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Association Between Infantile Colic and Carbohydrate Malabsorption From Fruit Juices in Infancy

Debora Duro, MD, MS; Russell Rising, PhD[a]; Maribel Cedillo, BS; and Fima Lifshitz, MD

ABSTRACT. ***Objective.*** **To determine whether infantile colic (IC) is associated with malabsorption of carbohydrates present in fruit juices.**

Methods. **In this double-blind study, parents of 30 healthy infants (5.1 ± 0.7 months, 7.4 ± 1.0 kg, 64 ± 4 cm) were administered a questionnaire to quantitatively assess IC. Thereafter, they were divided into 2 groups, 16 infants with and 14 without IC. Within each treatment group infants were fed 120 mL (16.3 ± 2.0 mL/kg) of either white grape (sorbitol-free; 1:1 fructose-to-glucose ratio) or apple (sorbitol 0.5 g/dL; 2.6:1 fructose-to-glucose ratio) juice. Physical activity (PA), energy expenditure (EE), crying, and sleeping times were measured for 0.5 and 3.0 hours before and after juice feeding, respectively, using the Enhanced Metabolic Testing Activity Chamber. Carbohydrate malabsorption was determined by breath hydrogen (BH_2) gas analysis after juice feedings. Statistical differences between groups were determined by 2-way analysis of variance with the Tukey procedure.**

Results. **Infants with IC fed apple juice exhibited carbohydrate malabsorption as shown by increased BH_2 excretion, whereas those without IC absorbed carbohydrates normally when fed this juice. Infants fed apple juice with carbohydrate malabsorption cried more and consequently slept less during the last 1.5 hours of the study. This was associated with increased PA and EE as compared with infants without IC fed apple juice. In contrast, infants fed white grape juice, regardless of IC, showed no increase in BH_2 excretion, PA, and EE. Furthermore, crying and sleeping times were unchanged in infants fed white grape juice regardless of the presence or absence of IC.**

Conclusions. **IC was associated with carbohydrate malabsorption from fruit juices containing sorbitol and a high fructose-to-glucose ratio.** ***Pediatrics*** **2002;109:797–805;** ***infantile colic, carbohydrate malabsorption, breath hydrogen excretion, energy expenditure, physical activity, fruit juice.***

ABBREVIATIONS. IC, infantile colic; BH_2, breath hydrogen; PA, physical activity; EMTAC, Enhanced Metabolic Testing Activity Chamber; EE, energy expenditure; GER, gastroesophogeal reflux; MI, milk intolerance; URI, upper respiratory infection.

Paroxysmal high-pitched crying, irregular sleeping pattern, and difficulty with feeding characterize infantile colic (IC). It occurs in 10% to 25% of infants and usually improves by 3 to 4 months of age.[1,2] The most frequently applied diagnostic criterion is Wessel's "rule of threes"—crying more than 3 hours per day, more than 3 days per week, for more than 3 weeks.[2] Gas-related symptoms are the most common defining criteria of IC used by mothers and the second most common used by investigators. The symptoms of abdominal distention, passage of flatus, borborygmi, and abdominal pain have led to a widely held impression that excessive gastrointestinal gas is the cause of IC. The possible sources of the excessive gas are swallowed air and colonic fermentation attributable to unabsorbed carbohydrates.[3] Furthermore, some investigators have attributed behavioral problems, and not IC, to be the cause of crying and fussing in infants during the first few months of life.[4]

Malabsorbed carbohydrates from fruit juices produce excess hydrogen gas.[3] Apple and pear juices that contain sorbitol, along with a high fructose-to-glucose ratio, have been associated with increased breath hydrogen (BH_2) gas excretion levels,[5,6] metabolic rate, and physical activity (PA).[7] Such changes were recently demonstrated by a new Enhanced Metabolic Testing Activity Chamber (EMTAC) that measures total energy expenditure (EE), resting metabolic rate, sleeping metabolic rate, as well as PA.[7,8] However, no studies have been conducted to determine whether IC plays a role in an infant's ability to absorb carbohydrates from certain fruit juices. Therefore, the purpose of this study was to determine whether there is an association between IC and carbohydrate malabsorption in infants consuming fruit juices.

MATERIALS AND METHODS

Study Design

Thirty healthy 4- to 6-month-old infants were recruited from the outpatient clinics at Miami Children's Hospital in Miami, Florida, from October 1998 through November 1999. None of them had fever, minor gastrointestinal upset, diarrhea, nor usage of antibiotics in the previous 3 weeks before the study. The infants were removed from any other medications 24 hours before the study. Supine length (crown to heel) was measured in duplicate with a horizontal stadiometer (Perspective Enterprises, Kalamazoo, MI) and body weight was the average of 2 measurements obtained with an infant scale (Cardinal Detecto, Webb City, MO). From these measurements, weight for length was determined using appropriate National Center for Health Statistics growth charts. Of the 30 infants selected for the study, 15 of them were growing between the 10th and 85th percentile for length and weight. The remainder of the infants selected for the study comprised of 4 below the 10th and 11 above the 85th percentiles for length and weight (Table 1). Skinfold thickness was the mean of 2 measures at each of 5 sites (biceps, triceps, subscapular, flank, and quadriceps) on the right side of the body using a Lange skinfold

From the Research Institute, Miami Children's Hospital, Miami, Florida.
[a]Current address: EMTAC Inc, 5045 SW 82nd St, Miami, FL 33143.
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Reprint requests to (F.L.) Research Institute, Miami Children's Hospital, 3100 SW 62nd Ave, Miami, FL 33155. E-mail: fima.lifshitz@mch.com

caliper (Beta Technology, Cambridge, MD) according to a standard procedure.[9] Body fat and fat-free mass were calculated by appropriate equations.[10]

