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Anthropometric Indicators of Children and Young Adults and Rainfall in a Native Amazonian Society of Bolivia

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ABSTRACT Culture evolved to help people adapt to their environment, but when culture cannot buffer the person against environmental adversity, anthropometric indicators might adaptively change to afford protection. To assess phenotypic variability in relation to climate variables, we link anthropometric, demographic, and socioeconomic data from *(a)* 266 females and 293 males ages 3-20 and *(b)* their parents with *(c)* local rainfall records during 1943-2005. Data comes from a native Amazonian society of farmers-foragers in Bolivia (Tsimane'). We estimate the relation between anthropometric indicators (outcome) and: *i)* amount and coefficient of variation (CV) of rainfall during subject's gestation (age 0), birth year (age 1), and age 2-4, *ii)* ethnobotanical knowledge of each parent, and *iii)* rainfall amount and CV when parents were 2-4 years old. For each sex we regress separately height, weight, and BMI on *i-iii* and other covariates. Rainfall during birth year did not affect outcomes, but rainfall during gestation and age 2-4 was associated with lower height, particularly among females. Rainfall during age 2-4 was associated with increased weight and BMI. Parental ethnobotanical knowledge bore no significant association with offspring nutritional status. Rainfall had trans-generational effects; rainfall while fathers were 2-4 years old bore a positive association with anthropometric indicators of daughters. By lowering height and increasing weight and BMI, rainfall might give the body energy reserves to cope with environmental adversity, trigger earlier menarche, and lock females into lower final adult height.

Central to anthropology is the tenant that small-scale, kin-based, horticultural and foraging societies (hereafter pre-industrial societies) adapted to their habitat by developing a cultural tapestry that included institutions, norms, local knowledge of the environment, and technology (Johnson and Earle, 2000; Steward, 1955). The cultural tapestry generally buffers the person against environmental adversity, but when it cannot, anthropometric indicators might adaptively change to afford protection (Wilson, 1994; Worthman and Kohrt, 2005), or be perturbed from adaptive developmental tracks. Changes in anthropometric indicators from environmental adversity are most likely among vulnerable groups with fewest resources, such as children (Bogin, 2001; PCH, 2004), particularly boys (Leonard, 1991; Stinson, 1985).

Pre-industrial societies vary in how well they protect people from environmental adversity (Cashdan, 1990). Wiessner (1986, 2004) describes how the flood of 1974 in the territory of the Ju/'hoansi !Kung destroyed foraging but did not undermine nutritional status because foragers migrated to live with exchange partners residing beyond the area destroyed by the flood. Dirks (1980) provides a cross-disciplinary review of the cross-cultural literature on social responses to famines and finds much variation in the use of sharing and reciprocity across time and cultures. Reliance on sharing and reciprocity increased as food supplies started to decline, but plummeted as food disappeared. In the Amazon shamans often acted as a safety net, offering food, shelter, and advice during droughts and floods (Huanca, 2007; Sugiyama and Chacon, 2000).

Despite several ethnographic descriptions of how pre-industrial societies cope with environmental adversity, we have few quantitative estimates of how well those strategies work and whether they work equally well for females and males. Here we use rainfall and survey data from a native Amazonian society of farmers and foragers in Bolivia (Tsimane') to achieve four aims. *First*, we estimate the relation between *(i)* anthropometric indicators of nutritional status of people 3-20 years of age and *(ii)* rainfall amounts and variability during three stages in their life cycle: *(a)* gestation (age 0), *(b)* birth year (age 1), and *(c)* age 2-4. In so doing we assess how the body responds to rainfall perturbations. *Second*, we assess whether parental indigenous knowledge of plants (hereafter ethnobotanical knowledge) protects offspring nutritional status from rainfall perturbations. *Third*, we estimate the association between rainfall while mothers and fathers were 2-4 years old with the anthropometric indicators of their offspring. In so doing we assess the trans-generational effects of rainfall perturbations. *Fourth*, we compare how female and male anthropometric indicators respond to rainfall perturbations.

