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## Social rank and adult male nutritional status: Evidence of the social gradient in health from a foraging-farming society<sup>☆</sup>

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### ABSTRACT

Research with humans and non-human primate species has found an association between social rank and individual health. Among humans, a robust literature in industrial societies has shown that each step down the rank hierarchy is associated with increased morbidity and mortality. Here, we present supportive evidence for the social gradient in health drawing on data from 289 men (18+ years of age) from a society of foragers-farmers in the Bolivian Amazon (Tsimane'). We use a measure of social rank that captures the locally perceived position of a man in the hierarchy of important people in a village. In multivariate regression analysis we found a positive and statistically significant association between social rank and three standard indicators of nutritional status: body mass index (BMI), mid-arm circumference, and the sum of four skinfolds. Results persisted after controlling for material and psychosocial pathways that have been shown to mediate the association between individual socioeconomic status and health in industrial societies. Future research should explore locally-relevant psychosocial factors that may mediate the association between social status and health in non-industrial societies.

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### Introduction

Research with humans and non-human primate species has found an association between social rank, or position in dominance hierarchies, and individual health (Marmot, 2006; Sapolsky, 2004). When examining the association between dominance hierarchy and individual health among humans, researchers have argued that socioeconomic status proxies for social rank (Sapolsky, 2004). A large and growing literature in industrial societies suggests that each step down the socioeconomic ladder is associated with increased morbidity and mortality (Adler, Boyce, Chesney, Folkman, & Syme, 1993; Marmot, 2004; Marmot, Ryff, Bumpass, Shipley, & Marks, 1997; Wilkinson, 2000).

Researchers have found evidence for social gradients in health in many industrialized societies that are independent of a wide range of confounders and risk factors (Wilkinson, 2000).

Research on the social gradient in health suggests that socioeconomic status is a strong predictor of health. Both material and psychosocial causes contribute to health differences between people. Differences in individual resources (e.g., income, access to health care) explain about one third of the variation in health outcomes in industrial nations (Wilkinson, 2000). Social epidemiologists have proposed that psychosocial factors related to stress also mediate the relation between socioeconomic status and health. For example, research in industrial nations suggests that job attributes might contribute to stress and poor health because different jobs have different physical and psychological demands, risks, and rewards (Bosma, 1998; Sorenson et al., 1985). In addition, the strongest socioeconomic status gradients occur for diseases with the greatest sensitivity to stress (Wilkinson, 2000).

Researchers have also shown that the decline of social capital associated with the rise of income inequality might contribute to the relation between socioeconomic status and health (Kawachi, 2002; Kawachi & Kennedy, 1999). Social capital refers to the trust, safety nets, membership in local organizations, and other expressions of pro-social behavior that enable people to act collectively (Coleman, 1990; Kawachi, 2002; Ostrom, 2000). Men with higher socioeconomic status have a wider and thicker social network than men with lower socioeconomic status; the network allows them to gain access to resources and information that might protect health (Mare, 1990; Moore & Hayward, 1990). For example, Marmot and Smith (1991) found that men of lower socioeconomic status were less likely to have a confidant in whom they could rely in times of need. Research suggests that social capital may also play an important role in small-scale societies, where gift giving, communal work, and labor contributed to other households represent pro-social expressions of generosity (Godoy et al., 2005a). Anthropological evidence from small-scale societies suggests that people with higher socioeconomic status might be more likely to receive help and gifts than people with lower socioeconomic status (Henrich & Gil-White, 2001).

Prior research on the association between social rank and individual health comes from industrial societies and has used economic (i.e., income, occupation) rather than social measures to assess social status (Deaton, 2003; Kawachi, 2002; Marmot, 2004, 2005; Subramanian & Kawachi, 2004; Wilkinson, 1996). Due to the paucity of data, little is known about how socioeconomic status might affect individual health in small-scale, rural societies.

The use of data from a small-scale society to study the social gradient in health allows one to circumvent relations that become harder to identify once societies grow in complexity. For instance, in small-scale societies people enjoy high levels of job autonomy and social capital (Johnson, 2003; Kaplan & Hill, 1985). Such societies have relatively little division of labor beyond the sexual division of labor. As a result, one can largely ignore the confounding role of occupations and stressful events associated with

occupations and focus on how social status itself might shape health.

