Original Article

Dietary patterns and obesity in preschool children in Australia: a cross-sectional study

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Background and Objectives: Dietary patterns have been linked to the risk of obesity in adults but little is known about such a link in young children. To examine the association between dietary patterns, nutrient intake and obesity in a representative population of preschool children in Australia. **Methods and Study Design:** Dietary intake was assessed using a 3-day weighed food diary. Dietary patterns were identified by factor analysis. Children were classified as overweight or obesity if their BMI z-score was between the 85th–95th percentiles or was above the 95th percentile, respectively. **Results:** Three dietary patterns were identified. The 'Traditional' pattern was characterised by grains, fruit, vegetables, and red meat. The 'Processed' pattern was characterised by processed meats, snack foods and confectionary. The 'Health conscious' pattern was characterised by eggs, fish, polyunsaturated margarines and low fat dairy products. The "Traditional' pattern was positively associated with protein and zinc intake while the 'Processed' pattern was inversely associated. Both patterns were inversely associated with calcium intake. No associations were found between the 'Health conscious' pattern and macronutrients and key micronutrients intakes. The 'Traditional' pattern was positively associated with obesity but the association became non-significant after adjustment for energy and protein intake. No association was observed between the other two dietary patterns and weight status. **Conclusions:** In this cross-sectional study, dietary patterns were not associated with obesity. Longitudinal follow up will help to better understand the relationship between dietary patterns in early childhood and the risk of obesity later in life.

Key Words: dietary patterns, intake, preschool children, overweight, obesity

INTRODUCTION

Appropriate nutrition in early childhood plays an important role in normal growth and development as well as the long term health of individuals. Research on dietary intake and nutritional adequacy in young children has been focused on the intake of single nutrients. However, diet comprises a variety of foods and nutrients that can interact with each other and the effect of overall diet on health is more complex than a simple additive of the effects of individual nutrients. There is increasing recognition that dietary pattern (a combination of foods commonly eaten together) better reflects the overall quality of the diet.

Dietary patterns have been shown to be associated with nutrient intakes and linked to chronic diseases including obesity,[1] diabetes,[2] and metabolic syndrome[3] in adults. However, the association between dietary patterns and health outcomes is not well studied in young children. Only a handful of studies have investigated the association between dietary patterns and nutrient intakes in young children,[4-6] and a limited number of studies have assessed the association between dietary pattern and overweight/obesity among children.[1,7-11] None of these studies were conducted among preschool children aged one to four years in Australia.

Preschool children are at a stage of life when dietary habits are developing, and it is an important stage for establishing healthy eating patterns as dietary patterns established in early childhood often carry through to adulthood.[12] Australia is one of the countries with a high burden of obesity. Early prevention of overweight/obesity is an important strategy as obesity in childhood increases the risk of developing obesity in adulthood. Although many factors contribute to the aetiology of obesity, unhealthy eating habits and sedentary lifestyles are among the main contributors of the world obesity epidemic. The aims of this study were to characterise dietary patterns and to examine the association between dietary patterns and: 1) intakes of macronutrients and key micronutrients, 2) risk of childhood obesity, in preschool children from a

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representative population sample in Australia.

METHODS

Study design and participants

This study was undertaken utilising dietary survey data collected in the FINS (Food Intake and Nutritional Status of preschool children) study,[13] which is a cross sectional survey of preschool children. The detailed design of the FINS study has been reported elsewhere.[13-15] Briefly, the 2001 Census data from the Australian Bureau of Statistics was used to identify areas of low, medium and high socioeconomic status (SES), and a stratified sampling technique was used to obtain a representative population sample from the three different SES. Three hundred preschool children aged 1-4 yrs, who were born full term (gestational age at birth ≥37 weeks) with a birth weight ≥2500 g, were recruited between 2005 and 2007. The FINS study was approved by the Human Research Ethics Committee at the Children, Youth and Women's Health Service, Adelaide, Australia. Written informed consent was obtained from all participating families prior to study participation. For the present study, we excluded children who were still breastfed at the time of dietary assessment (n=12). The final sample for the present study included 288 children.

