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Brief Report

Same-sex twins are taller and heavier than opposite-sex twins (but only if breastfed): Possible evidence for sex bias in human breast milk

Satoshi Kanazawa [a,b,*], Nancy L. Segal [c]

[a] Department of Management, London School of Economics and Political Science, London WC2A 2AE, UK
[b] Department of Clinical, Educational, and Health Psychology, University College London, London WC1E 6BT, UK
[c] Department of Psychology, California State University, Fullerton, Fullerton, CA 92834, USA

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ABSTRACT

Recent studies show that human and other mammalian breast milk may be tailored for the sex of the offspring. Such sex bias suggests that opposite-sex twins, who receive breast milk that cannot simultaneously be tailored for both sexes, may be at a disadvantage for growth compared with same-sex twins. An analysis of data from the National Longitudinal Study of Adolescent Health (Add Health) shows that, controlling for sex, age, birth weight, and zygosity, breastfed same-sex twins are, on average, about 1 inch taller and 12 pounds heavier than their opposite-sex counterparts through adolescence and early adulthood. In contrast, never-breastfed same-sex twins tend to be shorter and lighter than their opposite-sex counterparts. These results may be potential evidence for sex bias in human breast milk and its long-term effects.
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Introduction

There has been recent emerging evidence that breast milk in various mammalian species may be tailored for the sex of each offspring such that mothers may produce different breast milk for male

* Corresponding author.
E-mail address: S.Kanazawa@lse.ac.uk (S. Kanazawa).

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and female newborns. For example, macaque mothers produced richer milk (with higher gross energy and fat content) for sons than for daughters, especially if they were primiparous (Hinde, 2007), but at the same time provided greater quantities of milk (Hinde, 2009) and higher concentrations of calcium (Hinde et al., 2013) for daughters than for sons. In addition, cows produced more milk when they were pregnant with a female fetus than when they were pregnant with a male fetus (Hinde, Carpenter, Clay, & Bradford, 2014). In contrast, Iberian red deer mothers produced more milk for sons than for daughters (Landete-Castillejos, García, López-Serrano, & Gallego, 2005). An experimental study with bank voles showed that mothers in all conditions produced more milk for daughters than for sons (Koskela, Mappes, Niskanen, & Rutkowska, 2009), and tammar wallaby mothers produced higher-quality milk with higher levels of protein for sons than for daughters (Robert & Braun, 2012).

There has been some evidence of sex-biased milk production among human mothers as well. Mothers both in Massachusetts (Powe, Knott, & Conklin-Brittain, 2010) and Singapore (Thakkar et al., 2013) produced higher-quality milk, with greater energy, lipids, polyunsaturated fatty acids, phospholipids, and gangliosides, for sons than for daughters. A study of Filipino mothers did not find a significant difference in fat, protein, sugars, and energy between breast milk for sons and daughters (Quinn, 2013). However, in this study, mothers of daughters had significantly greater daily caloric intake than mothers of sons (1545 vs. 1268 kcal), suggesting that breast milk for boys may be richer *per caloric intake*. Consistent with the Trivers–Willard hypothesis (Trivers & Willard, 1973), economically sufficient mothers in northern Kenya produced richer milk with higher fat concentration for sons than for daughters, whereas relatively poor mothers produced richer milk for daughters than for sons (Fujita et al., 2012).

If these findings are robust and generalizable, and if human mothers tailor the contents of their breast milk for the offspring of each sex to facilitate their health and growth most efficiently, then this has profound implications for developmental psychology in general and twin research in particular. Among other things, it suggests that breast milk might not be as beneficial to opposite-sex twins as it is to same-sex twins. Whether they are male or female, same-sex twins can benefit from the sex-tailored breast milk from their mothers just as can singletons. In contrast, breast milk of the mothers of opposite-sex twins cannot be specifically and simultaneously tailored for either sex; it must be either tailored for neither sex specifically or tailored for the wrong sex for half of the opposite-sex twins. Thus, on average, we would expect opposite-sex twins to be at a disadvantage for health and growth and, as a result, to be shorter and lighter than same-sex twins. We used data from the National Longitudinal Study of Adolescent Health (Add Health) to assess this prediction.

