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Child fosterage and sex-biased nutritional outcomes among Namibian pastoralists

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Abstract

Objectives: Across cultures, fosterage has been shown to impact child health. Contextual factors, such as the reason for fosterage and the relationship between foster parent and child, are known to magnify variance in nutritional outcomes for foster children. Another important, but less studied, factor is the role of gender. Sex-biases in physiology and cultural norms are both known to affect child nutrition, and we posit these effects might be magnified in the presence of fosterage. In this study, we investigate how sex interacts with fosterage to affect nutritional outcomes among Namibian pastoralists.

Methods: Anthropometrics for children and adults were collected using standard procedures, and linear models were used to predict the effects of age, sex, and fosterage on height, weight, and body mass index Z-scores. Semi-structured interviews with adults provided context for understanding sex specific reasons for fosterage and biases in investment.

Results: Boys in this population have lower nutritional scores than girls, and fostered boys have lower weight and BMI Z-scores than nonfostered boys. Fostered girls have lower height Z-scores and are more likely to be stunted and underweight than nonfostered girls. These effects extend into adulthood, with fostered women being shorter than their nonfostered counterparts.

Conclusions: Sex plays a role in the nutritional impact of fosterage among Himba children. These differences could be related to differential child labor demands, investment patterns, and the divergent reasons girls and boys are placed into fosterage. Future studies should consider how fosterage can magnify existing biases, like sex, when studying its impact on child health.

1 | INTRODUCTION

The custom of rearing nonbiological children, or fosterage, is a worldwide phenomenon, occurring for a variety of reasons and at different frequencies depending on local cultural norms (Isiugo-Abanihe, 1985). In some cases, children are fostered because of a negative shock, such as parental death, while in others fosterage may involve shifting a child from a household with fewer resources to one that is better off. Fosterage may also be used to form or reinforce alliances between families, or with individuals of a higher social class. Therefore, it is not surprising that the effects of fosterage on child health are quite variable. Children who are fostered because of parental death or other forced circumstances often fare worse than those fostered for other reasons (Castle, 1995; Madhavan & Townsend, 2007; Monasch & Boerma, 2004; Oleke, Blystad, Moland, Rekdal, & Heggenhougen, 2006). In addition to the reason for fosterage, other demographic factors have also been shown to interact with fosterage to affect child health. For example, the age of the foster child (Bledsoe, Ewbank, & Isiugo-Abanihe, 1988), the kin relationship between the child and the foster parent (Oleke et al., 2006), and the occupation and level of education of the mother (Klomegah, 2000) have been shown to account for some of the variation in child outcomes. Another important, but relatively understudied factor that may affect how fostered children are treated, and how they fare, is their sex. To demonstrate this, we first review the evidence that sex is a known predictor of variation in children's nutritional outcomes. We then make the case that fosterage might interact with sex in important ways.

There are multiple reasons to expect sex differences in children's nutritional outcomes. The first is that boys and girls have diverse nutritional requirements, which may make them differentially susceptible to malnutrition. Between ages one and ten, the World Health Organization recommends boys consume an average of 118.4 more calories per day than girls and for children who have high levels of physical activity, the difference rises to 156.3 calories daily (World Health Organization (WHO), 2004). These recommendations are based largely on differences in average body weight, which is a predictor of energy requirements. Boys also have a higher basal metabolic rate than girls, beginning in middle childhood (Garn, Clark, & Harper, 1953). In addition, some studies have shown physical activity levels to have a more substantial effect on body fatness in boys than girls (Ball et al., 2001; Ku, Shapiro, Crawford, & Huenemann, 1981), a sex difference which is also common among adults (Westerterp & Goran, 1997). As puberty approaches and boys begin to acquire a higher proportion of lean body mass than girls, caloric requirements continue to differ, with boys requiring more energy to support their more muscular frames (Tanner, 1971). There is also some evidence that boys are more sensitive to environmental stress. For example, studies have shown that, compared to girls, boys suffer slower rates of maturation (Bogin, Sullivan, Hauspie, & Macvean, 1989) and reduced growth (Malina, Little, Buschang, DeMoss, & Selby, 1985) in more resource-stressed environments. Also in support of the prediction that boys are more sensitive to environmental change than girls, a study of Polish children showed that boys show greater improvement than girls when environmental conditions improve (Bielicki & Charzewski, 1977).

With their increased caloric needs and higher susceptibility to environmental stress it is perhaps unsurprising that large-scale studies of nutritional status show that boys are at higher risk of malnourishment than girls (Svedberg, 1990; Wamani, Åstrøm, Peterson, Tumwine, & Tylleskär, 2007). Fosterage has the potential to magnify these sex differences, because of its effects on both energy intake and energy expenditure. Fostered children may be expected to work more than those living with their biological parents, or have less access to food. In addition, fosterage can coincide with emotional or environmental stress, when it is due to the death of a parent or when a child's relative position in the household declines. In cases where these factors matter, boys may be expected to suffer more from fosterage than girls.

