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The effect of dairy consumption on blood pressure in mid-childhood: CAPS cohort study

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Abstract

Background/objectives: It has been postulated that higher dairy consumption may affect blood pressure regulation. The aim of this study was to examine the association between dairy consumption and blood pressure in mid-childhood. Methods: Subjects (n=335) were participants of a birth cohort at high risk of asthma withinformation on diet at 18 months and blood pressure at 8 years. Multivariate analyses were used to assess the association of dairy consumption (serves) and micronutrient intakes (mg) at 18 m with blood pressure at 8 y. In a subgroup of children (n=201), dietary intake was measured at age 18 m and 9 y which allowed for comparisons of blood pressure of those who consistently consumed at least two dairy serves per day versus those who did not. Results: Children in the highest quintile of dairy consumption at 18 months had lower systolic blood pressure (SBP) and diastolic blood pressure (DBP) at 8 years (2.5 mm Hg, P=0.046 and 1.9 mm Hg, P=0.047; respectively) than those in the lowest quintiles. SBP was lowest among children in the highest quintiles of calcium, magnesium and potassium intakes. Significant negative linear trends were observed between SBP and intakes of dairy serves, calcium, magnesium and potassium. Furthermore, SBP and DBP were lowest in the group of children that consumed at least two dairy serves at both 18 months and 9 years, compared to all other children (SBP 98.7 vs 101.0 mm Hg, P=0.07; and DBP 56.5 vs 59.3 mm Hg, P=0.006; respectively). Conclusions: These results are consistent with a protective effect of dairy consumption in childhood on blood pressure at age 8 years.

Keywords

study, pressure, cohort, caps, blood, consumption, dairy, childhood, effect, mid

Disciplines

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The effect of dairy consumption on blood pressure in mid-childhood: CAPS cohort study

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Abstract

Background/objectives: It has been postulated that higher dairy consumption may affect blood pressure regulation. The aim of this study was to examine the association between dairy consumption and blood pressure in mid-childhood.

Methods: Subjects (n=335) were participants of a birth cohort at high risk of asthma with information on diet at 18 months and blood pressure at 8 years. Multivariate analyses were used to assess the association of dairy consumption (serves) and micronutrient intakes (mg) at 18 m with blood pressure at 8 y. In a subgroup of children (n=201), dietary intake was measured at age 18 m and 9 y which allowed for comparisons of blood pressure of those who consistently consumed at least two dairy serves per day versus those who did not.

Results: Children in the highest quintile of dairy consumption at 18 months had lower systolic blood pressure (SBP) and diastolic blood pressure (DBP) at 8 years (2.5 mm Hg, P=0.046 and 1.9 mm Hg, P=0.047; respectively) than those in the lowest quintiles. SBP was lowest among children in the highest quintiles of calcium, magnesium and potassium intakes. Significant negative linear trends were observed between SBP and intakes of dairy serves, calcium, magnesium and potassium. Furthermore, SBP and DBP were lowest in the group of children that consumed at least two dairy serves at both 18 months and 9 years, compared to all other children (SBP 98.7 vs 101.0 mm Hg, P=0.07; and DBP 56.5 vs 59.3 mm Hg, P=0.006; respectively).

Conclusions: These results are consistent with a protective effect of dairy consumption in childhood on blood pressure at age 8 years.

Key words: blood pressure, children, diet, dairy products

Introduction

High blood pressure is a major risk factor for heart disease, stroke, congestive heart failure and kidney disease (Huang *et al.,* 2008). As childhood blood pressure is known to track significantly into adulthood (Chen and Wang, 2008), maintaining an optimal blood pressure throughout childhood may be important to help prevent blood pressure related morbidities in later life. Although there are currently no prospective studies with sufficiently long follow-up to directly link childhood blood pressure levels to the occurrence of cardiovascular disease or mortality, surrogate markers have demonstrated an association between high blood pressure in childhood and later hypertensive end-organ damage to the heart, blood vessels, kidneys and retinas (Lurbe *et al.*, 2009; Mitchell *et al.*, 2007).