Method

Data

Add Health is a large, nationally representative, and prospectively longitudinal study of young Americans. A sample of 20,745 adolescents were personally interviewed in their homes in 1994–1995 (Wave I; mean age = 15.6 years). They were again interviewed in 1996 (Wave II; n = 14,738; mean age = 16.2 years), in 2001–2002 (Wave III; n = 15,197; mean age = 22.0 years), and in 2007–2008 (Wave IV; n = 15,701; mean age = 29.1 years). Additional details of sampling and study design are provided at http://www.cpc.unc.edu/projects/addhealth/design.

Dependent variable: height and weight

At each wave, respondents reported their height in inches and their weight in pounds. In addition, at Wave IV, interviewers measured each respondent's height with a carpenter's square and a steel tape measure in centimeters (to the nearest 0.5 cm) and measured the respondent's weight with a digital bathroom scale in kilograms (to the nearest 0.1 kg). We used all five measures of height and all five measures of weight.

Independent variable: same-sex/opposite-sex twin status

The Wave I sample included 779 twins for whom the sex of their co-twin could be determined; of these, 546 respondents (277 females and 269 males) had same-sex twins and 233 respondents (120 females and 113 males) had opposite-sex twins. Our analysis was limited to these 779 respondents. Note that, unlike most studies in twin research (Frazier et al., 2014; Segal, 2012), our sample contained only one of the twins, not both twins.

Breastfeeding

Add Health measured how long each twin respondent was breastfed by asking the twins' mother, "For how long was _____ breastfed?" The mother could respond as follows: 0 = *not at all*, 1 = *less than 3 months*, 2 = *3 to 6 months*, 3 = *6 to 9 months*, 4 = *9 to 12 months*, 5 = *12 to 24 months*, or 6 = *more than 24 months*. We analyzed ever-breastfed respondents (n = 285) and never-breastfed respondents (n = 469) separately.

Zygosity

Some studies show that dizygotic (DZ) twins tend to be taller and heavier than monozygotic (MZ) twins (Jelenkovic et al., 2015), whereas others show no significant difference (Dubois et al., 2012, Tables S2 and S3). Given that zygosity is partially confounded with same-sex/opposite-sex twin status (all opposite-sex twins are necessarily DZ, whereas some same-sex twins are MZ and some are DZ), it is important to control for zygosity. Add Health assessed the zygosity of each pair of twins by asking the mother, "In your opinion, are _____ and _____ identical twins or fraternal twins?" The mother could respond as follows: 1 = *definitely identical*, 2 = *probably identical*, 3 = *probably fraternal*, or 4 = *definitely fraternal*. We collapsed "definitely" and "probably" and created a binary measure of zygosity (1 = MZ, 2 = DZ). There were 238 MZ twins (119 females and 119 males) and 521 DZ twins (270 females and 251 males).

The inaccuracy of zygosity by self-report has been recognized (Segal, 2011). However, Add Health conducted DNA analysis at Wave III and discovered that only 9% (n = 34) of the twins' zygosity was misclassified by mothers' self-report at Wave I (Harris, Halpern, Smolen, & Haberstick, 2006, p. 992). Despite much smaller sample sizes, all of our substantive conclusions remained identical if we limited our analyses only to DZ twins or only to "definitely" MZ or DZ twins.

Other control variables

In our statistical analyses, we further controlled for each respondent's sex (0 = female, 1 = male), age (in years), and birth weight (in ounces, in order to estimate the effect of breastfeeding on *postnatal* growth).

Results

Table 1 presents the results of our ordinary least squares (OLS) regression analyses. All regression equations in our analyses controlled for sex, age, birth weight, and zygosity. Among the respondents who were breastfed (top panel, left column), same-sex twins were marginally significantly or significantly taller than their opposite-sex counterparts except in Wave I (Wave I: b = .371, p = .426, standardized coefficient = .042; Wave II: b = .752, p = .096, standardized coefficient = .087; Wave III: b = .765, p = .099, standardized coefficient = .086; Wave IV self-report: b = .951, p = .036, standardized coefficient = .104; Wave IV interviewer-measured: b = 2.145, p = .073; standardized coefficient = .092). The unstandardized regression coefficients suggested that same-sex twins were, on average, nearly 1 inch (or over 2 cm) taller than their opposite-sex counterparts.