In addition to physiological differences between the sexes, cultural and behavioral biases can also lead to differential investment in boys and girls, which in turn can affect child nutrition (Svedberg, 1990). Whereas in many cultures sons experience better nutrition and reduced mortality (Behrman, 1988; Klasen, 1996; Sen & Sengupta, 1983), in others daughter-biased investment results in better nutritional outcomes for girls (Cronk, 2000; Gillett-Netting & Perry, 2005). Still other studies find no sex differences (Gray, Wiebusch, & Akol, 2004; Quinlan, Quinlan, & Flinn, 2003). Where patterns of parental investment are biased toward one sex, it is reasonable to expect that these patterns might extend beyond biological children to those who are fostered. Some evidence of this exists. In West Africa, girls were more likely to be fostered than boys and tended to stay longer in foster care, which is thought to be due to the stronger emotional attachment parents have to their sons, and to the gendered division of labor, which makes girls more desirable to foster parents (Isiugo-Abanihe, 1985). Another study in Sierra Leone shows that fostered girls were less likely to receive medical treatment than their male counterparts, and they were more likely to be diagnosed as malnourished when care was sought (Bledsoe et al., 1988). Once again gendered expectations about domestic labor and proximity to the homestead appear to bear negatively on the nourishment of girls in this context. On the other hand, in a matrilineal society in Thailand where daughter preference is common, focus group interviews reveal that more care is often taken in choosing foster parents for girls to assure they will be well cared for (Taylor, 2005). These sex-biased outcomes are likely the result of the differential economic value of boys and girls between groups and the direction of sex-biased norms on either expected workload or access to resources (Svedberg, 1990). Following these studies, we expect fosterage to amplify these relationships, with the sex who experiences less investment or higher work requirements showing greater within-sex differences between those who are fostered and those who are not.

In this study, we investigate how sex-biased investment and work requirements, and differential physiology modulate nutritional outcomes among the Himba, a semi-nomadic pastoralist group in Namibia. Sex differences in nutritional outcomes are measured for both fostered and nonfostered children. Ethnographic data on divisions of child labor and investment biases are used to contextualize the quantitative findings. Additionally, we compare the effects of fosterage on adult anthropometrics, to see whether the effects of fosterage on growth extend into adulthood.

2 | STUDY POPULATION

The Himba are a semi-nomadic pastoralist group living in the northwest corner of Namibia. The vast majority of their diet continues to be subsistence-based, and they have minimal integration with the market economy (Bollig, 2006). In addition to caring for large and small stock, their diets are supplemented by garden products, mainly maize and various melons and gourds. Children are expected to assist with productive and reproductive labor from the time they are 5–7 years old, sometimes even younger. Young girls help with child-care, cooking, and as they age and acquire more physical strength and stamina, grinding maize and fetching water, and firewood. The main task of young boys is to look after goats, which requires them to be absent from the household compound for much of the day.

Himba parents do not convey overt biases about gender preferences, instead expressing the importance of having both sons and daughters. They do, however, report a skewed sex ratio after birth, which favors females. Himba claim that this occurs because of higher infant and child mortality in boys. These statements have yet to be corroborated with a large-scale analysis of quantitative data, as Himba women are generally reticent to discuss the details of infant deaths. However, census data from 22 compounds support the claim that boys are underrepresented in the 0–10 age group, with a sex ratio of 89.8/100 ($n = 205$, unpublished data). This same phenomenon of excess male mortality without strong cultural norms of biased investment has also been reported among the Herero, who are culturally and phylogenetically closely related to the Himba (Harpending & Pennington, 1991) and in Sub-Saharan Africa more generally (Svedberg, 1990; Wamani et al., 2007).

Fosterage is very common among the Himba (Scelza & Silk, 2014). In Otjihimba, the term *okukurisa omwatje womukwenu* ("taking care of someone else's child") is used to describe fosterage. Unlike adoption, children who are fostered typically maintain contact with their parents, and biological and social parentage are distinct. For example, even if a child was fostered from birth (if say her mother died in childbirth) that child would not refer to her foster-parent as "mother." Of 182 adults interviewed, 29% of women and 42% of men reported being raised by someone other than their biological parents. These rates are very similar to the 40% reported among Herero (Harpending & Pennington, 1990). Male rates are likely higher because men marry 5–15 years later than women and individuals reported being fostered if they lived with someone other than their mother at any point before marriage. Fosterage occurs for a variety of reasons, including the death of a parent, short inter-birth interval, large number of children, remarriage of the mother, and requests for help from relatives who have few children in their household (Scelza & Silk, 2014).