A healthy diet and lifestyle play an important role in blood pressure control. The role of dairy products in the regulation of blood pressure in children has not been studied widely. Most longitudinal studies that have examined the effect of dairy intake on blood pressure have been undertaken in adults (Ascherio *et al.*, 1996; Elwood *et al.,* 2004; Alsonso *et al.,* 2005; Snyder *et al.,* 2008; Wang *et al.*, 2008; Alonso *et al.,* 2009; Engberink *et al.*, 2009*a*; Engberink *et al.*, 2009*b*; Toledo *et al.*, 2009), some in young adults (Pereira *et al.*, 2002; Steffen *et al.*, 2005) and only one in young children (Moore *et al.*, 2005). Among adults, evidence is accumulating that dairy products are protective against high blood pressure (Huth *et al.*, 2005; Kris-Etherton *et al.,* 2009). The majority of longitudinal studies have shown a beneficial effect of dairy consumption on blood pressure or a reduced risk of hypertension (Elwood *et al.*, 2004; Alsonso *et al.*, 2005; Wang *et al.*, 2008; Alonso *et al.*, 2009; Engberink *et al.,* 2009*a*; Toledo *et al.,* 2009) although others have shown no effect (Ascherio *et al.*, 1996; Snyder *et al.,* 2008; Engberink *et al.,* 2009*b*). In addition, the Dietary Approaches to Stop Hypertension (DASH) trial showed that a dietary pattern rich in fruits, vegetables, low-fat dairy products and low in total fat was more effective than a control diet of fruits and vegetables alone in reducing blood pressure levels in adults (Appel *et al.,* 1997; Sacks *et al.,* 2001).

Among children, only one cohort study has investigated the effect of dairy products on blood pressure (Moore *et al.,* 2005). This study found dairy products to have a protective effect on children’s blood pressure after 8 years of follow-up. These results were supported by those of a short-term intervention study using a DASH-type diet among adolescents with elevated blood pressure (Couch *et al.*, 2008). Further research is required to determine the optimal diet and the role of dairy products for the prevention of high blood pressure among children.

In this paper, we examined whether dairy consumption at age 18 months is associated with blood pressure at age 8 years using data from the longitudinal Childhood Asthma Prevention Study (CAPS). We also examined whether a consistently high dairy consumption at 18 months and mid-childhood was associated with blood pressure.

Methods

Study background and subjects

The children were part of CAPS, a randomised controlled trial to assess the effects of two interventions on the primary prevention of asthma: an omega-3 supplemented diet and house dust mite reduction for the first five years of life. Pregnant women whose unborn children were at risk of developing asthma were recruited from antenatal clinics in western Sydney, Australia from 1997 to 2000. Ethics approval for the study was obtained from the human research ethics committees of each of the participating hospitals, the Area Health Services in which the hospitals were located, and the University of Sydney. A total of 616 children were randomized at birth into active intervention or control groups, and 538 completed the 18-month assessment. Further details about the intervention, recruitment and the extent to which the study population differed from the women who satisfied the selection criteria and the local population of comparable age have been reported previously (Mihrshahi *et al.,* 2001; Mihrshahi *et al.*, 2002). In brief, a higher proportion of both fathers and mothers of CAPS children had tertiary education and were Australian-born, compared with those who did not participate in the study and the population of western Sydney in general.

Dietary intake

A secondary aim of the study was to document dietary intakes at periodic follow-up visits to enable investigation of associations with disease risk factors, and to track changes in diet over time.

At 18 months

The first dietary assessment was undertaken at the 18-month assessment, together with medical and anthropometric assessments. Details of the dietary assessment methods and response rates for the 18-month assessment have been published elsewhere (Webb *et al.,* 2006). In summary, food consumption was assessed from three-day weighed food records. A research dietitian instructed mothers to keep records on any two weekdays and one weekend day as convenient. A food record booklet, a set of Tanita digital kitchen scales (2.0 kg ± 1.0 g) and instructions for weighing and recording were left with the mother. At the end of the recording period, the dietitian visited the mothers at home to check the completeness of the records.

