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

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

## 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.

## Keywords

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

## Disciplines

Arts and Humanities | Life Sciences | Medicine and Health Sciences | Social and Behavioral Sciences

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

3  
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24  
25       **Running title:** Dairy consumption and blood pressure in children

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29 **Abstract**

30

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

34 **Methods:** Subjects (n=335) were participants of a birth cohort at high risk of asthma with  
35 information on diet at 18 months and blood pressure at 8 years. Multivariate analyses were  
36 used to assess the association of dairy consumption (serves) and micronutrient intakes (mg) at  
37 18 m with blood pressure at 8 y. In a subgroup of children (n=201), dietary intake was  
38 measured at age 18 m and 9 y which allowed for comparisons of blood pressure of those who  
39 consistently consumed at least two dairy serves per day versus those who did not.

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

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

51

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

## 53 **Introduction**

54

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

64

65 A healthy diet and lifestyle play an important role in blood pressure control. The role of dairy  
66 products in the regulation of blood pressure in children has not been studied widely. Most  
67 longitudinal studies that have examined the effect of dairy intake on blood pressure have been  
68 undertaken in adults (Ascherio *et al.*, 1996; Elwood *et al.*, 2004; Alonso *et al.*, 2005; Snyder  
69 *et al.*, 2008; Wang *et al.*, 2008; Alonso *et al.*, 2009; Engberink *et al.*, 2009a; Engberink *et al.*,  
70 2009b; Toledo *et al.*, 2009), some in young adults (Pereira *et al.*, 2002; Steffen *et al.*, 2005)  
71 and only one in young children (Moore *et al.*, 2005). Among adults, evidence is accumulating  
72 that dairy products are protective against high blood pressure (Huth *et al.*, 2005; Kris-  
73 Etherton *et al.*, 2009). The majority of longitudinal studies have shown a beneficial effect of  
74 dairy consumption on blood pressure or a reduced risk of hypertension (Elwood *et al.*, 2004;  
75 Alonso *et al.*, 2005; Wang *et al.*, 2008; Alonso *et al.*, 2009; Engberink *et al.*, 2009a; Toledo  
76 *et al.*, 2009) although others have shown no effect (Ascherio *et al.*, 1996; Snyder *et al.*, 2008;  
77 Engberink *et al.*, 2009b). In addition, the Dietary Approaches to Stop Hypertension (DASH)  
78 trial showed that a dietary pattern rich in fruits, vegetables, low-fat dairy products and low in  
79 total fat was more effective than a control diet of fruits and vegetables alone in reducing  
80 blood pressure levels in adults (Appel *et al.*, 1997; Sacks *et al.*, 2001).

81

82 Among children, only one cohort study has investigated the effect of dairy products on blood  
83 pressure (Moore *et al.*, 2005). This study found dairy products to have a protective effect on  
84 children's blood pressure after 8 years of follow-up. These results were supported by those of  
85 a short-term intervention study using a DASH-type diet among adolescents with elevated

86 blood pressure (Couch *et al.*, 2008). Further research is required to determine the optimal diet  
87 and the role of dairy products for the prevention of high blood pressure among children.

88

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

93

## 94 **Methods**

95

### 96 *Study background and subjects*

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

111

### 112 *Dietary intake*

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

116

### 117 *At 18 months*

118 The first dietary assessment was undertaken at the 18-month assessment, together with  
119 medical and anthropometric assessments. Details of the dietary assessment methods and

120 response rates for the 18-month assessment have been published elsewhere (Webb *et al.*,  
121 2006). In summary, food consumption was assessed from three-day weighed food records. A  
122 research dietitian instructed mothers to keep records on any two weekdays and one weekend  
123 day as convenient. A food record booklet, a set of Tanita digital kitchen scales (2.0 kg  $\pm$  1.0 g)  
124 and instructions for weighing and recording were left with the mother. At the end of the  
125 recording period, the dietitian visited the mothers at home to check the completeness of the  
126 records.

127

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

137

### 138 *At nine years of age*

139 A second dietary assessment was undertaken in 2007-2008 on a sub-group of children aged  
140 approximately 9 years old (a year after they had completed the CAPS follow up medical  
141 assessments). Food and nutrient intakes were assessed from three 24-hour recalls using the  
142 multiple pass approach (AGDHA, 2008a). Use of 24-hour recalls was expected to give a  
143 higher response rate than weighed food records among children of this age (Livingstone *et al.*,  
144 2004; Burrows *et al.*, 2010). All interviews were conducted by telephone by trained research  
145 dietitians using a purpose-designed scripted computer-based data collection and entry  
146 program. Children reported their own food intake with the help of their parents as needed  
147 regarding brand names, food descriptions, ingredients in mixed dishes, cooking methods, and  
148 estimates of portion sizes. A food model booklet similar to those used in the National  
149 Children's Nutrition Survey (AGDHA, 2008a) was mailed ahead to all participants to assist  
150 in estimating portion sizes.

