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Comparison of anthropometric variability by sex and food-security in a native Amazonian society of Bolivia

Submitted by

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Anthropometric variability matters because it proxies for vulnerability and might mirror socioeconomic inequalities in a society. One expects greater anthropometric variability in poorer and more marginalized groups, yet this intuition has rarely been tested in developing nations. The goal of this paper is to compare anthropometric variability between males and females from food-insecure and food-secure households in a native Amazonian society of foragers-farmers. Subjects included 742 females and 762 males. Anthropometric indicators include physical stature, weight, and body-mass index (BMI). I use the coefficient of variation to measure variability and I use a composite measure of food security developed in situ.

Results suggest a) high anthropometric variability in early childhood, irrespective of food-security status of households; b) boys < 5 years of age from food-insecure households have higher variability in physical stature and in weight than their age peers from food-secure households; c) females 12-19 years of age from food-insecure households have higher variability than their same-age peers from food-secure households; d) measures of anthropometric variability between females and males from food secure and insecure household resemble each after 25 years of age. Results were robust to different measures of variability.

Conclusion: Higher anthropometric variability among boys < 5 years of age and females 12-19 years of age from food-insecure households suggests that they might be the most vulnerable groups among the Tsimane'.

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Abbreviations

BMI	Body-Mass Index
BRA	Boston Redevelopment Authority
CV	Coefficient of variation (Standard Deviation/Mean)
EARO	East Asia Regional Office of Oxfam America
FINCA	Foundation of International Community Assistance
FTA	Free Trade Agreement
GRP	Gross Regional Product
Kcal	Kilo calories
MDG	Millennium Development Goal
MIT	Massachusetts Institute of Technology
NGOs	Non-Governmental Organizations
OA	Oxfam America
PRADAN	Professional Assistance for Development Action
REMI	Regional Economic Models Inc
TAPS	Tsimane' Amazonian Panel Study

1.0 Introduction and Learning Objectives

At Heller School I developed strong aptitude for rigorous research and formulated my assumptions into academic query. I did not plan to be a technical person in the development sector. However, soon I realized the importance of having objectivity in policy discussion. As a development practitioner and student of sustainable development it is very crucial for me to comprehend the factual reality and build my interventions on the “evidence”. My future career goal is to work in poverty reduction programs. To this end, it is my hope that this paper will help me to design better implementation strategies for economic and social protection for the poor.

With a goal of overcoming my skills and knowledge limitations in comprehending the situation of economic disadvantaged people and in analyzing the public policy, I set the following learning objectives for my second year project proposal:

1. To build theoretical and empirical foundations for comprehending the impact of poverty on people
2. To measure the effect of food-insecurity on the quality of life of people and to identify associations between anthropometric variability and age with respect to sex and food-security status
3. To be able to scientifically identify the marginalized groups
4. To augment my analytical ability in exploring the possibility of linkage between research techniques with advocacy and policy recommendations
5. To enhance my ability in using quantitative skills in development settings

My natural aptitude for economics, theoretical frameworks and quantitative skills led me to take courses like Applied Econometrics, Advance Econometrics, Economics for Managers, Household Economics, Regional Socio-economic Impact Analysis and Modeling (MIT), Theory of Social Policy and Analysis, and Environment Impact Assessment. In my 2nd year, I attended the course Advanced Econometric which helped me to build further my knowledge and skill of econometrics. In Applied Econometrics, I learned how to do data analysis of panel data sets in development settings. I also learned how to do impact assessments of programs and policies and with respect to both internal and external threats to validity.

2.0 Description of the Sustainable Development Problem

More than 815 million people are suffering from hunger in the developing world (FAO, 2005) and 160 million children are malnourished (UNDP, 1999). Food-insecurity is characterized as lack of access of foods or lack of ability to acquire food in a socially acceptable way (Anderson, 1990). Hunger is the most extreme form of poverty, where families are unable to fulfill their minimum nutritional requirements.

Food-insecurity or lack of availability of food for consumption in a household results in hunger, malnutrition, and negative effects on the health of household members. Food insecurity is a prime indicator of poverty and a lack of nutritious food to individuals has profound negative effects on the well-being of people.

