Original Article

Maternal diet during pregnancy and infant respiratory morbidity: A prospective study

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Background and Objectives: Maternal diet during pregnancy may impact infant respiratory morbidity. The aim was to determine the association between antenatal maternal diet and respiratory morbidity of their infants during their first 6 months of life. **Methods and Study Design:** This prospective cohort study included healthy mother-infant pairs. Maternal diet during the last trimester was determined with a validated food frequency questionnaire. Infant respiratory morbidity was solicited at 1, 3 and 6 months. **Results:** Three hundred mother-baby pairs were recruited. Maternal consumption of milk and dairy products was associated with reduced respiratory symptoms at 1 month (aOR 0.29 [95% CI: 0.10, 0.86], p=0.03) and 3 months old (aOR 0.43 [95% CI: 0.20, 0.93], p=0.03), while intake of confectionery items was associated with increased unscheduled doctor visits at 3 months (aOR 2.01 [95% CI 1.33, 3.06], p=0.001) and increased nebuliser treatment at both 3 months (aOR 1.88 [95% CI 1.12, 3.17], p=0.02) and 6 months (aOR 1.64 [95% CI 1.05, 2.54], p=0.03). Finally, at 6 months, hypertensive disorders during pregnancy was associated with increased nebuliser treatment (aOR 17.3 [95% CI 1.50, 199], p=0.02) while exclusive breastfeeding was associated with reduced incidence of respiratory symptoms (OR 0.47 [95% CI 0.26, 0.83], p=0.01). **Conclusions:** Increased antenatal maternal consumption of milk and dairy products may reduce respiratory morbidity while increased consumption of confectionery items may increase respiratory morbidity in their infants during the first 6 months of life.

Key Words: Malaysia, infection, antenatal, diet, respiratory tract

INTRODUCTION

Maternal nutritional status is one of the major determinants of good infant health and this translates to increased neonatal and infant survival.[1,2] The World Health Organization (WHO) concluded that in utero nutritional deprivation predisposes infants to neonatal complications such as intrauterine growth restriction and low birth weight as well as an increased risk of non-communicable disease such as obesity, type 2 diabetes mellitus (T2DM) and cardiovascular and renal disorders in later childhood.[3]

Respiratory tract infections, which are characterized by symptoms including cough, coryza, fever, breathlessness, wheezing and chest pain,[4,5] are common illnesses among children within the first three years of life,[6,7] and contribute to significant morbidity and mortality in children younger than 5 years.[8,9] Previously published risk factors for respiratory tract infections including low socioeconomic status, overcrowding, environmental smoke exposure and air pollution.[10-20]

The impact of specific food types consumed during pregnancy on the respiratory health of infants has been

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evaluated, but the results have been inconsistent. Adequate consumption of food naturally enriched with vitamin D during the prenatal and perinatal period is important in preventing respiratory morbidity among offspring during early childhood, as this micronutrient plays a role in lung growth and development.[21,22] A Finnish prospective birth cohort involving 2,441 mother-child pairs found that increased maternal intake of vegetables and fruits during the third trimester of pregnancy was associated with a reduced risk of wheezing among children at 5 years of age.[23] However, others have shown no significant association.[24,25]

Inconsistent results between different studies across the world may be influenced by different nutritional patterns, cultures and traditions.[26] A study involving 763 mother-infant pairs from an Asian population demonstrated that increased maternal consumption of beef, pork, processed meat, chicken and eggs was associated with reduced risk of childhood respiratory symptoms such as wheezing at 16-24 months of age.[27] On the other hand, a study involving two Western cohorts (1,771 and 745 mother-infant pairs respectively) reported that increased maternal meat and processed meat intake during pregnancy was associated with a higher risk of wheezing among offspring during the first year.[28]

The hypothesis of this study was that a healthy maternal diet during pregnancy is associated with a reduced risk for respiratory tract illnesses in an infant. Therefore, the aims of this study were to determine the association between (a) maternal food consumption during pregnancy and (b) maternal demographic, clinical factors, breastfeeding and environmental factors with the respiratory morbidity of infants.

METHODS

Study site, study population and recruitment

This prospective cohort study was conducted in University Malaya Medical Centre (UMMC), Kuala Lumpur, Malaysia. Malaysia is a middle income country with a population of 32.6 million and access to a 2-tier health care system consisting of both a private as well as a public universal system. UMMC is a government-funded university hospital serving an urban population in Kuala Lumpur, the capital of Malaysia. It has 1,500 beds serving a population of more than 1,000,000 people. The Obstetrics and Gynaecology unit of UMMC, founded in 1964, provides antenatal and delivery services with approximately 1,200 deliveries per year.

Patients were recruited from 1st March 2019–31st January 2020 via universal sampling. The sample size required was 400 subjects, to achieve a confidence interval of 95% and 80% power of detection. This was based on odds ratio of 0.36 in prevalence of wheeze in children whose mothers who had a healthy diet.[28]

Healthy mother-infant pairs on the postnatal ward who were within 3 days of delivery were included. Mothers with underlying chronic medical illness, a language barrier, or who refused consent were excluded. Infants with a gestational age less than 37 weeks or who had any perinatal illness were also excluded. This was to remove confounders that could increase the risk of respiratory disease in the infants. The study flow is shown in Supplementary figure 1.