Here, we contribute to the literature on the social gradient in health by exploring whether results from industrial societies hold up in a very different socioeconomic setting. Using cross-sectional data from the Tsimane', a foraging-farming society of indigenous Amazonians in Bolivia, we estimate the association between socioeconomic status and individual-level anthropometric indices of short-run nutritional status among adult men. We use a locally-relevant measure of social rank that stresses individual position in the social hierarchy. We examine the association between social rank and anthropometric indices of nutritional status controlling for three paths – individual resources, job autonomy, and social capital – that prior research suggests may mediate the relation between socioeconomic status and individual health.

We hypothesize a positive association between anthropometric indices of short-run nutritional status and individual social rank. Research in industrial populations has found that higher levels of overweight and obesity are generally associated with low socioeconomic status, whereas in developing nations obesity and socioeconomic status are positively associated (McLaren, 2007; Sobal & Stunkard, 1989). Previous research among the Tsimane' suggests that the nutritional status of adults is low relative to reference values from industrial nations (Godoy, Reyes-García, Byron, Leonard, & Vadez, 2005b), and in this context of marginal nutrition higher levels of body mass index (BMI) indicate better health. We therefore expect to find a positive association between social rank and indices of short-run nutritional status: If higher social rank is associated with higher BMI, but without reaching levels associated with overweight and obesity, one could argue that social rank is associated with higher levels of caloric and nutrient reserves, an important safety net that these individuals can draw on during times of nutritional adversity.

### **Social hierarchies, job autonomy, and social capital among Tsimane'**

One of the largest native Amazonian groups in Bolivia, the Tsimane' number ~8000 people (Censo Indígena, 2001), live in ~100 villages mostly in the department of Beni, and have been in continuous contact with Westerners since the 1950s (Daillant, 2003; Huanca, 2008). Tsimane' in our sample reside in villages of ~20 households settled along riverbanks and logging roads. Villages consist of a loose number of households related by blood and marriage. Tsimane' rely on slash-and-burn farming supplemented by hunting, gathering, and wage labor in logging camps, cattle ranches, and in the homestead of colonist farmers. Their chief sources of cash come from the sale of thatch palm from the forest and cultivated rice from their farms.

Tsimane' nutritional status is comparable to other lowland South American indigenous peoples (Dufour, 1994; Orr, Dufour, & Patton, 2001). Prior research suggests that among the Tsimane' neither village income inequality nor individual income correlate systematically with nutritional status, although individual variables (e.g., schooling) correlate with improved nutritional status (Godoy et al.,

2005a, 2005c; Reyes-García et al., 2008a, 2008b). Village social capital and village income complement each other and are associated with higher BMI: the rich who are stingy have lower BMI than the rich who display generosity (Brabec, Godoy, Reyes-García, & Leonard, 2007).

#### Social hierarchies

Living for centuries at the doorsteps of a highly stratified empire, the Inkas, the Tsimane' nonetheless managed to remain highly autarkic and egalitarian until recently (Ellis, 1996). The only evidence of past formal, structured social hierarchy is the presence of shamans – healer, priest, and political leaders – called *cocojsi'* in the Tsimane' language (Huanca, 2008). Tsimane' respected the *cocojsi'* for their power to cure and communicate with humans, plants, and animal spirits (Daillant, 2003; Huanca, 2008). However, the power of the *cocojsi'* declined with the arrival of traders and missionaries in the 1950s. The last *cocojsi'* died during the 1980s.

At present, there are two sources of social status among the Tsimane'. First, informal social evaluations create social hierarchies. For example, Tsimane' show deference to people with specific skills and qualities. Tsimane' respect old, knowledgeable people (*baba*) whom they ask for advice on multiple issues. Tsimane' also show deference to some young people (e.g., Protestant preachers) or to good hunters. Second, new leaders have emerged as Tsimane' gain greater exposure to the outside world. During the 1980s, the Tsimane' started to organize politically. To elect members for the umbrella Tsimane' government, the Great Tsimane' Council, each village elects a representative (*corregidor*) who mediates the relations between the village and the outside world. Tsimane' usually elect as village representatives schooled men who can speak Spanish, Bolivia's national language.

#### Job autonomy

Like other native Amazonian societies (Johnson, 2003;), Tsimane' individuals and households have traditionally enjoyed high levels of autonomy in production and household activities. Until the late 1940s, the Tsimane' lived like any other pre-contact Amazonian society. They hunted, fished, gathered wild plants, and practiced slash-and-burn agriculture with stone and wood tools. To this day, they remain highly autonomous, freely allocating their time to various activities throughout the day.

