.05 level for trials 3 and 4.

Figure 2A shows a 1 min portion of the raw EGG recorded from a subject in the control group during the second time period, during the first trial. Figure 2B shows a 1 min EGG tracing from the same subject during trial 4. Note that there was only a modest change in the 3 cpm activity of this subject from trial 1 to 4.

Figure 3A shows on the top, a computer-generated 3 cpm signal that was seen by the subject, and on the bottom, a 1 min portion of the EGG tracing of a biofeedback subject during the second period, during trial 1. Figure 3B shows 1 min tracing of the EGG of

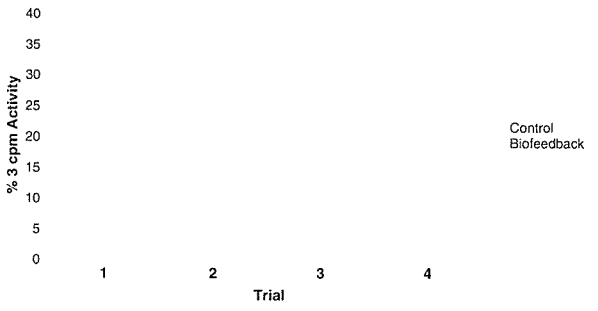

Figure 1 Mean percentage 3 cpm EGG activity recorded from both groups during the second time period for each of the four trials. Note the large increase in normal 3 cpm activity beginning at the third trial for the group that received biofeedback and the decrease in 3 cpm that occurred at the same time for the control group.

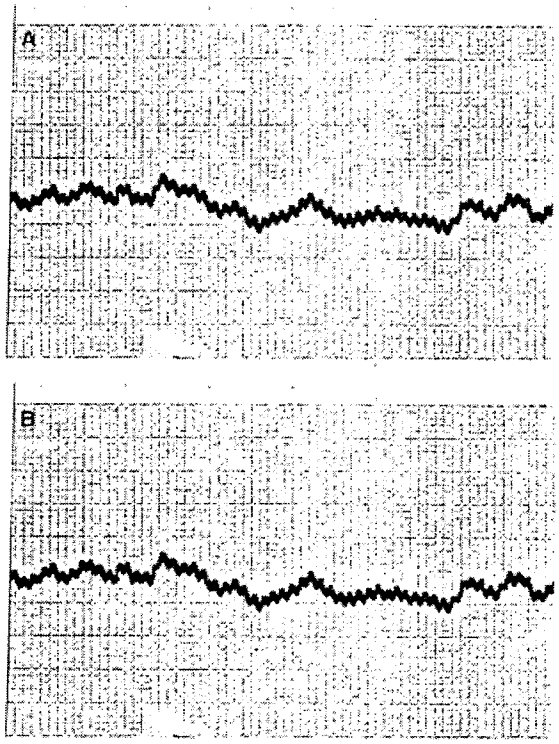

Figure 2 (A) 1 min segment of the electrogastrographic (EGG) tracing recorded during the second period of the first trial from a subject in the control (no-feedback) group. There was no obvious 3 cpm activity. (B) 1 min segment of the EGG recorded during the second period of the fourth trial from the same control subject. Note that there was very little change in the recording.

the same subject during the second period, during trial 4. Note that almost no 3 cpm activity is evident during trial 1, but the EGG record from the same subject for trial 4 shows consistent high amplitude 3 cpm activity.

Neither group showed much change in tachygastria during the second time period, when they were trying to increase their normal 3 cpm activity. The mean percentage of total power that was in the tachygastria range during the four sessions for the control group was 20, 23, 21 and 24. Mean percentage of tachygastria during the comparable period for the biofeedback group for the four sessions was 26, 23, 29 and 26.

Neither group showed a significant trend over trials for their 3 cpm activity during baseline or the third time period during which neither group received biofeedback. However, the control group showed a decreasing trend in 3 cpm activity during both of these periods, whereas the experimental group showed an increase in normal 3 cpm EGG activity during these periods. No subjects reported nausea at any time during or immediately after a session.