Dietary intake

Dietary intake was assessed using a 3-day weighed food diary. Parents were given instructions, a scale and measuring cups and spoons to complete a food diary of their child's intake on three consecutive days, including one weekend day. Completed food diaries were checked by a dietitian for errors, ambiguities or missing information. Nutrient intake was calculated using the FoodWork Professionals software (Xyris Software Pty Ltd, QLD, Australia) with the Australian Version of the Food Composition Tables (AusNut Version 18). All nutrient intakes were adjusted for energy using the residual method.[16] Commercial food products that were not available in the Food Composition Tables were manually added to the FoodWorks Program when nutritional information was available or were substituted with similar foods based on ingredients if nutritional information is not available. Energy intake was compared with the recommended estimated energy requirement (EER) for children.[17] In order to determine dietary patterns, the 3-day food record was recoded into food groups based on AusNut food grouping as well as food groups that have been shown to be important in constructing dietary patterns in children from the literature review. The resultant 28 food groups are comprised of the 14 main food groups in the AusNut with further categorisation to differentiate healthy from less healthy options within each food group,[18] for example, cheese was separated into low fat and full cream products whilst the meat products were separated into processed and unprocessed.

Intake (g/day) of each of the 28 food groups was used to construct dietary patterns. Dietary patterns were identified by factor analysis using principal component analysis method.[19,20] Factors were rotated with an orthogonal (varimax) rotation to improve interpretability and minimise correlation between the factors. The number of factors retained from each food classification method was determined by eigenvalue (>1), scree plot and factor interpretability. Using this approach, each identified dietary pattern represents a group of highly correlated foods consumed by the participants. Naming of the dietary patterns was primarily descriptive and was based on our interpretation of the pattern structures based on foods with factor loading score of ≥|0.3|. Participants were assigned pattern-specific factor scores on each of the three dietary patterns. Scores for each pattern were calculated by summing the product of a standardised daily intake of each food and its factor loading coefficients. Factor loadings of each food represent the correlation coefficient between individual food and specific food pattern. A loading >0.3 represents a high positive correlation between food and dietary pattern while a loading <-0.3 represents a high negative correlation.

Outcome measures

Weight and length/height were measured according to the WHO standard and body mass index (BMI) was calculated. Weight and length/height z-scores were calculated using WHO ANTHRO 2005 Version 3.1 (WHO, Geneva, Switzerland). Anthropometrics assessments were conducted within two weeks of the dietary assessment. Children were classified as overweight if their BMI z-score was between the 85th–95th percentile and obese if their BMI z-score was above the 95th percentile.

Covariates

Duration of breastfeeding was recorded by maternal recall and treated as a continuous variable in the analysis. Mother's education was coded into four categories based on self-report: 1) did not complete high school; 2) completed high school; 3) diploma; 4) degree.

Statistical analyses

Factor scores were divided into tertiles, implying increased intake from tertile 1 (T1) to tertile 3 (T3). Chi square test was used to compare differences between categorical variables. ANOVA was used to compare the difference in continuous variables (e.g. food and nutrients intake) between groups. Multivariable logistic regression was used to determine the association between food patterns and overweight or obesity adjusted for age, sex, mother's education, duration of breastfeeding, energy and protein intake. The effect is expressed as odd ratio (OR) with 95% confidence interval (CI). For comparison, factor scores were treated both as categorical and continuous variables in multivariable logistic regression models. Interactions between dietary patterns and age was tested by adding a multiplicative term of dietary patterns scores (continuous) and age (continuous) in the fully adjusted models. In sensitivity analysis, we excluded children aged below 2 years (n=83). All the analyses were performed using STATA 12 (Stata Corporation, College Station). Statistical significance was considered when $p<0.05$ (two sided).