In childhood, malnutrition can increase the incidence of mortality; impair physical and emotional growth (Horton, 1986), and negatively affect the health. In adulthood, malnutrition can reduce labor productivity (Strauss and Thomas, 1998). Poverty is the most unfortunate incidence which impairs the ability of individuals to realize their full potential for growth.

Poverty reduction has always been of prime importance to the development agenda. The first goal of the United Nations Millennium Development Goals (MDGs) is to eradicate the extreme hunger and poverty and to reduce poverty of less than a dollar in half by 2015. Every nation has its own definition of poor; some are based on income and others are based on caloric intake. The same relational definition of poverty is applied to indigenous people, though there is no consensus on who is indigenous. There is still little known about many indigenous communities and the importance of understanding an indigenous people in formulating development policies can not be overemphasized. Indigenous people like Tsimane' are generally off the radar of policy planners. This paper focuses on the identification of those among the Tsimane' in the Bolivian Amazon who are the most affected by hunger-an extreme form of poverty.

Around 40 million indigenous people live in Latin America (World Indigenous conference UN, 1992) and 60% of the Bolivian population is indigenous. Bolivia is one of the least developed countries in Latin America. Agriculture is the main source of livelihood for rural and indigenous people. In Bolivia, indigenous are always marginalized as they are sidelined in the process of the institutional decision-making process, despite comprising the majority. The feeling of marginalization that results from has led to a great degree of political turmoil. The most recent election, in which indigenous issues were at the forefront of the political discourse, and an indigenous president was elected, is an outcome of such turmoil. In spite of this, a continuing problem Bolivia faces is that modern development strategies are sometimes in conflict with indigenous culture, their habitat, and traditional knowledge.

The Tsimane', a foraging-farming community from Beni department, are one such indigenous group who are particularly marginalized and isolated from mainstream Bolivian society. This study assessed who among Tsimane' are the most affected by food-insecurity. Variability in anthropometric indicators like physical stature, weight, and BMI are used to assess the marginalization. Several research studies suggest that anthropometric variability in physical stature and weight have positive association with marginality. This study used variability in anthropometric to identify the more marginalized groups among Tsimane'. If the variation in physical stature, weight and in BMI is the same for the individuals, food-insecurity status does not have any effect on growth of the individuals. This study will cross-check the general understanding of whether foraging societies have access of adequate nutrition and general health (Godoy et al. 2005a).

It is important to develop the particular understanding about the indigenous people so policies and programs can be better designed which are sensitive to indigenous context and needs. This study is a continuation of efforts to build the understanding about indigenous people.

3.0 Definition of the Development Question

This paper attempts to identify the consequence of food-insecurity on health of the Tsimane' Bolivian Amazonian. Physical stature, weight, and BMI are used for as a proxy for health of women, men and children. Anthropometric variability in forager societies is not well known (Wong and Godoy 2003). Consequently, the results of this paper would expand our understanding of the trend of anthropometric variability over the life course in a foraging society.

3.1 Hypothesis 1

Food-insecure households do not have enough food to fulfill the nutritional requirement of household members and inadequate dietary intakes (food-insecurity) manifests in hunger, malnutrition, and negative effects on the quality of life of men, women and children. As a result, individuals from food-insecure households have greater anthropometric variability than individuals from food-secure households.

3.2 Hypothesis 2

Adolescence¹/ teenage is a transition phase between childhood and adulthood where a person goes through major physiological and psychological changes. One of the important features of this dynamic phase, from the study perspective, is growth spurt/pubertal spurt. Boys and girls experience rapid change in their body composition than at any other time in their life. More than 50% of bone

¹ Adolescence is a transition period between childhood and adulthood. It varies from culture to culture, WHO defines age from 9-10 to 19 years. "Teenager" is also synonymously used for adolescent in western English speaking countries. (See Wikipedia <http://en.wikipedia.org/wiki/Adolescence> , retrieved on 18 Feb.07)

mass in girls forms during this phase². Boys and girls need proper diets to meet the requirements of energy and micro-nutrients. Proper nutrition is a major determinant of normal growth and lack of food can hamper the growth spurt and pubertal growth that occurs in this period (Rogol et al., 2002). Hypothesis 2 predicts variability in physical stature, weight and BMI peak between 9 and 18 years of age among females and males in Tsimane' foraging-farming community in Bolivian Amazon. Literature also suggests that in industrial nations anthropometric variability peaks at teenage that is 7-12 years of age (Harrison and Schmitt, 1988; Godoy et al., 2005c).

