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ORIGINAL PAPER

An Evaluation of Adult Electrogastrography Criteria in Healthy Children

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Abstract The current study examined whether electrogastrogram (EGG) recordings obtained from healthy children would be considered normal by standards established for adults and whether EGG patterns differ between children/adolescents and adults. Twenty-eight healthy children (54% females; ages 8–17 years; mean = 12.4 years) were evaluated and compared to 15 healthy adults evaluated previously. EGGs were recorded for 30 min in the fasting state and for 1 hr following a standard meal. For both pediatric and adult participants, there was a significant increase in both the dominant frequency and the dominant power from the pre- to the postprandial period ($P < 0.001$ for each). Using adult standards, the percentage normal slow waves was $\geq 70\%$ of the recording time in 96% of children in the fasting state and in 100% in the postprandial period. A postprandial power increase was seen in 89% of the children. In conclusion, our data indicate that American Motility Society (AMS) consensus adult criteria for a normal EGG are appropriate to apply to children and adolescents when utilizing methodology and meal challenge similar to those used to establish the adult norms.

Keywords Electrogastrogram · Motility · Gastric dysrhythmias

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Introduction

Electrogastrography (EGG) is a noninvasive technique for recording gastric myoelectric activity utilizing cutaneous electrodes placed on the anterior abdominal wall overlying the stomach. An American Motility Society (AMS) Clinical GI Motility Testing Task Force has published EGG standards including the definition of a normal EGG for the adult population [1]. A normal study was defined as $\geq 70\%$ normal slow waves in both the fasting and the postprandial periods and a power increase following a meal. Criteria for a normal EGG result were based on four studies evaluating healthy adult participants [2–5]. These four studies utilized similar meals, generally consisting of eggs, toast, and water, though there was some minor variation. Criteria for a normal EGG in children and adolescents have not been established across centers. In part this may be attributed to the widely varying diets that have been utilized for EGG evaluations in healthy children [6–9]. In two of these previous studies of children, however, participants were fed a diet similar to the diet utilized to establish the adult standards [6, 7]. The 26 healthy children reported in these two studies from a single center had a percentage normal slow waves within the adult normal range in both the preprandial and the postprandial periods. In one of these two studies, the only direct comparison previously reported, Chen *et al*. found no significant differences in rhythm between nine healthy children 4 to 11 years of age and nine healthy adults fed the same meal

(eggs, toast, and water) [7]. Although these two pediatric studies suggest that the established adult criteria may be applicable to children/adolescents fed a diet similar to that used in the adult studies which established the criteria, these criteria need confirmation in an independent sample of healthy children/adolescents at an independent center.

The purpose of the current study was to investigate whether EGG recordings obtained from healthy children would be considered normal by standards established for adults. Additionally, we compared EGG recordings between healthy children and previously reported healthy adults whose studies were performed by the same investigator utilizing the same method as in the current study [2].

Materials and methods

Study participants

Twenty-eight healthy volunteers were enrolled in this study. Participants ranged in age from 8 to 17 years (mean $=$ 12.4 ± 2.9 years), with a relatively even split between males (46%) and females (54%). Participants were excluded for previous abdominal surgery or any chronic disease requiring regular medical care. Participants also were excluded for a history of chronic or recurrent abdominal pain or discomfort, nausea, vomiting, diarrhea, constipation, or bloating. Participants were compared to a sample of healthy adult subjects previously evaluated and reported by the authors (Z.L. and R.W.M.) [2]. The study protocol was approved by the Institutional Review Board at Children's Mercy Hospital, and written consent/assent was obtained for all participants prior to participation in the study.

EGG recording and analysis

All recordings were performed in the morning following an overnight fast of at least 8 hr. Subjects did not take any medications on the study day. The study area was separate from other clinical activities and the evaluation was carried out in a quiet room with the subjects resting throughout the study. The fasting EGG was recorded for 30 min in a supine position. The participant then sat up and consumed a standard meal within a 10-min period. The meal consisted of two scrambled eggs, one slice of whole wheat toast with one pat of butter, and 120 ml of water. The participant then resumed the supine position and the postprandial EGG was recorded for 1 hr. This study length has previously been shown to be sufficient to produce reliable EGG results [1]. All studies in the healthy children and the previously reported healthy adults were performed by the same investigator (Z.L.) using the same method with the exception of some minor differences in the test meal (e.g., butter versus jelly on the toast) [2].

Before the placement of electrodes, the epigastric skin where the electrodes were to be positioned was shaved to remove hair, cleaned, and abraded with sandy skin preparation jelly (Omni Prep, Weaver, Aurora, CO) to reduce impedance. Two silver-silver chloride ECG electrodes (DNM, Dayton, OH) were placed on the abdominal skin. One electrode was positioned at the midpoint between the xiphoid process and the umbilicus. The second electrode was placed 5 cm to the left and cephlad of the first active electrode, at least 2 cm below the rib cage, and in the midclavicular line. A reference electrode was placed in the lower quadrant close to the left costal margin. The electrodes were connected to a portable battery-operated recorder (Digitrapper EGG; Synectics Medical, Irving, TX) with low and high cutoff frequencies of 1 and 18 cycles per minute (cpm), respectively. On-line digitization was done at a sampling frequency of 4 Hz and digitized samples were stored on the recorder. Participants were asked not to talk and to remain as still as possible during the recording to avoid motion artifacts.