3 | METHODS

Anthropometric data were collected on 210 children between the ages of 2 and 20. Of these, 80 (38%) were currently in fosterage while 130 were being raised by either their mother alone or by two parents (mother and father, or mother and step-father). Although demographic definitions of fosterage differ across studies, here children were considered to be fostered if they were being raised by someone other than their biological mother. This is because in cases where children were living with their fathers, it was another woman in the household (typically a paternal grandmother or aunt) who was responsible for the bulk of child rearing. These data were collected between 2010 and 2012. Where a child was measured multiple times, only the most recent weight and height were analyzed. All measurements were taken during the dry season, though the 2012 set of data occurred after the time rains typically begin. A digital SECA medical scale with fixed stadiometer was used for all measurements. All children were weighed with minimal clothing and without shoes. At or before the time of measurement, adult caretakers were asked to age each child using the local system of year names (see Scelza, 2011 for details), to assert who was currently raising the child, and if they were in fosterage to describe the circumstances of the transfer (reason for fosterage and the biological relationship between the child and the foster parent). In a few cases where the child was old enough to explain their own circumstance and no caretaker was present, the child was asked directly. In addition to the child data, heights and weights from 252 adults (average age = 42) were collected between 2010 and 2016 using the same procedures. If multiple measures were taken per individual, only the most recent were used. Weights taken when women reported they were pregnant were discarded.

Z-scores for body mass index (BMI-Z), weight-for-age (WAZ), and height-for-age (HAZ) were calculated for the child sample using macros in R 3.3.2 (2016) provided by the World Health Organization, which uses growth data from a large, cross-cultural sample to estimate growth trajectories (World Health Organisation (WHO), 2006). This software does not include WAZ calculations for children older than 10, because the pubertal growth spurt can be easily misinterpreted, so a subset of the full data was used for this variable ($n = 176$). Improbable Z-score results are automatically flagged by the software, and were subsequently removed for analysis. For adults, of the 252 individuals, 243 had both height and weight for a given measurement year, so these individuals were used to calculate BMI.

To estimate the effects of sex and fosterage on each Z-score outcome, Bayesian linear models were utilized to estimate the effects of standardized age, sex, and fosterage. Interaction terms for sex and fosterage were included in all models. Similarly, binomial regressions were used to estimate the role of these covariates in predicting children with Z-scores less than 2 standard deviations below the mean to predict stunting (low HAZ), wasting (low WAZ), and thinness (low BMI-Z). Additionally, linear models were used to predict standardized adult height and BMI from standardized age, sex, fosterage, and the interaction of sex and fosterage using the adult sample. See Supporting Information for full model details and plotted posteriors (Supporting Information Figures S1–S3). Analyses were run in R 3.3.2 (2016) using the *rethinking* package (McElreath, 2016). All models utilized weakly normalizing priors with a warm-up sequence of 1000 iterations followed by 5000 iterations using four chains. Convergence was assessed via visual inspection of Markov chains and use of Gelman-Rubin convergence diagnostic ($\hat{R}=1$ in all model parameters). To determine the influence of each parameter, posterior means and prediction intervals as well as density plots of posteriors are reported (see Supporting Information). Here, 89% prediction intervals are used to avoid confusion with significance tests, and because they are standard with the statistical package (McElreath, 2015). Additionally, to determine differences between sex and fosterage categories, we calculate the percent difference in posterior distributions greater than zero (for larger group minus smaller group), independent of age for each model, as well as the mean and percentile interval of the difference in groups (see Supporting Information Tables S2 and S3).

To assess general fosterage and investment patters, semi-structured interviews were conducted with 183 adults (120 female, 63 male). These interviews were conducted in the native language of the Himba (*Otjiherero*) and translated instantaneously by a native speaker so that follow-up questions could be asked. All quotes are from direct translations provided during the interviews. Recruitment for interviews differed for men and women. Women were recruited during visits to 23 households in 2010 and all adult women were eligible for inclusion. Men were interviewed mainly at large ceremonies where many families were gathered together, with some additional interviews conducted during household visits in 2011. Relationships between sex and reason for fosterage were assessed via Bayesian test of association (Gunel & Dickey, 1974) using the *BayesFactor* package with default priors and Poisson sampling (Morey & Rouder, 2015). All data were collected in accordance with the UCLA Office of Human Research Protection (IRB#10-000238).

4 | RESULTS

Similar numbers of boys and girls were fostered in this sample (33.9% of boys versus 42.6% of girls); however, sex ratios varied according to the reason for fosterage (Table 1). Girls were fostered most often when mothers had many children or short birth intervals, whereas boys were more likely to be fostered when their mother remarried or had the child out-of-wedlock. A higher percentage of girls (22%) were also fostered out for labor assistance than boys (15%).

