Original Article

Water and nutrient intake in pregnant New Zealand women: association with wheeze in their infants at 18 months

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The association between water and nutrient intake in pregnant women, and wheeze in their 18 month old infants, was investigated in a prospective study. Volunteers (n=369) recruited from northern New Zealand were visited in months 4 and 7 of pregnancy. At each visit anthropometric measurements were taken, diet assessed by 24-hour recall and 3-day food records and questionnaires determining personal details administered. Eighteen months after birth, infants were measured, and questions on infant feeding and wheeze asked. Overall, mothers reported 32% of their infants had wheezed in the last 12 months. After adjusting for significant covariates and energy intake, higher maternal intakes of dietary water (p=0.009) and manganese (p=0.024) were associated with decreased wheeze, and glucose (p=0.003) with increased wheeze. Prevalence of infant wheeze decreased 18.5% from the lower to the upper quartile of water intake, and 17.4% from the lower to the upper quartile of manganese intake. Wheeze was more common in Polynesian than European infants (41.8% vs 28.9%). Polynesian mothers consumed significantly less dietary water (median 451 g less) and manganese (median 1374 μg less) than European mothers per day. Glucose was only significant because of strong association with infant wheeze at extremely high maternal intakes of >40 g/day in ~10% of the subjects. There was no association between maternal dietary supplement intake and wheeze. Mothers estimated at high risk of infant wheeze consumed less tap water, whole grains, tea, fruit; and more fruit juice, soft drink, processed meat and fish products, and refined grain products. This is the first study to report an intergenerational association between maternal water, and glucose intake with infant wheeze.

Key Words: pregnancy, water, nutrients, infant, wheezing

INTRODUCTION

The prevalence of wheeze in infants and asthma in New Zealand children is high with a reported prevalence of wheeze in infants of 33-34%,[1] and 39%,[2] and 22% for asthma in 6-7 year olds.[3] Asthma was also found to be more prevalent in 6-7 year old Maori (28.5%) and Pacific children (25.2%) than European (20.7%).[4] Medicated asthma was found to be present in 13.8% of European, 13.6% of Pacific and 19.2% of Maori 2-14 year olds in the 2011/2012 Health in New Zealand Children study.[5]

In infants diagnosis of asthma is difficult with recurrent wheeze in infancy being taken as an indicator that asthma may develop later. Associations have been found between mothers' diets during pregnancy and wheeze in their infants, leading to suggestions that prenatal nutrition may programme foetal lung and immune development leading to asthma. Various nutrients or foods have been implicated but no consistent picture has emerged. Higher maternal intakes of vitamin E, vitamin D, calcium and zinc have been found to be associated with reduced risk of wheezing in infants aged 16 months - 5 years,[6-11] while increased maternal vitamin C intakes have been associated with increased wheeze in infants at 2 years.[6] Consumption of foods containing olive oil during pregnancy was found to have a protective effect on wheezing in the first year of life[12] but another study[13] found no association with monounsaturated fatty acids, which includes oleic acid, the major fatty acid in olive oil. Intake of n-3 polyunsaturated fatty acids during pregnancy, and their food source oily fish, has been associated with decreased wheeze in children,[14-15] or no effect.[13,16] The beneficial association of increasing maternal apple intake with wheeze in 5 year olds found by Willers et al[16] was not found in 16-24 month old children.[10] Almost all studies on the association of mothers' diet during pregnancy with wheeze in their infants use single food frequency questionnaires with limited food lists to determine nutrient intake.

Several studies have investigated the association of dif-

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ferent maternal dietary patterns with wheeze, but again results have been conflicting. A close adherence to a Mediterranean style diet during pregnancy was found to decrease the risk of asthma in children[17] while another study,[18] investigating 4 different types of maternal dietary pattern including Mediterranean, found none to be associated with wheeze in their infants and concluded that maternal intake of individual nutrients may be more important than a dietary pattern.

While there is much lay discussion on the positive benefits of generous water intakes from pure water, or beverage water, in those with asthma, research into the role fluid intake and hydration play in the aetiology of asthma has produced differing results.[19] We have found no research considering an association between water intake during pregnancy and wheeze in infants. Information on usual intake of dietary and/or tap water intake is scarce. Dietary water includes all water in foods and beverages. Tap water includes all pure water drunk eg, bottled water. New Zealand National Nutrition Surveys[20-21] along with most other countries' nutrition surveys do not report dietary water or tap water consumption. Ershow et al[22] found adult women consumed median 1835 g of dietary water per day, and pregnant women, median 1928 g/day with 11% consuming >3000 g/day. For those that drank tap water, intake for pregnant women was median 1063 g/day with 15% consuming >2000 g/day.

The aim of this study was to investigate mothers' intakes of water, nutrients and dietary supplements in the second and third trimesters of pregnancy, and their association, if any, with symptoms of wheeze in their infants aged 18 months.

METHODS

Ethical approval was obtained from the Massey University Human Ethics Committee and the Auckland Ethics Committee. The funding body required 500 subjects with selection biased towards including a greater proportion of Polynesian women, and women of lower socioeconomic status, than in the general population. Women classified as Polynesian were New Zealand Maori and Pacific Island Polynesian. Subjects lived in rural and urban centres in the upper North Island of New Zealand. Participating clinics throughout the study area distributed information to potential volunteers. In total, 504 women around the 14th week of pregnancy were recruited.