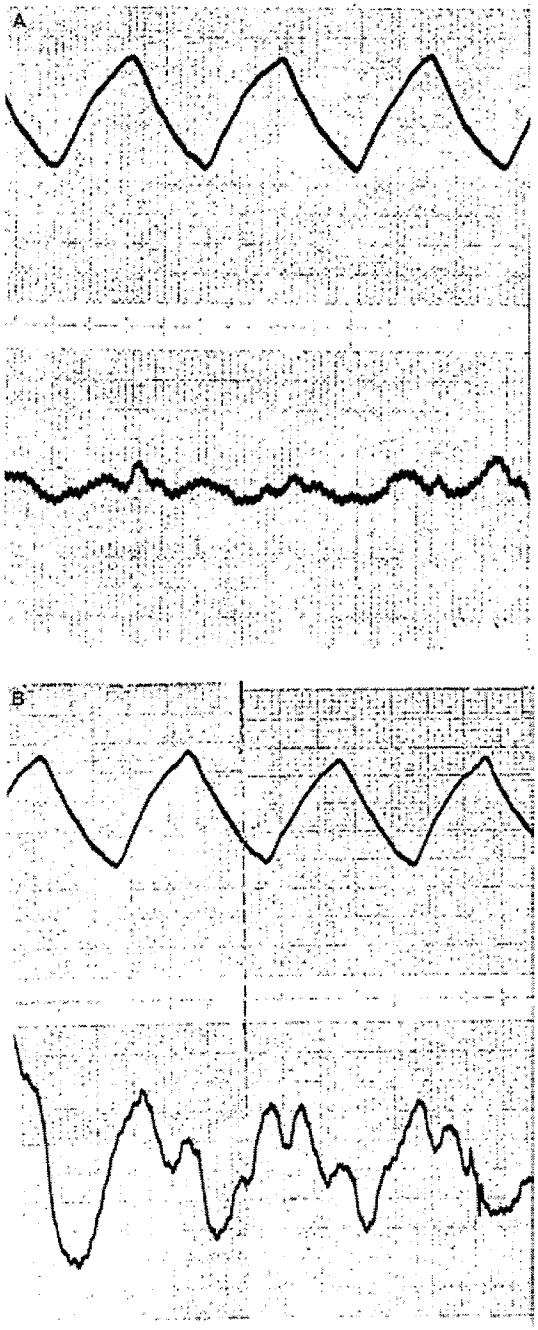

Figure 3 (A) 1 min segment of the electrogastrographic (EGG) tracing recorded during the second period of the first trial from a subject in the biofeedback group is shown in the bottom portion of the figure. The tracing on the top of the figure is the computer-generated 3 cpm signal that the subject observed while trying to increase his/her normal 3 cpm activity. Little 3 cpm activity was evident during this first trial. (B) This 1 min segment of the EGG recorded during the second period of the fourth trial of the same biofeedback subject shows a very large increase in normal 3 cpm activity.

DISCUSSION

The purpose of this study was to determine the extent to which healthy participants could increase normal 3 cpm stomach activity, without and with the aid of biofeedback. It is clear that when subjects were asked to relax and increase their awareness of their stomach's activity in order to increase the regularity of contractions, most were able to increase 3 cpm activity. When the results for the two groups are compared across trials, it is very clear that the experimental group showed an increase in 3 cpm activity during the time when they received biofeedback, and the control group showed a decrease over trials during this same time period. Neither group showed a significant change in tachygastria during this period. Schultz and Luthe[10] suggest that we make a distinction between active concentration that requires an effort to attend and concern about the results, and passive concentration that implies allowing responses to occur. The former would be expected to increase sympathetic activity, reduce parasympathetic activity, and reduce normal gastric motility, while the latter would increase relaxation and normal gastric motility. We assume that over trials, subjects in the biofeedback group learned to allow the desired response to happen rather than to try to make it happen. The control group, on the contrary, had no way of knowing when their effort to increase 3 cpm, active or passive, was successful.

As the biofeedback group did see a constant 3 cpm signal, and may have concentrated on it to varying degrees, while they were trying to increase their normal 3 cpm activity and the control did not, we did a post-hoc study to see if active concentration would actually *decrease* normal 3 cpm activity, as suggested by Schultz and Luthe.[10] We instructed 64 healthy subjects to do mental arithmetic, i.e., keep subtracting 7 from a very large number for 6 min. The subjects showed a 7% *decrease* in 3 cpm activity from baseline to the mental arithmetic task ($P < .004$). This finding is important because it suggests that the presence of the constant 3 cpm signal did not contribute to the *increase* in normal 3 cpm activity shown by the biofeedback subjects.

It should be noted that whereas the biofeedback subjects were able to use what they had learned in the absence of biofeedback to increase their 3 cpm activity during later baseline and no-feedback period trials, this increase was not significant. From the results of this study with healthy subjects, it is not possible to speculate whether with additional biofeedback trials or with a different schedule of when and how long biofeedback was presented, patients such as those experiencing nausea and showing little normal 3 cpm gastric activity would be able to use biofeedback to produce a clinically significant increase in their 3 cpm activity. However, it should be noted that in the present study all participants were in good health, at least 3 h fasted, and at baseline showed normal gastric activity. And with four biofeedback trials, these subjects showed a significant increase in their 3 cpm activity over their normal activity.

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