A questionnaire to quantitatively assess IC was administered to the parents by 1 investigator (M.C.) who was neither aware of the clinical status of the infants nor involved with the testing protocol. The questions were designed to assess parent's perceptions of the presence or absence of IC during the first 6 months of life, define the signs and symptoms of the problem, as well as allow a numerical score to be applied to the answers (Table 2). For example, the past presence or absence of colic scored 1 and 0, respectively. The parents' perception of their infant's colic was scored on a scale from 1 to 10 (10 being the worst). For this assessment, parents were asked about the presence and absence of symptoms like flatulence, abdominal distention, irritability, fussiness, and amount of crying per day. Two different methods were used to assess the amount of infant crying. The first was derived from the questionnaire and consisted of quantifying the history of infant crying during the period that the child had colic as reported by the parents. They described the severity and the duration of crying during colic episodes. The second method for assessment of crying was more precise and involved the amount of time infant's cried as recorded by 1 of the investigators during the metabolic measurements described below.

Other areas of concern addressed in the questionnaire evaluated the number of episodes of colic per day (0 = no colic, 1 = one episode, and so forth), usage of any medications for the treatment of colic (0 = no 1 = yes), and the amount and length of time medication was administered was also assessed. The duration of colic (0 = no 1 = up to a month, 2 = 2 months, 3 = 3 months, and so forth) and the amount of crying per day (0 = no crying, 1 = up to 10 minutes, 2 = up to 20 minutes, and so forth) were also quantified. Other qualitative questions to further define IC included the time of day when colic symptoms appeared, as well as the techniques used to calm the infant when suffering from colic. Furthermore, the type of feedings, formula fed, and the number of times parents changed their infant's formula were also assessed. Any, or all of these positive responses resulted in a high score, whereas negative responses resulted in a low score. All of the above provided a perception score based on the answers by the parents for each infant. The infants placed in the non-IC group were those without complaints relating to IC. There were 16 infants with IC and 14 infants without this problem. Furthermore, there were 5 infants in the non-IC and 10 in the IC groups who had associated medical conditions such as gastroesophageal reflux (GER), milk intolerance (MI), and frequent upper respiratory infections (URI) diagnosed by their pediatricians (Table 2).

In this study, 28 infants were fed milk- or soy-based formula, and 2 were strictly breastfed before the study. Of the 30 infants in this study, 10 of them had not consumed fruit juice before the study, whereas the other 20 infants had been fed fruit juices for at least 2 weeks before testing (Table 2). Among the 20 infants who consumed fruit juice, 13 ingested apple juice on a daily basis, whereas the other 7 consumed a variety of fruit juices such as orange, pear, and grape. The infants who had not previously consumed fruit juice were about to be introduced to this food supplement by their doctor. Furthermore, they were older than 4 months and greater than 6.0 kg.

Infants with IC, as well as those without this problem, were given either apple or white grape juice as a test in a double-blind fashion. White grape juice contains (g/dL) 7.5 g of fructose, 7.1 g of glucose, and has a pH of 3.25. Apple juice contains (g/dL) 6.2 g of fructose, 2.7 g of glucose, 0.5 g of sorbitol, 1.2 g of sucrose, and has a pH of 3.60. White grape juice has a 1:1, whereas apple juice is 2.6:1 fructose-to-glucose ratio. The juices were provided by Welch Foods Inc (Concord, MA) and were coded and blinded to the investigators. There were no detectable differences in regard to appearance and odor between the 2 types of fruit juices.

Infants were fasted for 2 hours and then placed in the EMTAC (Fig 1) and given the juice test. Continuous measurements of PA (oscillations in weight/min/kg body weight) and EE (kcal/min) for 3.5 hours including a half-hour baseline period were recorded by the EMTAC.[7,8] The EMTAC and method of PA and EE measurement were validated as described previously.[8] An activity log was kept during metabolic testing by 1 of the investigators who observed the infant throughout the study. The information gathered included activities such as crying, sleeping, and wakefulness. Information from this log was entered into the computer at the completion of each infant study for calculation of crying and sleeping times.

After a half-hour baseline period within the EMTAC (adjustment period), a breath sample (time 0) was collected while the infant remained in the EMTAC by drawing exhaled air from the infants nose in a 20-mL plastic syringe (Becton Dickinson, Franklyn Lakes, NJ) fitted with a stopcock during normal breathing. The syringe plunger was pulled back only during exhalation thus eliminating any contamination by outside air. Thereafter, a single serving of either white grape or apple juice (120 mL) was fed approximately 2.5 hours after the last formula feeding in a double-blind fashion. The amount of juice consumed by the infants was similar among the 4 groups (16.3 ± 2.0 mL/kg).

After juice consumption, carbohydrate absorption was determined by BH_2 gas analysis every half hour for 3 hours as described above. Thereafter, breath samples were analyzed for BH_2 by a hydrogen gas analyzer (Quintron 12i MicroLyzer, Quintron Instrument Co, Milwaukee, WI) according to the manufacturer's instructions. Carbohydrate malabsorption was determined by an increase of 20 ppm above the baseline as described in a previous study.[7]

Statistical Analysis

The sample size was calculated to detect a 5% difference in PA and EE and the variability was based on a previous study.[7] EE, PA, BH_2, crying, and sleeping time data were analyzed by 2-way analysis of variance over the course of the 3-hour study period. Differences among the 4 groups were assessed by the Tukey procedure. All data were presented as mean ± standard deviation except where noted.