This study was conducted according to the guidelines set by the Declaration of Helsinki and all procedures involving human subjects were approved by the Medical Research Ethics Committee in UMMC (MREC ID NO: 2018116-5961). Written informed consent was obtained from all mothers before any procedure was undertaken. The anonymity of participants was preserved.

Food Frequency Questionnaire (FFQ)

The maternal diet over the last four weeks of pregnancy was assessed by dietary recall post-delivery. A locally validated Food Frequency Questionnaire (FFQ) which was reproduced from a population of pregnant mothers in Malaysia was used.[29] This FFQ analysed maternal diet based on two main components: frequency and amount of intake. This FFQ contained 11 main food groups (e.g. cereal and cereal products; poultry, meat, and egg; etc.), with each food groups contained around 3-10 food categories. The frequency and amount of intake for each food category were recorded and then added up to be presented as the total intake for each food group.

For example, under the cereal and cereal products food group, it included 8 food categories including rice, cereals, bread etc. The frequency and amount of intake for each food category was recorded before the intake of all 8 food categories were added up and presented as total intake of cereal and cereal products. Calculation of frequency of food intake and amount of intake are presented in the Supplementary table 1.

Categorization of intake for each food group

In this study, the adequacy for food groups including cereal and cereal products; poultry, meat, and egg; fish, fish products and shellfish; milk and dairy products; nuts and legumes products as well as vegetables and fruits was categorised based on the recommended nutrient intake (RNI) i.e. fulfil or above (≥ RNI) or below (< RNI) the recommended nutrient intake.[30] The value of RNI for these food groups was determined based on the Malaysian Food Pyramid,[31] where the upper limit of intake for each food group stated in the food pyramid (in serving sizes) were used as RNI values for pregnant mothers (Supplementary table 3).

Meanwhile, intake of plain water was categorized based on the recommended intake for pregnant mothers during the third trimester of pregnancy of an extra 470 mL of water per day as compared to a normal adult intake of 1.5–2 L per day (Malaysian Dietary Guidelines 2010). Thus water consumption should be 2–2.5 L per day.[31] Hence, the RNI value for plain water intake in our study population was set at 2 L per day.

As for sweetened beverages, fats, oil, confectioneries, and condiments intake, it is recommended that the amount should be minimal, whereas alcoholic beverages should not be consumed during pregnancy.[32] However, as a specific minimal volume was unavailable,[31] the intake of sweetened beverages, fats, oil, confectioneries, and condiments was analysed as continuous variables. Meanwhile, alcoholic beverages intake was recorded as intake (Yes) or no intake (No) during pregnancy.

Respiratory morbidity and breastfeeding history at follow-up

Respiratory morbidity surveys were done at 1, 3 and 6 months of age using a structured online Google form. As a validated respiratory questionnaire was not available, questions were initially drafted in English and then translated. Medical Malay and back translations as well as non-medical Malay and back translations were performed before the final version of the questionnaire in the Malay language was finalised. A pilot testing of the translated version of the questionnaire was conducted and issues regarding understanding were harmonised before the final version was administered to the study population.

The following questions were administered to the mothers: the presence and number of episodes of respiratory symptoms such as cough, runny nose, noisy breathing, and/or shortness of breath; the number of unscheduled doctor visits or hospital admissions due to respiratory symptoms; number of episodes of nebuliser treatment received, if any.

Breastfeeding history of the infants was also collected: whether infants were breastfed exclusively (breastmilk only), non-exclusively (breastmilk supplemented with powdered milk, water, or other supplementary drinks), or did not breastfeed at all.

The questionnaire was administered via a Google form and sent to the mothers via WhatsApp application. Phone call interviews were done if there was lack of response from the mothers. Non-responders were contacted on at least 5 separate occasions before they were considered as missing data and not analysed.

Demographics, antenatal and environmental information

Demographics, antenatal and environmental information collected were as follow: maternal age, ethnicity, maternal working status and educational level, total household income per month, complications during pregnancy (e.g. gestational diabetes mellitus, hypertensive disorders during pregnancy), mode of delivery, exposure to pollution from construction sites, factories or main roads and number of adults and children at home. Categorisation of household income per month was based on the National financial report in 2018, and sub-divided into Bottom-40 (B40), Middle-40 (M40), and Top-20 (T20) categories.[33] Patients from the B40 were considered as low-income families.

Statistical analysis

Statistical analyses were performed using SPSS 24.0 (SPSS Inc., Chicago, IL, USA). The primary exposure of interest was the maternal intake of each food group during pregnancy, and the primary outcome variable of interest was respiratory morbidity of infants at 1, 3 and 6 months of age. For descriptive statistics, categorical variables were reported in frequencies and percentages, while continuous data were reported in means. Differences between independent categorical variables were examined using Pearson's chi-square (χ^2) test or Fisher test, while for continuous variables, regression tests were done to determine the association. The cohort-specific odds ratios (OR) with 95% confidence interval (CI) were computed to estimate the degree of association. Significant associations obtained in univariate analysis ($p<0.05$) between maternal food diet and respiratory outcome of infants were adjusted with significant confounders ($p<0.05$) including maternal demographics, antenatal complications, mode of delivery, breastfeeding status and environmental factors using logistic regression (LR) and reported as adjusted odds ratios (aOR) with 95% CI. Association testing was conducted assuming a statistical significance level of p value less than 0.05 and a two-sided alternative hypothesis.