To achieve the aims we build on several lines of research. *First*, we build on research from industrial nations suggesting that events during gestation and infancy leave an imprint on health throughout life (Barker et al., 2002; Behrman and Rosenzweig, 2004; Cruickshank et al., 2005; Doblhammer and Vaupel, 2001). We have no reason to think pre-industrial societies will differ. *Second*, we draw on findings from panel studies in industrial nations suggesting that adverse environmental and socioeconomic events have trans-generational effects on health (Case et al., 2005; Hypoonen et al., 2004; Pembrey et al., 2006). *Third*, we draw on research in developing nations and among foragers suggesting that people generally protect well health against mild adverse mishaps that strike only the individual, but not against environmental adversity when it strikes a large area and many communities (Gertler and Gruber, 2002; Sugiyama and

Chacon, 2000). We expect the same in a pre-industrial society. *Fourth*, we test the ethnographic observation that ethnobotanical knowledge protects nutritional status against environmental adversity (Colson, 1979; Dirks, 1980). *Fifth*, we build on findings from studies of part-time foragers and smallholders in developing nations suggesting that environmental adversity produces larger changes in anthropometric indicators among females than males (Godoy et al., 2007; Maccini and Yang, 2006; Rose, 1999).

METHODS

Population

In recent articles we provide background information on the Tsimane' and show that Tsimane' children resemble other native Amazonian children in growth stunting (Foster et al., 2005; McDade et al., 2005). Among Tsimane', growth stunting results from the prevalence of parasitic infections and poor dietary quality (Tanner, 2005). Previous studies with the Tsimane' suggest that parents protect well the nutritional status of their children against mishaps unique to the person or household (Godoy et al., 2006c), and that protection from such mishaps works equally well for girls and boys (Godoy et al., 2006b). In a recent study we found that rainfall variability during ages 2-4 bore a negative association with adult height, but only among women (Godoy et al., 2007). A 10% increase in the coefficient of variation (CV hereafter) of rainfall during ages 2-5 was associated with 0.7-1.2% lower height among adult women (1.08-1.93cm). We found no significant and large association between own ethnobotanical knowledge and height.

We build on our previous work by: *(a)* studying the effect of rainfall on youth rather than adults, *(b)* using other anthropometric indicators (weight and BMI) besides height to gain a fuller understanding of how rainfall might affect nutritional status, and *(c)* estimating sex-specific trans-generational effects.

Sample and measures

Data for subjects comes from a panel study in progress that started in 1999 in 13 Tsimane' villages along the Maniqui River, Department of Beni, Bolivia. The villages differed in their proximity to the town of San Borja. The average village in the sample was 25.96 Km in a straight trajectory from San Borja (SD=16.70). With a population of ~19,000 people and a local airport built during the 1930s, San Borja is the most important market town and administrative center for the Tsimane' along the Maniqui River.

We use data from the 2005 survey, which occurred during June-September, and included all people in all households (n=252) of the 13 villages. The sample of people 3-20 years old (mean=9.01; SD=4.60) with complete data about themselves and their parents included 266 (non-pregnant) females and 293 males; these subjects were born during 1985-2002. Since we estimate the link between rainfall during ages 2-4 and anthropometric outcomes and the survey occurred in 2005, our youngest subjects had to be at least three years old (born 2002); for them we had rainfall data for 2003-2005. Surveyors who worked in the panel study since its inception collected data.

Elsewhere we describe how we measured height, weight, and BMI (Foster et al., 2005; McDade et al., 2005). We measured ethnobotanical knowledge among people age 16+ (or younger if they headed a household). To measure knowledge we collected similarity judgments using a multiple-choice test of 15 plants selected at random from a list of 92 plants developed in an earlier study (Reyes-García, 2001). In the test we asked subjects whether they could use plants for food or medicine. We used cultural consensus (Romney et al., 1986) to estimate the most common answer among people age 55+, and used the latter to calculate individual knowledge scores (Reyes-García et al., 2003, 2005).

We asked adults about their age and maximum school attainment, and we asked the principal caretaker about the maximum school attainment and age of children <16. We used age to estimate birth year, and birth year to link personal data with rainfall data. Elsewhere we show that reported age had random measurement errors, particularly among people age 5+, who were born before the start of the panel study (Godoy et al., 2007). Because of measurement error we did not use age-standardized anthropometric indicators. The error will also produce an attenuation bias in the coefficient of rainfall variables because we used birth year to link personal data with rainfall data.