Table 1 (top panel, right column) shows that ever-breastfed same-sex twins were statistically significantly heavier than their opposite-sex counterparts except in Wave I (Wave I: b = 6.305, p = .101,

Table 1
Partial effect associated with twin-status dummy variable (1 = same-sex twins, 0 = opposite-sex twins) on respondents' height and weight.

	Height	Weight
	Ever breastfed (n = 285)	
Wave I	.371	6.305
(inches/pounds)	(.465)	(3.830)
	.042	*.094*
Wave II	.752†	11.032**
(inches/pounds)	(.450)	(3.997)
	.087	*.159*
Wave III	.765†	11.967*
(inches/pounds)	(.461)	(5.480)
	.086	*.137*
Wave IV	.951*	12.249*
(self-report)	(.450)	(5.858)
(inches/pounds)	*.104*	*.126*
Wave IV	2.145†	5.642*
(interviewer-measured)	(1.188)	(2.808)
(cm/kg)	*.092*	*.123*
	Never breastfed (n = 469)	
Wave I	−.018	1.193
(inches/pounds)	(.377)	(3.455)
	−.002	*.017*
Wave II	−.476	2.096
(inches/pounds)	(.376)	(3.784)
	−.052	*.029*
Wave III	−.233	−12.755
(inches/pounds)	(.387)	(8.775)
	−.026	*−.087*
Wave IV	−.159	−6.690
(self-report)	(.371)	(5.152)
(inches/pounds)	*−.017*	*−.070*
Wave IV	−.402	−2.230
(interviewer-measured)	(.970)	(2.565)
(cm/kg)	*−.018*	*−.048*

Note: † $p < .10$, * $p < .05$, ** $p < .01$.
All equations control for sex, age, birth weight, and zygosity.
Main entries are unstandardized regression coefficients.
(Entries in parentheses are standard errors.)
Italicized entries are standardized regression coefficients.

standardized coefficient = .094; Wave II: $b = 11.032$, $p = .006$, standardized coefficient = .159; Wave III: $b = 11.967$, $p = .030$, standardized coefficient = .137; Wave IV self-report: $b = 12.249$, $p = .038$, standardized coefficient = .126; Wave IV interviewer-measured: $b = 5.642$, $p = .046$, standardized coefficient = .123). The unstandardized regression coefficients suggested that, controlling for sex, age, birth weight, and zygosity, same-sex twins were on average about 12 pounds (or 6 kg) heavier than their opposite-sex counterparts.

Table 1 (bottom panel) shows that, despite the fact that the size of the never-breastfed sample of twins was much larger than that of the ever-breastfed sample ($n = 469$ vs. $n = 285$), none of the coefficients for the same-sex/opposite-sex status was statistically significant for either height or weight. All of the (nonsignificant) coefficients for height, and three of five (nonsignificant) coefficients for weight, were negative. Therefore, it appeared that, among the never-breastfed twins, same-sex twins were no taller or heavier, and might even have tended to be shorter and lighter, than their opposite-sex counterparts.

In addition to OLS regression, we performed repeated-measures analysis of variance (ANOVA) using five separate measures of height as a within-subject measure of height, five separate measures of weight as a within-subject measure of weight, and then 10 measures of height and weight simultaneously as a within-subject measure of body size. The results showed that, among the ever-breastfed twins, same-sex twins were marginally significantly taller, $F(1, 176) = 3.784$, $p = .053$, significantly heavier, $F(1, 170) = 5.400$, $p = .021$, and significantly larger (either taller or heavier), $F(1, 165) = 5.900$, $p = .016$, than opposite-sex twins. In sharp contrast, among never-breastfed twins, same-sex/opposite-sex twin status was not significantly associated with height, $F(1, 275) = 0.228$, $p = .633$, weight, $F(1, 266) = 0.417$, $p = .519$, or body size, $F(1, 259) = 0.798$, $p = .373$.