With the arrival of highland colonists to the area in the early 1970s, some Tsimane' gave up some of their job autonomy in exchange for jobs that provided a monetary wage. At present, some Tsimane' seek employment in cattle ranches, logging camps, and in the farms of colonist farmers. Tsimane' also work as village teachers for the government or as professionals for various organizations active in the Tsimane' territory. Work for loggers, cattle ranchers, and colonists partially restricts the autonomy of Tsimane', but the jobs are temporary, both because the jobs themselves come and go in response to market prices for logs, and because Tsimane' often take up the jobs temporarily, and do so chiefly during lulls in the agricultural season.

#### Social capital

As is true of other native Amazonian societies (Kaplan & Hill, 1985, Winterhalder, 1997), social capital is strong among Tsimane' (Brabec et al., 2007; Reyes-García, Godoy, Vadez, Huanca, & Leonard, 2006). For example, Tsimane' routinely share drinks and food with other Tsimane' and outsiders. In a previous study it was found that only 7% of households reported not making any gifts to other households, and only 39% of households did not do any communal work or offer any labor help during the week before the day of the interview (Godoy et al., 2005a). However, social capital does not seem to get activated to help people cope with large-scale, covariant shocks (Godoy et al., 2007).

In sum, the Tsimane' represent an ideal case to study the relation between social status and health for three reasons. First, social hierarchies are not new in Tsimane' society, but they are growing in importance as Tsimane' increase their participation in the national society. Second, Tsimane' enjoy high levels of autonomy in production and household activities and widespread sharing and reciprocity, so one can test whether the social gradient holds up after controlling for those explanatory paths. Third, Tsimane' share characteristics in common with other small-scale indigenous groups, which suggests that results from this research might apply to other non-industrial, indigenous populations around the world.

#### Estimation strategy

Our main aim is to estimate the association between social rank and anthropometric indices of short-run nutritional status among adult men while controlling for three paths that may explain the social gradient in health: individual resources, job autonomy, and social capital. For the empirical analysis, we assess the association between (a) three outcome variables: adult body mass index (weight in kg/height in m<sup>2</sup>), mid-arm circumference, and sum of four skinfolds (biceps, triceps, subscapular, and supra-iliac) and (b) individual social rank while controlling for the three paths just noted. In subsequent analysis, we test the robustness of our findings by including (i) self-reported poor health, a standard covariate of BMI, (ii) smiles, an indicator of level of stress, and (iii) alcohol consumption, a risk factor for health. We use the following expression to model the association between anthropometric indices of nutritional status ( $Y$ ) and covariates:

$$\log Y_{ihv} = \alpha + \gamma \log S_{ihv} + \lambda P_{ihv} + \Psi I_{ihv} + \zeta H_{ihv} + \eta C_v + \varepsilon_{ihv} \quad (1)$$

Assume, first, that  $Y$  captures the BMI of an adult – transformed to logarithms – where  $i$  is the subject,  $h$  the household, and  $v$  the village. We use BMI for ease of exposition, but the expression also applies to the other indicators of nutritional status.  $\log S_{ihv}$  refers to the logarithm of the social rank of the subject, defined as the position of an individual within the social hierarchy in the village.  $P_{ihv}$  is a vector of variables for the three paths that researchers have proposed to explain the social gradient in health in industrial nations (i.e., income, occupation, and

social capital).  $I_{ihv}$  is a vector of variables for the subject (e.g., age and schooling) that directly affects nutritional status.  $H_{hv}$  stands for household size.  $C_v$  stands for a set of village indicator variables to control for factors that could directly affect nutritional status and social rank (e.g., proximity to market towns).  $\varepsilon_{ihv}$  is a random error term with standard properties. If the coefficient of the variable for social rank ( $\gamma$ ) bears a positive association with indices of nutritional status it will support the hypothesis that socioeconomic status might influence health through other pathways beyond the ones examined here.

### Potential biases and limitations of the study

Potential biases in our estimations relate to (1) measurement errors of dependent and explanatory variables, (2) omitted variables, and (3) possible reverse causality. First, we find random measurement error in height (Godoy et al., 2006a). Random measurement error in the outcome variable would inflate the standard error. Since we find measurement error in height, we cannot discard the possibility that other outcome and explanatory variables might also be affected by random or systematic measurement error. For example, assume that in the study context power and prestige are different. Informants might have systematically named powerful (but not prestigious) people in the village, thus systematically increasing the number of nominations of powerful people. Unfortunately, we do not have information to detect measurement bias in the variables used in the analysis.