Measures of rainfall included the years 1943-2005, came from Bolivia's national aeronautical agency, came aggregated by month, and refer to the San Borja airport. Twelve of the 63 years had >1 missing values for monthly rainfall; for missing values we imputed the predicted value of monthly rain using known rainfall in three lowland towns: Rurrenabaque (93 Km from San Borja), San Ignacio (101 Km), and Trinidad (194 Km).

We used monthly rainfall data to compute the following: *(a)* total amount of annual rainfall, *(b)* intra-annual monthly CV of rainfall, *(c)* z score of *(a)* or standardized deviations from the mean annual rainfall for 1943-2005, *(d)* natural logarithm of *(b)*, *(e)* average of *(c)* and average of *(d)* for ages 2-4, and *(f)* lagged values of *(c)*-*(d)* by one year. Values under *(f)* capture rainfall during gestation (age 0), values under *(c)* and *(d)* capture rainfall during birth year (age 1), and values under *(e)* capture rainfall during ages 2-4.

Analysis

We took natural logarithms of height, weight, and BMI for people 3-20 years of age in 2005, and used the measures as dependent variables. Covariates included: *(1)* z scores of rainfall during gestation, age 1, and ages 2-4, *(2)* natural logarithms of the CV of rainfall during gestation, age 1, and ages 2-4, *(3)* mother's maximum school attainment, ethnobotanical knowledge, height, average z score of rainfall while she was 2-4 years of age, and the average yearly CV of rainfall while she was 2-4 years of age, *(4)* the same variables as in *(3)* but for fathers, *(5)* subject's birth quinquennium, *(6)* and subject's age. Regressions with weight as an outcome included subject's height as a covariate. We used STATA 9.0 for Windows to run separate ordinary-least squares regressions for each sex and outcome, and used robust standard errors when the $p>\chi^2$ in the Breusch-Pagan test for heteroskedasticity was <5%.

RESULTS

Rainfall during subject's early life and subject's anthropometric indicators

Rainfall generally bore a negative association with height, particularly among females (Table 1). Female height bore an association with rainfall during gestation and age 2-4, but male height bore a negative association with rainfall only during gestation. An increase of one SD in the amount of rainfall during gestation was associated with 4% lower height (3.85 cm) among females and with 2% lower height among males (2.42 cm). An increase of 1% in the CV of rainfall during gestation was associated with 0.10% lower height among females (0.11 cm) and with 0.06% lower height among males (0.04

cm). Among females, an increase of 1% in the CV of rainfall during age 2-4 was associated with 0.29% lower height (0.30 cm) and an increase of one SD in the amount of rainfall during the same age was associated with 3% taller stature (6.04 cm).

INSERT TABLE 1 ABOUT HERE

Unlike the relation between rainfall and height, the relation between rainfall and weight was positive. An increase of one SD in the amount of rainfall was associated with 6% more weight among females (3.47 kg). Among males, an increase of 1% in the CV of rainfall during gestation was associated with 0.07% more weight (0.07 kg) and an increase of 1% in the CV of rainfall during age 2-4 was associated with 0.17% more weight (0.19 kg).

We found no statistically significant association at the 95% confidence level or higher between rainfall and BMI of females or males.

The role of rainfall amount and rainfall variability

The F tests of rows VI.A suggest that the six rainfall variables together bore a statistically significant joint association at the 98% confidence level or higher with height, weight, and BMI among females and males. However, among rainfall variables the amount of rainfall bore a stronger association with anthropometric indicators than the CV of rainfall. For example, if we compare the F statistics of rows VI.B (amount of rainfall during gestation, age 1, and age 2-4) with the F statistics of rows VI.C (CV of rainfall for the same three ages) we see that the F statistics for the amount of rainfall are generally larger than the F statistics for the CV of rainfall. The only exception includes female height, which shows a stronger association with the CV of rainfall (F=13.02, p=0.001) than with the amount of rainfall (F=8.06, p=0.001).