Of 538 participants approached at the 18-month assessment, 465 (86%) kept weighed food records with the final number of records analysed being 429 (80% response rate). Records were excluded (n=36) if all three days were not completed, the quality of the data supplied was poor, the child's food intake on these days was atypical due to illness affecting food intake, or because the child was breastfeeding more than twice per day and therefore the quantity of energy and food intake could not be measured accurately. If the child was only breastfeeding once a day as a 'comfort feed' at night or early morning, the records were kept in the dataset (n=4), as were records that were maintained only on weekdays (n=16) or one weekday and two weekend days (n=27).

At nine years of age

A second dietary assessment was undertaken in 2007-2008 on a sub-group of children aged approximately 9 years old (a year after they had completed the CAPS follow up medical assessments). Food and nutrient intakes were assessed from three 24-hour recalls using the multiple pass approach (AGDHA, 2008*a*). Use of 24-hour recalls was expected to give a higher response rate than weighed food records among children of this age (Livingstone *et al.,* 2004; Burrows *et al.,* 2010). All interviews were conducted by telephone by trained research dietitians using a purpose-designed scripted computer-based data collection and entry program. Children reported their own food intake with the help of their parents as needed regarding brand names, food descriptions, ingredients in mixed dishes, cooking methods, and estimates of portion sizes. A food model booklet similar to those used in the National Children's Nutrition Survey (AGDHA, 2008*a*) was mailed ahead to all participants to assist in estimating portion sizes.

It was envisaged that all children who had participated in the first dietary assessment would be contacted and invited to participate in the second dietary assessment. However, due to budgetary constraints, only the first 259 out of the 429 children were contacted. These children did not differ from the uninvited children by weight, height, BMI, or energy intake at 18 months but father's education levels were higher in the sample of invited children and mother's age at birth of child was lower. Of these 259 children, 43 children (16.6%) were unwilling to participate; 15 children were excluded because all three recalls were not completed (n=12), or misreported energy intake (n=3) (Torun *et al.*, 1996). Overall, the final number of three day recalls analysed was 201. Interviews were intended to cover 2 weekdays and 1 weekend day and this was achieved for 70% of interviews. Participants were provided with two movie passes after successful completion of three dietary interviews as an incentive to participate.

Dietary data analysis

Food records from 18 month old children were checked, coded and entered into the SERVE nutrient analysis program based on the NUTTAB 95 food composition database (National Food Authority, Canberra, NUTTAB 95 version 3.0 1995) according to procedures described previously (Webb *et al.*, 2006).

Dietary recall data from 9 year olds were directly coded and entered into a custom-made dietary data entry and analysis program which used the NUTTAB 2006 food composition data base (FSANZ, 2006). This database is an updated version of the NUTTAB 95 database used in the first assessment and allows comparability of data. Food lists for each subject were exported and checked, and coding and data entry errors were corrected.

All dietary data were exported into SPSS and food and nutrient intakes were calculated for each individual as a mean of the three days. Information about nutrients contributed from vitamin and mineral supplements has not been considered in this analysis of dietary intakes.

Serves of dairy products were calculated by adding milk serves (258 g or 250 ml of any type of fluid milk), cheese serves (40g of any type of hard or soft cheese, including on composite dishes), yoghurt serves (200 g of any type of yoghurt) and custard serves (280 g or 250 ml of any type of milk-based custard). A serve of fruit was calculated as 150 g of fresh/canned fruit or 20 g of dried fruit. A serve of vegetables was calculated as 75 g of all types of raw and cooked vegetables and legumes but excluded hot chips.

Anthropometric and blood pressure measures

Children's weight, in kilograms, and recumbent length (for toddlers) and standing height (for 8 year olds), in centimetres, were measured by research nurses. Weight was measured to the nearest 0.1 kilogram and height to the nearest 1 centimetre. Children were dressed in light clothing without shoes. For children under 2 years of age, BMI z-scores were calculated using the 2000 CDC Growth Charts (NCCDPHP, 2000).

