Breastfeeding and Adolescent Blood Pressure: Evidence From Hong Kong’s “Children of 1997” Birth Cohort

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Observationally, breastfeeding is associated with lower blood pressure in Western developed settings, whereas little association exists in developing settings. However, postnatal characteristics (e.g., breast milk substitutes, infection rates, underweight, and pubertal timing) differ between these settings. We examined the association of breastfeeding with blood pressure at ∼13 years, using multivariable linear regression, in 5,247 term births in 1997 from a population-representative Hong Kong Chinese birth cohort where socioeconomic patterning of breastfeeding differs from that of Western and developing settings but standard of living, social infrastructure, and postnatal characteristics are similar to those of Western settings. Higher education is associated with short-term breastfeeding but recent migration with longer-term breastfeeding. Compared with never breastfeeding, exclusive breastfeeding for ≥3 months was not associated with blood pressure (systolic mean difference = 0.82 mm Hg, 95% confidence interval (CI): −0.46, 2.11 and diastolic mean difference = 0.49 mm Hg, 95% CI: −0.22, 1.21), nor was partial breastfeeding for any length of time or exclusive breastfeeding for <3 months (systolic mean difference = 0.01 mm Hg, 95% CI: −0.64, 0.66 and diastolic mean difference = 0.16 mm Hg, 95% CI: −0.52, 0.52), adjusted for socioeconomic position and infant characteristics. Lack of association in a non-Western developed setting further suggests that observations concerning breastfeeding and blood pressure vary with setting, thereby casting doubt on causality.

blood pressure; breastfeeding; child; cohort studies; socioeconomic position

Abbreviations: CI, confidence interval; SEP, socioeconomic position.

Breastfeeding protects infants from infections. Long-term effects on cardiovascular health are less clear (1). From a life-course perspective, the predominant paradigm has considered fetal and infant growth as key critical periods that program metabolism for life (2, 3). The type and quantity of postnatal feeding may be a driver of infant growth and developmental plasticity (4, 5) and a modifiable determinant of cardiovascular health. Blood pressure is a strong cardiovascular risk factor (6) and tracks from adolescence to adulthood (7). The exact mechanism linking breastfeeding to blood pressure is unknown, but it could be the long-term effects of lower sodium intake in infancy or of greater control over food intake and self-regulation in infancy, resulting in less vulnerability to obesity (8). Meta-analyses of observational studies suggest that breastfeeding has a modest effect on subsequent blood pressure, of about 1.1–1.4 mm Hg lower systolic blood pressure and 0.4–0.5 mm Hg lower diastolic blood pressure, for those breastfed compared with formula fed (9, 10). However, these meta-analyses pertain mainly to studies from developed Western settings where socioeconomic position (SEP) is positively associated with breastfeeding (11) and negatively associated with blood pressure (12). As such, even after adjustment for several measures of SEP, these observations are open to unmeasured residual confounding by SEP, given the impossibility of capturing and measuring all aspects of SEP (13).
Small randomized controlled trials among preterm infants found that those assigned to nutrient-enriched formula had higher adolescent blood pressure (14), but generalizability to term infants fed ordinary formula is unclear. In contrast, a randomized controlled trial of breastfeeding promotion in healthy term infants found that longer duration or increased exclusivity of breastfeeding was unrelated to childhood blood pressure (15), but this does not address the long-term effect of formula feeding in place of breastfeeding. In this situation, triangulating the evidence by examining consistency in different settings may provide some indication as to whether observations from developed Western settings are contextually specific or biologically based. Prospective birth cohorts from the economically developing settings of Guatemala (n = 1,272), India (n = 1,526), the Philippines (n = 2,048), South Africa (n = 1,620), and Brazil (1982 Pelotas, n = 4,446; 1993 Pelotas, n = 1,083) where SEP is negatively associated with breastfeeding generally found no association of breastfeeding with adult blood pressure (16, 17), although 1 study from Brazil (n = 1,076) found a positive association with adolescent diastolic blood pressure (18). However, these studies are limited by sample size, inclusion of partial and short-term breastfeeding, and no consideration of exclusivity for the breastfeeding group. As such, they may also be open to regression dilution from random misclassification of breastfeeding. Moreover, divergent findings in these settings from those in the West could be due to differences in breast milk substitute and other postnatal characteristics. Generally, formula is used in Western settings, but sometimes cow’s milk is used as a breast milk substitute in developing settings, which may increase renal solute load and affect subsequent blood pressure (19). In developing settings, serious infections in infancy are more common, and life history trade-offs of immediate survival and immune function with long-term cardiovascular risk may occur (20). Infants are born small and may experience weight faltering and stunted growth (21). Childhood overweight is prevalent, while underweight remains a concern (22). Smaller early size followed by greater later growth or being small throughout may adversely affect blood pressure (23). As such, any small effect of breastfeeding may not be evident in these studies from economically developing non-Western settings.