Parents were provided with a complete explanation regarding the purpose, procedure, risks, and benefits of the study. Informed consent was obtained from at least 1 parent of each infant. The Institutional Review Board of Miami Children's Hospital approved the study.

RESULTS

There were no significant differences in growth performance or physical characteristics among the 4

TABLE 1. Physical Characteristics of the Population Studied

Variables	WGNIC	WGIC	APNIC	APIC
N (infants)	6	8	8	8
Age (mo)	4.8 ± 0.7	5.0 ± 0.8	5.1 ± 0.4	5.2 ± 0.5
Weight (kg)	7.8 ± 1.1	7.5 ± 1.0	7.4 ± 0.8	7.0 ± 0.9
Length (cm)	64 ± 2	65 ± 3	64 ± 4	64 ± 6
Body fat (%)	31 ± 3	29 ± 3	29 ± 3	28 ± 4
Fat-free mass (kg)	5.4 ± 0.5	4.9 ± 1.0	5.2 ± 0.4	5.0 ± 0.5
Weight-for-age (percentile)	72 ± 37	61 ± 25	60 ± 26	44 ± 32
Length-for-age (percentile)	49 ± 32	51 ± 26	48 ± 18	50 ± 30
Weight-for-length (percentile)	84 ± 15	72 ± 28	63 ± 35	47 ± 40

Data presented as mean ± standard deviation. Differences were not significant.
Body fat percentage and fat-free mass were calculated according to the equation[8].
WGNIC indicates white grape juice no IC; WGIC, white grape juice with IC; APNIC, apple juice no IC; APIC, apple juice with IC.

TABLE 2. Results of Colic Assessment From the Questionnaire

Variables	WGNIC		WGIC		APNIC		APIC	
Colic during the first 6 months	No		Yes		No		Yes	
Onset of colic (number of infants/period)	Not applicable		<2 mo 2–4 mo >4 mo Undetermined	2 5 0 1	Not applicable		<2 mo 2–4 mo >4 mo Undetermined:	2 1 1 4
Colic duration (number of infants/period)	Not applicable		<2 mo 2–4 mo >4 mo	1 4 3	Not applicable		<2 mo 2–4 mo >4 mo Unknown:	1 2 3 2
Daily episodes of colic (mean ± SD)	0.0		2.6 ± 0.9*		0.0		3.1 ± 2.3*	
Time of the colic (number of infants/total)	Not applicable		Night All day	3/8 4/8	Not applicable		Night All day	6/8 3/8
Colic symptoms (number of infants/total)	Not applicable		Crying Flatulence Vomiting All symptoms	6/8 4/8 5/8 2/8	Not applicable		Crying Flatulence Vomiting All symptoms	5/8 4/8 1/8 1/8
Colic perception (scale: 1–10)	0.0		8.5 ± 1.3*		0.0		8.6 ± 1.5*	
Methods used to calm the baby (number of infants/total)	Not applicable		Changing position Abdominal massage Medications Feeding Other	7/8 3/8 3/8 1/8 3/8	Not applicable		Changing position Abdominal massage Medications Other	4/8 4/8 4/8 1/8
Estimated crying time (min/d ± SD)	3.5 ± 1.9		59 ± 66.1*		2.0 ± 1.7		53.3 ± 41.3*	
Associated medical conditions (number of infants/total)	GER	1/6	GER MI	3/8 2/8	GER URI	2/8 2/8	GER URI MI	2/8 2/8 1/8
Colic medications (number of infants/total)	Prilosec	1/6	Mylacon Zantac Propulsid	6/8 1/8 1/8	None		Mylacon Zantac	6/8 1/8
Type of feeding	Formula Formula/breast		Breast Formula Formula/breast		Breast Formula Formula/breast		Formula Formula/breast	
Formulas fed	Good Start Enfamil Isomil		Good Start Carnation Soy Similac Enfamil		Good Start Enfamil Preosobee		Good Start Enfamil	
Formula changes (number of changes/total)	2/6		6/8		1/8		4/8	
Juice introduction (weeks ± SD)	14.8 ± 4.2		16.5 ± 1.4		14.7 ± 5.8		17.8 ± 4.6	
Age of juice feeding (number infants <6 mo) (number of infants >6 mo)	 5 1		 8		 8		 8	
First juice fed (number of infants/juice)	Apple White grape	2 4	Apple White grape	4 4	Apple White grape Other Unknown	2 2 3 1	Apple White grape Unknown	5 1 2
Amount of juice fed (mL/day ± SD)	114 ± 60		72 ± 36		111 ± 69		60 ± 30.9	
Juice introduction the day of the study (number)	3		4		0		3	
Juice before the study (weeks ± SD)	4.5 ± 5.5		3.2 ± 3.7		6.2 ± 5.2		3.2 ± 2.9	
Other feedings during the first 6 mo (number of infants/total)	3/6		6/8		3/8		4/8	
Did other feedings alter colic?	Not applicable		No		Not applicable		No	

WGNIC indicates white grape juice no IC; WGIC, white grape juice with IC; APNIC, apple juice no IC; apple juice with IC; SD, standard deviation.