Brachial blood pressure was measured with the use of a validated automated oscillometric device (Welch Allyn Vital Signs Monitor) (Jones *et al.,* 2001). Supine blood pressure in the left brachial artery was measured after 10 min of quiet rest and repeated after a further 10 min; a third blood pressure measurement was taken if there was a variance of $\geq$10 mm Hg; the average of the two closest readings was recorded as the brachial blood pressure (Ayer *et al.,* 2009). As blood pressure was only measured on one occasion, a diagnosis of hypertension could not be established as this requires repeated measurements (minimum of three). Accordingly, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were used as continuous outcome variables.

For this paper, follow-up data on anthropometric measures and blood pressure were collected when children were 8 years old. These measures were available on 335 children who had previously completed the 3-day food records. No differences in weight status, energy intake or dairy intake were found between children with measures available at age 8 years (n=335) and children who did not participate in this follow-up study (n=94). However, the follow-up sample included a greater proportion of children with mothers who had attained a higher level of education compared to children who did not participate in the follow-up study (P=0.006).

Demographic and health information

Data on the following potential confounding factors were collected at baseline and used in our analysis; child's age, sex, postcode (used to derive a Socio-Economic Index for Areas, SEIFA, score (ABS, 2008)), parental education levels (defined as primary/secondary education or vocational/university education), parental countries of birth (Australia/New Zealand or others), maternal smoking status during pregnancy (yes or no), presence of gestational diabetes (yes or no), maternal age at birth (<25 or ≥25 years) breastfeeding (exclusive breastfeeding at 3 months, yes or no).

Statistical analysis

Quintiles of dairy consumption were obtained to examine associations with weight status and blood pressure measures. Each quintile contained 67 subjects. Tests for linear trend were performed, as well as analysis of variance (ANOVA) to test for differences between the quintiles. The nutrient residual model was used to adjust for energy intake (Willett, 1990). Food/nutrient intake was regressed on energy intake and the residuals were classified into quintiles and used in all analyses. Energy-adjusted food/nutrient intakes are presented by adding each person's residual to the mean for the population for that food/nutrient.

Linear regression analyses were used to adjust for potential confounders. Separate models were run for each of the food/nutrient variables and both outcome variables; SBP and DBP. Potential confounders included in the multivariate models were child's age, sex, SEIFA score and baseline weight status (weight-for-length z-score at 18 months), maternal and paternal education level, maternal and paternal countries of birth, maternal age at birth, maternal smoking status during pregnancy, gestational diabetes, breastfeeding, CAPS randomisation group (diet, active or control; and dust mites, active or control), total energy intake, fruit intake and vegetable intake. Linear trends across the quintiles were analysed by using the median value of the quintile category as a continuous variable in the linear regression analysis.

ANCOVA was used to determine differences in BP between children who consistently met recommended dairy intakes and those that did not. Analyses were adjusted for age and gender. Tracking of dairy consumption from 18 months to 9 years was examined using the Kappa statistic (meeting vs not meeting recommendations at 18 months and 9 years). P-values less than 0.05 were considered statistically significant. PASW Statistics release 18 (SPSS Inc., Chicago, IL, USA, 2009) were used for all analyses.

Results

Early diet and blood pressure at mid-childhood

The sample for this analysis consisted of 335 children; 169 boys and 166 girls. The mean age at baseline was 18.9 months (range, 16-24 months) and age at follow up was 8.0 years (range, 7.7-9.2 years). Parental characteristics included 75% of mothers and fathers born in Australia or New Zealand, 50% of mothers and fathers had more than 12 years of schooling, 22% of mothers smoked during pregnancy, and 6% had gestational diabetes. There were no significant differences in weight, height or BMI z-score between boys and girls.

