

BRIEF COMMUNICATION

Sex ratio and maternal age in a natural fertility, subsistence population: Daughters, sons, daughters

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Abstract

Objective: To evaluate putative links between birth sex ratios (BSR = male:female births) and maternal age in a traditional, agricultural, natural fertility population. Metabolic energy, social support, and the costs and benefits associated with producing sons versus daughters can affect BSR. These variables fluctuate with maternal age. Most studies evaluating links between maternal age and BSR have been based on industrialized populations, which differ importantly from traditional indigenous communities in terms of the aforementioned socio-ecological variables.

Materials and methods: We analyze data from 108 mothers and their 603 children living in an agricultural, pronatalist, Kakchiquel Mayan community.

Results: A logistic regression model, including linear and quadratic maternal age terms and women-specific random effects, shows a nonmonotonic ($p = .028$) relationship between log BSR and maternal age. For maternal age ≤ 22 , the upper bound of the 95% confidence interval (CI) for BSR is <1 , suggesting a bias toward girls. The probability of birthing a son increased early during the average mother's reproductive career, peaked at age 31.3 (approximately 95% CI = 27.1, 35.5), and decreased as she approached her perimenopausal period ($p = .014$).

Discussion: No changes in mating system, population sex ratio, mortality patterns, natural disasters, social risk, or toxic exposures were observed and thus are unlikely to explain our results. At this point, age-related changes in metabolic energy, social support, and costs and benefits associated with offspring sex cannot be excluded as possible explanations. BSR can affect growth, morbidity, and mortality. Thus, our results are relevant to numerous fields, including anthropology, ecology, demography, and public health.

KEYWORDS

birth order, maternal age, maternal fitness, sex ratio

1 | INTRODUCTION

"Birth" or "secondary" sex ratios (male:female births) have important effects on human growth, morbidity, and mortality as well as mothers'

biological fitness (Bessa-Gomes, Legendre, & Clobert, 2004; Donald, 2007; Eberhart-Phillips et al., 2017; Engen, Lande, & Sæther, 2003; Hesketh, Lu, & Xing, 2005; Kleindorfer & Wasser, 2004; Kokko & Jennions, 2008; Le Galliard, Fitze, Ferrière, & Clobert, 2005; McNamara, Szekely, Webb, & Houston, 2000; Telschow, Engelstädter, Yamamura, Hammerstein, & Hurst, 2006; Wells, 2000). Thus, understanding

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variations in birth sex ratios (BSR) is of relevance for a wide range of disciplines, including anthropology, public health, demography, ecology, evolutionary biology, and conservation.

A large body of literature has been devoted to exploring a wide variety of maternal exposures that could lead to sex ratio biases in humans (Amalie et al., 2017; Balise et al., 2016; Blaffer Hrdy, 1987; Fukuda, Fukuda, Shimizu, Andersen, & Byskov, 2002; James & Grech, 2017; Koshy, Delpisheh, Brabin, Attia, & Brabin, 2010; Navara, 2010; Safe, 2000; Scialli et al., 2010; Terrell, Hartnett, & Marcus, 2011; Williams & Gloster, 1992; Williams, Lawson, & Lloyd, 1992). Articles vary from those that focus on the effects of specific socio-ecological exposures (Amalie et al., 2017; Balise et al., 2016; Safe, 2000; Scialli et al., 2010; Terrell et al., 2011), to those that examine the biological mechanisms that mediate their effects (Navara, 2010, 2013), to those that investigate the evolution of the links between exposures and outcomes (Myers, 1978; Sieff et al., 1990). Within this last category, the Trivers and Willard hypothesis (1973) stands out as particularly useful for understanding sex ratio in several mammalian species, including humans (also see, Myers (1978) and Williams (1979)). These authors proposed that, for species whose reproductive success (RS) variance is higher for one sex and depends on maternal investment, mothers should bias their investment toward the sex with higher RS variance when in peak condition, and toward the other sex when in suboptimal condition.