Subjects were matched to an interviewer of their own ethnicity. Interviewers visited each subject at a place of her choosing, near the start of month 4 and month 7 of her pregnancy. Questionnaires were administered in the subject's preferred language to determine demographic, medical, health and lifestyle details. The questionnaires were similar in content and format to those used to determine this information in New Zealand national nutrition surveys.[23] Anthropometric measurements were taken and the subject's diet assessed as described below. The same interviewer visited subjects at mean 18.1 months postpartum (SD=3.8), took anthropometric measurements of mother and child, and completed a questionnaire to determine details of infant feeding from birth, developmental milestones and symptoms of wheeze. Based on the ISAAC phase 1 questionnaire,[24] wheeze was defined as present if the mother responded positively to the question "Has your child had wheezing or whistling in the chest in the last 12 months?" and/or "Has your child ever had asthma"? The present work is based on data from the 369 subjects who completed these questions.

Maternal height, weight and triceps, biceps and costal skinfolds were measured using calibrated standard equipment according to the procedures set out in Gibson.[25] Gestational age was calculated from the last date of menstruation. Birth measures were taken from the infant's clinical record. Infant weight at 18 months was measured by the difference between the mother's weights when holding and not holding the child, length was measured in a custom made box with sliding foot, and head circumference with an insertion tape.

Dietary intake was assessed by two methods in both month 4 and month 7. The interviewer administered a 24-hour dietary recall, followed by a 3-day food record kept by the subject. In the recall the interviewer used numerous aids to assess the weight or volume of each food and beverage portion consumed in the previous 24 hours. The recalls included questions on the brand name and dose of any dietary supplements taken that day. After the recall interview, and training, subjects recorded in their preferred language all food and beverage portions consumed over 3 days, using the measuring cups and spoons provided to assess volume ingested. Days were not necessarily consecutive: each four days of diet assessment included one weekend day. Subsequent analysis of variance of nutrient intake found no significant difference overall between the 24-hour recalls and 3-day food records in month 4 and month 7 diets (p=0.099, Pillai's test), nor were there significant differences in nutrient density between methods (MANOVA p=0.158). Therefore the 24-hour recall data was combined with the 3-day diet record data to give a mean intake of each nutrient for each woman, in month 4 and month 7 of pregnancy. Mean maternal nutrient intake during pregnancy was calculated from these 8 days of dietary data. In 90% of cases, the mean was calculated from the combination of month 4 and month 7 dietary data, but only month 4 data was available in 8% cases, and only month 7 in 2%. Where one or other was not available, the average data from the available month was used. Tap water intake was estimated in separate questionnaires in month 4 and month 7 by recall, without aids to estimate volume, and hence the values are less accurate than those for dietary water.

Food works, utilizing the New Zealand Food Composition database (New Zealand Institute for Plant and Food Research), was employed to calculate the nutrient intake for each woman. The New Zealand Institute of Environmental Science and Research Dietary Supplement database, which provided manufacturers' information on supplement composition and dosage, was used to calculate the nutrient load provided by the supplements taken. As the nutrient content of supplements may have varied considerably from the stated dose[26] and their bioavailability may have differed to nutrients from food, supplement nutrients were treated as separate variables to food nutrients which also means that their effects could be assessed separately.

Data were checked using standard statistical techniques (eg, crosstabs, scatterplots). Minitab 16 was used for statistical analysis. Binary logistic regression was used to identify significant associations between wheeze and nutrients or other variables, and all associations carefully checked to ensure they were not due to outliers or multicollinearity. Variables considered as possible covariates included maternal anthropometric measures, infant anthropometric measures at birth and 18 months, ethnicity, socioeconomic measures, family, lifestyle and childcare details, medical details including incidence of maternal or paternal asthma, eczema, rhinitis or allergy, geographical location, infant gender, and feeding details from birth to 18 months. We could not adjust for all possible confounders because of our relatively small sample: instead we first adjusted for significant non-nutritional covariates in a multivariable logistic regression model for wheeze. The maximal multivariable model with all variables significant ($p \leq 0.05$) was chosen, but to ensure no effect was missed all reasonable alternative variables were reexamined for any significant predictor. The finalised multivariable model for covariates was based on cases with complete data for the included predictors. Individual nutrients were then added to the model, expressed on a logarithmic scale to reduce skewness. To reduce the effect of multicollinearity, we analysed log (nutrient) intakes after adjusting for total log (energy) intake. The results were further checked by nutrient pattern analysis based on factor analysis by principal components or maximum likelihood with varimax rotation, and based on cluster analysis.

We investigated the differences in food intakes between the 30 mothers estimated by the regression equation as being at highest risk of having infants with wheeze, and the 30 mothers estimated as being at lowest risk. Foods were grouped as: milk only; dairy products eg, ice cream, yoghurt, cheeses; fruit including tomatoes, capsicums and avocado; fruit juices; legumes and nuts; green leafy vegetables; root and other vegetables; meat, fish and eggs; meat, fish and egg products eg, sausages, savoury pies, burgers and takeaways; refined grains eg, white rice, plain pasta; refined grain products eg, white bread, biscuits and cakes, pasta dishes, some breakfast cereals; whole grains eg, whole wheat biscuits; whole grain products eg, mueslis, breads; tap water; tea; soft drinks and cordials; other beverages eg, coffee, milo, alcoholic drinks; fats and oils; other eg, sugar, sweets, sweet and savoury spreads and condiments.