Hong Kong provides a contrasting, economically developed, non-Western setting to help address whether the association of breastfeeding with blood pressure is biologically based or a reflection of setting specific unmeasured or residual confounding. The Hong Kong Chinese population is ethnically homogeneous, largely comprising first, second, or third generation migrants from neighboring Guangdong province (24), with a common Chinese dialect (Cantonese). However, because of different social and economic backgrounds (25), in Hong Kong, more educated mothers tend to start but not to sustain breastfeeding, whereas migrant mothers tend to start and sustain breastfeeding (26), so that higher SEP is associated with partial breastfeeding, and lower SEP is associated with sustained breastfeeding and, thus, not as clearly socially patterned as in most Western settings. As in economically developed Western countries, formula (not cow’s milk) is used as a breast milk substitute (27). The infant mortality rate is very low (28), and incidence of infection is similar to that of other economically developed settings (29). Although Hong Kong infants are lighter at birth, they reach weight similar to that of infants from developed Western countries by early infancy (30), and the prevalence of childhood overweight is also similar (31). Few (<4%) Hong Kong women smoke (32), and maternal adiposity is not common (33). Thus, these factors may be less influential confounders in our study than elsewhere. We examined the association of breastfeeding with systolic and diastolic blood pressure at ~13 years using a large, population-representative, non-Western birth cohort, Hong Kong’s “Children of 1997.”

MATERIALS AND METHODS

Data source

Hong Kong’s “Children of 1997” birth cohort is a population representative Chinese birth cohort (n = 8,327) that covered 88.0% of all births in Hong Kong from April 1, 1997, to May 31, 1997, described in detail elsewhere (34). The study was initially established to investigate the effect of secondhand smoke exposure on infant health. Families were recruited at the first postnatal visit (usually in the first few days after birth) to any of the 49 Maternal and Child Health Centers in Hong Kong, where parents of all newborns are strongly encouraged to bring their infants for free vaccinations and well-baby checks. The characteristics obtained by using a self-administered questionnaire in Chinese at recruitment and subsequent routine visits include maternal and birth characteristics and family socioeconomic position. Passive follow-up via record linkage was instituted in 2005 to obtain routinely collected information including the following: 1) weight and height from birth to 5 years from the maternal and child health centers (n = 7,999, 96% successful matching); 2) annual measurements of weight and height from grade 1 (age 6–7 years) onward, biannual assessments of pubertal status from grade 1 (age 6–7 years) onward, and blood pressure from grade 5 (age 10–11 years) onward from the Student Health Service, Department of Health, which provides free annual check-ups for all school students (n = 7,809, 94% successful matching).

Exposure

Information on breastfeeding was obtained from self-administered questionnaires completed mainly by mothers at the first (generally shortly after birth) and subsequent (at about 3, 9, and 18 months) routine visits to the maternal and child health centers. At the first visit, the respondent was asked: “How is the infant currently fed?” specified as “exclusively breastfed,” “partially breastfed,” and “only formula fed.” At follow-up visits, the respondent was asked: “How has the infant been fed from birth until now?” specified as 1 of the 3 original options or an additional option applying to the initially exclusively breastfed of “initially breastfed, but now formula fed” with the age in months when breastfeeding terminated. In Hong Kong, breastfeeding is usually of limited duration perhaps because of short maternity leave. We categorized breastfeeding, as previously (31), using a relatively short duration of 3 months, into 3 groups: “exclusively breastfed for ≥3 months” (at 3 months or next available follow-
up) reported as exclusively breastfed or reported breastfeeding termination at 3 months or older), “partially breastfed for any length of time or exclusively breastfed for <3 months” (because exclusive breastfeeding for <3 months terminated at 1 or 2 months making breastfeeding for <3 months and partial breastfeeding physiologically rather similar), and “never breastfed.” Initial analysis showed that “partially breastfed for any length of duration” and “exclusively breastfed for <3 months” had similar associations with systolic and diastolic blood pressure, so these 2 groups were kept combined to reduce misclassification and to be consistent with our previous studies (31, 35–37).