Identifying vulnerable stages

Results under VI.E suggest that Tsimane' females and males are both protected against rainfall perturbations during their birth year. The results of tests of joint statistical significance of both rainfall variables (amount and CV of rainfall) for age 1 (rows VI.E.2) bore no statistically significant association at the 95% confidence level or higher with the height, weight, or BMI of females or males.

Tsimane' are less protected against rainfall perturbations during gestation and age 2-4. Rainfall amounts and variability during gestation bore a negative association with the height of females and males; results were stronger for females than males (females: F=14.75, p=0.001; males: F=5.35, p=0.005)(rows VI.E.1). Rainfall amounts and variability during age 2-4 bore statistically significant joint associations with weight and BMI, with stronger results among males. The tests of joint statistical significance for the amount and the CV of rainfall for male weight and BMI produced F statistics of 9.23 (weight; p=0.001) and 8.05 (BMI; p=0.004)(row VI.E.3); in contrast, the F statistics for the same variables for females were only 5.56 for weight (p=0.004) and 6.56 for BMI (p=0.001). Rainfall amounts and variability during age 2-4 bore a statistically significant association only with female height (F=15.79, p=0.001) (row VI.E.3). In sum, rainfall while *in utero* bore a stronger negative association with female height, but rainfall during age 2-4 bore a stronger positive association with male weight. Rainfall during age 2-4 bore an association only with female height.

Parental human capital and anthropometric indicators of offspring

Neither parental schooling nor ethnobotanical knowledge bore a statistically significant independent association at the 95% confidence level or higher with the anthropometric indicators of their offspring (rows II.A.-B). Jointly, the four variables for human capital (schooling and ethnobotanical knowledge of mothers and fathers) also bore no statistically significant association with the anthropometric indicators of their offspring (rows VII.A).

Rainfall effects across generations

We found evidence of links between rainfall while fathers were 2-4 years old and the height, weight, and BMI of his daughters. A 1% increase in the CV of rainfall when fathers were age 2-4 was associated with 0.04% taller stature (0.04 cm) among his daughters (row III.D.2 for females). An increase of one SD in the amount of rainfall when fathers were age 2-4 was associated with a 1% increase in his daughter's weight (0.71 kg) and with a 1% increase in his daughter's BMI (0.37 kg/mt^2)(row III.D.1 for females). Rainfall amounts or variability while parents were 2-4 years old bore no statistically significant association with anthropometric indicators of sons, with one exception. An increase of one SD in the amount of rainfall while the mother was age 2-4 was associated with sons having 1% more weight (0.55 kg) (row II.D.1. for males). Tests of joint statistical significant for the four rainfall variables affecting both parents (amount and CV of rainfall while mothers and fathers were 2-4 years of age) suggest that the variables bore a statistically significant association only with the weight and BMI of daughters (row VI.D for females)(weight: F=4.14, p=0.002; BMI: F=4.07, p=0.003).

Does rainfall affect anthropometric indicators of females and males differently?

Anthropometric indicators of females and males displayed similarities and differences in their response to rainfall perturbations.

If we focus on the sign and size of the parameters of individual rainfall variables (rows I.A. and I.B) rather than on the level of statistical significance of the variables, we see that exposure to rainfall early in life generally changed anthropometric indicators of females and males in the same direction. For example, among females and males rainfall amount and variability generally bore a negative association with height and a positive association with weight and BMI. Females and males displayed other similarities. Rainfall during gestation bore a negative association with height among females and males (rows VI.E.1), and rainfall during age 2-4 bore a statistically significant (positive) association with weight and BMI of females and males (rows VI.E.3). The amount of rainfall bore stronger associations with anthropometric outcomes than the CV of rainfall among females and males (rows VI.B versus rows VI.C).