RESULTS

The recruitment process was stated in Figure 1. A total of 1550 mother-baby pairs were eligible for recruitment during the study period. However, 1250 were excluded and final analysis was based on 300 healthy mother-infant pairs. Response rates regarding their infant's respiratory morbidity and breastfeeding status from mothers was 94.0% (n=282), 89.0% (n=267), and 64.7% (n=194) for infants at 1, 3 and 6 months of age respectively.

Maternal demographics, antenatal complications, and mode of delivery (Table 1)

The majority of mothers were Malay (65.7%), had graduated from tertiary institutions (80.9%), and were working (82.0%). More than half (56.0%) had a total household income per month in the middle 40% of the country's population income.

Complications during pregnancy were present in more than two-thirds of the mothers (69.7%). Common complications were gestational diabetes mellitus (GDM, 38.8%), upper respiratory tract infection (URTI, 31.5%) anytime during pregnancy, vaginal infection (13.4%) and urinary tract infection (UTI, 12.4%). Two-thirds of the babies (67.7%) were delivered via spontaneous vertex delivery (SVD).

Maternal diet during pregnancy (Table 2)

As for maternal diet during pregnancy, the majority did not fulfil the RNI for most food groups, except for poultry, meat, and egg intake (52.0%). The food group with the least adequate consumption was nuts and legumes products (6.4%). Condiments and alcoholic intake were not analysed as alcoholic beverage was consumed by only one mother and there was poor recall of condiments (39.0%) by most mothers.

Respiratory morbidity, breastfeeding rate and environmental exposure among infants (Table 3)

More than half (59.8%) experienced respiratory tract symptoms within the first 6 months of life while 25.9% had at least one episode of noisy breathing by 6 months. About half (51.7%) sought medical treatment although very few were serious enough to require hospital admission.

The exclusive breastfeeding rate of babies was low and decreased over time, with less than half of the babies being exclusively breast-fed at 6 months of age.

Around 30% of the families were exposed to pollution from construction sites, factories, or main roads. More than half of the families (77.4%) had more than two people at home with 31.5% of the families having 2 or more children at home.

Primary objective: Association between maternal diet during pregnancy and respiratory morbidity of infants during the first 6 months of life (Table 4)

In univariate analysis, maternal consumption of milk and dairy products during pregnancy was associated with a lower incidence of respiratory symptoms among infants at 1 month (OR 0.27 [95% CI 0.09, 0.78], *p*=0.01) and 3 months of age (OR 0.42 [95% CI 0.20, 0.87], *p*=0.02). Conversely, maternal consumption of confectionery items during pregnancy was associated with more unscheduled doctor visits at 3 months (OR 1.32, 95% CI 1.02, 1.70, *p*=0.03) and increased need for nebuliser treatment at both 3 months (OR 1.94 [95% CI 1.20, 3.14], *p*=0.01) and 6 months (OR 1.61 [95% CI 1.07, 2.43], *p*=0.02). Maternal consumption of fats and oil showed a tendency for increased risk of nebuliser treatment among infants at 3 months of age (OR 1.02, 95% CI 1.00, 1.03, *p*=0.05).

In logistic regression analysis, all factors significant in univariate analyses were entered into logistic regression to identify independent factors associated with respiratory morbidity of infants, as shown in Table 4. Higher maternal milk and dairy products intake was significantly associated with a lower incidence of respiratory symptoms among infants at 1 month (aOR 0.29 [95% CI 0.10, 0.86], *p*=0.03) and 3 months of age (aOR 0.43 [95% CI 0.20, 0.93], *p*=0.03), even after adjustment with significant confounders. Conversely, increased confectionery intake during pregnancy was associated with a higher incidence of unscheduled doctor visits among infants up to 3 months of age (aOR 2.01 [95% CI 1.33, 3.06], *p*=0.001). Increased confectionery intake during pregnancy was also associated with a higher incidence of nebuliser treatment among infants at 3 months (aOR 1.88 [95% CI 1.12, 3.17], *p*=0.02) and 6 months of age (aOR 1.64 [95% CI 1.05, 2.54], *p*=0.03).