Compared to children in the US, Himba children are generally small for their age, with both weights and heights falling between the 5th and 50th percentiles of the CDC 2000 growth charts (Scelza & Silk, 2014; Figure 1). However, compared to other pastoralists, Himba children fare relatively well (Little, Galvin, & Mugambi, 1983; Sellen, 2000). Girls appear to show more catch-up growth near puberty, with mean values for height and weight reaching or exceeding the 50th percentile by about 12 years of age. Boys' growth is more stable, with mean height and weight remaining in the bottom 50% throughout both childhood and adolescence.

Results from the linear models indicate significant differences between gender and fosterage categories (see Table 2 and Supporting Information Table S1). Boys have lower mean HAZ and WAZ than girls, although sex appears to have no impact on BMI Z-scores (percent difference in posterior distributions are 99.4%, 97.3%, and 62.1% respectively). Fosterage negatively impacts nutritional indices in sex specific ways. Predicted effects of sex and fosterage are shown in Figure 1. Although fostered girls have lower HAZ and WAZ scores relative to nonfostered girls, only HAZ is substantially different (see Table 2). Fostered boys experience decreases in all three indices compared to nonfostered boys, but the difference in BMI-Z is greatest (see Table 2). Just as boys generally fare worse than girls, so too do fostered boys, compared to fostered girls, with lower predicted HAZ, WAZ, and BMI-Z (88.6%, 99.0%, and 99.5% difference in posterior distributions respectively, Supporting Information Table S2). When we compare the effects of fosterage on girls versus boys, girls are at greater risk of chronic nutritional stress (girls lose an estimated 0.6 HAZ when fostered compared to 0.35 in boys), whereas boys are at greater risk of suffering acute stress (boys lose 0.33 WAZ when fostered, compared to 0.11 for girls, and 0.47 BMI-Z compared to 0.07 for girls)

Similarly, results of the binomial regression models that focus on cases of clinical malnutrition indicate that, overall, boys have a higher likelihood of being stunted, wasted, and thin (98.2%, 98.6%, and 97.2% difference in posterior distributions respectively). Additionally, relative to nonfostered boys, fostered boys are more likely to suffer from stunting and thinness (94.8% and 89.1% percent difference in posterior distributions respectively). For girls, fosterage substantially increases the likelihood of stunting and wasting (Table 2). Indicators of chronic malnutrition are in line with the previous results; fostered girls are more likely to suffer stunting than fostered boys (18.34% difference in absolute odds for fostered compared to nonfostered girls compared to an 11.99% difference for boys). However, whereas the overall comparisons show fosterage is associated with greater

TABLE 1 Reasons for fosterage

	Boys $N = 33$	Girls $N = 36$	Difference in Posterior
Parental Death or Sickness	8 (24%)	5 (14%)	79.0%
Short IBI/Too many children	8 (24%)	16 (44%)	94.7%
Remarriage/Out-of-wedlock birth	11 (33%)	4 (11%)	95.9%
Fosterer requested help	5 (15%)	8 (22%)	77.7%
Keeping up family relations	1 (3%)	3 (8%)	81.0%

Bayes factor = 9.67 in favor of nonindependence in gender by reason for fosterage. Difference in posterior represents the percent difference in posteriors greater than zero (for higher group—lower group).

decreases in WAZ for boys, model results predicting wasting show that fosterage places girls at greater risk (95.7% difference in posterior distributions for girls, compared to a 22.4% difference for boys). Conversely, fostered boys are more likely to suffer from thinness relative to fostered girls (97.8%). Model results are plotted in Figure 2.

Models of the adult data indicate that the effects of fosterage on height, but not BMI, extend into adulthood (see Supporting Information Figure S4). Comparison of the percent deviation of the posterior distributions indicates that fosterage negatively impacts standardized adult height in males (91.9%) but particularly in females (97.5%), with fostered women having an estimated decrease in height of 2.15 cm relative to their nonfostered counterparts.