But anthropometric indicators of females and males also differed in their response to rainfall. If we focus on the one outcome (height) in which the same rainfall variables (amount and CV of rainfall during gestation) bore statistically significant associations with females and males we see that the magnitude of the association was twice as large among females. For example, an increase of one SD in rainfall during gestation was associated with 4% lower height among females but with only 2% lower height among males (rows I.A.1). Rainfall had a stronger (negative) association with female height than male height, but a slightly stronger (positive) association with male weight than female weight. If we focus on the stage in life in which rainfall bore the strongest association with anthropometric outcomes, we see that exposure to rainfall by females during age 2-4 bore a strong association with their height. In contrast, exposure to rainfall by males during age 2-4 bore no association with their height. The type of rainfall variables that bore an association with anthropometric outcomes also differed between females and males. Among males, the CV of rainfall during gestation and age 2-4 bore a positive association with weight, but among females the same variables produced no association with weight, but did produce a negative association with height (rows I.B.1 and 3). Last, we find evidence of links between rainfall exposure by fathers while they were 2-4 years old and their daughter's height, weight, and BMI; among sons we see almost no statistically significant links between their anthropometric indicators and their parents' childhood exposure to rainfall.

DISCUSSION

Anthropometric indicators and rainfall

Among females and males 3-20 years of age, rainfall perturbations during gestation was associated with lower height, but rainfall perturbations during age one bore no significant association with height, weight, or BMI. Rainfall perturbation during age 2-4 was association with female height and male weight.

The results fit with growing evidence from industrial nations (cited earlier) and with a study in rural Africa suggesting that rainfall perturbations early in life leave an imprint on health later in life. Alderman et al. (2006) found that children in Zimbabwe six months to six years of age affected by the droughts of 1982-1984 attained 0.72 lower z scores of height-for-age by the time they reached age 17-18. Maccini and Yang (2006) estimated the effect of rainfall amounts during birth year on adult height in rural Indonesia, and found that rainfall amounts bore a positive association with height, but only among women. Women born during years with 20% more rainfall relative to the regional norm were 0.14 cm taller than their peers born during drier years. Rose (1999) found that favorable rainfall conditions in rural India during the first two years of life raised the probabilities that girls would survive to reach school age.

Anthropometric indicators bear an association with rainfall during age 2-4 probably because of the cessation of breastfeeding, which occurs at ~2 years among the Tsimane'. Across many cultures of developing nations, weaning is associated with increased pathogen exposure and decreased nutritional quality to the child (McDade and Worthman, 1998). The interpretation fits with our research in progress among Tsimane' on parasitic infections and biomarkers of immune activity. Tanner (2005) found that rates of parasitic infections increased when children started to walk, peaked in late childhood and adolescence, and remained high throughout old age. Research on C-reactive protein (CRP) as a biomarker of immunostimulation suggests that infection rates are highest for children age 2-3 (23.3%), decline to 15.2% among children age 4-5, and to ~10% among children age 6-15 (McDade et al., 2005). Elevated CRP among children was associated with lower growth rates over the subsequent three months, suggesting that infection may contribute to growth faltering. Foster et al. (2005) also found that growth faltering begins ~18 months of age and continues throughout childhood.

Exposure to rainfall during early life was generally associated with lower height and higher weight and BMI. These seemingly counter-intuitive results mesh with: *(a)* research that finds an association between childhood stunting and later weight gain and corresponding metabolic changes (Florencio et al., 2001; Grillo et al., 2005; Martins 2006; Worthman and Kohrt, 2005) and *(b)* the thrifty-phenotype hypothesis, which posits a causal link between early growth retardation and energy-sparing and promotion of weight gain (Hales, 2001). Research under *(b)* suggests that rainfall perturbations during age 2-4 will be related to lower resting metabolic rates and decreased lean mass (Grillo 2005). Researchers typically view the thrifty phenotype as resulting in mal-adaptive outcome due to a mismatch between evolved propensities and modern diets rich in calories. Among the Tsimane', such a response may be adaptive.

The finding that rainfall amounts during age 2-4 of a female's life (row I.A.3 females) bears a positive association with her height as a child or young adult finds indirect support from other studies. In a study in progress by Richard Steckel (personal communication) among North American Indians during the 19th century, Steckel found that rainfall's impact on height varied. Among the Plains Indians, more rainfall allowed for increased food production, thus improving nutrition, health, and height, but in the semi-tropical region of the Southwest rainfall increased the disease burden and lowered height. Our results resemble Steckel's finding among the Plains Indians. Like Maccini and Yang (2006), we found a positive association between rainfall amount early in life (ages 2-4) and female height; neither study found an association between rainfall early in life and male height.