* $P < .05$ in comparison to the non-IC group.

groups of infants studied (Table 1). Parents reported that their infants had most of their colic episodes between 2 and 4 months of age (Table 2). Furthermore, there was an average of 3 episodes of IC, occurring both at night and during the day. The symptoms included crying, flatulence, vomiting, and a combination of all 3. Infants with IC were calmed down by either position changes, abdominal massages, medications, feeding, and other techniques with position changes being the one most used. Finally, the perception of IC was over 8 on a scale of 1 to 10. In contrast, those with no IC had none of the

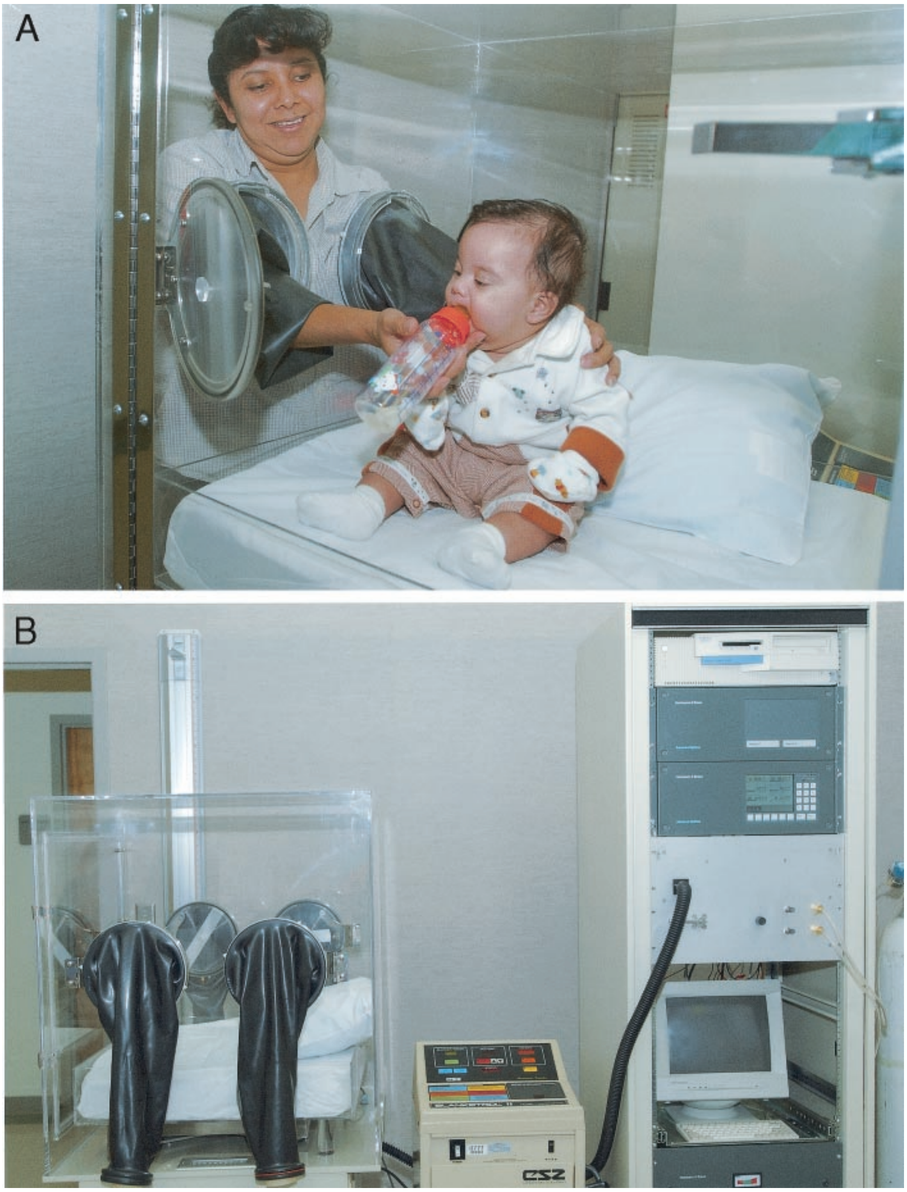

Fig 1. The EMTAC (A). Note the glove ports surrounding the chamber allowing for unrestricted access to infants by the parents (B).

reported symptoms and a perception score of 0 (Table 2). Only 6 infants, 3 in each IC group, had IC symptoms lasting >4 months.

The estimated crying times, as reported by the parents, was significantly increased ($P < .05$) in the IC groups in comparison to those in the non-IC groups (Table 2). These infants also had more lengthy and severe crying episodes than those in the non-IC groups. Furthermore, infants in both IC groups were given medications for their symptoms that included Mylacon (Merck; Whitehouse Station, NJ), Zantac (Pfizer Inc; Brooklyn, NY), and Propulsid (Janssen; Titusville, NJ). Only 1 infant in the non-IC white grape juice fed group was given medication (Prilosec; AstraZeneca, Wayne, PA). Furthermore, parents of infants in both IC groups reported more formula changes in an attempt to alleviate IC symptoms versus those in both non-IC groups (Table 2).

There were also more associated conditions present in both IC groups of infants versus those infants in the non-IC groups. These included GER, MI, and URI, with GER being the most frequently reported. The infant that was given Prilosec in the non-IC group had GER. The infants in the IC groups who had persistence of symptoms after 4 months of age were those with associated medical conditions. Also the infants with IC, along with the other associated medical conditions, had significant increases in the number of colic episodes (2.4 ± 2.2) in comparison to those with IC without these associated entities (0.8 ± 1.0).

IC was associated with carbohydrate malabsorption from fruit juice containing sorbitol and a high fructose-to-glucose ratio. Infants with IC fed apple juice exhibited carbohydrate malabsorption as shown by increased BH_2 excretion levels ($P < .05$). Mean BH_2 excretion during the study period increased up to 25 ppm during the last 1.5 hours of the study (Fig 2). In contrast, infants without IC fed this fruit juice showed no increases in BH_2 excretion, mean levels remaining <10 ppm during the study (Fig 2a). Infants with IC fed apple juice cried more ($P < .05$) during metabolic testing and consequently slept less during the last 1.5 hours of the study (Fig 2B and C) as compared with infants without IC fed this juice. Furthermore, these same infants also exhibited increases in PA ($P < .05$) and EE ($P < .05$) along with the increased BH_2 excretion (Fig 3A and B) as compared with those infants without IC fed apple juice.