5 | DISCUSSION

Fosterage status and sex both have important effects on nutrition among Himba children. In general, boys experience lower mean Z-scores and increased risk of suffering from both chronic malnutrition and thinness. Fosterage also has generally detrimental effects on children's nutritional status,

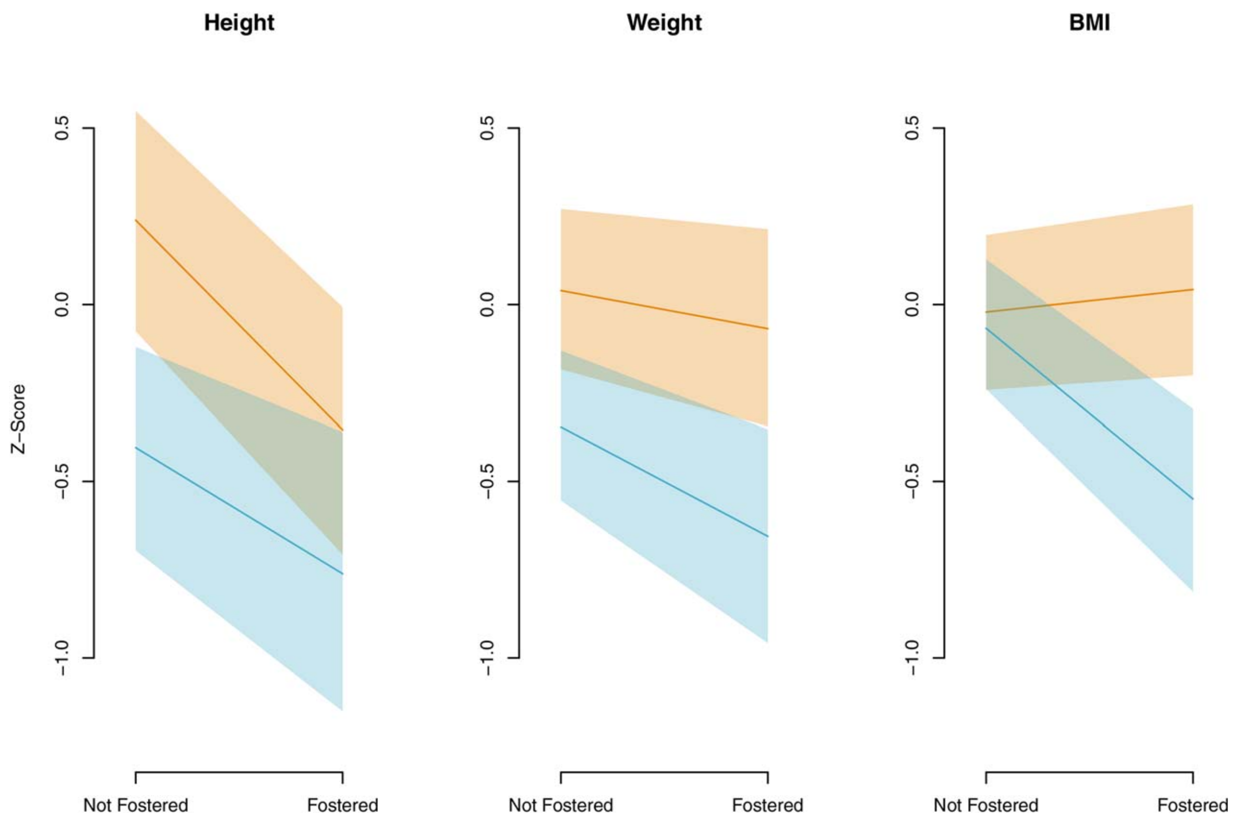

FIGURE 1 Counterfactual plots illustrating the effect of fosterage on Z-scores in Himba children. Males in blue, females in orange. Lines and shading represent posterior means and 89% percentile intervals respectively

TABLE 2 Effects of fosterage by sex

	Males		Females	
Model results for Children	*Fostered*	*Not Fostered*	*Fostered*	*Not Fostered*
Sample size	37	72	43	58
Age (year)	7.00 (4.56)	5.65 (4.54)	8 (3.96)	6.52 (4.07)
Height-for-age Z-score	−0.751 (1.41)	−0.425 (1.56)	−0.333 (1.46)	0.246 (1.38)
Z-score effect of Fosterage/Sex	−0.35/–0.4	0.35/–0.65	−0.6/0.4	0.6/0.65
Difference in Posterior Distributions	87.4%		97.8%	
% > 2 S.D. below the mean	24.3%	13.9%	20.9%	3.4%
Absolute odds of Fosterage/Sex	11.99%/2.25%	−11.99%/8.6%	18.34%/–2.25%	−18.34%/–8.6%
Difference in Posterior Distributions	94.8%		99.9%	
Weight-for-age Z-score	−0.677 (0.79)	−0.304 (1.09)	−0.101 (1.05)	−0.031 (1.03)
Z-score effect of Fosterage/Sex	−0.33/–0.6	0.33/–0.38	−0.11/0.6	0.11/0.38
Difference in Posterior Distributions	91.9%		69.8%	
% > 2 S.D. below the mean	3.3%	8.2%	5.9%	0%
Absolute odds of Fosterage/Sex	−3.22%/–1.96%	3.22%/5.11%	3.84%/1.96%	−3.84%/–5.11%
Difference in Posterior Distributions	77.6%		95.7%	
BMI Z-score	−0.57 (1.17)	−0.02 (0.94)	−0.03 (1.05)	−0.02 (0.96)
Z-score effect of Fosterage/Sex	−0.47/–0.49	0.47/0.05	0.07/0.49	−0.07/–0.05
Difference in Posterior Distributions	99.0%		62.8%	
% > 2 S.D. below the mean	10.8%	4.2%	2.3%	0%
Absolute odds of Foserage/Sex	4.77%/6.76%	−4.77%/2.62%	0.62%/–6.76%	−0.62%/–2.62%
Difference in Posterior Distributions	89.1%		81.1%	
Model results for Adults				
Sample Size	35	65	40	112
Age (year)	40.5 (14.9)	43.4 (17.6)	39.0 (16.3)	42.8 (17.2)
Average Height (cm)	174.2 (6.1)	175.9 (6.9)	162.4 (5.9)	164.4 (5.5)
Effect of Fosterage	−1.82	1.82	−2.15	2.15
Difference in Posterior Distributions	91.9%		97.5%	
Average BMI	22.9 (3.1)	22.6 (3.2)	24.3 (4.2)	24.3 (3.7)
Effect of Fosterage	0.29	−0.32	0.18	−0.18
Difference in Posterior Distributions	66.2%		60.2%	