At the end of the EGG recording, data stored were downloaded to an IBM 586 personal computer for data analysis. After the EGG segments with motion artifacts were identified by visual analysis and removed using a locally developed program, the following parameters were computed using spectral analysis methods [10]: (1) dominant frequency, defined as the frequency at which the power spectrum of an EGG recording had a peak power in the range of 0.5 to 9 cpm; (2) dominant power, defined as the power at the dominant frequency in the power spectrum of the EGG recording, expressed as decibels (dB); (3) change in postprandial EGG dominant power (δP), which was defined as the difference between the dominant power after and that before the meal; (4) the percentage of normal slow waves, defined as the percentage time during which regular 2- to 4-cpm slow waves were present over the entire observation period; and (5) the percentage of dysrhythmias, defined as the percentage of time during which frequencies of either >4 cpm (tachygastria) or <2 cpm (bradygastria) were recorded. A dysrhythmic episode had to be recorded for ≥ 2 min with the normal signal simultaneously absent. The percentage of normal slow waves and percentage of dysrhythmia were computed from the running power spectra of the EGG by the adaptive spectral analysis method [10].

Statistical analysis

EGG parameters were compared between children and adults and between children <12 years and children ≥ 12 years, respectively, by Student's t test. Consistent with established adult criteria, an EGG was considered normal if a normal rhythm was present for $\geq 70\%$ of the recording time in both

the pre- and the postprandial periods and the δP was >0 [3]. The proportion of children with a normal rhythm present for $\geq 70\%$ of the recording time and of those with a $\delta P > 0$, respectively, were determined for the children and compared to the proportions previously found in the adult sample by Fischer's exact test. As an indicator of the data distribution, the 10th percentile values were determined for the percentage normal slow waves in the pre- and the postprandial periods, respectively, and for the δP. A P value < 0.05 was considered to be significant.

Results

The test meal was well tolerated. All participants ingested at least 70% of the test meal and the meal was consumed completely by 89% (25/28) of the subjects.

Normal rhythm present for $\geq 70\%$ of the recording time was seen in 96% (27/28) of the participants in the preprandial period and in 100% of the participants in the postprandial period. An increase in power after the meal ($\delta P > 0$) was seen in 89% (25/28) of participants. These proportions did not differ significantly from those previously found for adult participants. The 10th percentile values were 70.0 for the preprandial percentage normal slow waves, 72.7 for the postprandial percentage normal slow waves, and -0.51 dB for the δP.

For both pediatric and adult participants, there was a significant increase in both the dominant frequency and the dominant power from the pre- to the postprandial period ($P < 0.001$ for each). There was a significant postprandial increase in the percentage normal slow waves in pediatric participants only ($P < 0.001$). Means for EGG parameters for adult and pediatric participants are listed in Table 1. The mean preprandial percentage normal slow waves was significantly lower in pediatric participants (81.5% vs. 94.2%; $P < 0.001$), while the preprandial percentage tachygastria was significantly greater in pediatric than in adult participants (8.9% vs. 2.3%; $P = 0.04$). The other parameters did not differ significantly between the two groups.

Pediatric participants <12 years of age did not differ from participants ≥ 12 years of age for any parameters except that the preprandial percentage tachygastria was significantly greater ($P = 0.015$) and the preprandial percentage bradygastria was significantly lower ($P = 0.04$) in the younger participants. In comparison to adults, the preprandial percentage normal slow waves was lower ($P = 0.002$) and the preprandial percentage bradygastria was greater ($P = 0.002$) in adolescent participants (i.e., ≥ 12 years). For participants <12 years, the preprandial percentage normal slow waves was lower ($P = 0.001$) and the preprandial percentage tachygastria ($P < 0.001$) and δP ($P = 0.01$) were greater than previously found in adults.

Discussion

EGG patterns have been shown to differ between groups of children with dyspepsia compared to healthy controls [6, 11]. Although studies of group differences provide physiologic information of interest, the clinical utility of EGG for children will ultimately be determined by defining normal vs. abnormal studies and evaluating the implications of this distinction, e.g., differences in therapeutic responses. Criteria for a normal EGG have been established for adults by consensus opinion [1]. These criteria were based on four studies of EGG in healthy adults [2–5]. Two of these studies were performed by authors of the current study (Z.L. and R.W.M.) including one reporting the adult normative data utilized for comparison in the current study [2]. Criteria for a normal EGG have not been established for children/adolescents, and whether the adult standards might also apply to children is not known. Our data indicate that healthy children generally fall within the normal ranges established for adults and are in this normal range as frequently as are healthy adults. For the

Table 1 Mean ($\pm$ SD) EGG results for adults, all pediatric participants, and pediatric participants by age group