Weight, height, blood pressure and fruit and vegetable intake data by dairy consumption quintile are presented in Table 1. Associations between energy-adjusted dairy consumption quintiles at 18 months and weight status at 18 months and 8 years were not significant. Fruit and vegetable serves were not associated with dairy consumption at age 18 months. At 8 years, a significant inverse trend was found between early dairy consumption and lower SBP (P_{trend}=0.042). ANOVA showed no significant differences between quintile groups for any of the parameters examined.

TABLE 1

Table 2 shows the linear regression models of dairy consumption on blood pressure status. A high dairy intake was found to be protective for SBP (P=0.046) and DBP (P=0.047), with children in the highest quintile of dairy intake having lower blood pressure levels compared with children in the lowest quintile of dairy intake. Children in the highest quintile of dairy intake (i.e. consuming >2.9 serves per day) had a lower mean SBP of 2.5 mm Hg and DBP of 1.9 mm Hg compared with children in the lowest quintile (i.e. those consuming <1.4 serves per day). Furthermore, a significant negative linear trend was found between quintiles of dairy consumption and SBP (P_{trend}=0.046) but not for DBP.

Further modelling was undertaken to investigate the association between blood pressure and micronutrients of interest including calcium, magnesium, potassium and sodium. Calcium, magnesium and potassium all showed a significant inverse association with blood pressure. Children in the highest quintiles of calcium, magnesium or potassium intake (i.e. calcium intakes > 976 mg; magnesium >160 mg; or potassium >1920 mg per day) had significantly lower SBP levels — 2.8 mm Hg, compared with children in the lowest quintiles. In addition, significant negative linear trends were found between the quintiles of these three micronutrients and SBP (P_{trend}=0.023 for calcium; P_{trend}=0.044 for magnesium; P_{trend}=0.031 for potassium). Conversely, positive regression coefficients were seen with sodium intake and SBP, although these were not statistically significant. No significant associations were found between any of the micronutrients studied and DBP.

Additional adjustment for BMI z-score or waist circumference at the time of BP measurement (i.e. at 8 years of age), showed that both anthropometric measures were significant mediators in the association between dairy consumption and blood pressure. However, beta-coefficients and significant levels between dairy consumption and blood pressure remained similar after adjustment for BMI z-score and waist circumference (data not shown).

Overall, the energy-adjusted models explained only about 5% of variability in blood pressure.

TABLE 2

Association between blood pressure at 8 years and high dairy consumption at two time points (18 months and 9 years)

Dairy intakes at age 18 months were compared with those at the mid-childhood assessment when the children were a mean age of 9.2 years (range 8.2-10.5 years). This sample included 201 children, 109 boys and 92 girls, with similar sociodemographic and anthropometric characteristics to the previous cohort of 335 children.

Children who met the recommended intakes at 18 months and 9 years (a minimum of 2 dairy serves at both time points (Smith *et al.*, 1998)) were compared with those who failed to do so using ANCOVA. Analysis of blood pressure in relation to high dairy consumption at two time points (Table 3) reveals a significant association with DBP (P=0.006) and a nonsignificant association with SBP (P=0.069), after adjusting for age, sex and WHZ score. SBP and DBP were lowest for children who consumed at least two dairy serves per day at 18 months and 9 years. It must be noted that out of 108 toddlers with recommended dairy intakes, only 35 consumed recommended intakes at age 9 years (Kappa= 0.02).

TABLE 3

Discussion

The findings of this study suggest that higher dairy consumption in early childhood may have a beneficial effect on blood pressure in mid-childhood. SBP and DBP were significantly lower for children in the highest dairy consumption quintile compared with those in the lowest quintile, after adjustment for potential confounders including energy intake and fruit and vegetable consumption. In addition, a significant linear trend was observed between dairy quintiles and SBP, suggesting a dose-response relationship. When dairy consumption was assessed at 9 years of age, we found that those who consumed at least two dairy serves per day at both 18 months and 9 years were more likely to have significantly lower SBP and DBP levels compared to other children.