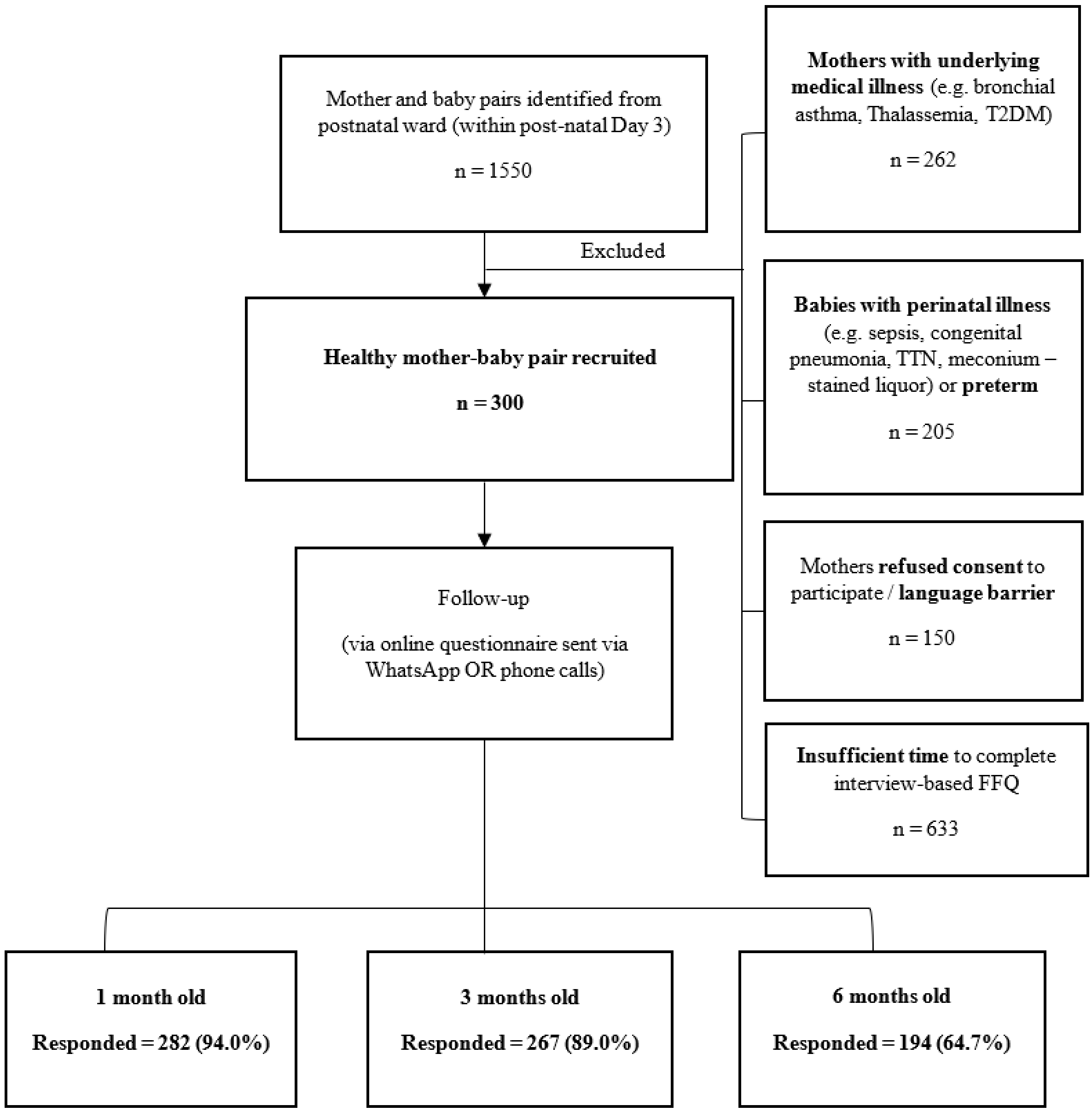

Figure 1. Recruitment process. T2DM: type 2 diabetes mellitus; TTN: transient tachypnea of newborn; FFQ: food frequency questionnaire.

Table 1. Maternal demographics, antenatal complications and mode of delivery

Information	Mean	SD	n	%
Age (years) (N=300)	31.4	3.97		
Ethnicity (N=300)				
Malay			197	65.7
Chinese			53	17.7
Indian			39	13.0
Foreigner			8	2.7
Local natives			3	1.0
Mother's educational level (N=299)				
Primary education			1	0.3
Secondary education			56	18.7
Tertiary education			242	80.9
Mother's working status (N=300)				
Yes			246	82.0
No			54	18.0
Total household income per month (N=298)				
B40† category			49	16.4
M40‡ category			167	56.0
T20§ category			82	27.5
Types of maternal complications (N=209)¶				
Gestational diabetes mellitus			81	38.8
Upper respiratory tract infections			66	31.5
Vaginal infection (GBS, Candidiasis)			28	13.4
Urinary tract infections			26	12.4
Hypertensive disorders (PIH, pre-eclampsia)			9	4.3
Other respiratory illness††			4	1.9
Oligohydramnios			3	1.4
Polyhydramnios			1	0.5
Mode of delivery				
Spontaneous vertex delivery (SVD)			203	67.7
Lower segment caesarean section (LSCS)			84	28.0
Assisted delivery			13	4.3

SD: standard deviation; GBS: Group B Streptococcus; PIH: pregnancy-induced hypertension.
†Bottom-40: household income per month for families under this category is at bottom 40% of Malaysia's population (at the range of ≤RM 4359). ‡Middle-40: household income per month for families under this category is at middle 40% of Malaysia's population (at the range of RM 4360–RM 9619). §Top-20: household income per month for families under this category is at top 20% of Malaysia's population (at the range of ≥RM 9620).
¶Each participant may have more than one complication.
††Bronchial asthma and/or bronchitis.