Interaction with breastfeeding length

If human breast milk is efficiently tailored for the maximum health and growth of each sex, and if that is the reason that breastfed same-sex twins are taller and heavier than breastfed opposite-sex twins, then we can make further predictions. Specifically, it follows that there should be a positive interaction between the same-sex twinship and the length of breastfeeding. In other words, the physical advantage of same-sex twins over opposite-sex twins should increase with the length of breastfeeding. We combined the ever-breastfed and never-breastfed twin samples, and included the length of breastfeeding and the interaction term between the same-sex/opposite-sex twinship and the length of breastfeeding. This procedure yielded an interaction term that was always positive, as predicted (except for weight in Wave I), but it never reached statistical significance, either for OLS regression or for repeated-measures ANOVA, except for height in Wave II ($b = .349$, $p = .058$, standardized coefficient = .091).

The lack of a significant interaction effect may be due to the relatively small variance in the breastfeeding length. A majority (62.2%) of Add Health twins were never breastfed, and 92.8% were breastfed for less than 9 months. Alternatively, it could mean that the benefit of sex-tailored breast milk for health and growth is equally available to all breastfed babies regardless of the length. Studies show that breastfeeding length is either not significantly associated with height and weight during childhood and adolescence (Kramer et al., 2007) or negatively associated with them (Scott, Ng, & Cobiac, 2012; Sezer et al., 2013). In the Add Health sample of twins analyzed here, breastfeeding length was not significantly associated with height at any wave but was significantly, or marginally significantly, *negatively* associated with weight for all waves.

Discussion

The analysis of the Add Health data showed that breastfed same-sex twins were consistently taller and heavier than their opposite-sex counterparts throughout adolescence and early adulthood (from Age 16 to 29). In contrast, never-breastfed same-sex twins were no taller or heavier, and might even have tended to be shorter and lighter, than their opposite-sex counterparts. Our results are consistent with the recent findings that human breast milk may be tailored for each sex to facilitate its health and growth most efficiently. Same-sex twins can benefit from such sex-tailored breast milk, just as singletons can, but opposite-sex twins cannot do so and, therefore, may be at a disadvantage.

Our finding could conceivably be explained if same-sex and opposite-sex twins were breastfed for different lengths of time. Perhaps same-sex twins are taller and heavier than opposite-sex twins because they are breastfed longer. This was not the case. In fact, opposite-sex twins were breastfed significantly longer than same-sex twins (1.00 vs. .73), $t(752) = 2.534$, $p = .011$. Remarkably, same-sex twins were taller and heavier than opposite-sex twins even though they were breastfed for a shorter length of time.

Ever-breastfed same-sex and opposite-sex twins should be very similar to never-breastfed same-sex and opposite-sex twins in every respect. Therefore, it is difficult to formulate an alternative explanation for why ever-breastfed same-sex twins are taller and heavier than ever-breastfed opposite-sex twins, whereas never-breastfed same-sex twins are no different from (and may even be shorter and lighter than) never-breastfed opposite-sex twins. It is easy to imagine how same-sex twins may be very different from opposite-sex twins while growing up. Same-sex twins, especially during childhood and adolescence, probably spend more time together than do opposite-sex twins (McGuire & Segal, 2013), and some of their joint activities may include snacking, dining, and drinking, which may increase their weight (albeit less likely their height). However, this explanation could not account for our findings. First, it is not obvious why some of the joint activities in which same-sex twins engage cannot include working out at a gym or jogging, which may decrease their weight relative to their opposite-sex counterparts. Second, this does not explain why there are no differences between same-sex and opposite-sex twins when they were not breastfed, as most twins (and non-twins) are usually unaware of whether they were breastfed as infants.

To the best of our knowledge, our study is the first to document the actual developmental and physiological consequences of sex bias in human breast milk (instead of measuring its chemical contents). More research is clearly necessary in this emerging field to explore whether there is indeed sex bias in human breast milk and, if so, what observable and meaningful consequences it might have.

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