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Child nutritional status among births exceeding ideal family size in a high fertility population

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Abstract

Ideal family size (IFS) is measured in social surveys to indicate unmet need for contraception and impending shifts in fertility behaviour. Whether exceeding IFS affects parental behaviour in ways that result in lower investments in child nutrition, well-being, and educational attainment is not known. This study examines parental IFS and the association between exceeding stated ideals and child nutritional status in a high-fertility, high-mortality population in the Bolivian Amazon. Height-for-age *z*-scores, weight-for-age *z*-scores, weight-for-height *z*-scores, stunting, haemoglobin, and anaemia status in 638 children aged 0–5 years are predicted as a function of birth order in relation to parental IFS, adjusting for household characteristics and mother and child random effects. Children of birth orders above paternal IFS experience higher weight-for-age *z*-scores when living further away from the market town of San Borja, consistent with underlying motivations for higher IFS and lower human capital investment in children in more remote areas ($\beta = .009$, $p = .027$). Overall, we find no statistical evidence that birth orders in excess of parental ideals are associated with compromised child nutrition below age 2, a period of intensive breastfeeding in this population. Despite a vulnerability to nutritional deficiencies postweaning for children age 2–5, there was no association between birth order in excess of parental ideals and lower nutritional status. Further studies examining this association at various stages of the fertility transition will elucidate whether reported ideal or optimal family sizes are flexible as trade-offs between quality and quantity of children shift during the transition to lower fertility.

KEYWORDS

child nutrition, fertility preferences, high fertility, ideal family size, stunting, Tsimane

1 | INTRODUCTION

Over half of the world's population lives in regions with total fertility rates (TFR) below replacement levels of 2.1 children per woman (Myrskylä, Kohler, & Billari, 2009). From the 1960s to 2005, the TFR of the developing world declined from 6.0 to 2.9 births per woman (Bongaarts, 2008). Changes in desired number of children and ideal family size (IFS) are often viewed as a precursor to fertility decline (Behrman, 2015), though no research to date directly assesses whether a mismatch between stated fertility ideals and subsequent parent behaviour might have harmful consequences on the welfare of "unwanted" children. Analyses of World Fertility Surveys and Demographic and Health Surveys undertaken in 64 country-years suggest consistent mismatches between desired family size and realized fertility, with an average excess of one child per woman in low-income countries (Pritchett, 1994). It is unclear whether a mismatch between fertility ideals and behaviour during the early stages of the fertility decline in low-income countries is associated with worse child health outcomes and reduced child investment. Alternatively, stated ideals in high fertility contexts might reflect relatively weak preferences that are continually updated to incorporate subsequent births, and thus, exceeding prior fertility ideals might have little influence on child health and nutrition.

High fertility populations in marginalized, resource-limited settings are at increased risk of nutritional deprivation. Demographic surveillance in a remote region of Bolivia with little access to social services offers an opportunity to examine the nutritional costs of exceeding IFS in a high fertility population where achieved fertility substantially exceeds IFS. The Tsimane are an indigenous population living in the Bolivian lowlands practicing a relatively traditional lifestyle of slash-and-burn horticulture, fishing, hunting, and gathering (Gurven et al., 2017). There are low levels of fluency in the national language (Spanish), overall low levels of market integration, high fertility, high infant mortality, and environmental stressors including food insecurity and heavy infectious burden (Blackwell et al., 2016; Gurven et al., 2016; Kaplan et al., 2017). Assessing fertility ideals in this context allows for exploration of the flexibility of concepts such as IFS and whether there are negative consequences when parents exceed ideals in terms of child height, weight, and anaemia. Stunting, underweight, and anaemia are highly prevalent conditions affecting Tsimane children (Blackwell et al., 2016; Foster et al., 2005); therefore, any neglect, low investment, or parental investment decisions resulting from having "unwanted" children may be reflected in these measures.

This study describes Tsimane population-level fertility patterns and examines the association between nutritional status and exceeding IFS for 638 children born after measurement of parental IFS in 207 partner pairs. Fertility levels and trends in this population demonstrate high and even increasing fertility by maternal birth cohort (Mcallister, Gurven, Kaplan, & Stieglitz, 2012). The recent increase may be due to improved nutritional status and health care similar to initial increases in fertility observed across transitioning contexts, including sub-Saharan Africa (Ellison, 2003; Gibson & Mace, 2006). Although fertility remains high, stated IFS among men and women is lower among more recent birth cohorts in this population (TFR = 9.1, IFS = 4.6, for all women in sample; IFS = 3.85, for 1980 cohort; Figure 1). Baseline measurements of IFS and follow-up measures of child anthropometry and anaemia status are used to examine predictors of child nutritional status when fertility preferences and realized family sizes are mismatched.