Nutrients discussed below are those that were significant in the presence of significant background covariates and remained significant when other nutrients were included.

RESULTS

Details of the subjects' anthropometric measurements, demographic details, lifestyle habits, and prevalence of asthma, eczema, hay fever and other allergies (eg, food allergies) in the subject and father of her child are reported in Table 1. The table also details infant measurements, length of exclusive breast feeding, and presence of symptoms of wheezing. Results are reported for mothers of wheezing and non-wheezing infants.

Median nutrient intake during pregnancy for mothers of wheezing and non-wheezing infants at 18 months, including p-values for difference for each nutrient alone or adjusted for energy, are shown in Table 2. Median intake of dietary water was 2237 g for European mothers and 1786 g for Polynesian mothers ($p<0.001$). Nutrient supplements were taken by 48% of women. No association was found between the taking of supplements in general ($p=0.211$), or the intake of any individual supplement, and wheeze in the infants.

Mothers reported that 32% of their 18 month old infants had wheezed in the last 12 months. Wheeze was more common in Polynesian (41.8%) than in European (28.9%) infants ($p=0.019$). Table 3 shows odds ratios for the significant predictors of infant wheeze, first in the main model, second in a model including maternal skinfolds, and third in a model including both skinfolds and ethnicity as covariates. Nutrients significantly associated with infant wheeze were water, manganese and glucose.

Presence of maternal asthma, eczema or allergy was used to represent inherited effects: alternative covariates maternal allergy ($p=0.002$), maternal eczema ($p=0.047$) and any parental asthma were considered ($p=0.086$), but gave multivariate models that were slightly less significant overall. Since our focus was on nutritional effects we chose to use the most significant predictor. Mothers receiving income support welfare were more likely to be living outside the cities of Auckland or Hamilton ($p=0.021$), have more children ($p<0.001$), and live in larger households ($p<0.001$). Polynesian mothers were more likely to receive income support welfare payments than Europeans (40.6% vs 23.1%, $p=0.028$). Higher maternal subcutaneous fat levels as measured by sum of skinfolds have been shown to be associated with increased infant wheeze.[27] Median sum of skinfolds at month 4 was 30% higher for Polynesians than for Europeans ($p<0.001$). We found no association between wheeze and infant measures at birth or 18 months, nor between wheeze and maternal pre-pregnancy or month 4 BMI. Maternal smoking was not a significant covariate in our sample ($p=0.726$).

Table 3 shows the odds of infant wheeze at 18 months was significantly lower with increasing intakes of dietary water and manganese during pregnancy. Prevalence of infant wheeze decreased from 47.8% in the lower quartile of maternal dietary water intake (≤1779 mL) to 29.3% in the upper quartile (≥2611 mL). Similarly prevalence of infant wheeze decreased from 45.7% in the lower quartile of manganese intake (≤3402 μg) to 28.3% in the upper quartile (≥5722 μg). Polynesian mothers consumed significantly less manganese (median 1374 μg, $p<0.001$), per day, than European mothers.

One component of dietary water is tap water. No tap water was drunk in month 4 by 11.1% of European and 37.8% of Polynesian women; and in month 7 by 21.5% of European and 31.2% of Polynesian. Table 4 shows for mothers of infants that wheezed vs those who did not, their median daily consumption of total dietary water, and tap water alone (for those who drank it). The more water consumed in beverages and food, the more tap water also was drunk ($p<0.001$). Polynesian mothers consumed less total dietary water, than European mothers. Mothers of infants that wheezed consumed less total dietary water ($p=0.007$) and less tap water ($p=0.077$).

Table 1. Anthropometric, demographic, and health details of mothers and infant at 18 months, for wheezing and non-wheezing infants

	Wheezing infants n=118	Non-wheezing infants n=251	*p*-value†
Maternal variables			
Age (yrs), median	32.0	32.0	0.456
Pre-pregnancy weight (kg), median	65.0	63.0	0.290
Weight month 4 (kg), median	72.2	70.3	0.500
Weight month 7 (kg), median	77.4	75.2	0.297
Weight gain between month 4 and month 7 (kg), median	4.3	4.7	0.621
Height (cm), median	168	167	0.411
BMI month 0‡ (kg/m^2), median	24.5	24.6	0.420
BMI month 4 (kg/m^2), median	25.6	25.3	0.862
Sum skinfolds month 4 (mm), median	51.1	50.3	0.117
Sum skinfolds month 7 (mm), median	56.2	52.1	0.005
Difference month 7, month 4 skinfolds (mm), median	2.8	2.0	0.142
Lower occupational group, %	60.1	46.6	0.015
University education, %	18	28	0.036
Receiving family support welfare, %	14.4	6.0	0.007
Income from welfare only, %	5.9	3.6	0.302
Polynesian ethnicity, %	32.2	21.1	0.021
Parity, median	1	1	0.328
Household size, median	3	3	0.220
Smoker, %	13.6	11.2	0.506
Maternal asthma, %	28	20	0.107
Paternal asthma, %	20	14	0.127
Maternal eczema, %	33	26	0.177
Paternal eczema, %	16	13	0.449
Maternal hay fever, %	30	32	0.764
Paternal hay fever, %	29	35	0.266
Maternal other allergies, %§	41	24	0.002
Paternal other allergies, %§	15	16	0.747
Infant birth variables			
Male infant, %	41.6	53.0	0.041
Birth weight (kg), median	3.58	3.59	0.384
Birth length (cm), median	52.0	52.0	0.943
Head circumference (cm), median	35.2	35.0	0.297
Infant 18mth variables			
Weight (kg), median	11.6	11.6	0.514
Length (cm), median	81.2	81.9	0.998
Head circumference (cm), median	48.0	47.9	0.219
Breast fed only (≥2 months), %	72	81	0.050