Second, our estimations might be biased by the role of omitted variables. For example, people with higher social rank might have more access to outside resources (e.g. hospitals), which might improve their health or nutritional status. Failure to control for access to outside resources might bias our estimation. It is also possible that the covariates we use are inadequate to measure the association between social status and health. For example, it is possible that social capital has a non-linear relation with health, and by not including a quadratic term for social capital we might accidentally attribute some of the effects of social capital to the social status measure, assuming they are positively associated. We include some of those confounders (i.e., self-reported health, mother's height, age squared), but we cannot rule out the possibility the existence of other omitted variables (i.e., kinship).

Third, we do not have convincing instrumental variables to control for the potential endogeneity of social rank. It is possible that social rank contributes to improve nutritional status, but the causality could also run in the other direction. Therefore, we cannot speak about causality and limit our discussion to the association between the variables explored.

Two main limitations in our measurements make it difficult to compare our results with previous research on the social gradient of health. First, we focus on indices of short-run nutritional status rather than on mortality or morbidity. Second, we use measures of psychosocial factors adapted from research in industrial nations, but those measures might be less relevant in small-scale societies.

The first limitation of our study is that we use anthropometric indices of nutritional status as a proxy for health whereas most of the previous literature on the social gradient of health has used mortality or morbidity as outcomes (Adler et al., 1993; Marmot, 2004; Marmot et al., 1997; Wilkinson, 2000). Differences in the outcomes measured make it difficult to compare the results of our study with results from previous research. Furthermore, at least one of our indices of short-run nutritional status, BMI, is not a good universal measure of under-nutrition and obesity (Garn, Leonard, & Hawthorne, 1986; Norgan, 1994). Previous research among indigenous peoples throughout the world suggests that the relationship between BMI and percent body fat varies according to differences in body proportions (Charbonneau-Roberts, Saudny-Unterberger, Kuhnlein, & Egeland, 2005; Godoy et al., 2005b; Norgan, 1994; Rode & Shephard, 1994; Shephard & Rode, 1996). For example, in a study among the Inuit population of Canada (Charbonneau-Roberts et al., 2005) Inuits were found to have shorter legs than non-Caucasian people, which results in an overestimation of percent of body fat when calculating BMI. Similarly, Shephard and Rode (1996) have shown that among the traditionally-living Inuit of the Northwest Territories, percent body fat levels are quite low, despite having BMIs of 24 kg/m<sup>2</sup> and above. In contrast, indigenous populations with more linear builds (e.g., Australian aboriginal and South Asian populations) appear to have relatively higher body fat levels than suggested by their BMIs (Deurenberg-Yap & Deurenberg, 2003; Norgan, 1994). Our own data suggest that BMI probably overestimates Tsimane' percent of fatness and risk of obesity (that is, they are actually leaner than their BMI would suggest). For example, the mean BMI of Tsimane' men falls at about the 25th percentile relative to the US reference values (Frisancho, 1990), whereas their sum of four skinfolds (a direct measure of fatness) approximates the 15th. At the same BMI, Tsimane', on average, have less body fat than their peers in the US. Because of the limitations of BMI, the results of this measure should be read with caution.

The second important limitation of our study relates to the measures chosen to proxy the psychosocial factors that might mediate the relation between social status and health. We use measures of psychosocial factors adapted from research in industrial nations, i.e., job autonomy and social capital. Both measures might not be relevant in small-scale societies. The measure of job autonomy is problematic because it might clump together people with real autonomy to decide how to allocate their time and people who want – but are unable – to obtain paid jobs. People unable to enter the wage system might feel marginalized, and feelings of exclusion might offset the predictable positive effect of job autonomy on health. Social capital might also be problematic. Social capital is strong among the Tsimane' and might not show enough variation across individuals. Low variation in social capital limits the ability of the measure to capture the lack of social integration that is believed to be a risk factor for health in industrialized nations. Lack of adequacy of our measures of psychosocial factors does not allow us to fully control for this pathway.

## Materials and methods

Data for this analysis come from a panel study in progress among the Tsimane' (2002–present). Experienced interviewers and translators conducted the 2005 survey. Previous publications describe methods used to collect data on anthropometric measures (Godoy et al., 2005a), income (Godoy et al., 2005c), and social capital (Reyes-García et al., 2006). Those methods are covered briefly, and we explain in more detail methods used to collect information on social rank.