Key messages

- Ideal family size measures a woman's hypothetical ideal number of children to have; in a high-fertility, high-mortality population, this number is higher for men than women. Most women in this population will ultimately exceed their stated ideal family size by 4.5 children on average.
- Children under 5 years of age bear no negative consequences for having a birth order in excess of maternal or paternal ideal family size, and this relationship is positive for children exceeding paternal ideal family size who live in remote areas with limited market access and higher childhood mortality.
- Further research among populations experiencing the transition to lower fertility will elucidate whether children experience worse nutritional outcomes for being unwanted as the calculus of childbearing changes.

1.1 | Background

Before the demographic transition, larger family sizes were generally favoured worldwide. Today, parents living in more remote and rural areas report higher IFS due to increased utility and relatively low cost of each additional child (Mace, 2008). Children may provide labour, childcare for siblings, and support over the life course, including old-age insurance (Caldwell, 2005). Alternately, parents living in cities often opt for different investment strategies, motivating a quality–quantity trade-off in favour of fewer children receiving greater investments due to increased accessibility to schools, increased cost of raising children, and perceived future access to competitive labour markets (Kaplan 1996; Mace, 2008; Montgomery & Casterline, 1996). As the social and economic calculus of bearing each additional child begins to shift, so does IFS and eventually fertility behaviour. We propose that within the realm of fertility preferences, consequences of exceeding IFS are minimal in early stages of the fertility transition. When increased material and time investments are required to enhance competitiveness of offspring, family size preferences decline and the costs of exceeding IFS should increase. Thus, moving from

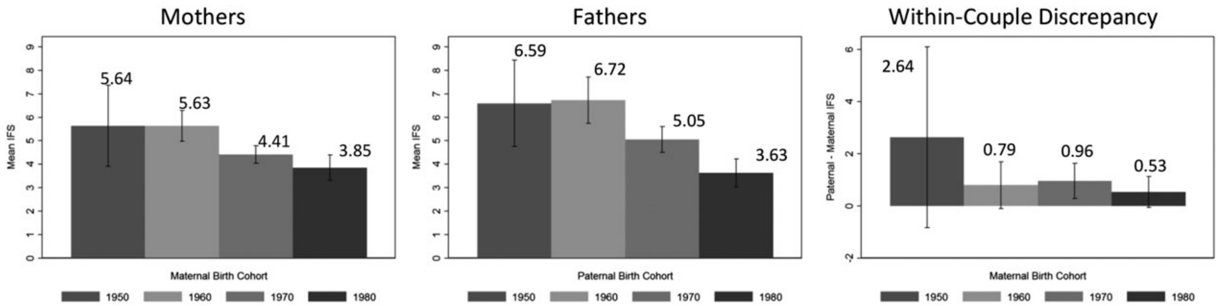

FIGURE 1 Mothers' and fathers' mean ideal family size by birth cohort and within-couple discrepancies, IFS subsample (N = 211). IFS = ideal family size

early to late stages of the fertility transition should coincide with decreasing flexibility of fertility preferences. Given the importance of material wealth for parental investment in later stages of the fertility transition, socio-economic status is expected to play a significant role in the ability to cope with additional "unwanted" children.

In low-income countries, there is some evidence of elevated mortality and higher rates of infection for higher birth orders, though it is difficult to disentangle increasing birth complications with maternal age from exceeding IFS (Scrimshaw, 1978) and endogenous characteristics of high parity households. Understanding whether children in resource-sparse, early, or midtransition settings pay a nutritional penalty for birth order in excess of parental ideals helps to elucidate the strength and long-term impacts of family size preferences and holds implications for the types of assistance high-fertility families might need. In a context where ideals are consistently exceeded, do families adapt via effective buffering strategies as the number of children increases? Or does being unwanted imply unequal distribution of resources among wanted and unwanted children, reflected in height for age, weight for age, or anaemia status, possibly motivating supplementation in households where ideals are exceeded?

1.2 | Study context: The Tsimane

The Tsimane Health and Life History Project (THLHP) is an ongoing longitudinal study conducting socio-economic and demographic surveys continuously from 2002 to present among Bolivian Amerindians living in the Beni Department of Bolivia (Gurven et al., 2017). Broad aims of this project include improving the understanding of the impact of environment and evolution on the life course and focuses on health, ageing, economics, and biodemography in forager-farmers practicing a traditional lifestyle. The Tsimane (population approximately 16,000) occupy over 90 villages consisting of extended family groups ranging from 30 to 600 people. Villages vary in access to market goods and health care that are largely available in the market town of San Borja (population approximately 25,000 in 2010), by navigating the Maniqui River or seasonal logging roads (von Rueden et al., 2014). No villages have running water, and only a third contained schools teaching both Tsimane and Spanish during most of the study period. Mean age at marriage is 21 years old for men and 16.5 years old for women (Winking, 2005). Approximately two thirds of foodstuffs consist of horticultural goods from small-scale cultivation, including plantains, manioc, corn, and rice, supplemented by fishing and hunting (Martin et al., 2012). Market integration is limited; cash crops, sporadic wage labour, sales of woven *jatata* palm leaf panels (used to construct rooves), and trade with merchants comprise the primary market activities, though low-income wage labour is available primarily to men in communities near San Borja (Mcallister et al., 2012).