These findings are consistent with those of the Framingham Children's Study, the only other cohort study specifically examining the relationship between dairy intake and blood pressure in children (Moore *et al.*, 2005). In this study, 95 children aged 3–5 years were followed for 8 years. Children who consumed more than 2 servings per day of dairy products at baseline had a lower mean SBP of 4 mm Hg in early adolescence (10–12 years) compared to children who consumed less than 2 servings per day. In addition, children who consumed higher intakes of dairy products at ages 6 to 12 years had lower SBPs in early adolescence. No clear association was found between dairy intake and DBP.

Very few intervention studies have been undertaken in early childhood to examine diet and BP. Salt restriction during the first year of life was found to have a significant protective effect on the BP rise in childhood (Geleijnse *et al.*, 1997), as did a low saturated fat diet from age 13 months to 15 years (Niinikoski *et al.*, 2009). These studies suggest that nutrition during early childhood may have a central role in the programming of future BP. Whether tracking of dietary intake from early childhood plays a role is unclear but our study found little evidence of tracking from age 18 months to mid-childhood. Although the underlying mechanisms remain to be established, associations between various dietary factors and BP have been found in studies among children and adults.

A diet rich in fruit, vegetables and low fat dairy products has been shown to be beneficial for blood pressure control in at-risk adolescents as well as adults (Couch *et al.*, 2008). Adolescents with elevated blood pressure who followed a DASH-type intervention diet for 3 months had greater reductions in SBP compared to those who followed the routine dietary intervention (reducing sodium intake and controlling weight). In our analysis, however, intake of fruit and vegetables was not associated with dairy consumption at 18 months, nor with blood pressure at 8 years, either adjusted or unadjusted for dairy consumption.

In a previous analysis of CAPS, we reported a protective effect of early dairy consumption (as a percent of total energy) on weight status at eight years (Garden *et al.*, 2011). Previous cohort studies in children have demonstrated conflicting results (Carruth and Skinner, 2001; Phillips *et al.*, 2003; Berkey *et al.*, 2005; Moore *et al.*, 2006). In our study, body weight and body fat (measured as BMI z-score and waist circumference) in mid childhood were significant mediators in the association between dairy consumption and BP, which has been described previously (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004)). However, adjustment for body weight had little effect on the association between dairy consumption and BP.

Dairy products are high in calcium, magnesium and potassium — nutrients that have been associated with blood pressure reduction (Huth *et al.*, 2005; Kris-Etherton *et al.*, 2009; Simons-Morton *et al.*, 1997). In our study, all of these micronutrients were significant predictors of SBP at age 8 years. Children in the highest quintile of intake for calcium, magnesium or potassium had lower SBP (-2.8 mm Hg) compared with those in the lowest quintiles. Furthermore, significant linear trends between these micronutrients and SBP suggested a possible dose-response relationship. None of the micronutrients studied were associated with DBP in our analysis.

These results are compatible with several other studies undertaken in children. In a cross-sectional study, adolescents at risk of hypertension with higher intakes of a combination of nutrients including calcium, potassium and magnesium had lower blood pressure than those who had lower intakes (Falkner *et al.,* 2000). Simon-Morten *et al.* (1997) reported inverse relationships between calcium, potassium and magnesium, and SBP, as well as DBP among 662 children aged 8-11 years followed for 3 years. A cohort of over 2300 girls aged 9-10 years participating in the National Heart, Lung, and Blood Institute Growth and Health Study followed for 8 years showed that girls who never developed hypertension had higher baseline intakes of potassium, magnesium, and calcium than those who developed hypertension (Obarzanek *et al.,* 2010).

In our study, children who consumed two or more serves of dairy products at 18 months and 9 years had lower blood pressure than children who did not meet recommendations at either time point. DBP was approximately 3 mm Hg lower, and SBP about 2.5 mm Hg lower among children who consumed two or more dairy serves at both time points. These results suggest a protective effect of dairy products on blood pressure when intake was maintained from early to mid-childhood. The magnitude of SBP change between highest and lowest intake children would, if sustained through life, be associated with an approximately 12% decrease in risk for major cardiovascular endpoints such as heart attack and stroke (extrapolated data from Law *et al.*, 2009).