### Sample

We collected data through a survey that took place during June–September 2005 among nearly all households ( $n = 252$ ) in 13 Tsimane' villages straddling the Maniqui river. The villages surveyed differed in their proximity to the market town of San Borja (pop ~19,000) (mean = 25.96 km; SD = 16.70). We selected villages at varying distances from market towns because previous research suggests that village-to-town distance might affect the nutritional status (Follér, 1995; Leonard & Thomas, 1988) and notions of social status (Reyes-García et al., 2008a) of indigenous populations.

We asked every person over 16 years of age (or younger if they headed a household) ( $n = 611$ ) to list “the name of all the important people in the village”. In results reported shortly we found that participants were more likely to name men. We are not sure why women received few nominations but this might reflect our poor understanding of how to ask about female social rank. Because women received so few nominations, we limit the multivariate analysis to men. The total sample with complete information included 289 adult men.

### Anthropometric indices of short-run nutritional status

We trained surveyors on how to measure physical stature, weight, mid-arm circumference, and skinfold thickness (see Godoy et al., 2005a for a description of the protocols). We use three different anthropometric indices of short-run nutritional status as outcome variables: (a) body mass index, (b) mid-arm circumference (cm), and (c) sum of four skinfolds (biceps, triceps, subscapular, supra-iliac; mm). BMI is a measure of body composition and the most widely used measure of nutritional status among adults (National Institutes of Health, 1998; Shetty & James, 1994). Mid-arm circumference provides an index of both protein and energy status (Frisancho, 1990). The skinfold measures are sensitive to short-term change in subcutaneous fat stores and are thus good measures of energy reserves (Frisancho, 1990).

For (b) and (c), we use raw scores rather than age-standardized z scores because many Tsimane' do not know their exact age so the variable age contains random measurement error. Using age-standardized anthropometric indices would have inflated standard error and weakened statistical power. Instead, we include age as a covariate. Partial correlation coefficients between the three indices of short-term nutritional status were as follows: BMI and mid-arm

circumference = 0.74 ( $p < 0.0001$ ), BMI and sum of four skinfold = 0.69 ( $p < 0.0001$ ), and mid-arm circumference and sum of four skinfold = 0.56 ( $p < 0.0001$ ).

### Social rank

To measure a person's position in the social hierarchy we collected relational data. We asked participants to provide an exhaustive list with “the name of all the important people in the village”. To analyze the list of nominations of “important people in the village” we used social network analysis and calculated the centrality of each person in the village network of influence, defined as the number of nominations received by a person. The measure, known as in-degree centrality, has been previously used to identify influential people in communities (Costenbader & Valente, 2003). We then used the measure of in-degree centrality to construct a measure of social rank. The variable *social rank* refers to the relative rather than to the absolute position in the hierarchy of nominations in the village, where more nominations are equated with a higher value in our measure of social rank, and equal observations are assigned the average rank. All the people in a village who were not nominated received the lowest ranking in the village. For example, if four persons received 15, 4, 0, and 0 nominations, the person with the most nominations will be assigned rank 4, the person with the second highest number of nominations will be assigned rank 3, and the two people with the fewest nominations will be assigned rank 1.5.

### Income

Because Tsimane' market purchases account for less than 3% of the value of household consumption (Godoy et al., 2002), production and consumption almost fully overlap. Therefore, we defined personal daily income as the sum of (a) the average monetary value of a basket of farm and forest items consumed during a day (i.e., excluding items that were acquired through the market), which on average represented 73% of the daily income value, (b) the average monetary value of goods sold or bartered during a day (17%), and (c) the daily average monetary earnings from wage labor (11%).

### Job autonomy

To control for job autonomy we asked people whether they had engaged in any type of wage labor during the 2 months before the day of the interview. Because wage labor is an uncommon activity, it is a well-remembered event among the Tsimane'. For the regression analysis we created a dummy variable that took the value of one if the participant had earned any cash from wage labor during the 2 months before the interview, and zero otherwise.

### Social capital

We asked participants to report all the times they had received gifts from kin or other Tsimane' inside or outside the village (but not gifts received from people in their

household) during the week before the day of the interview. We collected information on the receiver of the gift, independently of whether the gift was later shared in the household.