In addition to a mostly traditional lifestyle, fertility and mortality rates resemble those observed in early stages of the demographic transition. Fertility and infant mortality are high, with a TFR of 9.1 and infant mortality rate of 137 deaths per 1,000 live births, though this varies with proximity to San Borja (Gurven, 2012). Women living furthest from San Borja experience slightly lower fertility rates (TFR = 8.0) and higher infant mortality (IMR ≈ 178 per 1,000 live births; Gurven, 2012; Gurven, Kaplan, & Supa, 2007; Mcallister et al., 2012). Closer to San Borja, fertility is higher (TFR = 9.5), and infant mortality is lower (IMR ≈ 100 per 1,000 live births; Gurven et al., 2007; Mcallister et al., 2012). The population growth rate is high (3.8%), with a population doubling time of 18 years. Women living closer to town may have improved nutritional status and access to medical care, improving energy balance, which may have indirect impacts on fecundity and offspring survival (Ellison, 2003). Despite greater access to schooling and other modern amenities over the past several decades, there is little evidence that age-specific fertility rates across female cohorts are shifting (see Figure S2).

1.3 | Aims of the current study

This study examines whether exceeding parental IFS is associated with child growth or nutritional penalties for children by using 10 years of follow-up data, integrating all births from the time of initial IFS measurement in 2002–2006 to the most recent census in 2012. Including child growth in the analysis elucidates whether cross-sectional measurements of fertility preferences are associated with household resource allocation in the longer term and if exceeding maternal or paternal ideals are more predictive of child nutritional outcomes (height-for-age z-score [HAZ], weight-for-age z-score [WAZ], stunting, anaemia). Age-specific fertility rates, completed fertility, and IFS by sex and birth cohort are calculated to provide descriptive evidence of fertility ideal-behaviour mismatch (see Data S1). Cross-sectional within-couple IFS discrepancies (Figure 1) suggest lower discord among men and women from recent cohorts, who also prefer smaller IFS. This apparent within-couple discrepancy in IFS may increase with age and parity differently among men and women if each perceives costs of fertility (e.g., childbearing and lactation) or potential benefits (e.g., adult children providing assistance to parents at late ages) differently.

The hypothesis that exceeding parental IFS is associated with negative child growth is tested using the child's nutritional status including WAZ, HAZ, and haemoglobin. We employ clinical cut-offs to assess underweight (WAZ ≤ -2), stunting (HAZ ≤ -2), and anaemia (Hb $\leq$ 10 g/dl; see Table S1, Figures S4 and S6). Stunting indicates longer term nutritional deprivation, whereas underweight and wasting are associated with acute deficits in nutritional status (Onis, 2006).

2 | METHODS

2.1 | Participants and materials

Demographic information including reproductive histories and IFS were collected from 2002 to 2006 from 217 partner pairs as part of THLHP interviews (see Data S1). The 2012 census included demographic information on all individuals in a household including household rosters and reproductive histories. This census in addition to periodic demographic surveys by the THLHP was used to add children born from the time of initial interview when IFS was measured up to 2011–2012, so all children from a parents' initial interview to the 2012 census were included in the analyses. Approximately once per year the THLHP mobile medical team arrived in each Tsimane community to conduct medical exams and collect biodemographic data. Anthropometric data were collected on all members present in the household at time of survey, resulting in a varying number of measurements per child. Child height was measured with a portable SECA 213 Stadiometer (Seca, Inc.; Birmingham UK), and weight was measured with a Tanita BC-1500 scale (Tanita Inc, Arlington Heights, IL). Haemoglobin was measured using a QBC Autoread Plus dry haematology autoanalyser (Drucker Diagnostics, Port Mathilda, PA).

A total of 1,573 child measurements of 643 children aged 0–5 were linked to 217 husband–wife pairs. Missing information on literacy and Spanish speaking ability of parents reduced the final sample size to 207 parents and 638 children, resulting in 1,549 child measurements. Hypotheses predicting the odds of exceeding IFS were tested on a dataset containing 207 parents (see Figure S1). Hypotheses predicting HAZ, WAZ, weight-for-height *z*-score (WHZ), and stunting were tested on the child dataset containing 1,549 child measurements. Some children appear in multiple analyses, as all analyses are stratified from ages 0–2 and 2–5. For example, if a child is measured at ages 2 and 4, they will be included in both regressions. Anaemia is assessed on a subset of children for whom data were available (n = 552 children).