Means (and standard deviations) for variables of interest, followed by percent of sample that fall below −2 for each Z score category. Absolute odds indicates the absolute odds percent change of being below −2 for each Z score category relative to fosterage status and sex. Difference in posterior indicates the percent difference in posterior distributions for the larger group minus the smaller group above zero. See Supporting Information Tables S3 and S4 for distribution of differences.

increasing the probability of acute and chronic malnutrition. These results match with reports from some Himba about their fosterage experiences. Despite stated norms for treating fostered and biological children equally, Himba report favoritism toward biological children in the distribution of food and gifts. One man stated, "It is different when you are raised by someone else. They may not treat you well. When they bring food or a treat, first they give it to the biological children, not to you."

Fostered children fare worse than nonfostered children in most nutritional outcomes. However, these children may still be faring better than they would have if they had remained in their natal homes. Significant sex differences in the effects of fosterage indicate that, while fostered boys are more likely to have lower HAZ and WAZ, fostered girls are more likely to be categorized as malnourished (stunted and wasted), relative to their nonfostered counterparts. Additionally, results from the adult sample indicate that these effects stretch into adulthood, with fostered adults, and particularly women having lower standardized height when fostered. These results highlight two phenomena that therefore need to be explained: why do Himba boys suffer more than girls, and why is