Table 2. Maternal intake of each food group during last trimester of pregnancy

Maternal intake of each food group during pregnancy	Mean	SD	n	%
A - Cereal and cereal products (N=298)				
Fulfil RNI			118	39.6
Below RNI			180	60.4
B - Poultry, meat, and eggs (N=293)				
Fulfil RNI			155	52.2
Below RNI			142	47.8
C - Fish, fish products, and shellfish (N=294)				
Fulfil RNI			91	31.0
Below RNI			203	69.0
D - Milk and dairy products (N=300)				
Fulfil RNI			42	14.0
Below RNI			258	86.0
E - Nuts and legumes products (N=297)				
Fulfil RNI			19	6.4
Below RNI			278	93.6
F - Vegetables and fruits (N=290)				
Fulfil RNI			52	17.9
Below RNI			238	82.1
G1 - Plain water (N=300)				
Fulfil RNI			141	47.0
Below RNI			159	53.0
G2 - Sweetened Beverages (N=297)	2.03	1.50		
H - Fats and oil (N=284)	14.7	23.1		
I - Confectionery (N=297)	1.47	1.07		

SD: standard deviation; RNI: Recommended Nutrient Intake.

Table 3. Respiratory morbidity, breastfeeding rate and environmental exposure among infants

Respiratory morbidity	≤1-month-old, n (%) N=282	≤3-months-old, n (%) N=267	≤6-months-old, n (%) N=194
Incidence of respiratory symptoms			
Yes	77 (27.3)	132 (49.4)	116 (59.8)
No	205 (72.7)	135 (50.6)	78 (40.2)
Details of respiratory morbidity	**≤1-month-old, n (%) N=77**	**≤3-months-old, n (%) N=132**	**≤6-months-old, n (%) N=116**
Symptoms reported			
cough	20 (26.0)	62 (47.0)	81 (69.8)
runny nose	31 (40.3)	68 (51.5)	86 (74.1)
noisy breathing	20 (26.0)	26 (19.7)	30 (25.9)
shortness of breath	4 (5.2)	5 (3.8)	6 (5.2)
Unscheduled doctor visits			
Yes	27 (35.1)	59 (44.7)	60 (51.7)
No	50 (64.9)	73 (55.3)	56 (48.3)
Hospital admission due to respiratory illness			
Yes	2 (2.6)	2 (1.5)	0
No	75 (97.4)	130 (98.5)	116 (100.0)
Nebuliser treatment			
Yes	8 (10.4)	15 (11.4)	21 (18.1)
No	69 (89.6)	117 (88.6)	95 (81.9)
Breastfeeding history	**≤1-month-old, n (%) N=282**	**≤3-months-old, n (%) N=267**	**≤6-months-old, n (%) N=194**
Exclusive	193 (68.4)	147 (55.1)	90 (46.4)
Non-exclusive	75 (26.6)	110 (41.2)	98 (50.5)
No breastfeeding	14 (5.0)	10 (3.7)	6 (3.1)
Environmental exposure	**n (%)**		
Environmental smoke exposure†			
Yes	90 (30.0)		
No	210 (70.0)		
Total number of people at home (N=297)			
>2 people	230 (77.4)		
≤2 people	67 (22.6)		
Number of children at home (N=298)			
≥2 children at home	94 (31.5)		
<2 children at home	204 (68.5)		

†Exposure from construction sites, factories or near to main road.

Secondary objectives: Association between maternal demographics, antenatal complications, mode of delivery, breastfeeding status, and environmental factors with respiratory morbidity of infants during first 6 months of life (Table 4)

All factors significant in univariate analyses were entered into logistic regression to identify independent factors associated with respiratory morbidity of infants, as shown in Table 4. In logistic regression analyses, UTI during pregnancy (aOR 2.95 [95% CI 1.23, 7.10], p=0.02) and smoke exposure during pregnancy (aOR 1.91 [95% CI 1.08, 3.37], p=0.03) were associated with an increased incidence of respiratory symptoms among infants at 1 month of age. Low socioeconomic status was associated with an increased incidence of respiratory symptoms at 3 months of age (aOR 2.38 [95% CI 1.18, 4.76], p=0.02), while having more children at home was protective (aOR 0.48 [95% CI 0.28, 0.83], p=0.01). Caesarean section birth was associated with increased need for nebuliser treatment among infants at 3 months of age (aOR 3.66 [95% CI 1.08, 12.5], p=0.04). Finally, hypertensive disorders during pregnancy was also associated with increased need for nebuliser treatment at 6 months of age (aOR 17.3 [95% CI 1.50, 199], p=0.02).

Exclusive breastfeeding was the only factor associated with a reduced incidence of respiratory symptoms among infants at 6 months of age (OR 0.47 [95% CI 0.26, 0.83], p=0.01).

DISCUSSION

This study aimed to determine if there was an association between maternal diet during pregnancy and respiratory morbidity of their infants during the first 6 months of life. We found that a higher intake of milk and dairy products was significantly associated with a lower incidence of respiratory symptoms among infants, up to 3 months. Conversely, increased confectionery intake during pregnancy was associated with a higher incidence of unscheduled doctor visits among infants up to 3 months, as well as a higher incidence of nebuliser treatment at 3 and 6 months.