In contrast, those infants with IC who were fed white grape juice showed no carbohydrate malabsorption as determined by BH_2 gas excretion levels (Fig 4A). Furthermore, crying during metabolic testing and sleeping times were also unchanged as compared with similarly fed infants without IC (Fig 4B

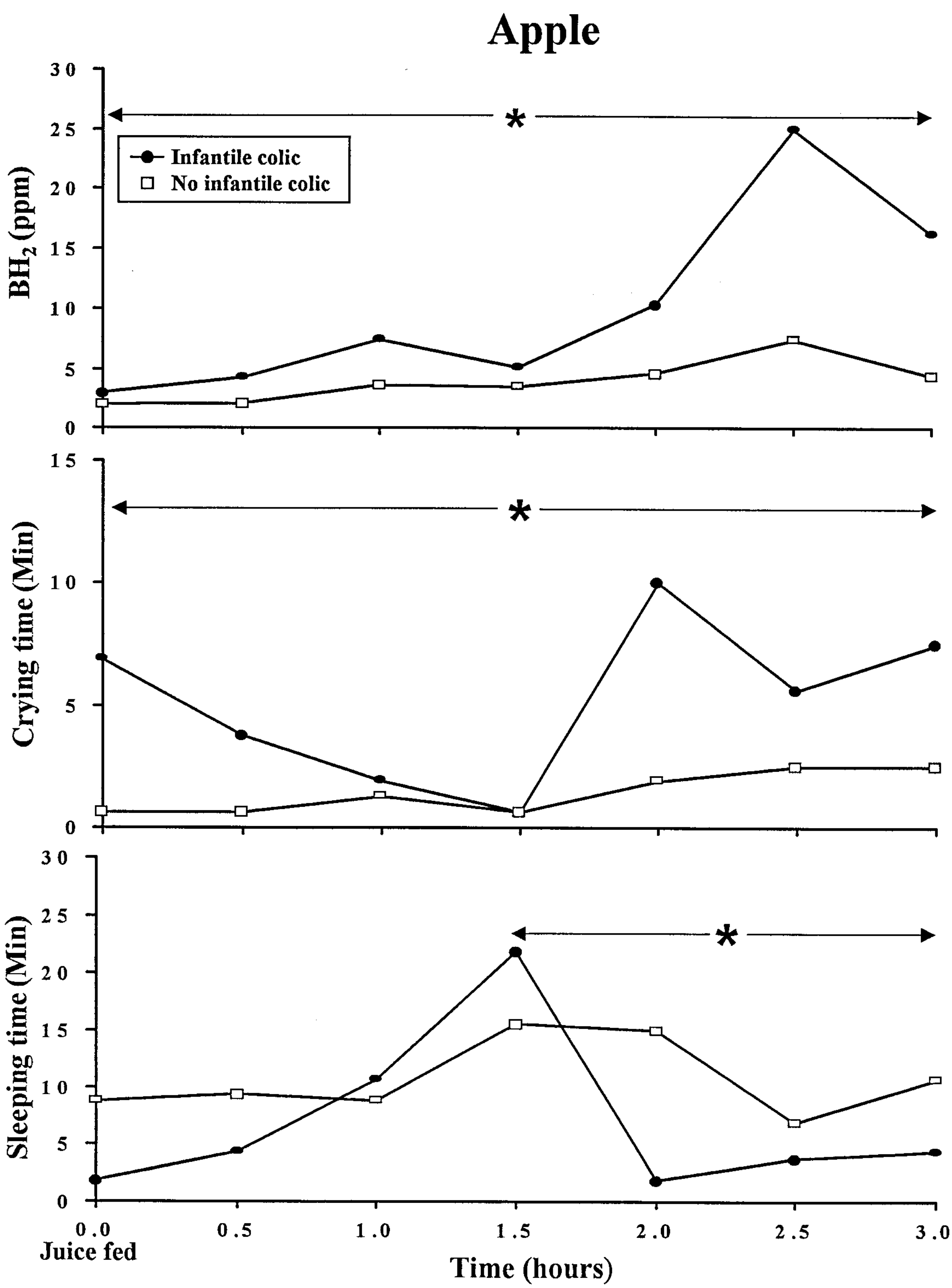

Fig 2. Mean BH_2 gas levels (upper graph), crying time (center graph), and sleeping time (lower graph) in infants fed apple juice with and without IC (* = $P < .05$). Mean peak BH_2 excretion levels were 20 ± 13 and 14 ± 11 ppm for the non-IC and IC infant groups, respectively. Data points on the graphs represent the mean of the values of all infants in each group at each 30-minute interval.