	Adults ($N = 15$)	All pediatric ($N = 28$)	Pediatric <12 yr ($N = 13$)	Pediatric >12 yr ($N = 15$)
Preprandial				
Dominant frequency	2.88 ± 0.28	2.92 ± 0.44	3.04 ± 0.51	2.81 ± 0.36
% Normal	94.2 ± 7.48	81.54 ± 11.12^a	81.77 ± 9.26	81.33 ± 12.85
% Tachygastria	2.27 ± 5.01	8.86 ± 8.81^b	13.08 ± 8.55	5.20 ± 7.49^c
% Bradygastria	3.53 ± 5.55	9.61 ± 10.61	5.15 ± 6.48	13.47 ± 12.11^c
Postprandial				
Dominant frequency	3.08 ± 0.22	3.16 ± 0.37	3.17 ± 0.43	3.16 ± 0.33
% Normal	92.53 ± 7.52	89.04 ± 10.78	90.69 ± 10.67	87.6 ± 11.03
% Tachygastria	4.73 ± 6.56	8.68 ± 8.58	8.00 ± 9.27	9.27 ± 8.22
% Bradygastria	2.73 ± 5.22	2.29 ± 4.11	1.31 ± 3.25	3.13 ± 4.67
Delta power	2.91 ± 4.14	6.69 ± 6.01	8.68 ± 6.73	4.97 ± 4.91

[a] $P < 0.001$ vs. adults.
[b] $P < 0.05$ vs. adults.
[c] $P < 0.05$ vs. <12 yr.

Table 2 Summary of previous studies reporting normative EGG data in children

Author	Test meal	*N*	% Normal slow waves	
			Fasting	Fed
Chen *et al*. [7][a]	Eggs, toast, and water	9	84.6 ± 3.2	86.7 ± 2.8
Riezzo *et al*. [8][b]	Bread, ham, butter, and juice	114	81.5 (59.3–100)	76.9 (54.3–97.2)
Chen *et al*. [6][a]	Eggs, toast, and water	17	79.7 ± 3.1	85.0 ± 2.9
Levy *et al*. [9][c]	Turkey sandwich, potato chips, cookies, and juice	55	79.9 ± 13.4	84.8 ± 11.5

[a] Mean ± SE.
[b] Median (5th–95th percentiles).
[c] Mean ± SD.

percentage normal rhythm, nearly all of the children in this study would have been considered normal in the preprandial period by the AMS standard and all were in the normal range in the postprandial period. In the current study, all but three patients had a postprandial power increase similar to that of healthy adults, where 90–95% exhibit an increase in postprandial power [1].

In the current study, similarly to healthy adults, children exhibited an increase in both the dominant frequency and the dominant power with feeding. EGG parameters were similar between the children and the adults with the exception that children had a lower percentage normal slow waves (and higher percentage tachygastria) in the fasting state. Although lower in the pediatric subjects, the mean preprandial percentage normal slow waves remained well above the lower limit of the normal adult range and only one patient had a value below the normal adult range. This difference between the children and the previously reported adults did not result from the slight differences in the test meal, as the only differences between the two groups were found in the fasting state. The only previous direct comparison between children and adults found no EGG differences between healthy children and adults in either the pre- or the postprandial period [7].

Previous data have been published for healthy children with significantly varied types of test meals and also may have value in helping establish child norms for EGG [6–9]. Types of test meals and results of previous studies are summarized in Table 2. Despite the varied meals, data from these previous studies, as well as the current study, have been similar with regard to the percentage normal slow waves in both the fasting and the fed states. Group means have placed within the normal adult range for all of the identified studies, regardless of the test meal. Only one of the previous pediatric studies reported ranges for the percentage normal rhythm in the pre- and postprandial periods [8]. This study, reported by Riezzo *et al*., employed a diet very different from that used to create the adult standard, and although multiple participants had values below the 70% cutoff, the overall proportion of participants below this limit is not reported [8]. The δP in the current study also was similar to that reported by Levy *et al*. (mean ± SD: 6.0 ± 5.96 dB) and that reported by Chen *et al*. (mean ± SE: 4.36 ± 1.90 dB) [6, 9].

Further, EGG patterns do not appear to be strongly affected by age over childhood and adolescence. We found only minor differences in EGG patterns between participants <12 years and those ≥ 12 years. The differences are unlikely to be clinically significant, as the percentage of time in a normal rhythm was well within the normal adult range for both groups. This finding may also be a minor statistical aberration, as this finding has not been consistently reported in previous studies. For example, Chen and colleagues previously reported an adult EGG pattern in a sample of children aged 4–11 years [7]. Riezzo *et al*. found only minor influences of age in a group of participants 6–12 years of age [8]. Levy *et al*. found no age effect on EGG patterns over the 6- to 18-year-old range [9].

In conclusion, our data indicate that AMS consensus adult criteria for a normal EGG are appropriate to apply to children and adolescents when utilizing a test meal similar to that used to establish the adult norms. Ultimately, however, the clinical utility of EGG will be determined by evaluating whether this distinction (normal versus abnormal) has therapeutic or prognostic significance in patients.

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