Evidence is accumulating regarding the role of dietary micronutrients such as sodium, potassium, calcium and magnesium on blood pressure regulation with animal and human studies showing relationships between in vivo changes in these micronutrients and effects on vascular smooth muscle cells, vasoconstriction, arterial stiffness and ultimately hypertension (Kris-Etherton *et al.,* 2009). In addition, the whey proteins in dairy products exhibit strong angiotensin-converting enzyme inhibitory activity which reduces angiotensin II production, the active agent in the renin-angiotensin system that is known to cause arteriole constriction (Huang and McCrory, 2005). The mechanism by which dairy products reduce blood pressure remains to be established. As there is a close correlation between dairy consumption and intakes of calcium, magnesium and potassium, it is difficult to identify which food component, nutrient or combination of these, is responsible for the protective effect on BP. More research is also needed to identify the optimal quantities of foods or nutrients required to provide a protective effect, on SBP and DBP.

The Childhood Asthma Prevention Study provides a valuable resource for studying the relationship between blood pressure and dietary variables in young children. However, several limitations need to be mentioned. There was incomplete follow-up from 18 months to 8 years and 18 months to 9 years, due to insufficient funding for dietary analysis at the latter time point. Food recalls were used at the mid-childhood assessment instead of weighed food records, as used at the 18 month assessment. This decision was made in the expectation of improving response rates in this population of children exposed to repeated and invasive measurements required for their participation in CAPS. However, a three-day measurement period to capture within-person variation was kept constant and rigorous methods of data collection were applied at both time points. Error in portion size estimation would be different between the two methods but there is no reason to suspect a bias in portion size estimation among the children at the 9 year assessment. Another limitation was that blood pressure measurements were not taken at the same time as the dietary assessment, and therefore a cross-sectional analysis could not be undertaken for a direct comparison. However, all blood pressure measurements were taken at least in duplicate resulting in more accurate estimates than a single reading only. The children involved in CAPS were not a random sample of the population; their parents were more likely to be tertiary educated and Australian-born compared to the population of western Sydney, and all had a family history of asthma (Mihrshahi *et al.*, 2001). However, the anthropometric data collected at 18 months and eight years in the CAPS study were comparable to other Australian data on children (AGDHA, 2008*b*).

In conclusion, these results are consistent with a protective effect of dairy consumption in early childhood on blood pressure at mid-childhood. Further prospective studies are required to examine the association between dairy consumption and blood pressure among children. The investigation of dietary factors influencing blood pressure control among children is warranted as blood pressure levels have increased substantially among children over the past decade (Muntner *et al.*, 2004), and an elevated blood pressure in childhood is likely to predict adult hypertension (Chen and Wang, 2008). These findings together with our previous publication showing a protective association of early dairy intake against overweight in mid-childhood (Garden *et al.*, 2011) suggest value in further investigation of these relationships.

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Authors' contributions

TPG, VMF and AMR developed the study proposal. AMR coded and analysed the data, interpreted the results and wrote the first draft of the manuscript. All authors were involved in the subsequent edits of the manuscript, and read and approved the final manuscript.

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Table 1. Characteristics of study population at 18 months and 8 years by quintile of energy-adjusted dairy consumption (n=336)

Quintile (dairy serves)	**Q1 <1.40**	**Q2 01.40-1.91**	**Q3 1.92-2.35**	**Q4 2.36-2.86**	**Q5 >2.86**	**P for trend**
At 18 months						
Age (m)	19.1	18.8	18.7	18.8	18.9	0.33
Weight (kg)	11.5	11.5	11.5	11.7	11.6	0.35
Length (cm)	83.3	82.9	83.2	83.7	83.6	0.26
Weight for length z-score	0.007	0.031	0.023	0.147	0.042	0.67
Fruit (serves)	0.63	0.55	0.69	0.64	0.53	0.61
Vegetables (serves)	0.71	0.55	0.62	0.66	0.61	0.69
At 8 years						
Age (y)	7.9	8.0	8.0	8.0	8.0	0.65
Weight (kg)	28.9	29.8	29.3	28.4	27.8	0.14
Height (cm)	128.1	128.3	129.0	128.9	127.5	0.76
BMI (kg/m^2)	17.5	17.9	17.5	17.0	17.0	0.09
Systolic BP (mm Hg)	101.3	101.0	100.6	100.3	98.9	0.042
Diastolic BP (mm Hg)	59.9	58.4	59.2	59.8	58.0	0.29