### Outcomes

The outcomes were systolic and diastolic blood pressure in adolescence, that is, at ∼13 years (based on the closest measurement available from 12 to 15 years). Blood pressure was measured on the right arm in a seated position after at least 10 minutes of resting at the Student Health Service by trained school nurses, using a cuff size appropriate to the age and size of the child. The initial blood pressure measurement used an automated oscillometric device, abnormal results (i.e., systolic or diastolic blood pressure >90th percentile for age) were reassessed manually via sphygmomanometer after 15 minutes.

### Table 1. Baseline Characteristics by Breastfeeding Status for 5,247 Term Adolescents From Hong Kong’s “Children of 1997” Birth Cohort

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No.</th>
<th>%</th>
<th>Never Breastfed (n = 2,950)</th>
<th>Partially Breastfed for Any Length of Time or Exclusively Breastfed for &lt;3 Months (n = 1,961)</th>
<th>Exclusively Breastfed for ≥3 Months (n = 336)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
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<tr>
<td>Child’s sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2,615</td>
<td>49.8</td>
<td>49.8</td>
<td>48.4</td>
<td>58.5</td>
</tr>
<tr>
<td>Male</td>
<td>2,632</td>
<td>50.2</td>
<td>50.2</td>
<td>51.6</td>
<td>41.5</td>
</tr>
<tr>
<td>Birth weight z score</td>
<td>5,247</td>
<td>100.0</td>
<td>-0.19 (0.86)</td>
<td>-0.16 (0.82)</td>
<td>-0.11 (0.81)</td>
</tr>
<tr>
<td>Gestational age, weeks</td>
<td>5,247</td>
<td>100.0</td>
<td>39.1 (1.2)</td>
<td>39.2 (1.2)</td>
<td>39.3 (1.2)</td>
</tr>
<tr>
<td>Birth order</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>2,656</td>
<td>50.6</td>
<td>46.7</td>
<td>58.0</td>
<td>41.9</td>
</tr>
<tr>
<td>2nd</td>
<td>2,092</td>
<td>39.9</td>
<td>42.9</td>
<td>34.9</td>
<td>41.8</td>
</tr>
<tr>
<td>≥3rd</td>
<td>499</td>
<td>9.5</td>
<td>10.3</td>
<td>7.1</td>
<td>16.3</td>
</tr>
<tr>
<td>Mode of delivery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural labor</td>
<td>2,927</td>
<td>55.8</td>
<td>53.0</td>
<td>57.4</td>
<td>70.8</td>
</tr>
<tr>
<td>Assisted natural labor</td>
<td>926</td>
<td>17.6</td>
<td>16.8</td>
<td>19.4</td>
<td>14.2</td>
</tr>
<tr>
<td>Cesarean</td>
<td>1,394</td>
<td>26.6</td>
<td>30.2</td>
<td>23.1</td>
<td>15.0</td>
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<tr>
<td>Early life secondhand smoke exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>None</td>
<td>1,447</td>
<td>27.6</td>
<td>27.0</td>
<td>27.4</td>
<td>33.9</td>
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<tr>
<td>Nonparental household smoking after birth</td>
<td>2,072</td>
<td>39.5</td>
<td>37.3</td>
<td>44.2</td>
<td>31.5</td>
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<td>Paternal smoking after birth</td>
<td>1,511</td>
<td>28.8</td>
<td>30.5</td>
<td>25.5</td>
<td>33.1</td>
</tr>
<tr>
<td>Maternal smoking during pregnancy or after birth</td>
<td>217</td>
<td>4.1</td>
<td>5.2</td>
<td>2.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Mother’s age at birth, years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>≤24</td>
<td>565</td>
<td>10.8</td>
<td>11.0</td>
<td>10.2</td>
<td>12.4</td>
</tr>
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<td>25–29</td>
<td>1,654</td>
<td>31.5</td>
<td>31.3</td>
<td>31.0</td>
<td>36.1</td>
</tr>
<tr>
<td>30–34</td>
<td>2,059</td>
<td>39.2</td>
<td>38.6</td>
<td>41.3</td>
<td>33.0</td>
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<tr>
<td>≥35</td>
<td>969</td>
<td>18.5</td>
<td>19.1</td>
<td>17.5</td>
<td>18.5</td>
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<tr>
<td>Mother’s place of birth</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Mainland China or elsewhere</td>
<td>1,999</td>
<td>38.1</td>
<td>34.9</td>
<td>37.0</td>
<td>72.7</td>
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<tr>
<td>Hong Kong</td>
<td>3,248</td>
<td>61.9</td>
<td>65.1</td>
<td>63.0</td>
<td>27.3</td>
</tr>
<tr>
<td>Mother’s education at recruitment</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade 9 or below</td>
<td>2,114</td>
<td>40.3</td>
<td>43.1</td>
<td>33.0</td>
<td>58.1</td>
</tr>
<tr>
<td>Grade 10–11</td>
<td>2,349</td>
<td>44.8</td>
<td>46.6</td>
<td>44.8</td>
<td>28.9</td>
</tr>
<tr>
<td>Grade 12 or above</td>
<td>785</td>
<td>15.0</td>
<td>10.4</td>
<td>22.2</td>
<td>13.0</td>
</tr>
</tbody>
</table>