A number of socio-ecological exposures, such as those associated with access to social or nutritional resources, are known to vary with maternal age (McDonald & Mair, 2010), and so may the fitness benefits and costs linked to producing sons or daughters (Sieff et al., 1990; Stubblefield & Orzack, 2013). Thus, in such contexts, sex ratios may also vary with maternal age. Several studies have evaluated maternal age as a predictor of BSR (Jacobsen, Møller, & Mouritsen, 1999; James, 1987; Low, 1991; Orvos, Kozinszky, & Brtfai, 2001; Rueness, Vatten, & Eskild, 2012; Takahashi, 1954). However, many of them have been carried out in industrialized populations where the relationship of interest may be affected by several relatively "modern" factors. Specifically, compared to individuals living in more traditional communities, urban dwellers tend to have easier access to reliable family planning methods (Daniels, Mosher, & Jones, 2013) and institutions specializing in the provision of allomaternal care and other forms of social support (Sinha, 2014), high calorie diets (WHO, 2015), greater exposure to chemical contaminants (Abass, Emelyanova, & Rautio, 2018; Bastos et al., 2006; Díaz et al., 2007; Gracey & King, 2009; Kovesi et al., 2007; UNDESA, 2015), and lower morbidity and mortality levels (Gracey & King, 2009; UNDESA, 2015). All of these conditions have been reported to affect sex ratios (Daniels et al., 2013; Safe, 2000).

To increase our understanding of the relationship between maternal age and sex ratio in humans, we analyzed a data set collected from a traditional, agricultural, pronatalist, Kakchiquel Mayan population in which exposure to the "modern" factors listed above was comparatively minimal during the data collection period (2000–2013).

2 | MATERIALS AND METHODS

2.1 | Population

The "Society, Environment, and Reproduction" (SER) Study is a prospective, longitudinal study that has followed the reproductive careers of 108 women and their 603 children since 2000. Participants reside in two neighboring indigenous, rural, Kakchikel Mayan communities in the southwest highlands of Guatemala. At SER's onset, all women in the study communities who met the following selection criteria were invited to participate: married with co-resident husband, parity ≥ 1 and not using any form of contraception. Data regarding women's reproductive life history, including their 603 children's birth order and sex, were obtained via the administration of questionnaires between 2000 and 2013.

2.2 | Statistical analyses

We base our analysis on a logistic regression model that includes linear and quadratic maternal age terms. This model provides a flexible structure for the relationship between log sex ratio and maternal age; for example, it could be monotonic or non-monotonic. The model also includes a woman-specific random effect to allow the sexes of children born to the same woman to be correlated. Model parameters were estimated using the method of maximum likelihood. Since the scale on which maternal age is measured has no impact on the form or strength of its relationship with log sex ratio, we used the scale of years/100 to achieve numeric stability in these estimates.

The significance level was set at $\alpha = .05$ for all tests. All analyses were carried out in R (version 3.5.1) and the R packages lme4, dplyr, and ggplot2.

2.3 | Ethics

Data collection, analysis, and consent forms were initially approved by the University of Michigan's Institutional Review Board in 2000 (H03-00001759-R2) and then, in 2013, by Simon Fraser University's Ethics Review Board (2012 s0668). Illiterate participants provided informed consent orally and literate individuals did so in written form. In all cases, the consent document was initially read in Kakchiquel Mayan to each prospective participant by a local, female, native Kakchiquel-speaking research assistant and signed by the participants with a cross, fingerprint, name initials, or full signature according to their individual preferences.

3 | RESULTS

3.1 | Descriptive statistics

At the onset of the study (2000), the average age of the 108 mothers was 26.4 years (range = 16–43, $SD = 5.80$, median = 26). By the end of the field season in 2013, they had given birth to a total 603 of children (average per mother = 5.58, range = 1–10, $SD = 2.00$,

TABLE 1 Sample sizes and birth sex ratio by maternal age

Maternal age (years)	Total male births	Total female births	Total births	Birth sex ratio (male:female)
19 or under	29	49	78	0.592
(19,23]	58	81	139	0.716
(23,27]	62	71	133	0.873
(27,31]	57	44	101	1.300
(31,35]	44	39	83	1.130
(25,39]	21	26	47	0.808
40 or over	10	12	22	0.833

median = 5). Table 1 gives the observed birth sex ratios and sample sizes for women in different age groups.