3.3 Hypothesis 3

The potential negative effects of malnutrition among children are high. So this study predicts that children from food-insecure households have higher variability than children from food-secure households. This difference of anthropometric variability in young boys should be higher than the young females. Literature supports that with environmental factors such as food-insecurity, the growth path of young males is more easily disrupted than that of females (Bielicki and Charzewski, 1977; Godoy et al.; 2005c).

This paper is useful for researchers to build the understanding of anthropometric trends in forager societies. Comparisons of variability in anthropometric of individuals from food-secure households and food-insecure households by sex and age can help policy planners to identify the more marginalized groups among the Tsimane'. Consequently, policy planners can use the findings of this study to channel resources to the most marginalized groups among Tsimane'. In a resource-scare situation, it is vital to identify the target (most marginalized section) so resources can be better targeted towards that particular section or activity.

4.0 Methods

4.1 Tsimane' and Sample

The Tsimane' is a typical foraging-farming community. They live along the Maniqui River in Beni department of Bolivian Amazon and are involved in hunting, fishing, slash and burn farming and logging for their livelihoods. Some of Tsimane' work as unskilled labor in San borja and in wood logging camps in Bolivian Amazon. Largely, Tsimane' marry in same ethnic group and practice cross-cousin marriage and monogamy which limits genetic diversity pool and results in a close-knit network of relatives tied together through marriage and bloodline. After marriage, Tsimane' dwell in matrilineal and finally settle down in neolocal nuclear family. San Borja is a nearest town and administrative center for the Tsimane' villages dwelling in the Maniqui River basin. The average distance of a village to San Borja is 25.96 km. After 1980, missionary and non profit

² National Women's Health Resource Center
<http://www.healthywomen.org/columns/drpeekescolumn/dbcolumn/teengirlsexercisenutritionalneeds> (Retrieved on 18 Feb. 07)

organizations are started working with Tsimane'. In spite of this, the Tsimane' have intermittent interactions with outside world and they remain highly autarkic (Godoy et al., 2006 b).

Information used for the analysis was obtained from a survey done in 2005 during June and September among 252 households in 13 Tsimane villages. These villages straddle the Maniqui River. This 2005 survey is a part of an ongoing panel study TAPS (Tsimane' Amazonian Panel Study) which started in 1999 (Godoy et al 2007). According to latest Bolivian census, Tsimane' population is roughly 8,000 (Instituto Nacional de Estadística 2003) and villages constitutes around 18-20 households along the river (Patel et al., 2007).

4.2. Food-security Index

By following the Phillips and Taylor's definition of household food- insecurity, if members of a household are in a state where they can not fulfill their adequate dietary requirements through out the year or part of it; or if they perceive that in the future they will face difficulty to do so, then such a household can be considered as food-insecure households. Taking into account of this definition of household food-insecurity and the forager characteristics of Tsimane', the following criteria were used to construct a food security index

1. Food consumption in kcal: Food consumption is the core variable of this index which directly indicates the present nutritional status of the family. We used protocol to convert different nutrients like protein, carbohydrates and fat from beef, pork, chicken, duck, coil fish, maize, rice, pigeon pea, bread, and flour into a uniform nutritive value kcal. We combined thirteen raw variables from the data set and finally created the new variable 'total food consumption', measured in kcals of a household in the last seven days.
2. Value of modern assets: Value of modern assets in a household provides direct evidence about the families' food purchasing power. As the literature suggests, during crisis time a family sells its assets to smooth consumption. In other words modern assets are used as a buffer in hard times. A family builds its asset base during normal times and liquidates assets at the time of crisis. This process thus describes a coping mechanism (Godoy, 2006a; Dercon, 2005; Morduch, 1995).
3. Availability of Seeds: At first appearance, availability of seeds for crops does not seem to have any direct linkage with the current food consumption of households. However, in rural area, families save grains/ seeds from the present harvest for future crops and that can only be possible if households have sufficient grains. So, availability of seeds in household can provide insights about the food sufficiency of households. Also stored seeds (saving) can help households to meet temporary shortages of food.