Table continues
of resting, and the second blood pressure measurement was recorded instead.

Statistical analysis

We compared baseline characteristics between cohort members with and without blood pressure measurements using the Cohen effect size (38), which indicates the magnitude of differences between groups independently of sample size, where Cohen effect sizes of 0.1, 0.3, and 0.5 indicate small, medium, and large differences, respectively. We used multivariable linear regression to examine the adjusted associations of socioeconomic position and breastfeeding with blood pressure. Mean differences in mm Hg with 95% confidence intervals are presented. We assessed whether the associations varied with sex or preterm birth (<37 complete gestational weeks) or parents’ education from the heterogeneity of effect across strata and the significance of interaction terms, including any confounding interactions (39).

To illustrate possible confounding by SEP and other characteristics of the association between breastfeeding and blood pressure, we present 6 models hierarchically. Model 1 adjusted for sex, age at blood pressure measurement, and the interaction between sex and age, because boys have a greater increase in blood pressure with age than girls do. Model 2 additionally adjusted for mother’s place of birth, given differences in
breastfeeding (27). Model 3 additionally adjusted for mother’s and father’s education. Model 4 additionally adjusted for other measures of SEP (mother’s and father’s occupation, housing type, and household income). Model 5 additionally adjusted for early life secondhand smoke exposure. Model 6 additionally adjusted for birth weight z score (standard deviation) relative to the 2005 World Health Organization growth standards (40), gestational age, birth order, mode of delivery, and mother’s age at birth. Finally, we also adjusted for concurrent body mass index (weight (kg)/height (m)²) and pubertal status, classified as “lower than average” and “equal to or earlier than average” as a sensitivity analysis. The estimated mean age at pubertal onset, as the earliest age when Tanner stage II for genitalia (boys) or breast (girls) was recorded, is 11.7 years in boys and 9.6 years in girls in this cohort (36), similar to a recent population-representative survey in Hong Kong and comparable to Western populations (41).

We used multiple imputations for missing exposures (breastfeeding imputed for 1.8%) and confounders (education for mothers, 1.8%, and fathers, 1.8%; occupation for mothers, 10.8%, and fathers, 17.0%; household income for 11.3%; and mother’s place of birth for 7.8%) based on a flexible additive model with a predictive mean matching incorporating data on the outcomes (systolic and diastolic blood pressure) (42), exposure (breastfeeding), and other covariates (sex, age at measurement, birth weight z score, gestational age, birth order, mode of delivery, secondhand smoke exposure, mother’s place of birth, mother’s age at birth, mother’s and father’s education, mother’s and father’s occupation, household income, housing type, child’s weight, height, body mass index and pubertal status at the age of blood pressure measurement, infant residency, and the interaction between mother’s birthplace and mother’s education) (43, 44). We summarized the results from 10 imputed data set into single estimated beta-coefficients with confidence intervals adjusted for missing data uncertainty (45). We also performed an available case analysis, that is, deleting cases with missing data on variables in an analysis-by-analysis basis, for comparison. Statistical analyses were performed by using Stata, version 10 (Stata Corp, College Station, Texas), and R, version 2.12.1 (R Development Core Team, Vienna, Austria).