†*p*-value by Mann-Whitney U test for medians, Pearson chi-square for percentages. ‡By recall; §Food allergies or allergy to insect bites etc., as mentioned by the volunteers.

High intakes of glucose (p=0.002) during pregnancy were associated with greater prevalence of wheeze in the multivariate model. However glucose intake was not associated with wheeze when considered alone. Glucose only appears in the model because of a significantly higher prevalence of infant wheeze at extremely high maternal intakes >40 g/day in ~10% of the subjects. Figure 1 shows the steep rise in incidence of wheeze at this high intake of glucose. Above 40 g/day for glucose 42.3% of infants wheezed, compared with 20% at 20 g/day for glucose.

Nutrient pattern analysis supported these results but yielded no further insights.

Table 5 shows differences in maternal food group intakes between the 30 mothers at highest risk of infant wheeze and the 30 mothers at lowest risk, as predicted by the main regression model in Table 3. Of the 30 at highest risk, 23 had infants that actually wheezed, while of the 30 estimated as lowest risk, 5 wheezed. When the food sources of the significant nutrients were considered, the percentage of total intake coming from the richest food sources was similar in each group. Most manganese came from whole grains and whole grain products, beverage tea, and refined grain products (59% in high risk and 69% in low risk groups). However the low risk group consumed more whole grains and their products and beverage tea, with overall 83% more manganese in their diets on average. Most glucose came from fruit, fruit juice, soft drinks and cordials (71% in the high risk and 69% in the low risk groups). The high risk group consumed more fruit juice and soft drinks, and overall on average 29% more glucose than the low risk group. Most water came from soft drink, tap water, fruit, then milk in the high risk group, whereas in the low risk group most water came from tap water, beverage tea, fruit then milk (48% in the high risk and 69% in the low risk groups) with overall 56% more water on average in the diets of the low risk group.

Table 2. Median maternal nutrient intake during pregnancy, for mothers of wheezing and non-wheezing infants at 18 months

	Median maternal intake Wheezing infants n=118	Median maternal intake Non-wheezing infants n=251	*p*-value†	*p*-value‡ Adjusted for energy
Energy (kJ)	9364	9290	0.956	
Protein (g)	80	83	0.179	0.047
Carbohydrate (g)	269	265	0.951	0.978
Total sugar (g)	131	133	0.869	0.863
Glucose (g)	25	25	0.685	0.624
Fructose (g)	26	26	0.875	0.834
Sucrose (g)	58	60	0.828	0.820
Lactose (g)	14	16	0.180	0.167
Maltose (g)	3	3	0.573	0.494
Starch (g)	130	130	0.896	0.888
Dietary fibre (g)	21	23	0.049	0.018
Water (g)	2030	2277	0.003	0.001
Cholesterol (mg)	259	271	0.427	0.285
Total fat (g)	87	86	0.627	0.297
Saturated fat (g)	39	38	0.719	0.502
Monounsaturated fat (g)	27	27	0.797	0.726
Polyunsaturated fat(g)	10	11	0.682	0.559
β-Carotene (μg)	3556	3183	0.959	0.971
Retinol (μg)	427	425	0.771	0.686
Vitamin A (μg)	1024	1013	0.881	0.836
Vitamin C (mg)	131	145	0.314	0.284
Vitamin D (μg)	1.7	1.6	0.872	0.846
Vitamin E (mg)	8.8	9.3	0.278	0.175
Thiamine (mg)	1.5	1.7	0.173	0.153
Riboflavin (mg)	1.7	1.9	0.046	0.015
Niacin (mg)	16.1	16.8	0.460	0.372
Vitamin B_6 (mg)	1.6	1.8	0.029	0.010
Vitamin B_{12} (μg)	3.7	3.9	0.117	0.156
Pantothenic (mg)	4.9	5.2	0.370	0.219
Biotin (mg)	35.8	38.1	0.271	0.182
Folate (μg)	251	277	0.189	0.113
Sodium (mg)	2931	3082	0.768	0.665
Potassium (mg)	3331	3437	0.118	0.031
Magnesium (mg)	303	315	0.064	0.011
Calcium (mg)	858	880	0.125	0.080
Phosphorous (mg)	1358	1435	0.079	0.011
Manganese (μg)	4142	4692	0.019	0.008
Iron (mg)	11.3	12.2	0.159	0.045
Zinc (mg)	10.2	10.8	0.068	0.015
Sulphur (mg)	856	882	0.329	0.150
Chloride (mg)	4487	4748	0.499	0.415
Copper (mg)	1.4	1.5	0.060	0.009
Selenium (μg)	51	53	0.247	0.241

†*p*-value for logistic discrimination of wheezers and non-wheezers using log (nutrient intake).
‡*p*-value for logistic discrimination of wheezers and non-wheezers using log (nutrient intake) after adjusting for log (Energy intake).