4. Availability of food stocks: Like seeds, food buffering also illustrates the capability of a household to meet its food requirements in the future, both, in normal situations and in crises. This buffer shields or provides insurance to households at the time of encounter of unforeseeable shocks.
5. Variety of crops planted: Studies suggest that farmers diversify crops to minimize the risks and vulnerability of crop failure and down side price fluctuations of crops (Godoy, 2006a; Dercon, 2005; Morduch, 1995). As a result we assume that by counting the variety of crops planted by farmers, we can highlight the household's coping strategies. From nutritionist point of view, crop diversity provides variety of nutrients to household's members to ensure the balance growth.
6. Forest area cleared by the household for cultivation: Since, Tsimane' are involved in slash and burn farming in the Bolivian Amazon and forest land is commonly owned by Tsimane' there is no individual ownership of land. The more a household clears forest lands for the cultivation, the greater the agriculture production for that household would be. Hence, in Tsimane', it is an important measure to estimate the coming quantity of agriculture production to a household. Also because of high chance of measurement errors in the estimation of agricultural production, total forest land cleared for cultivation can work as a good proxy for the total agricultural production.

2005 TAPS survey provides us enough data to create a food-insecurity index of households by using the above mention variables. We used Principle Component and Factor (pcf) techniques to create a food-insecurity index (FII) in order to capture the multi-dimensionality of household food-insecurity. This new factor variable is constructed by this new factor variable by using cut off (higher than 1.3) eigen values³. In other words, this new factor variable is the best possible combination of all six variables. This factor variable is a food insecurity index which has 1.24 as maximum value (highly food-secure); 0.21 as median value (moderate food-secure); and -2.79 as minimum value (extremely food- insecure). This index variable is further converted into a dummy variable; one which represents food-insecure households having a factor value less than zero (all negative values).

4.3 Variables: Physical Stature, Weight, and Body-mass Index (BMI)

Physical stature, weight, and BMI (= weight in kg/standing physical stature in meter square) variables are used as anthropometric indicators. Anthropometric variability was calculated for the following age categories ≤ 2 years, 3-5 years, 6-11 years, 12-19 years, 20-25 years and 26+ for the analysis. Digit heaping found in stature ending at zero for women and at 5 for men (Godoy et al., 2007). Random measurement errors in age were also reported and digit heaping was also noticed at multiples of five such as at age 5, 10, 15, 20 (Godoy et al., 2005b). However, raw data is used for analysis to keep the sanctity of raw data.

³ Eigen values are variances of the original components

4.4 Statistical Analysis

Coefficient of variation (CV) was used for the measurement of variability.

$$\text{Coefficient of variation (CV)} = \frac{\text{Standard deviation}}{\text{Mean}}$$

Coefficient of variation of a variable was measured as standard deviation/mean. Several past research studies (Harrison and Schmit, 1988; Godoy, 2005c) have used the coefficient of variation for measuring anthropometric variability. Results are further cross-checked on other measures of inequality like standard deviation of the logarithms and Gini-coefficient. The statistical package STATA version 9 was used to calculate the coefficient of variation, standard deviation of logarithms, and Gini-coefficient.

4.5 Literature Research

Peer review journals were reviewed to build the understanding of existing literature on the relationship between: anthropometric variability and age; conceptual linkage between food-insecurity and anthropometric; and anthropometric trends in developed and developing nations through the course of life. Initial library research helped to build the theoretical frame to conceive the study and define the findings in a wider perspective.

4.6 Limitations

4.6.1 Food-insecurity index categories people into food-secure and food-insecure households. If food-insecurity index had been segregated into categories like highly food-secure, moderate food-secure, moderate food-insecure and extreme food-insecure, anthropometric variability would have given more precise understanding of effects of food-insecurity on extreme and moderate poor. This data set does not allow further segregation because of small number of sample in each category. Detail anthropometric variability analysis of extreme and moderate poor would have portrayed more precise destitute situation of extreme poverty.