2.2 | Statistical methods

HAZ, WAZ, and WHZ were calculated for children aged 0–5 using the World Health Organization 2006 Multicentre Growth Study growth curves (de Onis et al., 2004; Leroy, 2011). This multipopulation reference includes optimal growth patterns for children from six countries (Brazil, Ghana, India, Norway, Oman, and the United States; Borghi et al., 2006). Anthropometric *z*-scores measure the number of standard deviations from the reference median by child age. A deficit in HAZ represents consistent undernutrition and infection, whereas lower WAZ (referred to as "underweight") is a symptom of acute changes in nutrition (UNICEF, 2013). HAZ, WAZ, and WHZ are predicted for age groups 0–2 and 2–5 as a function of child's age, sex, birth order, maternal body mass index (BMI), whether the child's birth order exceeds parental ideals (binary, equal to 1 if birth order > IFS), mother and fathers' IFS, parental literacy, and Spanish speaking ability using multilevel linear regression with maternal and child identifiers to account for the non-independence of multiple child observations nested within mother observations (Tables 2, 3, S4–S5). Models are stratified by these broad age groups (0–2 years, 2–5 years) to account for the fact that mean interbirth interval is 2.47 years in this sample, and ad libitum breastfeeding is widespread in this population up to 2 years of age (Martin, Garcia, Kaplan, & Gurven, 2016; Veile, Martin, McAllister, & Gurven, 2014). To capture the extent of exceeding ideals, a dummy variable is first used (Tables 2 and 3), and then, a continuous variable indicating the difference between each child's birth order and parental IFS (birth order − parental ideal = number over/under ideal) is used to predict HAZ and WAZ for age groups 0–2 and 2–5 (Table 3). Additional analyses examining stunting (Table 3), haemoglobin, and anaemia (Table 4) explore whether birth order in excess of parental ideals is associated with other measures of nutritional deficiencies in children.

2.3 | Ethics statement

All analyses are secondary analyses of existing data determined to be IRB exempt by the University of Pennsylvania HS-ERA (protocol #820240). All individuals in the study provided informed consent, and procedures were approved by the institutional review boards at the University of California, Santa Barbara and University of New Mexico. Approval for all study components was also obtained from the Tsimane governing council and from village leaders.

3 | RESULTS

3.1 | Exceeding IFS

By the 2012 census, 76% of mothers and 67% of fathers exceeded their reported IFS (Table S1). Mean IFS is higher among fathers than mothers ($\bar{x}^{\text{Father}}$ = 5.51, $\bar{x}^{\text{Mother}}$ = 4.62). Mothers and fathers' IFS are lower for more recent birth cohorts, with younger cohorts reporting a smaller IFS (Figure 1).

3.2 | Factors associated with IFS

Factors hypothesized to affect IFS include literacy, Spanish proficiency, maternal BMI, and partner IFS (Figure S1). Count models predicting parental IFS include the best fit using Akaike information criterion and *r*-squared statistics (Tables S2 and S3). Controlling for household and individual characteristics, parity at interview is positively associated with greater maternal IFS (β = .04, p < .05, Table S2, Models 1 and 2). As might be expected in a high fertility population, parity and age are highly correlated. Models include age and parity independently and jointly. There is no evidence of an association between maternal or paternal literacy or Spanish proficiency and IFS. Husband's IFS is strongly associated with wife's IFS; a one-child increase in husband's IFS is associated with a 0.03 increase in wife's IFS that might suggest some degree of postsocialization or assortative mating (p < .001, Table S2).

A similar count framework is used to predict paternal IFS (Table S3). Parity at interview is positively associated with greater reported IFS, where a one-unit increase in parity is associated with a 0.07–0.08 child increase in paternal IFS (p < .001, Table S3: Models 1 and 2). Wife's IFS is positively associated with paternal IFS, consistent with the previous prediction of maternal IFS (β = .054–β = .078, p < .001, Table S3). A one standard deviation (*SD*) increase in distance from the market town of San Borja is associated with 0.006 higher paternal IFS, consistent with a quality–quantity trade-off favouring more children in remote areas (p < .001, Table S2).

3.3 | Odds of exceeding IFS

Odds of exceeding IFS were hypothesized to be lower with greater Spanish fluency and literacy. Effects of Spanish fluency and literacy vary depending on which parent's IFS is estimated; however, all associations are nonsignificant (Table 1). Respondent's parity at interview is positively associated with the odds of exceeding IFS by the end of the follow-up period; for both mothers and fathers, higher parity at

TABLE 1 Predicted odds of exceeding paternal and maternal ideal family size

	Paternal						Maternal					
	Age and parity		Parity		Age		Age and parity		Parity		Age	
	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*
Respondent's IFS	**0.326**	**<.001**	**0.321**	**<.001**	**0.414**	**<.001**	**0.416**	**<.001**	**0.418**	**<0.001**	**0.544**	**<.001**
Partner IFS	1.251	.066	1.256	.062	**1.275**	**.037**	0.978	.724	0.977	.704	1.003	.959
Maternal BMI	1.012	.843	1.015	.804	1.001	.986	1.031	.599	1.021	.704	1.007	.893
One living son in household	1.410	.732	1.443	.717	1.559	.654	0.322	.392	0.267	.324	0.317	.353
Respondent's parity at interview	**1.470**	**.002**	**1.546**	**<.001**			**1.847**	**<.001**	**1.618**	**<.001**		
Respondent's age at interview	1.024	.503			**1.107**	**<.001**	0.938	.145			**1.099**	**.001**
Mother speaks Spanish	0.899	.837	0.924	.876	0.967	.946	0.713	.508	0.681	.451	0.918	.856
Father speaks Spanish	2.370	.260	2.163	.303	3.133	.124	1.402	.619	1.540	.530	1.908	.307
Mother literate	0.910	.858	0.882	.810	0.753	.579	1.453	.462	1.502	.420	1.064	.896
Father literate	1.150	.763	1.090	.850	1.298	.560	0.977	.959	1.119	.797	1.111	.800
Distance to San Borja (km)	1.004	.674	1.004	.696	1.001	.926	0.999	.875	0.999	.925	0.997	.683
Number of parents	207		207		207		207		207		207	
Pseudo *R*-squared	0.35		0.35		0.32		0.28		0.28		0.19	
AIC	208		207		217		228		228		252	