In terms of the overall diet, the low risk group consumed more food and drink per day (mean 3372 g vs 2333 g for the high risk group), and a more varied diet (mean number of food/beverage data lines each day 27.4 vs 22.5 for the high risk group, *p*=0.004). Compared with the high risk group, the low risk group drank on average each day: 837 g more tap water, 83 g more milk, 236 g more tea, 85 g less fruit juice, and 156 g less soft drink. Each day they ate on average 70 g more fruit, 39 g more leafy vegetables, 19 g more legumes, 20 g more whole grains, 54 g more whole grain products, 57 g less processed meat fish and egg products, 45 g less refined grain products, and 15 g less sugar, sweets, and condiments.

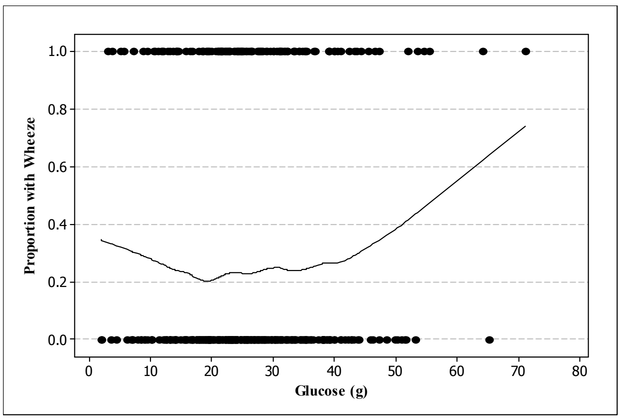

Figure 1. Infant wheeze vs maternal glucose intake

Table 3. Odds Ratios for significant nutrients and other covariates in logistic regression models for infant wheeze

Variable	Main model OR [95% CI]‡	*p*-value	Model including skinfolds OR [95% CI]§	*p*-value	Model including ethnicity and skinfolds OR [95% CI]§	*p*-value
Log (water, g)	0.25 [0.09,0.69]	0.007	0.22 [0.07,0.68]	0.009	0.24 [0.08,0.78]	0.017
Log (manganese, μg)	0.34 [0.15,0.74]	0.007	0.35 [0.14,0.87]	0.024	0.42 [0.16,1.07]	0.069
Log (glucose, g)	2.09 [1.09,4.01]	0.026	3.38 [1.51,7.53]	0.003	3.54 [1.58,7.92]	0.002
Log (energy, kJ)	2.68 [0.67,10.7]	0.165	1.95 [0.42,9.03]	0.391	1.59 [0.33,7.60]	0.562
Maternal asthma, eczema or allergy†	2.26 [1.33,3.84]	0.003	2.62 [1.45,4.72]	0.001	2.71 [1.49,4.93]	0.001
Exclusively breast fed to 2 months†	0.52 [0.29,0.94]	0.029	0.47 [0.25,0.91]	0.025	0.47 [0.25,0.90]	0.024
Income support welfare†	2.66 [1.12,6.31]	0.026	4.15 [1.53,11.2]	0.005	4.11 [1.50,11.3]	0.006
Male gender†	0.51 [0.30,0.84]	0.009	0.62 [0.35,1.09]	0.096	0.63 [0.36,1.10]	0.102
Sum of skinfolds in mth4 (per 10 mm)			1.23 [1.04,1.45]	0.015	1.19 [1.00,1.42]	0.046
Difference between mth7 and mth4 sum of skinfolds (per 10 mm)			1.59 [1.15,2.19]	0.005	1.60 [1.15,2.22]	0.005
Polynesian ethnicity†					1.73 [0.80,3.72]	0.162¶

†1= yes, 0=no; ‡n=336; §n=297; ¶In a model excluding nutrients, *p*-value for Polynesian ethnicity was 0.019.

Table 4. Total maternal dietary and tap water intake, by ethnicity and infant wheeze at 18 months

	All subjects		European subjects		Polynesian subjects	
	n=118† Infant wheezes Median (g)	n=251† No infant wheeze Median (g)	n=80† Infant wheezes Median (g)	n=198† No infant wheeze Median (g)	n=38† Infant wheezes Median (g)	n=53† No infant wheeze Median (g)
Dietary water in all food and beverages including tap water						
Month 4	2067	2223	2175	2289	1826	1923
Month 7	1909	2269	2047	2341	1765	1948
Tap water only‡						
Month 4	750	980	700	1000	800	900
Month 7	750	1000	625	1000	900	950

†Maximum sample size. Sample size varies by question. ‡Figures are only for those who drank any tap water. Overall in month 4, 82.8% drank tap water, in month 7, 76.3%. The estimation of tap water is less accurate than dietary water as no aids were used to help subjects estimate volume.