Ethics approval

The study obtained ethics approval from the University of Hong Kong–Hospital Authority Hong Kong West Cluster Joint Institutional Review Board.

RESULTS

Of the original 8,327 cohort members, as of August 31, 2011, 26 had permanently withdrawn. The associations of breastfeeding with systolic and diastolic blood pressure did not vary with sex ($P_{interaction} > 0.77$) or mother’s or father’s education ($P > 0.22$) but did with preterm birth ($P < 0.05$). Given that prematurity per se is associated with hypertension (46), 433 preterm births and 59 with unknown gestational age were excluded. Of the remaining 7,809, 5,247 (67% follow-up) had blood pressure measurements at ~13 years. The 2,562 term births excluded from the analyses because of missing blood pressure measurements did not differ from the 5,247 included with regard to sex, breastfeeding, birth weight, gestational age, birth order, mode of delivery, early life secondhand smoke exposure, mother’s age at birth, mother’s place of birth, mother’s and father’s education, mother’s and father’s occupation, housing type, and household income, with relatively small Cohen effect sizes of <0.2 as shown in Web Table 1 available at http://aje.oxfordjournals.org/.

Among these 5,247 cohort members, 56.2% were never breastfed, 37.3% were partially breastfed for any length of time or exclusively breastfed for <3 months, and 6.4% were exclusively breastfed for ≥3 months. The mean systolic blood pressure at ~13 years was 107 mm Hg in girls and 111 mm Hg in boys, and the mean diastolic blood pressure was 61 mm Hg in both sexes. Table 1 shows that exclusive breastfeeding for ≥3 months was associated with higher birth order, natural labor, and no early life secondhand smoke exposure (47). Higher SEP was associated with partial breastfeeding for any length of time or exclusive breastfeeding for <3 months, whereas lower SEP was associated with sustained exclusive breastfeeding. Mothers born in Hong Kong were less likely to breastfeed than were mothers born in the rest of China, who were also more likely to exclusively breastfeed for ≥3 months. When adjusted for age, sex, and the interaction of age and sex, having a mother born in Hong Kong was associated with a lower systolic (mean difference = −0.69 mm Hg, 95% confidence interval (CI): −1.31, −0.07) and diastolic (mean difference = −0.93 mm Hg, 95% CI: −1.28, −0.58) blood pressure. Mother’s or father’s education was associated with lower systolic (mothers: mean difference = −1.01 mm Hg, 95% CI: −1.92, −0.10 and fathers: mean difference = −1.23 mm Hg, 95% CI: −2.01, −0.44) and diastolic (mothers: mean difference = −0.65 mm Hg, 95% CI: −1.16, −0.15 and fathers: mean difference = −0.80 mm Hg, 95% CI: −1.24, −0.36) blood pressure, although other markers of SEP were not clearly associated with blood pressure.

Table 2 shows that in model 1 compared with never breastfeeding, partial breastfeeding for any length of time or exclusive breastfeeding for <3 months and exclusive breastfeeding for ≥3 months were not clearly associated with blood pressure, adjusted for sex, age, and the interaction between sex and age, and this estimate was further attenuated after additionally adjusting for mother’s place of birth (model 2). These associations were little altered by further adjustment for other measures of SEP (models 3 and 4), secondhand smoke exposure (model 5), and other infant and maternal characteristics (model 6). Compared with never breastfeeding, partial breastfeeding for any length of time or exclusive breastfeeding for <3 months had little association with diastolic blood pressure, whereas exclusive breastfeeding for ≥3 months was positively associated with diastolic blood pressure, adjusted for sex, age, and the interaction between sex and age (model 1); this estimate was attenuated after additionally adjusting for mother’s place of birth (model 2). Further adjustment in models 3–6 little changed the estimates. The available case analysis produced similar results (Web Table 2). We further adjusted for concurrent body mass index and pubertal status as sensitivity analyses, which rarely changed the estimates (Web Table 3).
Table 2. Adjusted Association of Breastfeeding With Systolic and Diastolic Blood Pressure (mm Hg) With 95% Confidence Intervals at 13 Years for 5,247 Term Adolescents From Hong Kong’s “Children of 1997” Birth Cohort