151

152 It was envisaged that all children who had participated in the first dietary assessment would  
153 be contacted and invited to participate in the second dietary assessment. However, due to

154 budgetary constraints, only the first 259 out of the 429 children were contacted. These  
155 children did not differ from the uninvited children by weight, height, BMI, or energy intake at  
156 18 months but father's education levels were higher in the sample of invited children and  
157 mother's age at birth of child was lower. Of these 259 children, 43 children (16.6%) were  
158 unwilling to participate; 15 children were excluded because all three recalls were not  
159 completed (n=12), or misreported energy intake (n=3) (Torun *et al.*, 1996). Overall, the final  
160 number of three day recalls analysed was 201. Interviews were intended to cover 2 weekdays  
161 and 1 weekend day and this was achieved for 70% of interviews. Participants were provided  
162 with two movie passes after successful completion of three dietary interviews as an incentive  
163 to participate.

164  
165

### 166 ***Dietary data analysis***

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

171

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

177

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

181

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



188

189 ***Anthropometric and blood pressure measures***

190 Children's weight, in kilograms, and recumbent length (for toddlers) and standing height (for  
191 8 year olds), in centimetres, were measured by research nurses. Weight was measured to the  
192 nearest 0.1 kilogram and height to the nearest 1 centimetre. Children were dressed in light  
193 clothing without shoes. For children under 2 years of age, BMI z-scores were calculated  
194 using the 2000 CDC Growth Charts (NCCDPHP, 2000).

195

196 Brachial blood pressure was measured with the use of a validated automated oscillometric  
197 device (Welch Allyn Vital Signs Monitor) (Jones *et al.*, 2001). Supine blood pressure in the  
198 left brachial artery was measured after 10 min of quiet rest and repeated after a further 10 min;  
199 a third blood pressure measurement was taken if there was a variance of  $\geq 10$  mm Hg; the  
200 average of the two closest readings was recorded as the brachial blood pressure (Ayer *et al.*,  
201 2009). As blood pressure was only measured on one occasion, a diagnosis of hypertension  
202 could not be established as this requires repeated measurements (minimum of three).

203 Accordingly, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were used as  
204 continuous outcome variables.

205

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

213

214

215 ***Demographic and health information***

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

221 gestational diabetes (yes or no), maternal age at birth (<25 or ≥25 years) breastfeeding  
222 (exclusive breastfeeding at 3 months, yes or no).

223

#### 224 *Statistical analysis*

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

232

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

243

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

250

251

252

253

254

255 **Results**

256

257 *Early diet and blood pressure at mid-childhood*

258 The sample for this analysis consisted of 335 children; 169 boys and 166 girls. The mean age  
259 at baseline was 18.9 months (range, 16-24 months) and age at follow up was 8.0 years (range,  
260 7.7-9.2 years). Parental characteristics included 75% of mothers and fathers born in Australia  
261 or New Zealand, 50% of mothers and fathers had more than 12 years of schooling, 22% of  
262 mothers smoked during pregnancy, and 6% had gestational diabetes. There were no  
263 significant differences in weight, height or BMI z-score between boys and girls.

264

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

272

273

274

**TABLE 1**

275

276 Table 2 shows the linear regression models of dairy consumption on blood pressure status. A  
277 high dairy intake was found to be protective for SBP ( $P=0.046$ ) and DBP ( $P=0.047$ ), with  
278 children in the highest quintile of dairy intake having lower blood pressure levels compared  
279 with children in the lowest quintile of dairy intake. Children in the highest quintile of dairy  
280 intake (i.e. consuming >2.9 serves per day) had a lower mean SBP of 2.5 mm Hg and DBP of  
281 1.9 mm Hg compared with children in the lowest quintile (i.e. those consuming <1.4 serves  
282 per day). Furthermore, a significant negative linear trend was found between quintiles of  
283 dairy consumption and SBP ( $P_{\text{trend}}=0.046$ ) but not for DBP.