DISCUSSION

The prevalence of wheeze at 18 months in our sample (32%) was comparable to that reported in other New Zealand studies of this age group; i.e. 33-34%[1] and 39%.[2] It was also more common in Polynesian (41.8%) than in European (28.9%) infants. Ellison-Loschmann et al[4] studying New Zealand 6-7 year olds, similarly found asthma to be more prevalent in Maori (28.5%) and Pacific children (25.2%) than European children (20.7%).

Water intake in our study was similar to that reported in the United States: Ershow et al[22] found pregnant women in the US consumed median 1928 g/day of dietary water and median 1063 g/day of tap water. This compares with median water intake in our study of 2178 g for dietary water and 800 g for tap water. In our study 17.2% of all mothers drank no tap water in month 4, and in month 7, 23.7%. Using data from the US National Health and Nutrition Examination Surveys, Sebastian et al[28] reported 18.6% of women aged 19-30 drank no tap water in 2003-2004, increasing to 23.8% in 2005-2006. For those that drank tap water, intake was similar over this period, 1130 -1110 g. Median dietary water intakes in our study were less than the US adequate intake (AI) of 2700 mL/day for women of childbearing age[29] and European AI 2300 mL/day.[30]

We found that during pregnancy, mothers of children who subsequently wheezed consumed significantly less water overall per day from their diet (difference in medians 204 g) and significantly less tap water alone (difference in medians 200 g) than mothers of children who did not wheeze. To our knowledge the possibility of an intergenerational association between dietary water intake during pregnancy and wheeze in the infant after birth has not been reported previously, so there is no comparative data to discuss. At birth a 3500 g human foetus contains around 2500 mL of water, the placenta ~500 mL, and the amniotic fluid ~500-1200 mL. During the second half of pregnancy the main sources of amniotic fluid are foetal urine production and fluid secreted by the foetal lung. It is thought that foetal lung fluid secretion promotes pulmonary expansion which enhances airway and alveolar development.[31-32] It is possible foetal lung fluid secretion and associated lung development may be influenced by maternal water intake. Further research is necessary in this area.

In this study higher manganese intakes during pregnancy were significantly associated with lower risk of infant wheeze at 18 months. Median manganese intakes in this sample were; 4142 μg for mothers of infants that wheezed, and 4692 μg for mothers of infants that did not

Table 5. Differences in maternal food group intakes between the 30 highest and 30 lowest risk individuals for wheeze as predicted by regression model