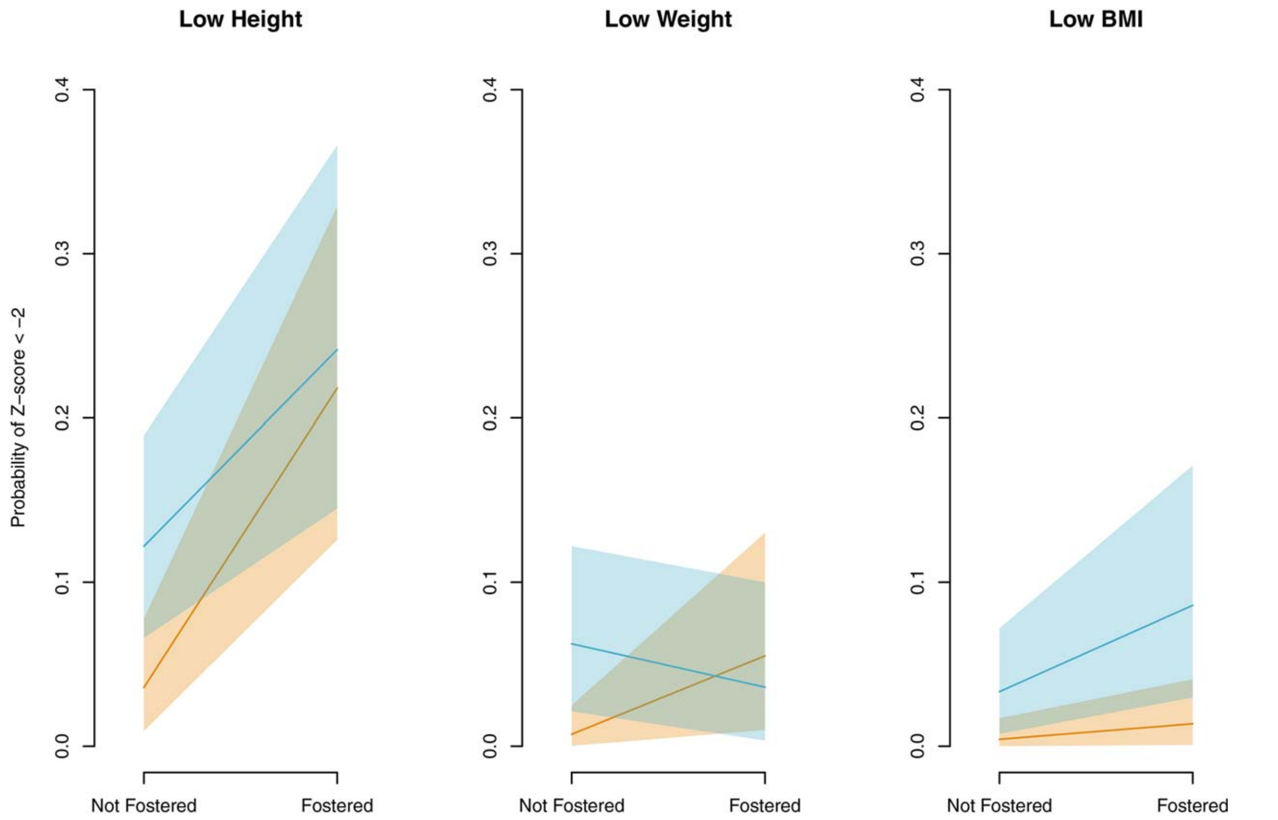

FIGURE 2 Counterfactual plots illustrating the effect of fosterage status in the probability of Z-scores falling below −2 in Himba children. Males in blue, females in orange. Lines and shading represent posterior means and 89% percentile intervals respectively

fosterage associated with more severe nutritional deficiencies for girls?

5.1 | Why do himba boys fare worse than girls?

In sub-Saharan Africa, it is not uncommon for girls to exhibit higher indices of nutrition (Wamani et al., 2007). This trend, which stands in stark contrast to South Asia where girls are typically at a nutritional disadvantage, is thought to be linked to the importance of female labor and the trend toward bride-price rather than dowry, further increasing women's economic value (Svedberg, 1990). These factors may be associated with better treatment for daughters, including advantages in health-care utilization and intra-household resource allocations. The findings here, that boys have lower WAZ and HAZ than girls, may therefore result from similar patterns of differential investment.

There are several potential causes of differential investment that may play a role among the Himba. The first is an imbalance in the division of childhood labor. Himba girls are expected to take on many more tasks than boys, and the work that they do is less substitutable. For example, girls can help with herding and milking goats if there are no boys available, but it is extremely rare to find a boy taking on jobs like grinding maize or cooking. The added value of female labor may lead to improved treatment of girls from a very young age. While Himba do not overtly express bias against boys, they do note that girls are seen as more valuable contributors to the household. One woman notes, "Young girls, they work harder [than boys]. They collect ash from the house, collect firewood, grind maize. Even when you are this big (points to an 8 year old girl) you can grind maize as well as an adult. Some adults are lazy, but girls they work hard, they can grind even more."

While girls may hold more economic value in Himba households, differences in the types of work boys and girls do could also contribute to boys' nutritional deficits. From a very young age, boys' main economic task is to herd sheep and goats. This can take them away from the compound for large parts of the day, without ready access to prepared meals. Because food is eaten communally by whichever children are at home at the time of serving, and occurs during the day as well as in the evening, boys who are out herding may be more likely to miss mid-day meals than girls. These boys may be able to drink from the goats they are herding, but they have reduced access to caloric staples like maize-meal and other garden products. Conversely, the food-centric tasks that are the primary responsibility of girls (including milking and grinding maize) allow them to stay closer to home throughout the day, and may also allow supplemental snacking outside of main meals, resulting in increased caloric intake overall.

In addition to differential workloads and caloric intakes, there are other factors that may be contributing to the sex differences in nutritional outcomes seen here. For example, disease burden has been consistently shown to be associated with an increased risk of malnutrition (Green, 1999). If boys are more susceptible to disease in this population, due to the effects of androgens (Muehlenbein & Bribiescas, 2005), because they are more sensitive to environmental stressors (Malina et al., 1985), or because they are cared for differently (a possibility, despite the spoken norms about child gender equality), this could explain why Himba boys are at greater risk of malnutrition than girls. The Herero, who are genetically and culturally similar to the Himba, also show male biases in childhood health, with boys more likely to suffer from infant and child mortality than girls (Harpending & Pennington, 1991). The significantly female-biased sex ratio in the 0–10 age group among the Himba points to the possibility that the results shown here actually underestimate sex differences in boys' and girls' nutritional status, as the most vulnerable boys may have succumbed to disease.

5.2 | Why do girls fare worse when fostered?