3.2 | Birth sex ratio by maternal age

Table 2 shows the estimates of the model's parameters. The relationship between log sex ratio and maternal age during the study period was non-monotonic (estimated coefficient of the quadratic term = -41.01 ; $p = .028$). Figure 1 displays the estimated relationship between sex ratio and maternal age for an average woman (i.e., a woman with a random effect of 0) along with pointwise 95% confidence intervals (CIs). For maternal age ≤ 22 , the negative upper bound of the 95% confidence interval (CI) is less than 1, suggesting that young mothers were more likely to have girls than boys. For the average woman, the probability of birthing a son peaked at maternal age 31.3 (95% CI [27.1, 35.5]) and then began to decrease as she approached her perimenopausal period ($p = .014$).

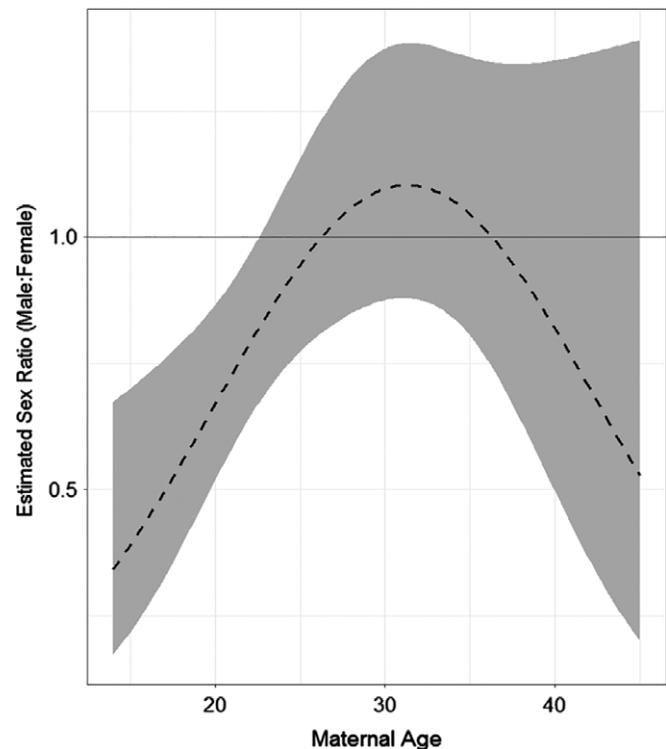
In addition, we conducted a likelihood ratio test comparing the fit of this model to that of the model with no random effects (see, e.g., Zhang & Lin, 2008). Under the null hypothesis of no random effects, the model becomes a simple logistic regression model that assumes that the sexes of children are independent—even for those children born to the same mother. We found no evidence against the null, that is, no evidence of association between children's sexes ($p = .188$).

4 | DISCUSSION

In our agricultural, subsistence, pronatalist, indigenous Kakchiquel Mayan population, an average mother began her reproductive career producing more daughters than sons (for a random effect of 0, the upper limits of pointwise 95% CIs for sex ratio were less than 1 up to maternal

TABLE 2 Relationship between maternal age (measured in years/100) and birth sex ratio (male:female)

Model	Estimate	SE	z value	Two-sided p value
Intercept	-3.91	1.46	-2.68	.007
Maternal age	25.67	10.61	2.42	.016
(Maternal age) ²	-41.01	18.60	-2.20	.028

**FIGURE 1** Estimated birth sex ratio (male:female) by maternal age for an average woman (i.e., a woman with a random effect of 0). The gray shaded area indicates pointwise 95% confidence intervals for sex ratio at each maternal age. The horizontal line indicates sex ratio = 1

age of 22). The probability of birthing a son increased from the onset of her reproductive career until an estimated age of 31.3 (95% CI [27.1, 35.5]) and then decreased in later years ($p = .014$) (Figure 1).