Table 2. Multivariate linear regression models relating energy-adjusted dairy serves and energy-adjusted micronutrient intakes at 18 months to blood pressure at 8 years

		Systolic BP*		**Diastolic BP†**	
		β (SE)	**P**	**β (SE)**	**P**
Dairy serves –	Q1 (<1.40)	0		0	
	Q2 (1.40-1.91)	-0.24 (1.23)	0.84	-1.58 (0.97)	0.11
	Q3 (1.92-2.35)	-0.77 (1.21)	0.52	-0.85 (0.96)	0.38
	Q4 (2.36-2.86)	-0.90 (1.21)	0.46	-0.25 (0.96)	0.79
	Q5 (>2.86)	-2.44 (1.21)	**0.046**	-1.92 (0.96)	**0.047**
Calcium (mg) –	Q1 (<572)	0		0	
	Q2 (72-710)	0.37 (1.24)	0.76	0.23 (0.99)	0.81
	Q3 (711-832)	-0.93 (1.23)	0.45	0.14 (0.98)	0.89
	Q4 (833-976)	-0.43 (1.22)	0.73	0.33 (0.97)	0.74
	Q5 (>976)	-2.80 (1.23)	**0.024**	-1.53 (0.99)	0.12
Magnesium (mg) –	Q1 (<122)	0		0	
	Q2 (123-133)	-1.01 (1.20)	0.40	0.83 (0.96)	0.39
	Q3 (134-145)	-1.62 (1.22)	0.19	1.14 (0.97)	0.24
	Q4 (146-160)	-1.36 (1.24)	0.28	0.66 (0.99)	0.51
	Q5 (>160)	-2.82 (1.30)	**0.031**	-1.00 (1.04)	0.34
Potassium (mg) –	Q1 (<1372)	0		0	
	Q2 (1372-1550)	-0.69 (1.23)	0.58	0.11 (0.98)	0.91
	Q3 (1551-1700)	-0.89 (1.23)	0.47	0.04 (0.98)	0.97
	Q4 (1701-1920)	-1.71 (1.22)	0.16	0.28 (0.98)	0.77
	Q5 (>1920)	-2.75 (1.34)	**0.040**	-1.34 (1.07)	0.21
Sodium (mg) –	Q1 (<908)	0		0	
	Q2 (908-1038)	0.02 (1.21)	0.99	-1.39 (0.97)	0.15
	Q3 (1039-1172)	1.22 (1.25)	0.33	-0.38 (1.00)	0.71
	Q4 (1173-1335)	0.47 (1.25)	0.71	-0.81 (1.00)	0.42
	Q5 (>1335)	2.19 (1.22)	0.073	-0.10 (0.97)	0.92

***** Adjusted for child's age, sex, socioeconomic status, baseline weight status, maternal smoking status during pregnancy, maternal and paternal countries of birth, maternal and paternal education level, gestational diabetes, breastfeeding, CAPS intervention group, energy intake, fruit intake and vegetable intake

Table 3. Association between dairy consumption (consuming at least 2 dairy serves per day at 18 months and 9 years) and blood pressure at 8 years, adjusted for age, sex and WHZ score.

	≥2 dairy serves/d n=35	**<2 dairy serves/d** n=153	**P**
SBP (mm Hg), mean (SE)	98.7 (1.16)	101.0 (0.56)	0.069
DBP (mm Hg), mean (SE)	56.5 (0.91)	59.3 (0.44)	0.006