RESULTS

Among the 288 participants, 149 (51.7%) were boys. The mean age and BMI was 2.9 (SD 1.2) years and 16.5 (SD

1.6) kg/m^2, respectively. Three dietary patterns were identified by factor analysis. Factor loadings for the three dietary patterns are presented in Table 1. The 'Traditional' pattern was characterised by grains, fruit, vegetables, and red meat. The 'Processed' pattern was characterised by snack foods, processed meats, beverages and confessionary. The 'Health conscious' pattern was characterised by polyunsaturated margarines, low fat dairy products, fish, eggs and composite foods which contain vegetables as a key ingredient. The three patterns explained 19.6% of the variance in intake (Table 1).

Mean intake of macronutrients and key micronutrients according to tertiles of dietary pattern scores are reported in Table 2. Age and energy intake were positively associated with tertiles of all three dietary patterns' scores. Approximately 25% of the children had energy intake ≥120% EER. There was no significant difference in the percentage of children with energy intake ≥120% EER across tertiles within each dietary pattern. For the 'Traditional' dietary pattern, intakes of protein, iron, zinc and fibre were positively associated with tertiles of dietary pattern scores while total fat intake was inversely associated (Table 2). In contrast, intakes of zinc, protein and total fat were inversely associated with tertiles of the 'Processed' dietary pattern scores while intake of carbohydrate was positively associated (Table 2). Calcium intake was negatively associated with tertiles of dietary pattern scores for both the 'Traditional' and the 'Processed' patterns (Table 2). Intakes of carbohydrate, protein, total fat and key micronutrients were not significantly associated with tertiles of dietary pattern scores for the 'Health conscious' dietary pattern (Table 2). Mother's education level was inversely associated with the 'Processed' dietary pattern. Children whose mothers had a degree were less likely to have a high intake of the 'Processed' dietary pattern. There was no significant association between the mother's educational level and the 'Traditional' or 'Health conscious' dietary patterns (Table 2).

The prevalence of overweight and obesity was 17.4% and 14.2%, respectively. The OR for obesity increased across tertiles of the 'Traditional' dietary pattern scores (Table 3). Using dietary pattern score as a continuous variable, for each 1 SD increase in the 'Traditional' pattern score the OR was 1.73 for obesity and 1.35 for overweight and obesity combined (Table 3, Model 2). The positive association between this dietary pattern and overweight and obesity remained unchanged after exclusion of children under the age of 2 years (n=83) in sensitive analysis. As the 'Traditional' pattern was positively associated with protein intake, we further adjusted for the intake of energy and protein and found the association between the 'Traditional' pattern and obesity attenuated and became non-significant (Table 3 Model 3). The 'Processed' and the 'Health conscious' patterns were not as-

Table 1. Factor loadings of the 28 food groups for the three dietary patterns identified among Australian children[†]

Food group	Dietary pattern		
	Traditional	Processed	Health conscious
Grains & starches	0.456	0.238	0.186
Cereals & cereal products	0.063	0.065	0.033
Vegetables	0.490	0.048	-0.347
Vegetable in Composite food	-0.192	0.065	0.402
Fresh fruit	0.394	0.033	0.002
Canned/processed fruit	-0.144	0.303	-0.043
Milk & milk based drinks	-0.053	-0.383	-0.198
Beef/pork/lamb	0.682	-0.042	0.019
Game and poultry	0.274	0.179	-0.395
Fish	0.261	-0.189	0.400
Eggs	0.006	-0.053	0.582
Seeds and seed products	0.513	-0.003	0.047
Vegetarian meat Alternatives	-0.034	-0.156	0.072
Other sea & freshwater foods	-0.137	0.195	-0.074
Low fat cheeses	-0.009	0.023	0.345
Frozen milk products	-0.049	0.352	-0.194
Infant formulae	-0.299	-0.082	0.165
Commercial baby foods	-0.243	-0.313	-0.085
Polyunsaturated margarines	0.235	0.198	0.518
Butters	-0.011	0.095	-0.259
Sauces & condiments	0.278	-0.099	0.031
Sugars	0.224	-0.052	-0.048
Cakes cake mixes	-0.206	0.216	0.173
Biscuits	-0.020	0.233	0.230
Preserves & other Confectionary	-0.125	0.680	0.012
Snack foods	0.020	0.504	-0.013
Beverages	0.042	0.436	-0.073
Offal products & processed meats	0.060	0.368	0.028
Variance explained	7.0%	6.7%	5.9%