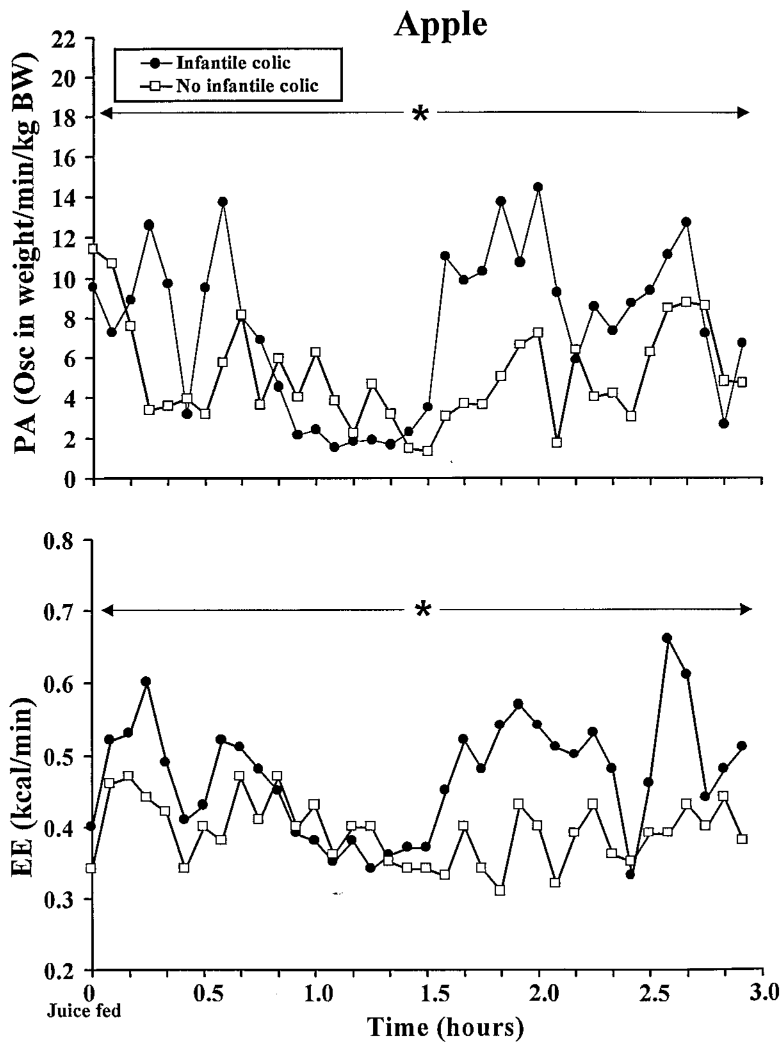

Fig 3. PA (upper graph) and EE (lower graph) in infants fed apple juice with and without IC (* = $P < .05$). Mean EE (kcal) and PA (oscillations in weight/min/kg body weight) over the 3-hour study period was 125 ± 42 and 8.9 ± 3.4 and 130 ± 42 and 9.5 ± 2.7 for the non-IC and IC groups, respectively. Data points represent the mean of each 5-minute summary for each of the 2 groups of infants.

and C). Moreover, infants fed white grape juice regardless of IC, demonstrated no significant differences ($P < .05$) in PA and EE during the study period (Fig 5A and B).

Similarly, there was a trend for greater BH_2 excretion (ppm; 23 ± 28 vs 15 ± 13), increased crying time (min; 61 ± 44 vs 45 ± 73) and EE (kcal/kg; 94 ± 24 vs 84 ± 12) in those infants with IC who had other associated medical conditions as compared with those without these entities.

The age of first fruit juice introduction and the duration and amount of consumption before the study may have been associated with the ability of the infants to tolerate carbohydrates (Table 2). All but the apple non-IC group had at least 3 infants who were first introduced to fruit juices the day of the study. Five of the 8 infants in the non-IC group fed apple juice were already consuming fruit juices at least 6 weeks before the study. The remaining 3 infants in the non-IC group fed apple juice were being fed at least 3 weeks before the study. Furthermore, the infants who were introduced to fruit juices at younger ages were exposed to these feedings for a longer period of time (Table 2). Moreover, 4 of the 8 infants with IC fed apple juice were given this juice <3 weeks before the study and exhibited increased BH_2 gas excretion with a mean peak level of 35 ppm. In contrast, the BH_2 gas excretion was not increased above 20 ppm in those infants who were fed juice for longer periods. All infants fed white grape juice were introduced to these feedings about 2 to 3 weeks before the study (Table 2).

DISCUSSION

This study demonstrated that IC might play a significant role in carbohydrate malabsorption from certain fruit juices. Infants with IC who consumed apple juice had carbohydrate malabsorption as demonstrated by increased BH_2 gas excretion. This was associated with increased PA, EE, and concomitant increases in crying along with decreased sleeping times as detected by the EMTAC. This instrument accurately measures these parameters in as close to a normal environment as possible. In previous studies, the EMTAC was useful in determining EE and PA in healthy as well as in infants with various metabolic disorders.[7,8] In accordance with our findings other investigators had demonstrated, through other methods, that infants who had IC seem to be predisposed to disturbances of sleep.[11,12] The increased PA and metabolic rate found in our study was more noticeable from 1.5 to 3 hours after apple juice intake