4.6.2 Limitations in statistical techniques,

This study can not claim statistically significant results. Techniques like regression analysis could have shown the statistical significance of the results. Had the panel data set been for at least 8-10 years, regression analysis could have been used to see the historical trends of variability in anthropometrics among individual from food-secure and food-insecure households. That result would have given more precise results to highlight the perpetuated marginalization individuals from food-insecure households face.

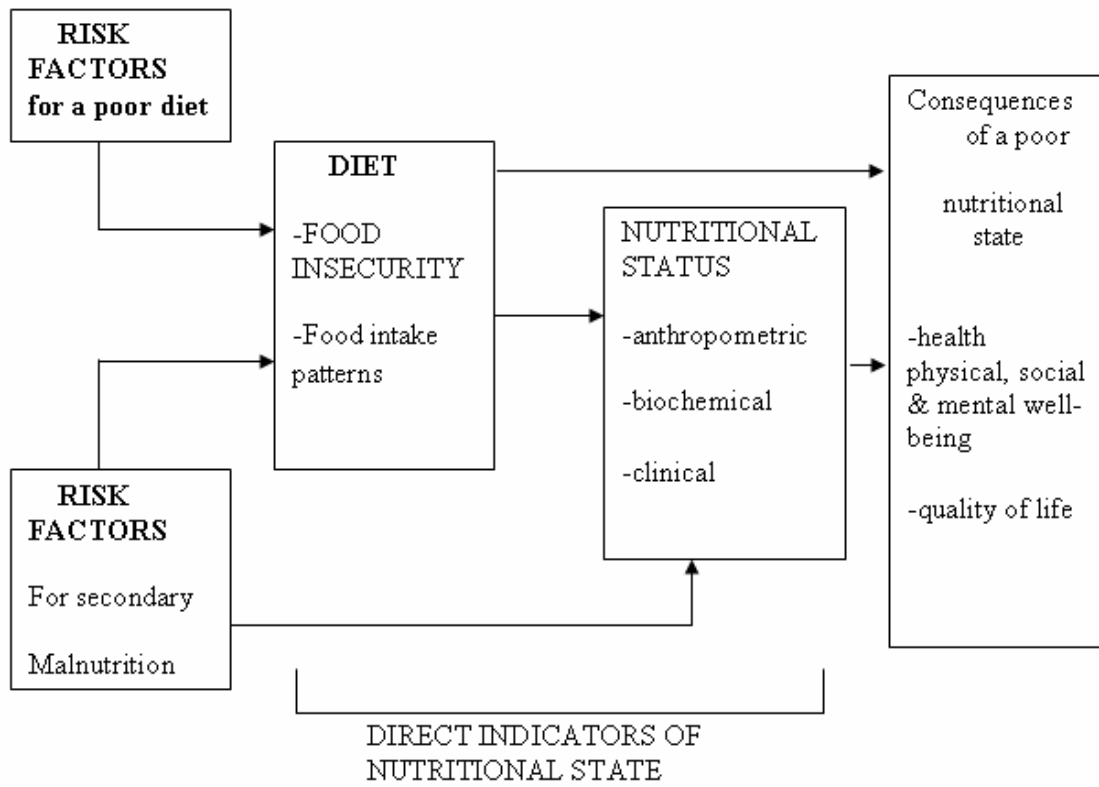
5.0 Literature review

Several research papers and case studies of developed and developing nations show that marginalized sections of society have higher anthropometric variability and are more vulnerable to income or wealth inequality (Schmitt and Harrison, 1988, 1989; Baten, 2000; Mishel et al., 2003; Godoy et al., 2005c). There is substantial evidence that anthropometric parameters like physical stature, weight, and BMI consistently correlate with quality of life parameters such as life expectancy, education, morbidity and mortality (health), income or wealth and labor productivity (Fogel, 1994; Komlos, 1994; Steckel, 1995; Strauss and Thomas, 1998; Goodman et al., 2004; Godoy et al., 2005c; Dinda, 2006). Anthropometric parameters are not just measurements of the shape and size of the human body. They also reflect the socio-economic inequality prevalent in society, effects of historical natural and artificial shocks, and the welfare policy of a country (Steckel, 1995; Sen, 1997; Strauss, 1998; Godoy et al., 2005c).