Note. AIC = Akaike information criterion; BMI = body mass index; IFS = Ideal family size. Bold denotes statistically significant *P* values at an alpha of 0.05.

interview is associated with 47–85% greater odds of exceeding IFS on follow-up (Table 1). For both women and men, higher IFS is associated with lower odds of exceeding IFS by the end of the period (Table 1). For men, a one-unit increase in wife's IFS is associated with a 25–28% higher odds of exceeding one's own IFS (Table 1). A husband's IFS was not significantly associated with a woman's likelihood of exceeding her own IFS. There is no evidence of an association between distance to the market town of San Borja and the odds of exceeding IFS for either parent.

3.4 | Child nutritional status

HAZ, WAZ, stunting, haemoglobin, and anaemia were predicted as a function of parental IFS and household and individual characteristics, including random intercepts for child and maternal identifiers (Table S1, Figures S4 and S5). WAZ and WHZ are normally distributed, with some right skew in HAZ (Figure S6). This is likely due in part to the high prevalence of parasitic and infectious disease in this population, where the majority of children are or have been infected for a prolonged period, affecting stature. For ages 0–2 HAZ and WAZ, primary models include individual and parental characteristics followed by a model including parental Spanish fluency (Table 2, Models 1, 2, 4, and 5). After including Spanish speaking abilities, the strongest predictor of both HAZ and WAZ is child's age at measurement, where a 1-year increase in age is associated with a one *SD* decline in HAZ and a 0.48 decline in WAZ. Initial multilevel models included a dummy variable indicating whether the child's birth order is in excess of the stated IFS for mothers and fathers separately (Tables 2 and 3). For ages 0–2, we find no effect of a child's birth order exceeding either maternal or paternal IFS on either child HAZ or WAZ. To test whether it is worse for a child to be in excess of both parent's ideals rather than only one parent, a binary indicator is included after dropping parental IFS from the model ("Exceeded both parents' Ideals," Table 2, Models 3 and 6). A child's birth order exceeding both parents' IFS is also unrelated to that child's HAZ or WAZ. For child ages 0–2 years, being male is associated with a 0.33 *SD* decrease in HAZ (p = .032, Table 2). Males tended to have a lower weight z-score (β = −.200, p = .095). Maternal BMI is positively associated with child WAZ ages 0–2 across all three models (β = .056, p = .019, Table 2, Model 4). All models presented in Table 2 were retested with interactions between exceeding parental IFS (categorical) and distance to San Borja and exceeding parental IFS and categorical Spanish fluency. For ages 0–2, interactions were not statistically significant (not shown).

Analogous models were tested for children ages 2–5. Sons had on average a lower HAZ than daughters; however, this association is not statistically significant (Table 2). Birth order greater than parental ideals (maternal, both) was neither associated with HAZ nor WAZ. Exceeding paternal ideals was associated with a 0.310 increase in HAZ (Table 2, p < .05, ages 2–5, Model 1), that is, the opposite direction of a nutritional deficiency among children born in excess of IFS. As among the 0–2 age group, maternal BMI is associated with an increased child WAZ (β = .046, p = .003, Table 2, Model 4). Exceeding paternal IFS is associated with higher WAZ among children aged 2–5, (β = .289, p = .028, Table 2, ages 2–5, Model 5). After including interactions between exceeding paternal IFS and distance to San Borja, the association between exceeding paternal IFS and WAZ is no longer statistically significant (β = −.104, p = .631, Table S6), and the interaction coefficient between exceeding paternal IFS and distance to San Borja is small but statistically significant (β = .009, p = .027, Table S6). This suggests positive relationship between birth order in excess of paternal IFS and higher WAZ in households further from town.

Across multilevel models predicting HAZ and WAZ for children aged 0–2 and 2–5, there was no observed association between z-scores and whether or not both parents exceeded their IFS. This is also the case with WHZ, where exceeding parental ideals was not associated with lower WHZ (Tables S4 and S5). We now consider whether the extent of exceeding ideals might be more predictive of child nutritional status.