		Glucose (g)		Water (g)		Mn (µg)		Weight (g)		Data lines /day	
		High	Low	High	Low	High	Low	High	Low	High	Low
Milk	mean (SD)	0.0 (0.0)	0.0 (0.0)	184 (125)	257 (168)	*5 (7)	11 (14)	210 (142)	293 (190)	2.1 (1.2)	2.8 (1.4)
	median	0.0	0.0	179	224	*4	7	203	257	*2.1	2.7
Dairy products	mean (SD)	0.6 (1.2)	0.4 (0.5)	62 (69)	67 (52)	25 (30)	22 (17)	96 (99)	98 (67)	1.1 (0.8)	1.4 (0.8)
	median	0.0	0.2	39	58	16	19	58	104	1.0	1.5
Fruit	mean (SD)	9.1 (7.2)	11.8 (7.8)	208 (200)	265 (137)	*201 (169)	389 (352)	250 (229)	320 (163)	*2.2 (1.5)	3.3 (1.6)
	median	7.7	10.5	*165	278	*162	313	*201	329	*1.9	3.6
Fruit juice	mean (SD)	*7.2 (8.8)	3.4 (4.1)	*152 (174)	78 (91)	16 (28)	136 (680)	*174 (201)	89 (104)	0.6 (0.7)	0.5 (0.4)
	median	4.9	1.7	86	45	0	6	100	51	0.5	0.5
Legume	mean (SD)	0.1 (0.2)	0.3 (0.5)	16 (32)	30 (40)	149 (195)	277 (332)	26 (40)	45 (54)	*0.4 (0.4)	0.7 (0.6)
	median	0.0	0.1	*6	21	94	207	*14	33	*0.4	0.6
Root vegetables	mean (SD)	0.9 (0.7)	0.8 (0.5)	125 (88)	127 (97)	331 (268)	283 (200)	179 (118)	170 (129)	1.8 (0.9)	1.7 (0.7)
	median	0.8	0.6	104	93	224	219	140	132	1.7	1.6
Leaf vegetables	mean (SD)	0.4 (0.5)	0.7 (1.6)	30 (27)	66 (123)	62 (58)	272 (801)	33 (30)	72 (141)	*0.6 (0.5)	1.0 (0.6)
	median	0.2	0.3	24	37	52	68	28	38	*0.5	1.1
Meat, fish and eggs	mean (SD)	0.1 (0.2)	0.3 (0.4)	60 (40)	79 (53)	38 (32)	82 (147)	90 (53)	121 (83)	1.1 (0.5)	1.1 (0.6)
	median	0.1	0.1	53	65	25	37	85	96	1.0	1.0
Meat, fish, egg products	mean (SD)	*2.7 (5.5)	0.5 (0.7)	*65 (44)	39 (36)	*276 (237)	124 (125)	*124 (83)	67 (60)	*0.9 (0.5)	0.4 (0.3)
	median	*0.8	0.2	*55	36	*217	92	*103	60	*0.8	0.4
Refined grains	mean (SD)	0.0 (0.0)	0.0 (0.0)	16 (26)	24 (29)	144 (232)	216 (245)	22 (35)	35 (40)	0.2 (0.2)	0.3 (0.2)
	median	0.0	0.0	0	15	0	136	0	25	0.0	0.3
Refined grain products	mean (SD)	1.5 (1.5)	1.1 (1.4)	*68 (44)	40 (31)	822 (475)	655 (565)	*170 (83)	125 (97)	2.6 (1.0)	2.2 (1.1)
	median	0.8	0.7	*62	29	*818	516	*165	109	2.5	2.3
Whole grains	mean (SD)	0.0 (0.1)	0.1 (0.1)	5 (25)	14 (30)	*379 (775)	1238 (1813)	*12 (32)	32 (42)	0.2 (0.3)	0.5 (0.5)
	median	0.0	0.0	0	1	*0	800	*0	23	*0.0	0.5
Whole grain products	mean (SD)	*0.3 (0.8)	1.2 (1.5)	*9 (16)	25 (17)	*468 (706)	1546 (1142)	*28 (41)	82 (52)	*0.5 (0.6)	1.4 (0.9)
	median	*0.0	0.5	*6	26	*248	1438	*19	89	*0.4	1.4
Tap water	mean (SD)	0.0 (0.0)	0.0 (0.0)	*228 (282)	1065 (822)	0 (0)	0 (0)	*228 (282)	1065 (822)	*0.7 (0.7)	2.2 (1.5)
	median	0.0	0.0	*153	988	0	0	*153	989	*0.5	1.9
Tea	mean (SD)	0.0 (0.0)	0.0 (0.0)	*156 (270)	391 (353)	*342 (592)	859 (774)	*156 (270)	392 (354)	*0.6 (1.0)	1.5 (1.3)
	median	0.0	0.0	*36	323	*80	709	*36	324	*0.2	1.1
Soft drink and cordials	mean (SD)	*5.8 (7.8)	1.4 (2.1)	*261 (284)	115 (152)	4 (13)	2 (8)	*282 (304)	126 (166)	*0.9 (0.7)	0.5 (0.5)
	median	*3.5	0.2	*189	64	0	0	*207	70	*0.7	0.4
Other beverages	mean (SD)	0.1 (0.1)	0.2 (0.5)	178 (197)	182 (230)	35 (32)	39 (51)	182 (199)	187 (236)	1.7 (1.7)	1.6 (1.6)
	median	0.0	0.1	123	111	40	27	127	117	1.3	1.3
Fats/oils	mean (SD)	0.0(0.0)	0.0 (0.0)	3 (2)	3 (3)	0 (0)	0 (1)	19 (14)	19 (17)	1.5 (0.7)	1.7 (0.8)
	median	0.0	0.0	2	1	0	0	12	8	0.7	1.1
Other	mean (SD)	2.4(3.2)	2.0 (2.2)	18 (20)	9 (12)	127 (92)	114 (117)	*49 (27)	34 (25)	2.9 (1.4)	2.6 (1.7)
	median	1.5	1.6	*11	4	106	93	*50	30	2.8	2.4
Total	mean (SD)	*31.2 (14.1)	24.2 (12.5)	*1843 (546)	2875 (831)	*3423 (1197)	6266 (2006)	*2333 (610)	3372 (865)	*22.5 (6.4)	27.4 (6.3)
	median	*28.7	22.8	*1715	2944	*3305	5883	*2225	3358	*21.3	27.0

*p-values for difference between high and low risk groups <0.05, by t-test or Mann-Whitney U test respectively.

Differences shown are the mean (SD) and median: glucose; water; manganese; weight of food or beverage; and number of data lines per day for each food group.

wheeze, both being below the Australian and New Zealand AI of 5000 μg.[33] Our study showed the richest sources of manganese were whole grains, whole grain products, tea and refined grain products.

Manganese superoxide dismutase, the main antioxidant enzyme in the mitochondria, is thought to play a role in asthma prevention.[34] The last months of pregnancy and birth exert considerable oxidative, metabolic and inflammatory stress on mother and foetus, which may result in oxidative damage.[35] Low antioxidant levels in the foetus may adversely affect lung development resulting in suboptimal airway function in early life which is associated with increased risk of wheeze and asthma in later childhood.[36] Manganese has been implicated as a risk factor for asthma in other studies: plasma manganese was found to be lower in children with childhood asthma ($p<0.05$) compared with healthy subjects;[37] the presence of a certain manganese superoxide dismutase genotype appeared related to an increased risk of asthma in children;[38] increased manganese intake in late pregnancy was associated with a non-significant trend towards decreased asthma in subjects' 5 year old children;[39] and in an adult study the lowest intake of manganese was associated with a five-fold increase in bronchial reactivity in adults.[40]

Differences in maternal diets during pregnancy may partly explain why the prevalence of wheeze in Polynesian infants in New Zealand is significantly higher than European. We found higher maternal intakes of dietary water and manganese were significantly associated with less wheeze in infants at 18 months. Polynesian mothers consumed significantly less water (median 445 mL less, $p<0.001$), and significantly less manganese (median 1374 μg less, $p<0.001$), per day, than European mothers. When compared with the AI for manganese, 81.3% of Polynesian mothers had intakes below the AI compared with 55% of European mothers.