Rainfall produced roughly the same effect on anthropometric indicators of short-run nutritional status (weight and BMI) among females and males, a result consistent with our prior work. Elsewhere we show no evidence of preferential treatment by parents for children of one sex and similarity between girls and boys in a broad range of outcomes related to health, human capital, and sex-standardized anthropometric indicators of short-run nutritional status (Foster et al., 2005; Godoy et al., 2006b).

With height we find that rainfall produced stronger negative associations among females than males. The finding supports the findings from another study of rainfall and adult height among the Tsimane' (Godoy et al, 2007). In the earlier study we found that rainfall during age 2-5 bore a negative association only with the height of adult women. The earlier finding complements the results presented here. If rainfall variables are associated with lower height among females and males 3-20 years of age, as shown here, but adult male height bears no association to rainfall exposure early in life while female height continues to bear a negative association to rainfall exposure early in life, as shown in Godoy et al. (2007), then males exposed to rainfall risks must have compensated and caught up in height with their peers while females failed to converge.

We offer a biological and a socioeconomic explanation for the findings. Rainfall amounts and variability are associated with lower height and with more weight among females and males. Among females, the increased weight might trigger earlier menarche and earlier attainment of final adult height. Rainfall perturbations will lock females earlier in life into shorter stature as an adult. Among males, the increased weight from rainfall perturbations early in life probably has positive (or neutral) effects on stature growth. Another interpretation would stress compensatory socioeconomic mechanisms put in place after adverse environmental conditions to favor boys. The problem with the second interpretation is that we have found no support for preferential treatment of children or young adults of one sex.

Parental ethnobotanical knowledge and offspring anthropometric indicators

We found weak support for the idea that parental ethnobotanical knowledge bore a significant association with the anthropometric indicators of offspring. In fact, a mother's ethnobotanical knowledge bore a negative (albeit statistically insignificant) association with all the anthropometric indicators of her children. The sign and the level of statistical significance aside, the coefficients for parental ethnobotanical knowledge were small. The coefficients imply that a doubling of parental ethnobotanical knowledge would produce changes in offspring anthropometric indicators of only 1-8%. Since doubling an adult's stock of indigenous knowledge is unlikely, the implied height change is unrealistic.

The finding buttresses an earlier study in which we estimated the association between own ethnobotanical knowledge and BMI among Tsimane' age 16+ (Reyes-García et al., 2006). We found that doubling own ethnobotanical knowledge was associated with a median increase in own BMI of 5.6-6.3%. Those estimates fall within the range of estimates reported here (1-8%). McDade et al. (2007) recently found that maternal ethnobotanical knowledge among Tsimane' bore a negative association with CRP and a positive association with skinfold thickness and height-for-age among children 2-10 years of age. One possible explanation for the difference in results has to do with how ethnobotanical knowledge developed. Ethnobotanical knowledge developed *in situ* chiefly to protect nutritional status against normal environmental conditions or mishaps unique to a habitat (Berkes et al., 2000). Ethnobotanical knowledge may prove less useful in protecting nutritional status against world-wide climate change. A second explanation has to do with the way we measured ethnobotanical knowledge. They used a composite score of practical and theoretical knowledge, and we used only theoretical knowledge.

Trans-generational effects of rainfall

We found two types of trans-generational effects. First, an increase in the amount or variability of rainfall during pregnancy was associated with shorter stature among the offspring. In this case, the effects of rainfall got transmitted via the mother to daughters and sons. Second, exposure to higher amounts and variability of rainfall while fathers were 2-4 years old was associated with better anthropometric outcomes of daughters. We cannot explain why among the Tsimane' the transmission occurs chiefly from fathers to daughters. To the contrary, the sexual division of labor might lead one to expect mother-daughter and father-son links.

The finding nevertheless fits with recent studies suggesting that some conditions experienced early in the life of the parent get transmitted through the male line. In Sweden the food supply available to grandparents before puberty bore an association with the longevity of adult children and grandchildren (Bygren et al., 2001; Kaati et al., 2002). Fathers who had poor food supplies had offspring with lower risks of cardiovascular death. Diabetes mortality bore a positive association with the amount of food available to paternal grandparents. Early paternal smoking was associated with sons (but not daughters) having larger BMI by age 9.