Our dataset does not allow us to test hypotheses regarding the proximate or ultimate origins of the observed relationship between maternal age and sex ratio. Nonetheless, we can discuss several hypotheses that may help inspire future studies focused on understanding causation. For clarity, we begin by discussing previously proposed hypotheses that, a priori, seem unlikely to explain our results. We then address hypotheses that, at this point, cannot be discounted as potential explanations.

4.1 | Least likely explanations

A variety of population level factors have been reported to affect sex ratio, including mating systems (Fisher, 1958; Hamilton, 1967; Kokko & Jennions, 2008; Leturque & Rousset, 2004; Trivers & Willard, 1973), overall population sex ratio (Fisher, 1958; Gowaty & Lennartz, 1985), and infant mortality patterns (Fisher, 1958). These variables remained stable in our study population during the 13-year data collection period (2000–2013) and, thus, are unlikely to explain our results. Similarly, there is some evidence of population-wide challenges such as natural disasters and severe social crises (e.g., wars, revolutions, starvation events) that have been linked to changes in birth sex ratio in humans (Catalano, Bruckner, Anderson, & Gould,

2005; Catalano, Bruckner, Marks, & Eskenazi, 2006; Fukuda, Fukuda, Shimizu, & Møøer, 1998; Graffelman & Hoekstra, 2000; James, 2009; Navara, 2010). However, no such events were observed during the period of data collection.

Individual exposures to toxicants, including polychlorinated biphenyls (Amalie et al., 2017; Terrell et al., 2011), smoking (Fukuda et al., 2002; Koshy et al., 2010), and specific types of pollution (Williams et al., 1992) have also been reported to affect the probability of conception and survival differentially for male and female fetuses. None of our participants reported being, or was known to be, a smoker, nor did we register any kind of personal exposures to chemical compounds that could account for our results. Furthermore, it is unlikely that any exposures that affected the population at large could account for the relationship that emerged between maternal age and sex ratio (i.e., create a "cohort effect") because our longitudinal design included the recruitment of women from a broad spectrum of ages (16–43 years) and our analyses were based on multiple births from the same mothers at different ages.

Sex ratios have also been linked to some individual traits, ranging broadly from race to handedness (James, 1987). Yet, since those traits do not vary with maternal age, they are also unlikely to explain our results.

4.2 | Explanations involving age-related changes in maternal ability to invest in reproduction

The potential of age-related changes in mothers' ability to invest in reproduction to explain the changes in sex ratios we observed is harder to discount. Evolutionary models predict that maternal investment will be allocated among male and female offspring in such a way that mothers' own fitness (quantified in terms of offspring or grand offspring) are, on average, optimized (Charnov, 1982). Specifically, Trivers and Willard (1973) proposed that, in species where RS and maternal investment are higher for one sex, maternal investment should be biased toward the sex with the higher RS variance in good conditions and toward the other sex in suboptimal conditions (see also Williams, 1979; Myers, 1978).

In polygenic mammals, males tend to be the sex with higher RS variance (Clutton-Brock, Albon, & Guinness, 1984; Lee & Moss, 1986; Trillmich, 1986; Wolff, 1988). In those species, males are energetically more expensive to produce, more vulnerable to *in-utero* energetic challenges, and less likely to be born alive than their sisters (Clutton-Brock & Iason, 1986; Stinson, 1985). Consistent with Trivers and Willard's hypothesis, in polygenic species, mothers in better energetic conditions tend to produce more sons than those who are in worse energetic conditions (Cameron, 2004; Clutton-Brock & Iason, 1986; Hardy, 2002; Sheldon & West, 2004). In social species, maternal access to social resources can also affect sex ratios. Among nonhuman, social primates, such as spider monkeys and Barbary macaques, high-ranking mothers tend to produce more sons than low-ranking ones (Paul & Kuester, 1987; Symington, 1987).