TABLE 2 Factors predicting HAZ and WAZ (underweight) in children aged 0–2 and 2–5, dummy for exceeding (unstandardized)

	HAZ (1) β	p	(2) β	p	(3) β	p	WAZ (4) β	p	(5) β	p	(6) β	p
Ages 0–2												
Age at measurement (years)	**−1.082**	**<.001**	**−1.067**	**<.001**	**−1.065**	**<.001**	**−0.478**	**<.001**	**−0.475**	**<.001**	**−0.476**	**<.001**
Male	**−0.329**	**.024**	**−0.345**	**.018**	**−0.327**	**.025**	−0.141	.252	−0.169	.170	−0.165	.181
Birth order	−0.030	.464	−0.022	.600	−0.054	.165	−0.041	.259	−0.038	.301	−0.046	.190
Maternal BMI	0.029	.242	0.026	.294	0.026	.297	**0.056**	**.019**	**0.058**	**.018**	**0.057**	**.018**
Exceeded Mom's ideals	−0.009	.972	−0.087	.731			0.087	.683	−0.009	.968		
Exceeded Dad's ideals	0.045	.852	0.103	.668			0.069	.742	0.129	.537		
Maternal IFS	−0.007	.890	−0.018	.704	0.007	.862	0.054	.218	0.045	.310	0.054	.174
Paternal IFS	0.019	.576	0.019	.585	0.027	.377	−0.021	.515	−0.015	.635	−0.015	.604
Mother speaks Spanish			−0.109	.474	−0.100	.509			0.015	.920	0.017	.911
Father speaks Spanish			−0.019	.953	−0.041	.900			0.080	.793	0.064	.834
Exceeded both parents' ideals					0.271	.226					0.174	.370
N Observation (individuals)	549 (385)		543 (381)		543 (381)		549 (385)		543 (381)		543 (381)	
AIC	1961.85		1939		1935.76		1812.62		1796.17		1793.79	
Ages 2–5												
Age at measurement (years)	−0.006	.791	−0.007	.765	−0.007	.782	0.009	.701	0.008	.725	0.009	.717
Male	−0.130	.136	−0.127	.148	−0.115	.189	0.027	.711	0.021	.772	0.029	.686
Birth order	−0.040	.121	−0.038	.139	−0.046	.055	−0.032	.147	−0.034	.128	−0.036	.076
Maternal BMI	0.015	.389	0.015	.362	0.014	.415	**0.046**	**.003**	**0.047**	**.002**	**0.045**	**.003**
Exceeded Mom's ideals	−0.221	.157	−0.224	.151			−0.113	.387	−0.125	.340		
Exceeded Dad's ideals	**0.310**	**.048**	0.306	.052			**0.289**	**.028**	**0.292**	**.027**		
Maternal IFS	0.002	.946	0.001	.985	0.023	.411	0.030	.277	0.026	.334	0.041	.098
Paternal IFS	0.016	.438	0.016	.444	0.002	.905	−0.017	.360	−0.010	.603	−0.020	.250
Mother speaks Spanish			0.032	.775	0.022	.840			0.180	.072	0.173	.083
Father speaks Spanish			0.118	.561	0.128	.530			0.134	.452	0.138	.440
Exceeded both parents' ideals					0.137	.342					0.184	.128
N Observation (individuals)	1,012 (533)		1,006 (530)		1,006 (530)		1,012 (533)		1,006 (530)		1,006 (530)	
AIC	2590.04		2581.92		2583.16		2434.63		2423.89		2424.44	

Note. AIC = Akaike information criterion; BMI = body mass index; HAZ = height-for-age *z*-scores; IFS = Ideal family size; WAZ = weight-for-age *z*-scores. Bold denotes statistically significant *P* values at an alpha of 0.05.

TABLE 3 Association between exceeding IFS and HAZ and WAZ in children ages 0–2 and 2–5: Number of children over/under ideal, multilevel models

	HAZ				Stunting				WAZ			
	Ages 0–2		Ages 2–5		Ages 0–2		Ages 2–5		Ages 0–2		Ages 2–5	
	β	*p*	B	*p*	OR	*p*	OR	*p*	β	*p*	β	*p*
Age at measurement (years)	**−1.067**	**<.001**	−0.007	.768	**5.231**	**<.001**	0.840	.209	**−0.477**	**<.001**	0.008	.743
Male	**−0.347**	**.017**	−0.117	.181	**1.887**	**.023**	2.152	.067	−0.174	.157	0.025	.733
Birth order	−0.020	.590	−0.019	.455	0.973	.691	1.039	.749	−0.008	.829	−0.013	.558
Maternal BMI	0.025	.304	0.015	.390	0.983	.712	0.950	.515	**0.057**	**.019**	**0.046**	**.002**
Number over/under maternal IFS	0.010	.789	−0.016	.557	1.029	.689	1.049	.699	−0.043	.253	−0.032	.187
Number over/under paternal IFS	−0.009	.730	0.006	.748	0.967	.482	0.968	.692	0.027	.302	**−0.031**	**.050**
Mother speaks Spanish	−0.114	.451	0.020	.859	0.890	.677	1.243	.671	0.007	.963	0.170	.086
Father speaks Spanish	−0.021	.948	0.133	.514	2.079	.240	0.743	.757	0.078	.797	0.144	.418
N Observation (individuals)	543 (381)		1,006 (530)		543 (381)		1,006 (530)		543 (381)		1,006 (530)	
AIC	1935.22		2582.05		644.70		1183.60		1792.59		2424.70	

Note. AIC = Akaike information criterion; BMI = body mass index; HAZ = height-for-age *z*-scores; IFS = Ideal family size; WAZ = weight-for-age *z*-scores. Bold denotes statistically significant *P* values at an alpha of 0.05.