In the past, the phenotypic nature of anthropometrics has been discussed a great deal. Since genetic and environmental factors are intertwined, separating environmental factors from hereditary factors, predicting trends, and establishing cause and effect relationships has been difficult (Harrison and Schmitt, 1988; Steckel, 1995). Now it has been accepted that phenotypic variability is predominantly due to the environmental factors and linked with the quality of life of people, even in animals. In the case of the Tsimane' who largely marry in same ethnic group, genetic factors are more or less same. Thus we can conclude that environmental factors are responsible for the anthropometric variability among individuals in the Tsimane' population.

The potential effect of food-insecurity (an environmental factor) on people is manifested in malnutrition, hunger, impaired cognitive growth, and low productivity (Campbell, 1991; Kelly, 1992; Tarasuk et al., 1999; Olson, 1999; Kasper et al., 2000; Nnakwe et al., 2002). Campbell (1991) proposed a conceptual framework of food-insecurity, including risk factors for the poor and consequences of food-insecurity (Figure 1). She also explained both the effect of food-insecurity on nutritional status that is evident in anthropometrics, and the consequences of food-insecurity on physical, mental and social wellbeing of the people. This conceptual framework establishes the direct relations between food-insecurity and anthropometrics and potential consequences on quality of life.

Figure 1: Campbell’s conceptual framework of food-insecurity; Campbell (1991)



Variability in anthropometrics reveals the unequal access of nutritional intake or lack of availability of foods to individuals at different developmental stages of the body. Less variability in anthropometric indicators is proof of normal health and overall wellbeing of individuals under given genetic and environmental conditions and indicates fewer chances of occurrence of inequality among them, except in extreme situations where all members suffer. Mainly economists have studied rural and small holders in Asia and Africa and have made inferences for forager societies. This paper expands our present understanding of the relation among food-insecurity, anthropometric variability and age by sex in a forager’s society.

There is a striking difference noticed during literature review in the anthropometric physical stature variability in developed nations like USA and UK; and developing nations like India and Thailand. In developed nations, the relation between variability in stature and age is an “inverted U” and variability in stature peaks during 9-14 years of age (Harrison and Schmitt, 1988; Godoy, 2005 c). High anthropometric variability in teenage years is expected because of the puberty-driven growth spurt during this age in males and females. However, in developing nations like India and Thailand, children ≤ 2 years have the highest variability in their life and variability in stature goes down along the life course with a little “inverted U” swing during teenage period (Harrison and Schmitt,

1988). The relation between age and anthropometric variability is downward in developing countries. Possible reasons can be that a lack of availability of sufficient dietary intake and high disease loads during early childhood in developing countries creates high variability in stature. Variability in stature and weight in early childhood has less to do with genes and depends on how children “catch up” and “catch down” (Tanner, 1986) in given environmental conditions. It would be interesting to notice the trends of anthropometric variability among Tsimane' foraging-farming society follows the same pattern of variability in anthropometric like developing nations or developed nations.

6.0 Evidence and Analysis

To ensure robustness of the results, I have also calculated the results using standard deviation of the logarithm (Table 2) and Gini-coefficient (Table 3) of physical stature, weight, and BMI. The results of these calculations are given below.

6.1 Descriptive Bivariate Comparisons

6.1.1 Physical Stature

a--Females

Females ≤ 11 years of age have more or less similar variability in physical stature irrespective of the food security condition of households. Adolescent girls 12-19 years of age from food-insecure households have 33% higher variability in physical stature than the same-age girls from food-secure households (Table 1, column 10). Between the ages 20 and 25, women from food-insecure households have 29% lower variability in physical stature than the same-age women from food-secure households. Adult females aged 26 and above years from food-insecure households have 17% greater variability in physical stature than the same-age females from food-secure households.

b-- Males

We found that young males from food-insecure household have greater variability in physical stature than the same-age boys from food-secure households in all the three measures of inequality – coefficient of variation, standard deviation of the logarithm (Table 2), and Gini-coefficient (Table 3). Boys ≤ 2 years and 3-5 years of age from food-insecure households have 8% and 32% higher variability in physical stature than the same-age boys from food-secure households (Table 1, column 11). Males 6-11 years of age from food-insecure households have 2% lower variability in physical stature than the same-age boys from food-secure households. After about 25 years of age, males from food-insecure and food-secure households have similar variability in physical stature (i.e. coefficient of variation 0.03).