284

285 Further modelling was undertaken to investigate the association between blood pressure and  
286 micronutrients of interest including calcium, magnesium, potassium and sodium. Calcium,  
287 magnesium and potassium all showed a significant inverse association with blood pressure.  
288 Children in the highest quintiles of calcium, magnesium or potassium intake (i.e. calcium

289 intakes > 976 mg; magnesium >160 mg; or potassium >1920 mg per day) had significantly  
290 lower SBP levels — 2.8 mm Hg, compared with children in the lowest quintiles. In addition,  
291 significant negative linear trends were found between the quintiles of these three  
292 micronutrients and SBP ( $P_{\text{trend}}=0.023$  for calcium;  $P_{\text{trend}}=0.044$  for magnesium;  $P_{\text{trend}}=0.031$   
293 for potassium). Conversely, positive regression coefficients were seen with sodium intake  
294 and SBP, although these were not statistically significant. No significant associations were  
295 found between any of the micronutrients studied and DBP.

296

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

303

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

305

306

307

## TABLE 2

308

309

310

311

312 *Association between blood pressure at 8 years and high dairy consumption at two time points*  
313 *(18 months and 9 years)*

314 Dairy intakes at age 18 months were compared with those at the mid-childhood assessment  
315 when the children were a mean age of 9.2 years (range 8.2-10.5 years). This sample included  
316 201 children, 109 boys and 92 girls, with similar sociodemographic and anthropometric  
317 characteristics to the previous cohort of 335 children.

318

319 Children who met the recommended intakes at 18 months and 9 years (a minimum of 2 dairy  
320 serves at both time points (Smith *et al.*, 1998)) were compared with those who failed to do so  
321 using ANCOVA. Analysis of blood pressure in relation to high dairy consumption at two  
322 time points (Table 3) reveals a significant association with DBP ( $P=0.006$ ) and a non-

323 significant association with SBP ( $P=0.069$ ), after adjusting for age, sex and WHZ score. SBP  
324 and DBP were lowest for children who consumed at least two dairy serves per day at 18  
325 months and 9 years. It must be noted that out of 108 toddlers with recommended dairy  
326 intakes, only 35 consumed recommended intakes at age 9 years ( $Kappa= 0.02$ ).

### 329 **TABLE 3**

#### 332 **Discussion**

333  
334 The findings of this study suggest that higher dairy consumption in early childhood may have  
335 a beneficial effect on blood pressure in mid-childhood. SBP and DBP were significantly  
336 lower for children in the highest dairy consumption quintile compared with those in the  
337 lowest quintile, after adjustment for potential confounders including energy intake and fruit  
338 and vegetable consumption. In addition, a significant linear trend was observed between dairy  
339 quintiles and SBP, suggesting a dose-response relationship. When dairy consumption was  
340 assessed at 9 years of age, we found that those who consumed at least two dairy serves per  
341 day at both 18 months and 9 years were more likely to have significantly lower SBP and DBP  
342 levels compared to other children.

343  
344 These findings are consistent with those of the Framingham Children's Study, the only other  
345 cohort study specifically examining the relationship between dairy intake and blood pressure  
346 in children (Moore *et al.*, 2005). In this study, 95 children aged 3–5 years were followed for 8  
347 years. Children who consumed more than 2 servings per day of dairy products at baseline had  
348 a lower mean SBP of 4 mm Hg in early adolescence (10–12 years) compared to children who  
349 consumed less than 2 servings per day. In addition, children who consumed higher intakes of  
350 dairy products at ages 6 to 12 years had lower SBPs in early adolescence. No clear  
351 association was found between dairy intake and DBP.

352  
353 Very few intervention studies have been undertaken in early childhood to examine diet and  
354 BP. Salt restriction during the first year of life was found to have a significant protective  
355 effect on the BP rise in childhood (Geleijnse *et al.*, 1997), as did a low saturated fat diet from  
356 age 13 months to 15 years (Niinikoski *et al.*, 2009). These studies suggest that nutrition

357 during early childhood may have a central role in the programming of future BP. Whether  
358 tracking of dietary intake from early childhood plays a role is unclear but our study found  
359 little evidence of tracking from age 18 months to mid-childhood. Although the underlying  
360 mechanisms remain to be established, associations between various dietary factors and BP  
361 have been found in studies among children and adults.

362

363 A diet rich in fruit, vegetables and low fat dairy products has been shown to be beneficial for  
364 blood pressure control in at-risk adolescents as well as adults (Couch *et al.*, 2008).