[†]Factor loading is the correlation coefficient between individual food and specific food pattern score. A loading >0.3 or <-0.3 represents a high correlation between food and dietary pattern positively or negatively. For example, Beef/pork/lamb is highly correlated with traditional pattern (correlation coefficient 0.682) but not associated with processed or health conscious patterns. A traditional pattern will have a high intake of beef/pork/lamb but a low intake of infant formula.

Table 2. Mean daily macro and key micronutrients intakes[†] according to tertiles of dietary pattern scores[‡]

	Traditional			*p*	Processed			*p*	Health conscious			*p*
	T1	T2	T3		T1	T2	T3		T1	T2	T3	
Age (yrs)	2.5	2.9	3.5	<0.001	2.2	3	3.6	<0.001	2.8	2.8	3.2	0.074
Energy (KJ)	4777	5089	5668	<0.001	4516	5102	5916.1	<0.001	4964	5062	5509	0.010
CHO (g)	150	149	150	0.979	143	150	156	<0.001	151	149	150	0.755
Protein (g)	47.2	48.0	54.6	<0.001	52.8	50.6	46.4	<0.001	50.0	51.4	48.4	0.070
Fat (g)	47.6	46.8	43.2	0.003	48.0	44.8	44.8	0.007	45.6	45.5	46.5	0.680
Mono- fat (g)	23.8	23.2	19.9	<0.001	24.2	21.6	21.0	<0.001	23.2	22.8	20.8	0.006
Poly- fat (g)	4.2	4.2	4.6	0.079	4.1	4.3	4.6	0.068	3.9	4.0	5.2	<0.001
Saturated fat (g)	14.7	15.3	14.6	0.281	15.1	14.7	14.9	0.690	14.2	14.9	15.6	0.017
Iron (mg)	6.8	6.5	7.4	0.006	6.9	7.2	6.5	0.055	6.6	6.8	7.3	0.053
Zinc (mg)	6.0	6.0	7.0	<0.001	6.7	6.4	5.8	<0.001	6.3	6.5	6.3	0.507
Ca (mg)	858	797	716	0.001	953	771	648	<0.001	807	802	762	0.415
Fibre (g)	10.0	11.1	13.5	<0.001	10.8	12.8	11.0	<0.001	11.5	11.3	11.8	0.675
Energy >120% EER (%)	25.0	25.0	25.0	1.000	21.9	29.2	24.0	0.486	19.8	22.9	32.3	0.115
Mother completed a degree (%)	29.2	30.9	29.5	0.964	32.6	36.5	20.2	0.038	22.1	31.3	36.2	0.100
Girls (%)	49.0	49.0	46.9	0.946	51.0	47.9	45.8	0.768	53.1	45.8	45.8	0.506

T1: first tertile; T2: second tertile; T3: third tertile; CHO: carbohydrate; EER: estimated energy requirement.
[†]All nutrient intakes were energy adjusted using the residual method.[16]
[‡]n=288.