We found other demographic factors that were associated with infant respiratory health. The protective effect of breastfeeding on respiratory symptoms was present at 6-months. UTI and environmental pollution exposure were both associated with increased incidence of respiratory symptoms at 1 month. Low socioeconomic background was associated with an increased incidence of respiratory symptoms at 3 months, while having more

Table 4. Logistic regression of significant factors, determined by univariate analysis, that were associated with respiratory morbidity of infants

	Incidence of Respiratory Symptoms											
	≤1 month of age[†]				≤3 month of age[‡§⁋]				≤6 month of age[††]			
	Crude OR (95% CI)	*p* value	Adjusted OR (95% CI)	*p* value	Crude OR (95% CI)	*p*value	Adjusted OR (95% CI)	*p* value	Crude OR (95% CI)	*p* value	Adjusted OR (95% CI)	*p* value
Milk and dairy products (intake ≥ RNI)	0.27 (0.09, 0.78)	0.01*	0.29 (0.10, 0.86)	0.03*	0.42 (0.20, 0.87)	0.02*	0.43 (0.20, 0.93)	0.03*	-	-	-	-
Urinary Tract infection (UTI) in pregnancy	3.58 (1.53, 8.39)	0.002*	2.95 (1.23, 7.10)	0.02*	-	-	-	-	-	-	-	-
Smoke exposure at home	1.79 (1.04, 3.11)	0.04*	1.91 (1.08, 3.37)	0.03*	-	-	-	-	-	-	-	-
Low socioeconomic status	-	-	-	-	2.06 (1.06, 4.01)	0.03*	2.38 (1.18, 4.76)	0.02*	-	-	-	-
≥2 children at home	0.44 (0.23, 0.83)	0.01*	0.55 (0.29, 1.05)	0.07	0.52 (0.30, 0.87)	0.01*	0.48 (0.28, 0.83)	0.01*	-	-	-	-
Exclusive breastfeeding	-	-	-	-	-	-	-	-	0.47 (0.26, 0.83)	0.01*	-	-
Unscheduled doctor visit												
Confectionery (intake ≥RNI)	-	-	-	-	1.32 (1.02, 1.70)	0.03*	2.01 (1.33, 3.06)	0.001*	-	-	-	-
Caesarean delivery vs vaginal delivery	0.31 (0.10, 0.96)	0.04*	-	-	0.44 (0.20, 0.96)	0.04*	0.47 (0.20, 1.10)	0.09	-	-	-	-
Respiratory symptoms requiring nebuliser treatment												
Fats and oil (intake ≥ RNI)	-	-	-	-	1.02 (1.00, 1.03)	0.05	1.01 (0.99, 1.04)	0.18	-	-	-	-
Confectionery (intake ≥ RNI)	-	-	-	-	1.94 (1.20, 3.14)	0.01*	1.88 (1.12, 3.17)	0.02*	1.61 (1.07, 2.43)	0.02*	1.64 (1.05, 2.54)	0.03*
Hypertensive disorders during pregnancy	-	-	-	-	-	-	-	-	15.67 (1.54, 159)	0.003*	17.31 (1.50, 199)	0.02*
Caesarean section vs vaginal delivery	-	-	-	-	3.17 (1.06, 9.47)	0.03*	3.66 (1.08, 12.5)	0.04*	-	-	-	-

OR: odd ratio; CI: confidence interval.
*p<0.05.
†Adjusted with maternal intake of milk and dairy products, UTI during pregnancy, smoke exposure at home and ≥2 children at home.
‡Adjusted with maternal intake of milk and dairy products, low socioeconomic status and ≥2 children at home.
§Adjusted with maternal intake of confectionery and caesarean delivery.
⁋Adjusted with maternal intake of fats and oil, confectionery and caesarean delivery.
††Adjusted with maternal intake of confectionery and hypertensive disorders during pregnancy.

children at home was protective. Caesarean section birth was associated with need for nebuliser treatment among infants at 3 months of age while having a hypertensive disorder during pregnancy was also associated with increased need for nebuliser treatment at 6 months.

This study found that most mothers did not achieve the recommended intake for milk, nuts, vegetables and fruits, but more than half achieved the recommended intake for poultry, meat, and eggs. This finding was similar to a both local and international studies, especially for fruits and vegetables.[34,35] Locally, dietary education is provided to all pregnant mothers in government clinics. Therefore, more effective strategies such as active dietary recall during follow-up and establishing dietary guidelines or meal plans for mothers to adhere to throughout pregnancy may be necessary to ensure a balanced and healthy diet among pregnant women.[36]

This study found that increased consumption of milk and dairy products was associated with a two-times reduced risk of respiratory symptoms up to 3 months. This finding is similar to that of a multi-centre cohort study among Spanish ('INMA' - INfancia y Medio Ambiente) and Greek children ('RHEA'), which reported an inverse relationship between milk intake during pregnancy and wheezing during the first year of life (RR 0·83 [95% CI: 0.72, 0.97]).[28] In another cohort study involving 763 mother-infant pairs in Japan, found that consumption of dairy products during pregnancy was associated with a lower risk of infantile wheeze.[37] Milk and dairy products contain high levels of vitamin D which could regulate the innate and adaptive immune response of a fetus by promoting the production of anti-microbial peptides in cord blood,[38] and protective against viral infections.[39,40]