For example, to be birth order six when parents' IFS is five may not be as detrimental as being birth order nine. Similar models as those presented above were run with a variable for each parent indicating the number over or under IFS for each child (Table 3). The larger the number, the more the child is over their parents' stated IFS. For children aged 2–5, there is an association between having birth order in excess of paternal ideals and decreased WAZ when considered continuously. Each one-unit increase in number over paternal ideals is associated with a 0.03 decrease in WAZ, holding all other variables in the model constant (β = −.031, p = .050, Table 3). The extent of parental excess IFS was not associated with HAZ or stunting. Child characteristics including age and sex are associated with HAZ and WAZ in these models.

We ran similar multilevel analyses on child haemoglobin (g/dl) and anaemia status for children ages 0–2 and 2–5. Neither binary nor continuous exceeding of parental IFS is associated with infant (0–2) haemoglobin or anaemia status (Table 4).

4 | DISCUSSION

4.1 | IFS and nutritional status

We tested for any potential associations between birth order exceeding parental ideals and worse child nutritional status prospectively. After stratifying by child age, we estimated a positive association between birth orders greater than paternal ideals and WAZ, though interactions between exceeding paternal IFS and distance to town attenuated this association, suggesting that children in excess of paternal ideals in more remote communities fare better than children living closer to the market town of San Borja (Table S6, column 4). In particular, children born in excess of paternal ideals exhibit slightly higher WAZ than their counterparts residing in households closer to town. This pattern was also observed for exceeding maternal IFS, though exceeding maternal IFS is associated with worse WAZ, yet the interaction between exceeding maternal WAZ and distance from

TABLE 4 Association between exceeding IFS and haemoglobin and odds of anaemia (Hb <10), multilevel models

	Hb		Odds (anaemia)		Hb		Odds (anaemia)	
	Ages 0–2		Ages 0–2		Ages 2–5		Ages 2–5	
	β	*p*	OR	*p*	β	*p*	OR	*p*
Age at measurement	**0.114**	**.011**	**0.271**	**.001**	**0.114**	**<.001**	0.918	.300
Male	1.002	.998	1.03	.959	−0.059	.482	1.049	.892
Birth order	0.953	.842	0.971	.819	−0.053	.052	0.999	.996
Maternal BMI	0.791	.183	0.867	.139	0.017	.349	0.960	.545
Number over/ under maternal IFS	0.978	.927	0.988	.936	−0.047	.105	1.017	.865
Number over/ under paternal IFS	1.049	.740	1.031	.684	−0.001	.968	0.992	.904
Mother speaks Spanish	0.564	.514	0.669	.451	0.005	.968	1.082	.838
Father speaks Spanish	0.027	.113	0.113	.109	0.196	.384	0.793	.772
N Observation (individuals)	102 (97)		102 (97)		658 (455)		658 (455)	
AIC	352.54		113.40		1873.43		303.09	

Note. AIC = Akaike information criterion; BMI = body mass index; IFS = Ideal family size. Bold denotes statistically significant *P* values at an alpha of 0.05.

the market town of San Borja is positive and statistically significant (Table S6, column 3). This may indicate a low marginal cost for each child born in excess of paternal and maternal IFS as distance from town increases. Significance of the main association is not mirrored in the WHZ measure, which is considered a more stable measure of weight for this age group (Waterlow et al., 1977). Overall, we do not find consistent evidence of a negative association between exceeding parental IFS and nutritional status across all available indicators; in this high fertility context, exceeding IFS does not appear to have strong negative consequences for child nutrition. Even though ages 2–5 years are a time of increased vulnerability when children are more likely to develop nutrient deficiencies and are at higher risk of consuming contaminated foods (Black et al., 2008), birth order in excess of IFS for either parent does not predict a nutritional difference during these years for Tsimane children.

Investment of scarce resources either in offspring quantity or quality is a fundamental life history trade-off experienced by all species including humans (Mace, 2008; Roff, 1993). In this study, we find that greater distance from San Borja is associated with higher reported paternal IFS (Table S3). Remote Tsimane communities are less involved in the wage economy and experience infant and childhood mortality rates 2–4 times higher than individuals living closer to town (Gurven et al., 2007). From a life history perspective, this may indicate that higher exogenous mortality risk combined with lower human capital investment has contributed to higher fertility ideals targeting a larger quantity of offspring rather than greater individual investment in a smaller number of offspring. Similar results are reported in high mortality areas worldwide (Meij et al., 2009). We estimate a small, positive coefficient for the interaction between exceeding paternal IFS and distance from the market town of San Borja. For Tsimane men, more remote residence is associated with higher IFS and better outcomes for children who are born in excess of those ideals. Better nutritional outcomes for children exceeding IFS in these remote communities may be a result of reduced per child investment costs (e.g., education and clothing). This observation is consistent with theoretical models suggesting that children may represent an asset in more remote areas where a larger quantity of children is favoured over high investment in fewer children (Mace, 2008).