RS variance also tends to be higher in men than women (Boone, 1986; Cronk, 1989a; Wilson, Miller, & Crouse, 2017), probably

because polygyny and serial monogamy are widely spread human practices (De La Croix & Mariani, 2013; Hammer, Mendez, Cox, Woerner, & Wall, 2008; Marlowe, 2000). Consequently, reproductively successful sons are more likely to produce more offspring than their sisters, resulting in higher inclusive fitness for their mothers (Alexander, 1974; Dickemann, 1979; Dickemann, 1979b, Dickemann, 1982). Yet, as in other polygenic species, sons are also costlier to produce. Boys grow faster in utero and they are, on average, 100 g heavier at birth than their sisters (Marsál et al., 1996; Tamimi et al., 2003). Consistent with these observations, the energy intake of mothers carrying sons is about 10% higher than that of those carrying daughters (Marsál et al., 1996; Tamimi et al., 2003). Boys are also more vulnerable to intrauterine challenges and, thus, their mortality is higher (Byrne & Warburton, 1987; Mace & Eardley, 2004; Navara, 2014; Shettles, 1961; Vatten & Skjærven, 2004). Sons' lower survival rate also adds to their production cost and highlights the importance of maternal energetic status when producing a boy. In humans too, mothers' social status has been linked to sex ratios (Bernstein, 1948, 1954; Fancher, 1956; Russell, 1936; Winston, 1931). An analysis of 40,000 births in the United States (Teitelbaum & Mantel, 1971), for example, showed that mothers with the lowest SES were more likely to give birth to daughters than those with the highest SES.

4.3 | Age-related changes in maternal social and energetic status vis-à-vis our results

4.3.1 | Early bias toward daughters

The higher costs of producing boys may help explain the bias toward daughters observed early during mothers' reproductive careers in our subsistence population. In natural fertility populations, women often start reproducing before completing their social, somatic, and somatic maturation. Specifically, in our study population, average maternal age at first birth is 19.7 years, that is, over 4 years prior to the age of 24, the age of peak reproductive function (Clutton-Brock & Iason, 1986; Cronk, 1989a; Marsál et al., 1996; Nelson et al., 2013; Tamimi et al., 2003; Vatten & Skjærven, 2004). Thus, young mothers could be facing energetic trade-offs between the completion of their own biological maturation and the conception, gestation, and raising of offspring during those 4 years. Consistent with this proposition, first born babies traditionally have lighter birthweight compared to later born ones (Bacci, Bartolucci, Chiavarini, Minelli, & Pieroni, 2014; Savage et al., 2013). This trade-off may help explain the bias toward daughters observed among younger mothers in our subsistence population.

4.3.2 | The initial increase in the proportion of sons

Energetic trade-offs should gradually subside as women approach the completion of their social and somatic development, allowing them to allocate more resources to reproduction. The resulting increase in energy and social resources available for reproduction could help explain the increased production of costlier sons observed during mothers' mid-reproductive careers. In many traditional, natural fertility