Table 3. Odds ratio for overweight and/or obesity according to tertile of dietary pattern scores (n=288)

	T1	T2	T3	Continuous	*p* for trend†
Obesity					
Traditional Pattern					
Model 1	1	2.74 (1.08-6.94)	2.74 (1.08-6.94)	1.57 (1.16-2.13)	0.003
Model 2	1	2.94 (1.10-7.85)	3.12 (1.11-8.74)	1.73 (1.20-2.47)	0.003
Model 3	1	2.70 (1.00-7.28)*	1.78 (0.59-5.43)	1.44 (0.93-2.22)	0.102
Processed Pattern					
Model 1	1	1.73 (0.79-3.79)	0.81(0.33-1.98)	0.74 (0.52-1.07)	0.113
Model 2	1	1.71 (0.73-3.97)	1.05(0.37-2.99)	0.83 (0.52-1.32)	0.430
Model 3	1	1.79 (0.76-4.25)	1.06 (0.35-3.24)	0.77 (0.47-1.28)	0.316
Health conscious Pattern					
Model 1	1	1.32 (0.57-3.07)	1.55 (0.68-3.53)	1.15 (0.84-1.57)	0.382
Model 2	1	1.38 (0.57-3.33)	1.80 (0.75-4.31)	1.20 (0.86-1.67)	0.280
Model 3	1	1.36 (0.55-3.35)	1.84 (0.75-4.52)	1.17 (0.85-1.63)	0.334
Overweight/obesity					
Traditional Pattern					
Model 1	1	1.41 (0.76-2.61)	1.35 (0.73-2.50)	1.25 (0.97-1.60)	0.079
Model 2	1	1.43 (0.74-2.76)	1.50 (0.74-3.02)	1.35 (1.00-1.80)	0.047
Model 3	1	1.35 (0.69-2.62)	1.02 (0.47-2.20)	1.15 (0.82-1.63)	0.412
Processed Pattern					
Model 1	1	1.33 (0.73-2.42)	0.90 (0.49-1.69)	0.87 (0.67-1.12)	0.276
Model 2	1	1.36 (0.71-2.59)	0.96 (0.45-2.05)	0.88 (0.63-1.22)	0.437
Model 3	1	1.40 (0.73-2.71)	0.98 (0.44-2.20)	0.84 (0.58-1.20)	0.333
Health conscious Pattern					
Model 1	1	1.00 (0.55-1.83)	0.91 (0.49-1.67)	0.84 (0.64-1.09)	0.195
Model 2	1	1.09 (0.58-2.04)	1.02 (0.54-1.94)	0.88 (0.66-1.16)	0.354
Model 3	1	1.04 (0.55-1.96)	1.02 (0.53-1.97)	0.86 (0.65-1.14)	0.292

†Calculated using factor scores as continuous variable.
Model 1: No adjustment.
Model 2: Adjusted for age, sex, duration of breastfeeding, mother's education and other dietary patterns.
Model 3: Model 2 plus additional adjustments for energy & protein intake.

sociated with the risk of overweight and/or obesity (Table 3). Adjustment for protein and energy intake did not change the null association between these two dietary patterns and the risk of obesity (Table 3). There was no significant interaction between dietary patterns and age (data not shown).

DISCUSSION

Three dietary patterns were identified in this population of preschool children. A positive association between the 'Traditional' pattern and overweight/obesity was observed while no association between the 'Processed' pattern or the 'Health conscious' pattern and the risk of overweight/obesity was found.

The positive association between the 'Traditional' dietary pattern and overweight/obesity was unexpected as this pattern was characterised by high loadings of grains, fruit and vegetables which are often linked to healthy diets. Although red meat had a high factor loading score in the 'Traditional' dietary pattern, this dietary pattern was not associated with saturated fat intake and was inversely associated with total fat intake. The 'Traditional' dietary pattern score was positively associated with protein intake and adjustment for protein intake rendered the association between the 'Traditional' dietary pattern and the risk of obesity non-significant. This suggests that protein intake may be the underlying factor for the association observed between the 'Traditional' dietary pattern and the risk of obesity because protein intake was positively associated with obesity in our study (data not shown). This view is consistent with current literature which suggests that high protein intake in infancy and early childhood increased the risk of childhood obesity. In the Childhood Obesity Project, infants who were randomly allocated to a high protein infant formula group in the first year of life had a higher risk of obesity at 2 and 6 years of age compared with infants who were allocated to an isocaloric low protein formula group.[21,22] Protein intake has also been shown to be positively associated with body fat among 6-8 years old Finnish children.[23] However, there was no difference in weight status between high vs. standard protein groups in another randomized trial.[24] Further research investigating the effect of protein intake on weight status in preschool children is warranted.