CONCLUSION

The study uncovers several areas for further research. *First*, if boys are more vulnerable than girls, and we find that rainfall has the same general effect on the weight and BMI of females and males, it would suggest that compensatory mechanisms might be at play. We know next to nothing about such mechanisms. *Second*, we find that ethnobotanical knowledge produced no salient results. Our measures of ethnobotanical knowledge may have been too crude and not focused enough on knowledge of edible wild plants and animals and health practices. Sharper measures might produce sharper results. Without an exogenous source of variation for ethnobotanical knowledge, estimates of the associations between ethnobotanical knowledge and health must be read with caution because the estimates will contain biases of an unknown size and magnitude. *Third*, despite centuries of living in the same place, the cultural tapestry of this Amazonian population still does not protect the nutritional status of children and young adults in full against rainfall perturbations, suggesting room for improvement. Future research will need to sort out the policy implications of the finding. *Fourth*, the effects of rainfall spill over across generations, but we lack a theory or data to explain the mechanism or adaptive role for such trans-generational effects.

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TABLE 1. Results of six multiple regressions of natural logarithm of height, weight, and BMI (dependent variables) on rainfall variables and individual covariates for Tsimane' females and males age 3-20 years in 2005[1]

FEMALES (n=266)			
Explanatory variables in multiple regressions:	**Dependent variables:**		
	Height	**Weight**	**BMI**
I. Rainfall during person's early life:			
A. Z score of amount during person's:			
[1] Year of gestation (age 0)	***-0.04*****	0.01	0.01
[2] Year of birth (age 1)	-0.007	0.02	0.02
[3] Years 2-4 (average z score for age 2-4)	***0.03*****	***0.06****	0.06
B. Natural logarithm of annual coefficient of variation (CV) during person's :			
[1] Year of gestation (age 0)	***-0.10*****	0.004	0.01
[2] Year of birth (age 1)	0.02	0.04	0.04
[3] Years 2-4 (average annual CV for age 2-4)	***-0.29*****	0.14	0.16
II. Parental attributes – mother:			
A. Schooling (completed years)	-0.001	-0.001	-0.001
B. Ethnobotanical knowledge-natural logarithm of score	-0.02	-0.06	-0.06
C. Height (in natural logarithms)	***0.31*****	0.23	0.21
D. Rainfall while mother was age 2-4:			
[1]. Average z score of annual amount	-0.005	-0.01	-0.01
[2]. Average annual natural logarithm of CV	-0.006	0.06	0.06
III. Parental attributes – father:			
A. Schooling (completed years)	$5.32e^{-06}$	-0.002	-0.002
B. Ethnobotanical knowledge-natural logarithm of score	0.01	0.08	0.08
C. Height (in natural logarithms)	0.15	0.23	-0.31
D. Rainfall while father was age 2-4:			
[1]. Average z score of annual amount	-0.001	***0.01*****	***0.01*****
[2]. Average annual natural logarithm of CV	***0.04****	0.03	0.03
IV. Birth period (reference category 1985-1989):			
1990-1994	***0.05*****	-0.02	-0.02
1995-1999	0.03	-0.11	-0.11
2000-2002	-0.05	-0.08	-0.07
V. Person's attributes:			
A. Age in years	***0.02*****	0.01	0.01
B. Height (in natural logarithms)	NA	***1.92*****	NA
Constant	***2.05*****	***-5.57*****	***3.47*****
R square	0.93	0.96	0.64
VI. Test of joint significance of rainfall variables (F and, in parenthesis, p>F):			
A. All variables under I (amount and CV)	***6.87 (0.001)***	***3.44 (0.002)***	***3.62 (0.001)***
B. All variables under I.A (amount)	***8.06 (0.001)***	***2.58 (0.05)***	***2.57 (0.05)***
C. All variables under I.B (CV)	***13.02 (0.001)***	1.87 (0.13)	2.12 (0.09)
D. All variables under IID+IIID (parental)	1.32 (0.26)	***4.14 (0.002)***	***4.07 (0.003)***
E. Stage in the life cycle of person:			
[1] Gestation (age 0) (I.A.[1]+I.B.[1])	***14.75 (0.001)***	0.41 (0.66)	0.56 (0.57)
[2] Birth year (age 1) (I.A.[2]+I.B.[2])	1.56 (0.21)	2.24 (0.10)	2.33 (0.09)
[3] Age 2-4 (I.A.[3]+I.B.[3])	***15.70 (0.001)***	***5.56 (0.004)***	***6.56 (0.001)***
VII. Test of joint significance of parental human-capital (F and, in parenthesis, p>F):			
A. All parental human capital (II.A-B and III.A-B)	0.85 (0.49)	1.06 (0.37)	1.07 (0.37)

TABLE 1. continue.