Another interesting finding in this study was that increased maternal consumption of confectionery items during pregnancy was associated with a higher incidence of unscheduled doctor visits and nebuliser treatment among infants up to 6 months. This finding has not been reported by other authors. Bédard et al who looked at 8,956 mother-infant pairs, reported a weak association between maternal sugar intake (both added and natural) during pregnancy with episodes of wheezing during early childhood (OR 1.42, [95% CI: 1.05, 1.92]).[41] It was hypothesised that added sugar contains high levels of fructose, which may negatively impact the gut microbiome[42] and thus the lung,[43] resulting in increased risk for respiratory illness.

This study confirmed the protective effect of exclusive breastfeeding against respiratory symptoms at 6 months. The protective effect of breastfeeding against respiratory tract infections has been shown in infants who were breastfed for 6 months or longer.[44] This may explain why the significant association was only seen later, at 6 months old, in this study.

Several other demographic factors investigated in this study were significantly associated with increased risk of respiratory illness: low socioeconomic status, environmental air pollution, pregnancy-induced hypertension and caesarean birth, similar to other studies.[13-16] Conversely, infants born in families with more children at home had lower respiratory morbidity, which has also been reported before.[12]

The main strength of this study is that this is a prospective study from a middle-income country. We also looked at the effect of maternal diet on other respiratory morbidities in infants, besides wheezing. Details regarding other important socioeconomonic and clinical factors were prospectively obtained and hence giving a complete picture of other important influencers of infant health. Finally, the FFQ utilized in this study has been validated on pregnant mothers in Malaysia, hence the inadvertent omission of other food groups consumed by our local population is less likely. The personal administration of the FFQ by the investigator also allowed for consistency in their responses.

However, limitations of this study are recognized. We missed 40.8% of mothers due to time constraints as administering the FFQ took a significant amount of time. While this may lead to biasness, these mothers were not systematically excluded. The calculated sample size was 400, but we could only recruit 300 mothers due to time constraints, achieving a statistical power of 66%. Besides, dietary information obtained from mothers was via recall, hence at risk of recall bias. We analysed maternal diet during the last month of pregnancy and not the first two trimesters. However, since the diet of mothers especially during the first few months of pregnancy may be affected by morning sickness, we decided that the third trimester would be more representative. The retention rate of infants by 6 months of age was 65% despite multiple reminders, which may result in bias towards mothers whose infants had symptoms. Finally, the respiratory morbidity of infants was based on parental symptom reports and not detailed examination. However, history of symptoms of respiratory illness is sufficient to cover the common respiratory conditions that afflict young babies, mainly upper respiratory tract infections and wheezing disorders and this is what we would have also done in a face-to-face follow-up.

Conclusion

In conclusion, this study found a significant association between higher maternal milk and dairy product consumption and reduced incidence of respiratory symptoms among infants. Conversely, increased consumption of confectionery items was associated with a higher incidence of respiratory nebuliser use and unscheduled doctor visits among infants. Other important demographic factors like maternal UTI, hypertensive disorders during pregnancy, smoke exposure, low socioecomonic status and delivery via caesarean section were associated with increased respiratory morbidity while breastfeeding and presence of more than 2 children in the household were associated with reduced respiratory morbidity.

AUTHOR DISCLOSURES

None of the authors have any conflict of interest to declare.

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Supplementary table 1. Supplementary information on frequency and amount of intake

Supplementary information
Frequency of intake
Mothers' frequency of intake for all food categories was categorised into 'per day', 'per week', 'per month', or 'never'. The frequency of intake per day was then calculated based on the conversion factor (Supplementary table 2).
Amount of intake†
The method to calculate the amount of intake differed between food groups. For food groups such as cereal and cereal products; poultry, meat and eggs; fish, fish products and shellfish; milk and dairy products; nuts and legumes products as well as vegetables and fruits, the total intake per day was recorded in serving sizes. The serving sizes consumed for each food category was estimated based on the frequency and types of portion size used. For example, the portion size used to estimate rice intake was a bowl, and as there were different sizes of bowls, the portion size was estimated based on the medium-size-bowl as shown in the Atlas of Food Exchange & Portion Sizes (Third edition)[1] and the book of Nutrient Composition of Malaysian Food.[2] Similar concepts were applied for other food categories, where the medium-sized portion was used to estimate the intake. The reason for choosing the medium-sized portion was to avoid overestimation or underestimation of intake (if measurement was based on small-sized portion, it may lead to overestimation of intake as higher number of portions is required to reflect their amount of intake). Photographs of portion sizes and household measurement equipment obtained from these books were shown to participants during the interview for an accurate estimation.
For each portion size, the serving sizes were then calculated by referring to the Malaysian Dietary Guidelines 2010.[3] For example, one cup of white rice equals to a standardized weightage of carbohydrates (30 g), which equals to one serving size. As for foods not found in the dietary guidelines, the atlas,[1] nutrient composition book,[2] or the Malaysian Food Composition Database (MyFCD)[4] was referred to. The frequency of portion sizes was then considered to compute the total serving sizes taken during each intake. For example, if the mother took two cups of white rice during each meal, she had a total of two serving sizes of white rice during each intake.
The total number of serving sizes taken per day was calculated using the following formula (for each food category): the amount of food per day (in serving sizes) = frequency of intake per day (conversion factor) x total serving sizes during each intake. By summing up the amount taken per day (in serving sizes) of all food categories under respective food groups, the total serving sizes taken per day for each food group was then obtained.
Water, fats and oil intake was recorded in volume, which was litre (L) for water and millilitre (mL) for fats and oil. The intake of sweetened beverages was recorded in the number of cups (150mL per cup). On the other hand, only the frequency of intake was recorded for confectionery items as the weightage of different foods would differ e.g. the type of biscuit taken by each mother differs, thus the weightage of biscuits consumed would differ as well. Meanwhile, condiments were reported in terms of the number of teaspoons (5 mL) per day. Alcoholic beverages were recorded in the number of alcohol units per day.
Information regarding condiments and cooking oil was recorded only if mothers or any members of the household cooked once daily for at least half a month (≥ 15 times per month), as a cooking frequency lesser than that would not accurately reflect the amount used per day.