The lag between period fertility and ideals is likely a product of the current level of market integration. The importance of more immediate factors for child nutrition such as maternal BMI as opposed to IFS indicates that the cost of raising undesired children has not yet reached a level that causes household economic strain, precipitating delay, or spacing of childbearing (Davis & Blake, 1956). Further, women's tendency to value traditional skills and hold women with large family sizes in high regard is consistent with previous observations that wealth correlates with family size in small, homogenous populations (Mace, 2008; Mcallister et al., 2012). In the Tsimane context where children are an expression of wealth and the financial cost of raising each additional child in this remote context is (as yet) marginal, exceeding ideals of either parent is not yet associated with nutritional or growth penalties for children in excess of parental ideals (Mace, 2008). This is interwoven with the possibility that at this level of fertility, exceeding stated ideals is not perceived as a disadvantage; instead, stated ideals may reflect flexible preferences that are adjusted upward over age to accommodate a woman's current parity. For this reason, a "moving target" conception of IFS may be more appropriate, in addition to longitudinal measurements of IFS (Lee, 1980). Further, recent studies modify IFS instruments to assess whether women would prefer one more or one fewer child than their IFS, measure second or third preferences, and ask whether preferences change in light of major life changes including HIV status, economic conditions, or other family conditions (Trinitapoli & Yeatman, 2017). Anecdotal discussions with Tsimane women after IFS data were collected also suggest that stated IFS is a relatively weak preference. Nonsignificant associations between IFS and child nutritional status suggest that in this high-fertility, low-resource setting, a mismatch between preferences and behaviour may not be a cause of great concern for parents and hence is not detrimental for child nutrition.

4.2 | Limitations

The Tsimane are a population that is in the process of a major lifestyle transition. Although we find little evidence of cohort changes in age-specific fertility rates (see Data S1), increasing access to contraceptives, formal schooling, and other socio-economic and cultural changes will likely lead to rapid changes in IFS and fertility rates. A central limitation is that we did not systematically interview participants regarding the consequences of having children above or below their stated IFS. Tsimane women may be more concerned about having too few rather than too many children and that their stated IFS may represent a relatively weak "optimum" with a high degree of flexibility. A method that elicits feedback about each potential family size would permit a formal assessment of the perceived costs of not reaching versus of exceeding one's IFS. Wealth was also not measured contemporaneously with anthropometry, which limits the socio-economic controls included in the study. However, the proxies of Spanish fluency and distance to town used here are strongly associated with household wealth among Tsimane (Gurven, Jaeggi, von Rueden, Hooper, & Kaplan, 2015). This study also does not formally consider other factors affected by exceeding IFS. For example, costs of exceeding IFS might be borne on existing children or parents, or other household members rather than children exceeding parental IFS. Alternately, gender composition of siblings (older daughters early in the birth order) might offset some costs of parental care given the high levels of domestic and childcare that older girls contribute to the household. Although we show that children born in excess of stated IFS do not show direct evidence of systematic nutritional shortfalls, it is possible that existing children suffer when new children are born in excess of IFS. This paper includes a large number of statistical tests; however, Bonferroni corrections for multiple comparisons would be too conservative given the correlations among anthropometric measures and between husband and wife IFS. Nonetheless, the lack of strong, negative associations despite the large number of tests bolsters the argument that there is no observed relationship between IFS and child nutritional status at this level of fertility. Finally, measures of child well-being employed in this analysis are limited to broad indices of child nutrition (anthropometrics and haemoglobin) rather than direct measurements of micronutrient consumption, or other measures of parental investment such as school attendance and performance, development, or psychological well-being.

5 | CONCLUSION

In a resource-limited high fertility subsistence population where two thirds of all women exceed their IFS, we find no evidence that birth orders in excess of parental ideals are associated with compromised child nutrition. There appears to be no nutritional penalty for children born in excess of parental IFS, either for infants buffered by breastfeeding in the first 2 years of life or those in the postweaning childhood period where children face significant nutritional and immunological stresses. Tsimane men living in remote communities with higher childhood mortality tend to have higher IFSs, and children living in more remote households pay less of a nutritional penalty (WAZ) if their birth order exceeds paternal ideals. This is consistent with the hypothesis that additional children represent a source of both labour and support in older ages and that exogenous mortality risk increases investment in quantity over quality. Whether exceeding IFS has different effects on child health and well-being in transitioning and low fertility settings where IFS is likely to represent a stronger fertility preference remains to be seen.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

MC conceptualized the study, conducted all statistical analyses, and wrote the paper; MG and BT revised the paper; and MG collected fertility preference data. HK and MG are co-directors of the Tsimane Health and Life History Project.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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