Although Himba boys fare worse than girls overall, fosterage has more severe effects on girls. Compared to their nonfostered counterparts, fostered girls are at greater risk of stunting and wasting than are fostered boys. These differences continue into adulthood, with fosterage having a greater impact on height in women versus men. To understand these patterns, the value of girls' work now needs to be viewed within the context of fosterage. Whereas, overall, girls may benefit from being viewed as key contributors to the household, this same value may place them at greater risk when they are fostered. To understand this pattern, we must look at how household demographics interact with the probability of being fostered. Himba girls' work ranges from low energy tasks such as passive child-care and cooking to vigorous activities such as grinding maize and fetching water and firewood. Which tasks a particular girl takes on depend on her age and the number of other women and girls in her household. Where a girl has fewer female counterparts, her labor burdens are likely to be higher.

There is some evidence to suggest that Himba use fosterage as a way to make up for these kinds of labor shortfalls, and this pattern is particularly apparent for girls. For example, girls are more likely to be fostered out to help a family member than are boys (Table 1). Girls are also more likely to be fostered out when mothers have too many children or births that are too closely spaced together. In these cases, mothers who have large families and therefore plenty of child labor in the household, might foster out a daughter to a family member in greater need. Complementary to these findings, previous research has shown that Himba women with few daughters are more likely to foster in girls, while the reverse pattern is not true of boys (Scelza & Silk, 2014). When girls are fostered into male-biased households they may have greater labor burdens placed on them, which could then place them at higher risk of malnutrition.

These factors appear to play a lesser role in the fosterage of boys, who may be seen as more of a burden than a help to the families they are fostered into. The most common reason for fostering a son is because his mother remarries. While her new in-laws may view bringing in daughters from previous relationships either neutrally or positively, sons may be seen as costly, and therefore get left behind.

5.3 | Limitations and future directions

While it is likely that nutritional differences between the sexes are multi-causal, these data clearly show two sex-linked outcomes, that boys are more likely to suffer in this population than girls, and that fosterage has more detrimental effects on girls than boys. However, these data are cross-sectional, and a longitudinal perspective would yield more information about the causes and timing of the nutritional effects of sex and fosterage. Additionally, the current analyses predicting the probability of stunting, wasting, and thinness suffer from small sample sizes in some categories, resulting in relatively wide prediction intervals. Larger datasets with larger sample sizes in these categories would more clearly illuminate the interaction between fosterage and sex on malnutrition.

Future analyses on the causes and effects of sex biased health outcomes due to fosterage would benefit from more detailed measures of energy intake and expenditure. Utilization of physical activity measures, including accelerometry devices, activity recall, or reporting the frequency of household tasks, will yield better insight into the effects of sex differences in household tasks. Observational data, including focal follows and detailed analyses of food intake, could similarly be used to determine whether different types of work (e.g., herding vs cooking) result in differential access to food. Inclusion of additional measures of health beyond anthropometrics may yield data on other health costs of interest, including variation in physiological stress, immune function, and disease. One main insight that these studies could provide would be to parse out the effects of energy intake and energy expenditure.

Finally, further delineating the reasons why children are fostered would also be useful. There were some cases where multiple reasons for fosterage were cited (e.g., "births closely spaced" and "keeping up relations"). For these analyses, the primary reason for fosterage was used (in the preceding example, this response would be coded as "Short IBI"). However, this likely undervalued the effects of "help" and "family relations," factors that are more likely to be determined to be secondary, as they affect who the child is fostered to as much as why the child was fostered. Further studies could explore fosterage as a multi-layered decision that looks separately at the initial decision to foster and then subsequently at where to place the child. More data on household composition, and relatedness between foster child and foster parents may yield additional information on the type, direction, and severity of the health effects of fosterage. In particular, the gender and age of the children already living in the household should moderate the effects of energy expenditure, which in turn could impact foster child health. For example, a girl fostered into a household with mostly boys may fare worse than one with mostly girls with whom she can partition productive labor.

6 | CONCLUSION

The interaction between sex and fosterage status, which has been the focus of this article, is but one example of how decisions about child-care exist within a complex biocultural milieu. Pre-existing biological differences between the sexes likely account for the finding that Himba boys are at greater risk of malnutrition than girls, and fosterage magnifies these effects. However, the relative effects of fosterage are greater for girls, who, compared to boys, show increased probability of malnutrition when fostered. One possible explanation for this trend is that girls' labor, the value of which may have a protective effect when she is living with her parents, becomes a detriment when girls are fostered. By shifting girls into households where the demands on their labor are higher, fosterage may result in increased susceptibility to malnutrition. Further studies that track energy intake and expenditure, mapped onto observational data about the childhood division of labor, could further illuminate these patterns.

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SUPPORTING INFORMATION

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