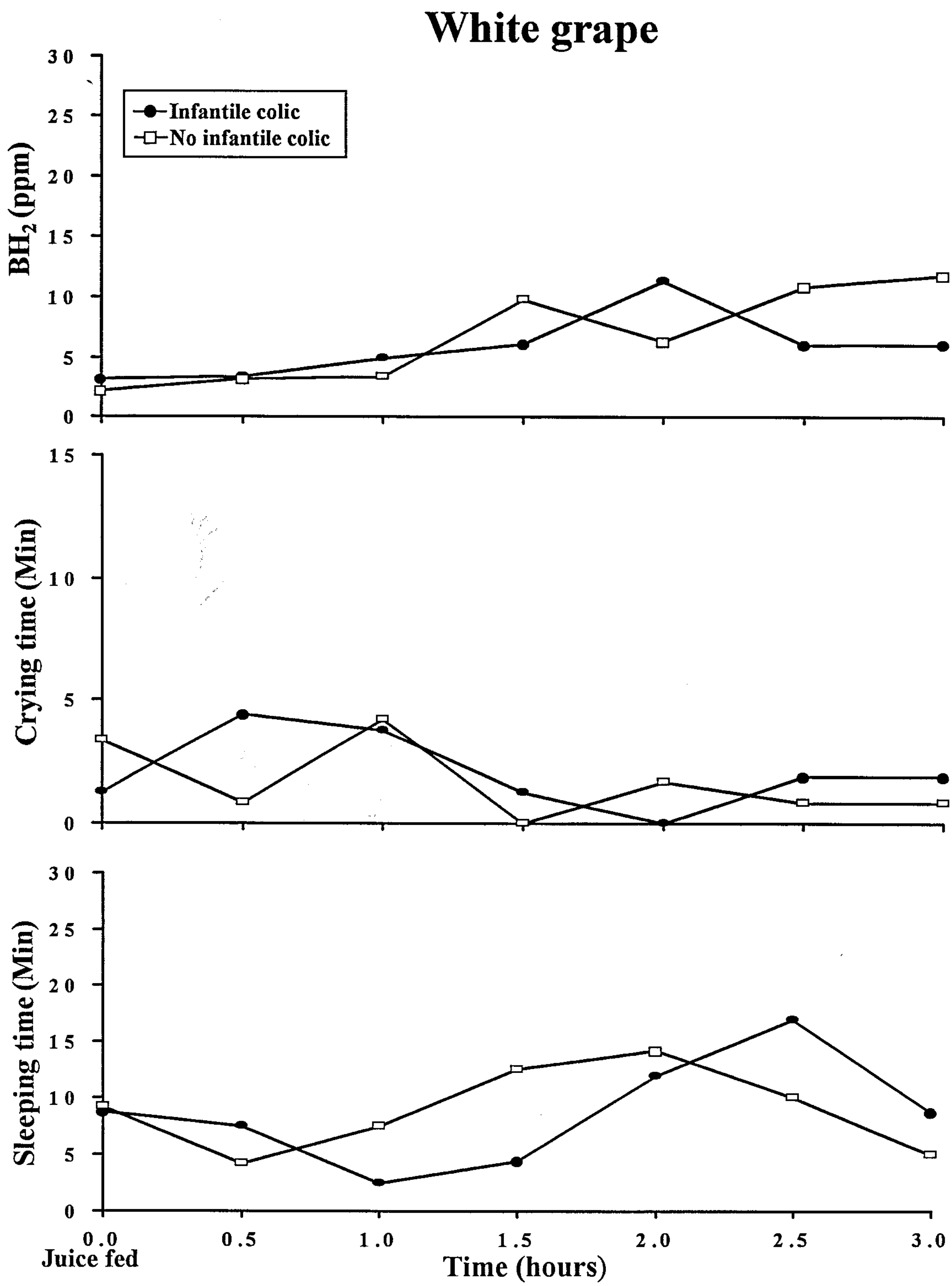

Fig 4. Mean BH_2 gas levels (upper graph), crying time (center graph), and sleeping time (lower graph) in infants fed white grape juice with and without IC (* = $P < .05$). Mean peak BH_2 excretion levels were 10 ± 6 and 35 ± 35 ppm for the non-IC and IC infant groups, respectively. Data points on the graphs represent the mean of the values of all infants in each group at each 30-minute interval.

concomitantly with increased BH_2 gas levels. The association of increased BH_2 gas excretion with measured PA and metabolic rate suggests that carbohydrate malabsorption may be the cause of these increases in infants with IC.

Previously, Cole et al[7] found similar associations between PA, metabolic rate, and BH_2 gas excretion in infants who malabsorbed carbohydrates after pear juice intake. However, the magnitude of these increases was greater in comparison to our study. Because pear juice has more than double the amount of sorbitol (2.4 g/dL) and a higher fructose-to-glucose ratio (2.8:1) than apple juice, there may have been more malabsorbed carbohydrates resulting in a greater production of excess intestinal gases. This was reflected in the detection of a greater BH_2 gas