365 Adolescents with elevated blood pressure who followed a DASH-type intervention diet for 3  
366 months had greater reductions in SBP compared to those who followed the routine dietary  
367 intervention (reducing sodium intake and controlling weight). In our analysis, however,  
368 intake of fruit and vegetables was not associated with dairy consumption at 18 months, nor  
369 with blood pressure at 8 years, either adjusted or unadjusted for dairy consumption.

370

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

380

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

389

390 These results are compatible with several other studies undertaken in children. In a cross-  
391 sectional study, adolescents at risk of hypertension with higher intakes of a combination of  
392 nutrients including calcium, potassium and magnesium had lower blood pressure than those  
393 who had lower intakes (Falkner *et al.*, 2000). Simon-Morten *et al.* (1997) reported inverse  
394 relationships between calcium, potassium and magnesium, and SBP, as well as DBP among  
395 662 children aged 8-11 years followed for 3 years. A cohort of over 2300 girls aged 9-10  
396 years participating in the National Heart, Lung, and Blood Institute Growth and Health Study  
397 followed for 8 years showed that girls who never developed hypertension had higher baseline  
398 intakes of potassium, magnesium, and calcium than those who developed hypertension  
399 (Obarzanek *et al.*, 2010).

400

401 In our study, children who consumed two or more serves of dairy products at 18 months and  
402 9 years had lower blood pressure than children who did not meet recommendations at either  
403 time point. DBP was approximately 3 mm Hg lower, and SBP about 2.5 mm Hg lower  
404 among children who consumed two or more dairy serves at both time points. These results  
405 suggest a protective effect of dairy products on blood pressure when intake was maintained  
406 from early to mid-childhood. The magnitude of SBP change between highest and lowest  
407 intake children would, if sustained through life, be associated with an approximately 12%  
408 decrease in risk for major cardiovascular endpoints such as heart attack and stroke  
409 (extrapolated data from Law *et al.*, 2009).

410

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

424

425 The Childhood Asthma Prevention Study provides a valuable resource for studying the  
426 relationship between blood pressure and dietary variables in young children. However,  
427 several limitations need to be mentioned. There was incomplete follow-up from 18 months to  
428 8 years and 18 months to 9 years, due to insufficient funding for dietary analysis at the latter  
429 time point. Food recalls were used at the mid-childhood assessment instead of weighed food  
430 records, as used at the 18 month assessment. This decision was made in the expectation of  
431 improving response rates in this population of children exposed to repeated and invasive  
432 measurements required for their participation in CAPS. However, a three-day measurement  
433 period to capture within-person variation was kept constant and rigorous methods of data  
434 collection were applied at both time points. Error in portion size estimation would be  
435 different between the two methods but there is no reason to suspect a bias in portion size  
436 estimation among the children at the 9 year assessment. Another limitation was that blood  
437 pressure measurements were not taken at the same time as the dietary assessment, and  
438 therefore a cross-sectional analysis could not be undertaken for a direct comparison. However,  
439 all blood pressure measurements were taken at least in duplicate resulting in more accurate  
440 estimates than a single reading only. The children involved in CAPS were not a random  
441 sample of the population; their parents were more likely to be tertiary educated and  
442 Australian-born compared to the population of western Sydney, and all had a family history  
443 of asthma (Mihirshahi *et al.*, 2001). However, the anthropometric data collected at 18 months  
444 and eight years in the CAPS study were comparable to other Australian data on children  
445 (AGDHA, 2008b).

446

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

456

457



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469

470 **Authors’ contributions**

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

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671 **Table 1.** Characteristics of study population at 18 months and 8 years by quintile of energy-adjusted  
 672 dairy consumption (n=336)  
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<b>Quintile (dairy serves)</b>	<b>Q1 &lt;1.40</b>	<b>Q2 01.40- 1.91</b>	<b>Q3 1.92- 2.35</b>	<b>Q4 2.36- 2.86</b>	<b>Q5 &gt;2.86</b>	<b>P for trend</b>
<b>At 18 months</b>						
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
<b>At 8 years</b>						
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 <sup>2</sup> )	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

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**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)	<b>0.046</b>	-1.92 (0.96)	<b>0.047</b>
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)	<b>0.024</b>	-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)	<b>0.031</b>	-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)	<b>0.040</b>	-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

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\* 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

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**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.

	<b>≥2 dairy serves/d</b> n=35	<b>&lt;2 dairy serves/d</b> n=153	<b>P</b>
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

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