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>Model 1&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Model 2&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Model 3&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Model 4&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Model 5&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Model 6&lt;sup&gt;f&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>95% CI</td>
<td>β</td>
<td>95% CI</td>
<td>β</td>
<td>95% CI</td>
<td>β</td>
</tr>
<tr>
<td>Systolic Blood Pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never breastfed</td>
<td>2,950</td>
<td>0</td>
<td>Referent</td>
<td>0</td>
<td>Referent</td>
<td>0</td>
<td>Referent</td>
</tr>
<tr>
<td>Partially breastfed for any length of time or exclusively breastfed for &lt;3 months</td>
<td>1,961</td>
<td>0.15</td>
<td>-0.78, 0.48</td>
<td>-0.16</td>
<td>-0.80, 0.47</td>
<td>-0.01</td>
<td>-0.66, 0.63</td>
</tr>
<tr>
<td>Exclusively breastfed for ≥3 months</td>
<td>336</td>
<td>0.95</td>
<td>-0.30, 2.20</td>
<td>0.71</td>
<td>-0.56, 1.99</td>
<td>0.75</td>
<td>-0.52, 2.03</td>
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<tr>
<td>Diastolic Blood Pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Never breastfed</td>
<td>2,950</td>
<td>0</td>
<td>Referent</td>
<td>0</td>
<td>Referent</td>
<td>0</td>
<td>Referent</td>
</tr>
<tr>
<td>Partially breastfed for any length of time or exclusively breastfed for &lt;3 months</td>
<td>1,961</td>
<td>0.10</td>
<td>-0.25, 0.45</td>
<td>0.08</td>
<td>-0.27, 0.43</td>
<td>0.15</td>
<td>-0.21, 0.51</td>
</tr>
<tr>
<td>Exclusively breastfed for ≥3 months</td>
<td>336</td>
<td>0.77</td>
<td>0.08, 1.47</td>
<td>0.44</td>
<td>-0.27, 1.14</td>
<td>0.44</td>
<td>-0.27, 1.14</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.

<sup>a</sup> Model 1 adjusted for sex, age, and interaction of sex and age.
<sup>b</sup> Model 2 adjusted for sex, age, interaction of sex and age, and mother’s place of birth.
<sup>c</sup> Model 3 adjusted for sex, age, interaction of sex and age, mother’s place of birth, and mother’s and father’s education.
<sup>d</sup> Model 4 adjusted for sex, age, interaction of sex and age, mother’s place of birth, and socioeconomic position (mother’s and father’s education, occupation, housing type, household income).
<sup>e</sup> Model 5 adjusted for sex, age, interaction of sex and age, mother’s place of birth, socioeconomic position (mother’s and father’s education, occupation, housing type, household income), and secondhand smoke exposure after birth.
<sup>f</sup> Model 6 adjusted for sex, age, interaction of sex and age, mother’s place of birth, socioeconomic position (mother’s and father’s education, occupation, housing type, household income), and infant and maternal characteristics (secondhand smoke exposure after birth, birth weight z score, gestational age, birth order, mode of delivery, mother’s age at birth).
DISCUSSION

In this large, population-representative, Hong Kong Chinese birth cohort where socioeconomic patterning of breastfeeding differs from that of Western developed and economically developing settings, breastfeeding was not associated with systolic or diastolic blood pressure in adolescence. Our findings are consistent with those of other smaller studies from developing settings, further suggesting that the observed negative associations of breastfeeding with blood pressure in Western settings are due to residual confounding by SEP and other related attributes that determine blood pressure. This study adds by providing evidence from a developed non-Western setting, where the size of the study reduces regression dilution, “purely” exposed and unexposed groups exist, the social patterning of blood pressure is similar to that in the West (16), postnatal attributes are similar to those of Western settings, but social patterns of breastfeeding are different, and confounding by maternal smoking and maternal adiposity is minimal. Specifically in Hong Kong, as in other developed settings, formula is a substitute for breast milk, little serious infectious morbidity in infancy occurs, little infant weight faltering occurs, childhood overweight and obesity but not underweight are of concern, and there is universal access to high-quality health care including regular well-baby and well-child checks. These findings provide little evidence for a long-term effect of breastfeeding on cardiovascular health or that breastfeeding plays a causal role in programming subsequent blood pressure.