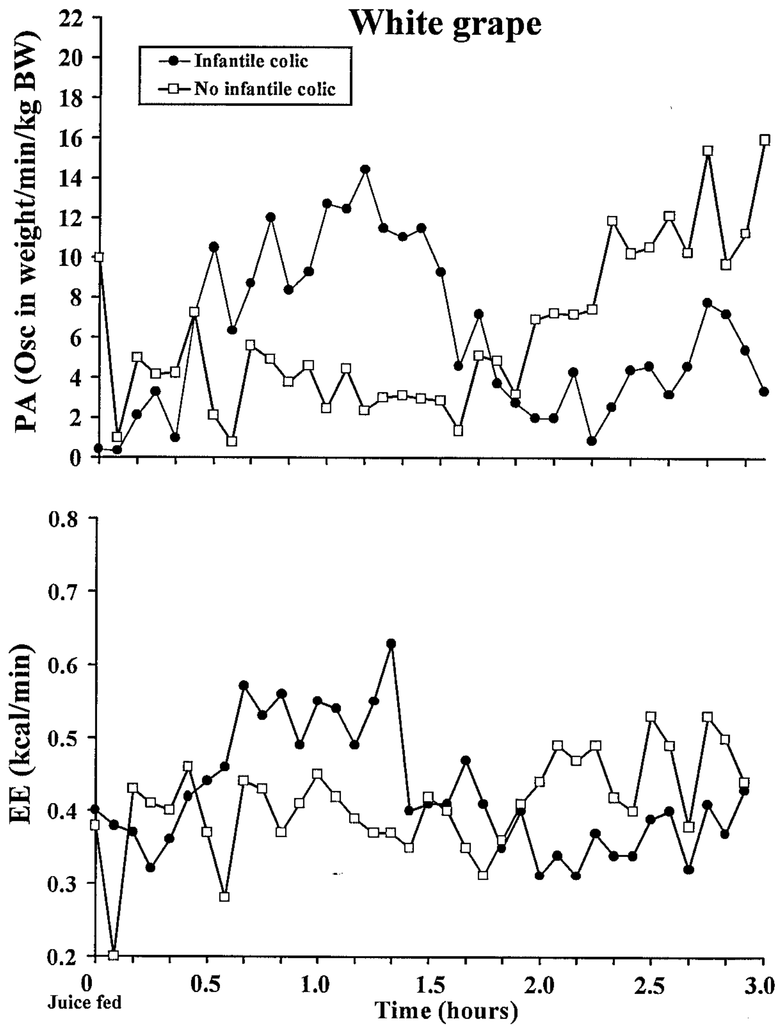

Fig 5. PA (upper graph) and EE (lower graph) in infants fed white grape juice with and without IC. Mean EE (kcal) and PA (oscillations in weight/min/kg body weight) over the 3-hour study period was 113 ± 23 and 7.9 ± 1.9 and 136 ± 24 and 10.7 ± 3.9 for the non-IC and IC groups, respectively. Data points represent the mean of each 5-minute summary for each of the 2 groups of infants.

excretion. The results of both of these studies suggest that a greater amount of sorbitol and higher fructose-to-glucose ratios of certain fruit juices may lead to increased PA and metabolic rate in young infants.

In our study, the infants who were first introduced to fruit juices on the day of the study were older than 4 months in age and were greater than 6 kg of body weight. All others had been fed fruit juices before the study. The American Academy of Pediatrics[13] recommends that fruit juices not be introduced to infant's before 6 months of age. Only 1 infant in the study met the criteria set forth by the American Academy of Pediatrics.

The diagnosis of IC is not easy to establish in a scientific manner. Therefore, we used a comprehensive questionnaire administered, by one of the investigators not aware of the infants clinical status, to the parents to determine whether their infants had, or did not have, IC and to assess this problem in a quantitative fashion. In our study, none of the infants with IC cried over 3 hours per day as suggested by Wessel's "rule of threes."[2] However, using other criteria to determine IC, such as age of onset, duration, daily episodes, various symptoms, medications given, formula changes per day, and the parent's perception of the severity of their infant's problem, clearly defined the population of infants with and without IC. However, the notes by physicians caring for the infants studied did not provide clear quantification symptoms of IC. Other studies involving the determination of IC suggested that parental interpretation of their infant's symptoms is as important as that determined by a physician.[14,15]

The results of this study demonstrated that the infants in the non-IC group tolerated the carbohydrates from apple juice, whereas those with IC did not tolerate it, as shown by the significant changes in BH_2 gas excretion, PA, EE, and crying and sleeping times during the study. The cause of the differences in response to apple juice feeding among infants with and without IC was not ascertained. However, in our study the length of exposure to fruit juice before the study may have played a role. Previous studies testing tolerance to fruit juices in young infants failed to accurately record the pattern of fruit juice intake and the presence or absence of IC.[5–7,16,17] The appropriate absorption of fruit juice in infancy depends on many factors. This includes the amount fed, carbohydrate content of the fruit juice, and the presence of IC. Furthermore, age of weaning, first fruit juice introduction, and length of juice consumption may also play a role.

A previous study found a correlation between intestinal hydrogen gas production and crying and fussing duration in infants.[18] Formula feeding changes involving proteins and carbohydrates influenced crying and fussing duration. There was a 40% decline in crying and fussing when infants were switched from a regular cow's milk protein-based, lactose-containing formula to a soy protein-based, lactose-free formula.[19] These observations are similar to the results obtained in our study; both crying duration time and BH_2 gas excretion increased simultaneously in infants with IC fed apple juice. This suggests that increases in crying and fussing duration may be an important clinical indicator of carbohydrate malabsorption.

The osmolality of ingested liquids and fruit juices has been found to have an impact on gastric emptying time.[20,21] The higher the osmolality, the slower the gastric emptying time. This was demonstrated by Moukarzel et al[20], who found slower gastric emptying times in children who were fed white grape juice with an osmolality of 1030 as compared with pear juice with an osmolality of 638 mosmol/kg H_2O. White grape juice probably remained longer in the stomach, thus leading to a smaller rate of delivery to the small bowel. This favored its absorption, resulting in lower BH_2 gas excretion levels. It has been shown that there was an association between IC and increased secretion of the gut hormone motilin, leading to increased gastric emptying time.[22] This may be another factor contributing to a rapid gastric emptying time of apple juice, thus reflecting in the capacity of absorbing carbohydrates.

Our results suggest that IC may be an important factor affecting carbohydrate malabsorption from certain fruit juices. Thus, the age of fruit juice introduction during weaning, the carbohydrate content, and the amount fed are also factors that should be considered in selecting the most appropriate fruit juice for young infants. Parents should be advised to avoid early introduction to their infants of fruit juices mostly of those containing sorbitol, along with high fructose-to-glucose ratios, especially if they have symptoms of IC.

ACKNOWLEDGMENTS

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THE OBESITY EPIDEMIC

"In Europe, about a third of all adults are overweight; in the United States, the figure is 61%. And in both areas, obesity (the extreme condition of overweight) rose dramatically in the 1990s—by 10% to 40% in most European countries, and by 50% in the United States."

Flavin C. *State of the World 2002.* World Watch Institute, 2002

Submitted by Student