*Control variables*

We controlled for age, schooling, household size, village of residency, and hereditary factors. Previous studies have shown that community attributes such as income inequality, institutions, or residential segregation contribute to health (Marmot, 2005). We could not control for this wide range of variables, but village dummy variables have the advantage of accounting for all of these community-level fixed confounders. We also attempted to control for hereditary factors. Since BMI includes weight and height, and height has a strong hereditary component (Henneberg & van den Berg, 1990) we included mother's height as a control.

Table 1 contains definitions and summary statistics for the variables used in the regression analyses.

**Results**

Table 2 contains the main regression results. We find a positive and statistically significant association between social rank and the three anthropometric indicators of nutritional status. Since we express social rank and the indicators of nutritional status in natural logarithms, we can read the coefficients as elasticities (%Δ outcome/1% Δ social rank). Given that our measure of social rank only gives us ordinal rankings, the magnitude of the associations found should be read with caution. For example, one cannot compare the relative magnitude of the coefficients across the three indicators of nutritional status, as a percentage variation of the average might represent different percent of the actual variation in the sample for each of the three outcome variables.

In Table 2 column [1], we find that a 1% increase in social rank is associated with an increase of BMI of 0.032%

( $p = 0.10$ ). The association implies that moving the lowest ranked men from position one to position two in the rank hierarchy would increase his BMI by 3.2%.

In column [2] we include the height of the man's mother. We could not obtain data from the mothers of all men in the sample, so the sample size of the regression using mother's height is smaller ( $n = 131$ ) than the sample size of regression [1] ( $n = 289$ ). Once we condition for mother's height, the point elasticity has a three-fold increase from 0.032 in model [1] to 0.090 in model [2].

We tested the association between social rank and mid-arm circumference (columns [3]–[4]) and sum of skinfold thickness (columns [5]–[6]). We found statistically significant, positive, and meaningful associations. For instance, doubling a person's social rank was associated with a 4.1% increase in mid-arm circumference in model [3] that does not control for mother's height, and with a 8.5% increase in mid-arm circumference in the model that controls for mother's height (column [4]). Doubling a person's social rank was associated with a 14.0% increase in the sum of four skinfolds in model [5] that does not control for mother's height, and with a 24.1% increase in the sum of four skinfolds in model [6] that controls for mother's height (column [6]).

In sum, social rank bears a positive association with the three anthropometric indices of nutritional status that we measured. For the three outcomes, the magnitude of the association was at least double in the model controlling for mother's height. All the results, except the association between social rank and BMI without controlling for mother's height, were statistically significant at the 95% confidence level.

*Robustness*

We tested the robustness of our results in four different ways (results not shown). First, we ran the regressions of Table 2 using a different proxy for social status. We generated a dummy variable that took the value of one if the person was nominated as important in the village at

**Table 1**  
Definition and summary statistics of variables used in regressions, men over 18 years of age

Variable	Definition	N	Mean	Standard deviation
<b>I. Outcome variables (in regressions entered in natural logarithm)</b>				
BMI	Body mass index (weight in kg/height in m <sup>2</sup> )	289	23.53	2.26
Mid-arm circumference	Mid-arm circumference of participant (cm)	289	27.21	2.22
Sum of four skinfolds	Sum of biceps, triceps, subscapular, supra-iliac skinfold thickness (mm)	289	36.38	12.89
<b>II. Explanatory variable (in regressions entered in natural logarithm)</b>				
Social rank	Person's rank in a village, from the lowest number of nominations (lower social rank) to the person with the highest number of nominations	289	14.25	7.88
<b>III. Control variables</b>				
Daily income	Average personal monetary income from (1) value of a basket of foods consumed during a day and (2) monetary income from sale, barter, and wage labor; in bolivianos (Bs) (1US \$ = 7.98 Bs)	289	31.24	23.68
Social capital	Total value in bolivianos of gifts received by subject in last 7 days	289	2.87	8.09
Job autonomy	Dummy variable. 1 = the person has not worked for wage labor during the last 2 months, 0 = the person has done some wage labor	289	0.60	0.48
Age	Age of participant (years)	289	37.84	17.57
Schooling	Maximum school grade achieved by participant	289	2.72	2.91
Household size	Number of people in the household	237	6.34	2.87
Mother's height	Measured standing physical stature of subject's mother (cm)	131	148.47	5.21

**Table 2**

Regression results of indicators of nutritional status (outcome variable) against social rank among Tsimane' men (>18 years)