This large birth cohort study, with its strength of contemporaneously collected breastfeeding history and routinely measured blood pressure, nonetheless has several limitations. First, the proportion of children exclusively breastfed beyond 3 months was relatively small. Our cohort may provide insight into the long-term effects of breastfeeding during a critical period of development, that is, in early infancy (3). We have previously observed exclusive breastfeeding associated with serious infectious morbidity as expected (48). However, our study had insufficient power to rule out a very small negative association of any breastfeeding with blood pressure (~1 mm Hg for systolic and ~0.5 mm Hg for diastolic) (9, 10). Second, we did not have information on mother’s dietary intake and physical activity, which may be associated with her decision to breastfeed and her child’s lifestyle and, hence, blood pressure. Third, we did not have complete information on SEP and mother’s place of birth. We used multiple imputation to capitalize on all available data, while preserving the uncertainty from the missing data, minimizing inclusion bias, and increasing statistical power (45). An available case analysis produced similar results. Fourth, we cannot rule out residual confounding by unmeasured or immeasurable confounders. However, the crude association of breastfeeding with diastolic blood pressure was attenuated after adjusting for several measures of SEP. Further adjustment for SEP would be unlikely to generate a negative association. Fifth, we cannot rule out selection bias (67% follow-up), because attendance at the Student Health Service is voluntary. Our results could have been biased if we had systematically excluded breastfeeding adolescents with lower blood pressure, which is unlikely, and we found little difference in sex, breastfeeding, SEP, and mother’s place of birth between included and excluded cohort members. Sixth, on each occasion, a single blood pressure measurement was obtained by using oscillometric devices or a sphygmomanometer for rechecking those with blood pressure exceeding the 90th percentile for age and sex. We cannot rule out the possibility of slight overestimation from using first-time blood pressure primarily from oscillometric devices rather than average blood pressure from sphygmomanometers (49). However, any such systematic overestimation is unlikely to bias comparisons by breastfeeding status. Finally, we are limited by the latest available measures of blood pressure at ~13 years. The effect of breastfeeding on blood pressure may be evident only after adolescence (50). However, previous meta-analyses did not find that associations varied by age (9, 10). Nevertheless, an effect of breastfeeding on blood pressure might be actuated by subsequent experiences.

Our study is inconsistent with most (9, 10), but not all (51, 52), observational studies from long-term developed Western countries, but it is consistent with those from developing settings (16, 17) and a randomized controlled trial of breastfeeding promotion (15). We did not find any clear association of breastfeeding with blood pressure. In developed Western populations, SEP tends to be negatively associated with childhood adiposity (53) and pubertal timing (54), whereas in Hong Kong, SEP is not clearly associated with childhood adiposity (55) or pubertal timing (36). The observed estimates in the West could be more socioeconomically confounded than ours due to residual confounding by SEP as well as other related attributes that determine breastfeeding and blood pressure. In addition, our null association of breastfeeding with blood pressure is not unexpected if the association is driven by childhood adiposity which is not associated with breastfeeding in our study (31). Nonetheless, we cannot rule out the possibility that measurement error or unmeasured confounding could have biased our results toward the null. Lack of replication in the developed non-Western setting of Hong Kong and developing countries may reflect unmeasured or residual confounding by SEP and related attributes, rather than biological effects, which vary with setting. Our study highlights the challenges of attaining complete control for confounding in all sociocultural contexts and the limitations of empirically derived hypotheses based on 1 particular setting. Our findings do not corroborate the hypothesis that early nutrition, particularly breastfeeding, may program blood pressure for life (4, 5), although breastfeeding may be beneficial to blood pressure in more vulnerable subgroups, such as preterm infants. Together with our previous study showing no association of breastfeeding with childhood adiposity (31), this Hong Kong Chinese birth cohort has demonstrated that breastfeeding may not exert long-term effects on key aspects of cardiovascular health. Nevertheless, it remains possible that breastfeeding may have long-term effects on other aspects of health, such as diabetes.

Breastfeeding has many infant and maternal benefits; however, longer term benefits of breastfeeding on blood pressure were not evident for adolescents in a non-Western developed setting, casting doubt as to whether the observed associations are causal as they vary with setting.

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