MALES (n=293)			
Explanatory variables in multiple regressions:	**Dependent variables:**		
	Height	**Weight**	**BMI**
I. Rainfall during person's early life:			
A. Z score of amount during person's:			
[1] Year of gestation (age 0)	***-0.02*****	0.01	0.01
[2] Year of birth (age 1)	-0.005	-0.002	-0.003
[3] Years 2-4 (average z score for age 2-4)	-0.006	0.04	0.03
B. Natural logarithm of annual coefficient of variation (CV) during person's :			
[1] Year of gestation (age 0)	***-0.06*****	***0.07****	0.06
[2] Year of birth (age 1)	0.01	0.006	0.01
[3] Years 2-4 (average annual CV for age 2-4)	-0.05	***0.17****	0.15
II. Parental attributes – mother:			
A. Schooling (completed years)	0.0008	-0.003	-0.002
B. Ethnobotanical knowledge-natural logarithm of score	-0.02	-0.01	-0.02
C. Height (in natural logarithms)	***0.46*****	0.14	0.24
D. Rainfall while mother was age 2-4:			
[1]. Average z score of annual amount	-0.006	***0.01****	0.01
[2]. Average annual natural logarithm of CV	0.003	-0.02	-0.02
III. Parental attributes – father:			
A. Schooling (completed years)	-0.002	0.001	0.0007
B. Ethnobotanical knowledge-natural logarithm of score	0.01	0.03	0.03
C. Height (in natural logarithms)	***0.46*****	-0.20	-0.10
D. Rainfall while father was age 2-4:			
[1]. Average z score of annual amount	-0.006	-0.001	-0.003
[2]. Average annual natural logarithm of CV	0.01	-0.02	-0.02
IV. Birth period (reference category 1985-1989):			
1990-1994	***0.06****	-0.01	-0.004
1995-1999	0.02	0.0007	0.005
2000-2002	-0.04	0.09	0.80
V. Person's attributes:			
A. Age in years	***0.03*****	***0.01*****	***0.02*****
B. Height (in natural logarithms)	NA	***2.22*****	NA
Constant	-0.26	***-7.21*****	1.93
R square	0.91	0.97	0.66
VI. Test of joint significance of rainfall variables (F and, in parenthesis, p>F):			
A. All variables under I (amount and CV)	***2.48 (0.02)***	***3.56 (0.002)***	***3.04 (0.006)***
B. All variables under I.A (amount)	***3.82 (0.01)***	***3.90 (0.009)***	***2.88 (0.036)***
C. All variables under I.B (CV)	2.45 (0.06)	2.19 (0.08)	1.72 (0.16)
D. All variables under IID+IIID (parental)	1.31 (0.26)	1.31 (0.26)	1.04 (0.38)
E. Stage in the life cycle of person:			
[1] Gestation (age 0) (I.A.[1]+I.B.[1])	***5.35 (0.005)***	2.24 (0.10)	1.52 (0.21)
[2] Birth year (age 1) (I.A.[2]+I.B.[2])	0.45 (0.63)	0.05 (0.95)	0.12 (0.88)
[3] Age 2-4 (I.A.[3]+I.B.[3])	0.82 (0.44)	***9.23 (0.001)***	***8.05 (0.004)***
VII. Test of joint significance of parental human-capital (F and, in parenthesis, p>F):			
A. All parental human capital (II.A-B and III.A-B)	0.96 (0.42)	0.95 (0.43)	0.84 (0.50)

[1] Pregnant females excluded (n=10). Under IV, coefficients should be read as marginal changes relative to people born during 1985-1989. * and ** significant at ≤5% and ≤10%. NA= not applicable.

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