Explanatory variables:	Outcome variable. Natural logarithm of:					
	BMI		Mid-arm circumference		Sum four skinfold	
	[1]	[2]	[3]	[4]	[5]	[6]
Social rank (log)	0.032 (0.018)*	0.090 (0.018)***	0.041 (0.013)***	0.085 (0.021)***	0.140 (0.043)***	0.241 (0.093)**
Controls						
Age	0.0004 (0.0002)*	0.001 (0.0008)**	−0.0002 (0.0002)	0.0007 (0.0005)	−0.0004 (0.0009)	0.003 (0.003)*
Schooling	0.004 (0.003)	0.005 (0.005)	0.001 (0.002)	0.001 (0.003)	0.005 (0.011)	0.012 (0.021)
Household size	0.001 (0.002)	−0.001 (0.001)	0.002 (0.001)	0.001 (0.002)	0.012 (0.007)	0.003 (0.012)
Daily income	0.0001 (0.0002)	0.0006 (0.0003)**	0.0001 (0.0002)	0.0008 (0.0008)**	0.0004 (0.0008)	0.0008 (0.001)
Social capital	0.0008 (0.0008)	0.0002 (0.0004)	0.0004 (0.0004)	0.0001 (0.0006)	−0.0008 (0.001)	−0.0004 (0.002)
Job autonomy	−0.009 (0.009)	−0.019 (0.006)**	−0.016 (0.010)	−0.022 (0.010)*	−0.001 (0.033)	−0.009 (0.048)
Mother's height	^	−0.0002 (0.001)	^	−0.0005 (0.001)	^	−0.003 (0.003)
Constant	3.14 (0.041)***	3.00 (0.166)***	3.30 (0.036)***	3.18 (0.298)***	3.51 (0.132)***	3.33 (0.636)***
N	289	131	289	131	289	131
R <sup>2</sup>	0.17	0.47	0.16	0.36	0.18	0.33

Note: Ordinary least squares (OLS) regressions with robust standard error and clustering by village. Regressions contain a full set of village dummies (13 – 1 = 12) not shown. For definition of variables see Table 1. Robust standard errors used when probability of exceeding critical value in Cook-Weisberg test of heteroskedasticity <0.10. In cells we show coefficients and, in parenthesis, standard errors. \*, \*\*, and \*\*\* significant at the 10%, 5%, and 1% level. ^ Variable intentionally excluded from the analysis.

least once and zero if the person was never nominated. Men who were nominated at least once had between 2.6% and 8.3% higher BMI, between 3.2% and 7.3% higher mid-arm circumference, and between 11.2% and 23.7% higher sum of four skinfold than men who were never nominated. All the associations were statistically significant at the 95% confidence level or higher except the regression using BMI as outcome but without controlling for mother's height ( $p = 0.14$ ).

Second, we tested whether the association persisted after controlling for (a) self-reported poor health, a standard covariate of BMI, (b) smiles, an objective indicator of level of stress, (c) alcohol consumption, a standard risk factor for health, (d) daily individual consumption (rather than income), and non-linear effects of (e) age and (f) household size. To proxy health, we collected information on the total number of days subjects reported being bed-ridden during the 2 weeks before the day of the interview. To proxy the level of stress of respondents, we used a direct measure of happiness, intensity of smiling during interviews, as coded by surveyors. Experimental and observational studies suggest that smiling bears a positive association with self-reported happiness across cultures (Pavot, Diener, Colvin, & Sandvik, 1991). We collected information on alcohol consumption by asking about the amount of alcohol and beer consumed over the 7 days before the day of the interview. We defined daily individual consumption as the sum of the average monetary value of all money spent during a day, the average monetary value of goods bartered during a day, and the average monetary value of a basket of farm and forest items consumed during a day (i.e., excluding items that were acquired through the market). To control for non-linear effects of age and household size we included squared terms. We ran a set of regressions similar to those in Table 2 adding the different variables just discussed one at a time. We found essentially the same results, with weaker significance for BMI than for the other two outcomes. We also ran a regression with all the variables in the benchmark model and all the covariates described in the previous paragraph (not shown). We found

weaker results to the ones presented in Table 2 for the regression that excluded maternal height, and similar results for the model controlling for maternal height.

Third, we used paternal, rather than maternal stature as control for hereditary factors. The coefficients for social rank in regressions including paternal stature are slightly lower than the coefficients in regressions using maternal stature, but statistically significant at the 95% confidence level.