The inverse association between mother's education and the 'Processed' dietary pattern is consistent with the literature that shows lower maternal education or low socioeconomic status is associated with less healthy dietary pattern in children. The lack of association between the 'Processed' dietary pattern and the risk of overweight and obesity in our study is comparable to a Netherlands study, which showed no association between a 'Western' like dietary pattern and weight or length z-score in over 2000 toddlers,[4] and an Australian study which showed no association between a high fat and sugar dietary pattern and BMI among adolescents in a national survey.[25] No consistent association between dietary patterns and weight status among American teenagers was reported in the EAT project.[9] In contrast, an energy dense high fat dietary pattern was associated with adiposity in school children in the ALSPAC study[7] whereas a 'healthy' eating pattern has been associated with lower risk of overweight in Korean preschool children.[5] It is difficult to directly compare the results from different studies examining the association between dietary patterns and the risk of overweight or obesity partly because the characteristics of the identified dietary patterns are often different in some aspects even among dietary patterns that are characterised as 'healthy' or 'unhealthy'. In our study although the 'Processed' dietary pattern had a high factor loading score for processed meats, snack foods and confectionary, it was not associated with saturated fat intake and was inversely associated with total fat and protein intake. This may partly explain the lack of association between the 'processed' dietary pattern and the risk of obesity.

Although dietary intake is an important determinant of weight status, other socioeconomic and lifestyle factors also contribute to the risk of obesity. One of the limitations of our study is that we did not assess and control for the physical activity of the children, an important lifestyle factor associated with the risk of obesity. Although the amount of variance in intake explained by the dietary patterns in our study is similar to other dietary patterns studies in young children,[4,26,27] there are large variances in intake that are not explained by the identified dietary patterns among the studies. Furthermore, each dietary pattern may be associated with foods that are linked to adverse health outcomes as well as foods that promote good health. The overall effect of a dietary pattern on health outcomes may vary depending on the actual composition of the dietary pattern. This may also contribute to the inconsistent findings between studies and the complexity in interpreting associations between dietary patterns and health outcomes.

Interpretation of the association between dietary patterns and the risk of overweight and obesity is limited due to the cross sectional nature of our study where dietary intake and weight status were assessed at the same time. The dietary pattern of the overweight/obese children may have changed from an unhealthy to a healthier eating pattern as a result of intervention for weight management. This view is supported by a Norwegian study which showed that children with high scores on a traditional pattern were more likely while children with a high score on a junk food pattern were less likely to be overweight or obese at 9 years of age in a cross-sectional study.[10] However, follow up of the same children three years later showed that children who continued to have high scores on the traditional pattern overtime were less likely to remain overweight or obese compared with children who did not continue to have high scores on this pattern.[28] This highlights the importance of longitudinal studies when investigating the relationship between dietary patterns in childhood and the risk of obesity later in life. Further research with longitudinal follow up design and adequate adjustment for key confounders is warranted to better understand the relationship between dietary pattern in early childhood and risk of overweight and obesity later in life.

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AUTHOR DISCLOSURES

Z Shi & SJ Zhou have no conflict of interest. M Makrides has been serving on the scientific advisory boards for Nestle and Fonterra. Associated honoraria for M Makrides are paid to her institution to support conference travel and continuing education for postgraduate students and early career researchers.

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