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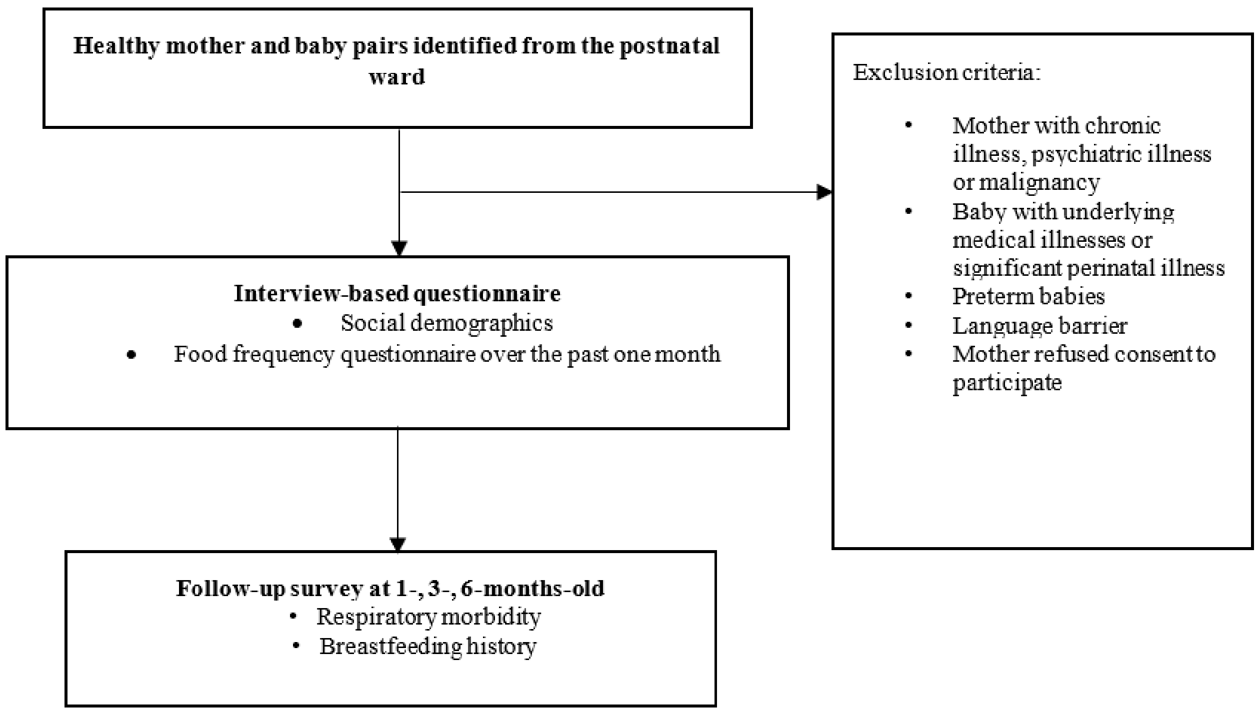
Supplementary table 2. Conversion of frequency of intake into conversion factor

Frequency of intake	Frequency	Conversion factor
Per day	1X	1
	2X	2
	3X	3
	…	…
Per week		
	1X	0.143 (1/7)
	2X	0.286 (2/7)
	3X	0.429 (3/7)
	…	…
Per month		
	1X	0.033 (1/30)
	2X	0.067 (2/30)
	3X	0.100 (3/30)
	…	…
Never	0	0

Supplementary table 3. Recommended Nutrient Intake (RNI) value for each food groups†

Food group	Details	Recommended Nutrient Intake (RNI) per day (in serving sizes)
A	Cereal and cereal products	8
B	Poultry, meat, and eggs	2
C	Fish, fish products and shellfish	1
D	Milk and dairy products	3
E	Nuts and legumes products	1
F	Vegetables and Fruits	5

†Source: Malaysian Dietary Guidelines 2010



Supplementary figure 1. Study flow.