In our final test of robustness, we ran the analysis of Table 2 columns [a], [c], and [e] but limiting the sample to men for whom we lack information on mother's height. We did so to test whether the effects we find when including mother's height are driven by changes in sample composition. We found that for this part of the sample none of our outcome variables were associated in a statistically significant way to social rank.

### Discussion and conclusion

We organize the discussion around three findings. First, we found that a locally-relevant measure of social rank has a positive association with anthropometric indicators of short-run nutritional status. Second, the association was limited to the part of the sample for which we had data on mother's height. Third, for this part of the sample, the association persisted after controlling for many confounders and standard pathways examined in research in industrial nations.

First, we found that the association between social rank and anthropometric indicators of short-run nutritional status is robust to the three indicators of nutritional status used. The magnitude of the association and the level of statistical significance were lower when using BMI than when using mid-arm circumference or the sum of four skinfolds as outcomes. As discussed in a previous section, a possible explanation for the lower significance of BMI relates to limitations of BMI as a universal measure of under-nutrition and obesity (Garn et al., 1986; Norgan, 1994).

Our first finding, the association between social rank and nutritional status, is consistent with findings from industrial and non-human primate societies (Marmot, 2006; Sapolsky, 2004; Wilkinson, 2000). The magnitude of the association was important in real terms, but probably not equally significant for the entire sample. Since less than a third of the sample was nominated as important, we are unsure of how hard would it be for a person to go from the group of non-nominated to the group of people who at least received one nomination.

Second, when splitting the sample between informants with and without data on mother's height, we found that the association between social status and indicators of short-run nutritional status persisted only for the sample of people for whom we have data on mother's height. The association was not statistically significant for the subsample of people for whom we do not have data on mother's height. Why would the results of the two subsamples be different? Using a series of *t*-test comparisons of means, we analyzed the socio-demographic and physical characteristics of the two subsamples (not shown). Men for whom we do not have data on mother's height were older than men for whom we do have data (45 versus 28 years of age,  $p < 0.00001$ ), probably because it is more likely that the mothers of older people were dead. We also found a positive and statistically significant association between age and social rank for the two subsamples. Our results, suggest that the association between social rank and indices of short-run nutritional status might decrease across the life span.

The last finding that deserves discussion is the robustness of the association after controlling for standard pathways. The finding supports the idea that dominance hierarchies might influence health through other channels beyond the channels examined in industrial societies, i.e., perceived stress, social capital, and own resources. Because of the limitations of our proxies for psychosocial factors (discussed before), our results do not allow us to conclude that the psychosocial path does not explain the association between social rank and nutritional status in a foraging-farming society, but rather it is possible that the proxies for the psychosocial factors used might not be adequate in this context. Which other channels might mediate the social gradient?

We suggest two other potential paths: exemption from social obligations, and psychological well-being associated with being respected. Ethnographic research and behavioral experiments suggest that individuals with higher social rank receive privileges and are excused from some social obligations (Henrich & Gil-White, 2001). Using behavioral experiments, researchers have also found that individuals of high social rank are more likely to be exempted from social sanctions (Bickman, 1971) and are more likely to be conferred special privileges (Ungar, 1981) than individuals of low social rank. Thus, it is possible that social rank changes the allocation of tasks and occupations and, in so doing, changes energy expenditures, which influences anthropometric indices of short-run nutritional status.

Second, in a Foraging-farming society, the sense of being respected by the community might be a better measure of the psychosocial factors that mediate the relation between

socioeconomic status and health than job autonomy and social capital. Researchers have argued that poor health reflects both the feeling of being poor and the objective status of poverty. Subjective indicators of socioeconomic status are as good or better predictors than objective indicators of socioeconomic status for stress-related outcomes (Goodman et al., 2003). Along the same lines, a subjective, culturally relevant indicator of respect might be a better measure of the pathway for the association between social rank and health.

In conclusion, this study opens three lines for future research on the social gradient in health among small-scale societies. First, further research should address the role of culturally defined notions of respect as potential pathways to explain the relationship between social rank and health. Second, further research should also address causality between the variables explored. Longitudinal surveys of the same informants have the potential to control for unobserved person-level fixed effects correlated with the regressors and outcomes, and could therefore move the analysis towards a causal interpretation. Last, results from this research point to the need for a better understanding of the association between social rank and indices of short-run nutritional status at different points in a lifetime. Further empirical research among small-scale societies should address the longitudinal dimension of the social gradient in health.

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