societies, women's aging is often associated not only with somatic maturation but also with increases in social status and experience (McDonald & Mair, 2010; Robertson & Weiss, 2017). Social status and experience can, in turn, facilitate access to higher quantities and quality of food resources (Meehan, Quinlan, & Malcom, 2013) and reduced energy expenditures. Indeed, third parties may be more willing to help higher status individuals with physically demanding activities (Ivey, Morelli, & Tronick, 2005). Such social subsidies can range from carrying fire wood, procuring water, or completing house chores to tasks directly related to reproduction, such as the provision of allomaternal care (Barha et al., 2016; Hawkes, O'Connell, & Blurton Jones, 1997; Kramer, 2005; Kramer & Ellison, 2010; Leslie et al., 2013; Meehan et al., 2013; Schoen & Tufis, 2003). In particular, as mothers age, they start to benefit from help provided by their early born offspring. Critically, the provision of allomaternal care for younger siblings falls, in many cultures, mainly on daughters' shoulders (Hames, 1988; Kramer, 2002; Turke, 1988; Weisner et al., 1977). That is the case in our study population where early born daughters start to carry their siblings on their backs at, approximately, age 6 (Nepomnaschy, pers. obs.). In this scenario, having daughters at the onset of their reproductive careers would provide a double advantage: Young mothers facing stringent energetic or social contexts would benefit early from producing energetically less costly daughters and later from the allomaternal care they provide to raise their younger siblings (Bove, Valeggia, & Ellison, 2002; Weisner et al., 1977). Some previous studies have reported early born daughters' having a positive effect on mothers' reproductive fitness (Berezkei & Dunbar, 2002; Turke, 1988) yet, others do not find such evidence (Flinn, 1989; Hames & Draper, 2004; Kemkes, 2006). Turke, a pioneer on the topic, noticed that Ifaluk mothers whose first or second-born were daughters had significantly more surviving children by the end of their reproductive careers than those who started by giving birth to sons (avg. number of children = 6.93 vs. 4.87) (Turke, 1988). Berezkei and Dunbar (2002) also reported that Roma mothers who gave birth to daughters first had more children overall than those who had sons first, consistent with their shorter inter-birth intervals and longer reproductive life spans (Berezkei & Dunbar, 2002). On the other hand, studies conducted among Trinidadian (Flinn, 1989), !Kung (Hames & Draper, 2004), and preindustrial German (Kemkes, 2006) mothers failed to find links between early borns' sex and maternal fitness, measured as maternal fertility or reproductive life span, inter-birth intervals, or sibling survivorship. Differences among studies' results may be partially explained by methodological challenges associated with measuring the actual impact that daughters' allomaternal care has on mothers' total direct fitness (Mulder, 1989). Additionally, differences among studies could also result from socio-cultural differences across populations in the balance between cooperation and competition of mothers and their children (Clark, 1978; Hamilton, 1967), a phenomenon that has been proposed to explain changes in sex ratio with maternal age in several nonhuman species (Armitage, 1987), including nonhuman primates (Altmann, Hansfater, & Altmann, 1988; Silk, 1983; Symington, 1987).

4.3.3 | Approaching menopause

In our sample, for the average mother, birth sex ratio stopped its initial increase after reaching an estimated peak at maternal age 31.3 years, falling afterward as mothers continued to age (Figure 1). The overall sex ratio by maternal age profile we observed is strikingly similar to the one Low (Low, 1991) reported when analyzing 19th century Swedish women data. Her results suggest, like ours, an initial increase followed by a slight fall in sex ratio toward the end of women's reproductive careers. A study by Orvos and colleagues, based on 9,060 Hungarian births taking place between 1995 and 1999, also revealed a lower sex ratio for mothers over the age of 40 than for those in their twenties (Orvos et al., 2001). Interestingly, Mace (Mace, 1990) observed a similar sex ratio profile in a group of captive gorillas where females also begin reproducing before they have completed their somatic growth. In this case, too, sex ratio increased with maternal age and then began to decrease at approximately 20 years of age as mothers began to approach the end of their reproductive careers (Mace, 1990).

Future studies should further investigate changes in sex ratios as mothers age, including tests of alternative and complementary hypotheses. For example, could the loss of allomaternal care resulting from the reproductive and social maturation of early born offspring, daughters in particular, play a role? As early-born daughters mature and start their own families, their provision of allomaternal care at home is expected to decrease. Furthermore, in our population, newly married daughters appear to compete with their mothers for allomaternal care providers as they often recruit their younger sisters to help care for their newborns.