There was no significant difference between median intakes of glucose in mothers of wheezers and non-wheezers (25.1 g vs 24.6 g). In our study only very high maternal glucose intakes >40 g per day found in ~10% of the sample were found to be significantly associated with infant wheeze. High intakes of sugary drinks have been associated with increased prevalence of asthma in pre-school children and adults,[41-42] and Shi et al[42] suggested that high intakes of sugar may increase allergic airway inflammation. In our study most dietary glucose came from fruit, fruit juice and soft drinks, in that order.

This study has some limitations: the symptoms of wheezing in the infant were not clinically diagnosed, the questions did not differentiate between wheezing with or without concurrent respiratory infection, and a clear diagnosis of asthma is difficult at 18 months. On the other hand we used questions from a validated international study of asthma.[24] We do not know whether the association of water, manganese and high glucose intakes during pregnancy with wheeze in infants persisted till children grew to an age when a clear diagnosis of asthma was possible. Nevertheless our findings are new and merit further research, and our study has several advantages. It was a prospective rather than retrospective study: women were followed from month 4 of pregnancy to 18 months after birth, so problems with recall were few. A major advantage was the detail of the dietary data collected. Intakes were recorded over four days in the second trimester and four in the third (eight days in all), listing all foods and drinks consumed, with a careful measurement of quantity. The majority of studies relating maternal diet to infant asthma use a single retrospective quantitative food frequency questionnaire, which collects information on the frequency of consumption of a restricted list of 145-181 commonly eaten foods using standard portion sizes or other indicators of quantity to calculate nutrient intake. A number of foods are not included, foods are often grouped using generalised nutrient contents, and different ethnic groups may eat few of the foods listed. Thus despite our smaller sample our methodology gives an accurate assessment of individual food and hence nutrient intake in the maternal diet.

Conclusion

We have found a significant intergenerational association between mothers' water, manganese and glucose intakes during pregnancy and wheeze in their infants at 18 months. Higher water and manganese intakes were associated with lower prevalence of wheeze and very high glucose intakes with higher prevalence. Perhaps the lower intake of water and manganese in Polynesian women during pregnancy may contribute in part to the higher incidence of wheeze in their infants at 18 months. Maternal intake of dietary supplements had no association with infant wheeze.

The intergenerational associations of water and very high glucose intakes with wheeze are new findings. Considering the food sources of the significant nutrients, our results suggest that during pregnancy higher maternal intakes of tap water; whole grains and whole grain products; fruit and beverage tea; and lower maternal intakes of fruit juices; soft drinks and cordials; meat, fish and egg products; and refined grain products may help reduce the prevalence of wheeze in New Zealand infants. Further research is required to confirm the association of these maternal nutrients with infant wheeze, and the beneficial dietary patterns they suggest.

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AUTHOR DISCLOSURES

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Original Article

Water and nutrient intake in pregnant New Zealand women: association with wheeze in their infants at 18 months

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新西兰妇女孕期水和营养素的摄入：与其 18 个月大的婴儿哮鸣音之间的关系

本研究为一项前瞻性研究，调查妇女孕期水和营养素的摄入与他们 18 个月大的婴儿哮鸣音之间的关系。从新西兰北部招募怀孕 4 到 7 个月的志愿者 369 名。每次随访检测其志愿者的人体测量参数，采用 24 小时回顾法和 3 天的膳食记录进行饮食评估，采用问卷调查确定入选者的个人资料。婴儿出生后 18 个月，检查并询问其喂养和哮鸣音情况。总体而言，据母亲报告，在过去的 12 个月里，她们的婴儿中有 32%的出现过气喘。校正重要的协变量和能量摄入后，母亲摄入较多的水（p=0.009）和锰（p=0.024）与哮鸣音的降低有关，摄入较多的葡萄糖与哮鸣音的增加有关（p=0.003）。与摄入最少的四分位数相比，母亲水摄入最多的四分位数婴儿哮鸣音的发生率降低了 18.5%，母亲锰摄入最多的四分位数婴儿哮鸣音的发生率降低了 17.4%。波利尼西亚婴儿哮鸣音的发生比欧洲常见（41.8%比 28.9%）。波利尼西亚母亲每天摄入的水（中位数为 451 克以下）和锰（中位数为 1374 微克以下）显著低于欧洲母亲。研究对象中约有 10%的母亲葡萄糖摄入量特别高（40 克/天），其葡萄糖摄入量与婴儿哮鸣音显著相关。母亲膳食补充剂与婴儿哮鸣音之间没有相关性。据估计，摄入较少的自来水、全谷、茶、水果和较多的果汁、软饮料、加工过的肉和鱼类产品以及精制谷物的产妇，其婴幼儿发生哮鸣音的危险性高。本研究首次报道母亲水和葡萄糖的摄入与婴儿哮鸣音之间的代际关系。

关键词：怀孕、水、营养素、婴幼儿、哮鸣音