Siblings' competition over finite material resources, such as land, is another hypothesis worth investigating (Grafen, 1984; Hamilton, 1967). As agricultural yield is linked to plot size, at some point, further dividing land among siblings would result in economically inviable plots. In many traditional, agricultural societies, land tends to be passed on to sons (Goody, 1973) and the earlier born tend to be favored over the later born (Hrdy & Judge, 1993). Thus, where male reproductive fitness is positively associated to land ownership, sons born late would be less likely to produce as many grand-children for their mothers as their earlier born brothers—or even their sisters, whose reproductive fitness is not as closely tied to land ownership (Faurie, Russell, & Lummaa, 2009; Gillespie, Russell, & Lummaa, 2013; Nitsch, Faurie, & Lummaa, 2013; Rickard, Lummaa, & Russell, 2009). Thus, under those conditions, producing daughters near menopause may result in higher maternal inclusive fitness.

It is important to note that results from two studies conducted in industrialized populations do not coincide with ours. Rueness et al. (2012) found no evidence of an association between sex ratio and maternal age in their analyses of 2,206,040 births taking place in Norway between 1967 through 2006. Takahashi (1954) analyzed Japanese births taking place between 1937 and 1943 and between 1947 and 1950 and, in both cases, found sex ratio to be highest for mothers under 20 and over 45. Differences between these results, and those previously discussed, highlight the importance of socio-ecological

contexts as possible modulators of the relationship of interest. Specifically, differences in energy availability and expenditures, morbidity, mortality, and family planning have all been previously reported to be linked to sex ratios (Catalano et al., 2005, 2006; Ding & Hesketh, 2006; Fisher, 1958; Fukuda et al., 1998; Graffelman & Hoekstra, 2000; James, 2009; Navara, 2010). Consistent with that argument, Rueness et al. (2012) and Takahashi (1954) report lower birth sex ratios for women facing challenging contexts. Specifically, Japanese women giving birth out of wedlock presented lower sex ratios than married mothers (sex ratios 92.9 vs. 105.3, respectively) (Takahashi, 1954) and Norwegian mothers suffering preeclampsia or fetal growth retardation experienced lower sex ratios than did their unaffected counterparts (OR 0.87, 95% CI 0.85–0.89) (Rueness et al., 2012).

4.4 | Study limitations

Our dataset precludes us from testing causal inferences. Future studies investigating ultimate and proximate level explanations should be based on longitudinal datasets that include measures of women's age-specific nutritional and immune status, energy levels, quality and quantity of social support, physical ability to conceive, gestate, and raise offspring, chemical exposures, as well as other relevant covariates.

4.5 | Strengths

Our study's longitudinal prospective design provides greater data accuracy than do retrospective studies. Retrospective studies are susceptible to recall biases, often associated with negative outcomes such as child deaths, particularly in communities with poor or no written records. The participant observation techniques we used allowed us to be firsthand witnesses of pregnancies and birth events and to check and cross-check the reproductive histories of each participant with other community members (Hill & Kaplan, 1988; Sieff et al., 1990). The result is a dataset with a lower frequency of errors, which would be expected to yield higher statistical power and more reliable results (Cronk, 1989b).

In sum, in our indigenous, agricultural, subsistence, pronatalist study population, birth sex ratio varied with maternal age. While young mothers were more likely to produce daughters, the proportion of sons increased with age, plateaued, and then began to decrease. Our results emphasize the importance of analyzing women's reproductive output as a dynamic process. The occurrence of similar nonlinear profiles linking sex ratio and maternal age in other natural fertility, nonindustrial populations (Low, 1991), and in nonhuman primates (Mace, 1990) underscores the value of further investigating said link. No changes in mating system, overall population sex ratio, infant mortality patterns, natural disasters, severe social crises, or exogenous chemical exposures were noted during the period of data collection and thus are unlikely to explain our results. However, changes in social and energetic resources related to maternal age cannot, at this point, be discounted as potential factors mediating the association we observed between maternal age and birth sex ratios. Future studies should specifically investigate the potential roles that

age-related changes in those resources may play in determining changes in sex ratios across mothers' reproductive life spans.

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