c-- Females & males

During infancy ≤ 2 years of age (Table 1, columns 12 & 13), girls have 19% and 25% more variability in physical stature than the same-age boys in both food-insecure and food-secure households. Between 3 and 19 years of age, males have higher variability in physical stature than females. Females between 20 and 25 years of age have 30% greater variability in physical stature than males in food-secure households. There is no difference in physical stature variability between males and females from food-secure households after 25 years of age. However in food-insecure households, females aged 26 and above years have higher variability in physical stature than the same-age males.

d-- Summary

Young males 0-5 years of age from food-insecure households have higher variability in physical stature than the same-age boys from food-secure households. Adolescent females 12-19 years of age from food-insecure households have 33% higher variability in physical stature than the same-age females from food-secure households. Males and females aged 26 years and above have similar coefficients of variation, excepting females from food-insecure households.

6.1.2 Weight

a-- Females

Table 1, column 10 suggests that girl children ≤ 2 years of age from food-insecure households have 22% higher variability in weight than the same-age girl children from food-secure households. Young girls 3-5 years of age from food-insecure households have 33% lower variability in stature than the same-age girls from food-secure households. Between 6 and 11 years of age, girls from food-secure and food-insecure households have same coefficient of variation. Adolescent females 12-19 years of age from food-insecure households have 12% higher variability than the same-age females from food-secure households. Females 20-25 years of age from food insecure households have 14% higher variability than the same-age females from food-secure households. Females aged 26 years of age and above from food-insecure households have 6% higher variability in weight than the same-age females from food-secure households.

b-- Males

Table 1, column 11 suggests that boys ≤ 2 years and 3-5 years of age from food-insecure households have 5% and 44% greater variability in weight than the same-age group boys from food-secure households. Variability in weight is 22% higher in males between 20 and 25 years of age from food-insecure households than the same-age males from food-secure households.

c-- Females & males

Table 1, column 12 & 13 suggests that infant girls from food-insecure have greater variability in weight than same-age females from food-secure households

and males. In food-insecure households, girls ≤ 2 years of age have 29% more variability than the same-age males and in food-secure households girls ≤ 2 years of age have 25% more variability than the same-age males. After about 20 years of age, females 20-25 years of age have 26% and 33% respectively more variability than the same-age males in food-insecure households and in food-secure households (Table 1, column 12 & 13). Females aged 26 and above years of age have 31% and 20% respectively higher variability in weight than the same-age males in food-insecure households and in food-secure households (Table 1, columns 12 & 13).

d-- Summary

Variability in weight among males from food-insecure households peaks at 19 years of age, after that variability declines sharply (Table 1, column 6), whereas variability among males from food-secure households peaks during ≤ 2 years and 6-11 years of age (Table 1, column 8). Among females, variability peaks ≤ 2 years and between 6 and 11 years of age (Table 1, columns 2 & 4). Young males 3-5 years of age from food-insecure households have higher variability than the same-age males from food-secure households (Table 1, column 11).

6.1.3 Body -mass Index (BMI)

a--Females

We found that girl children ≤ 2 years of age from food-insecure households have 23% lower variability in BMI than the same-age girl children from food-secure households (Table 1, column 10). Young girls 3-5 years of age from food insecure households have 17% higher variability in BMI than the same-age females from food-secure households. Furthermore, between 6 and 11 years, young females from food-insecure households have 11% higher variability than the same-age females from food-secure households. Adolescent females aged 12-25 years from food-insecure households have 9% lower variability in BMI than the same-age females from food-secure households. After about 26 years of age, the variability in BMI of food-insecure women is similar to the variability in BMI of women in food-secure households.

b-- Males

Young males ≤ 2 years and 3-5 years of age from food-insecure households have 7% and 21% higher variability in BMI than same-age groups of males from food-secure households (Table 1, column 11). After 5 years of age, this trend reverses as young males 6-11 years and 12-19 years from food-insecure households have 30% and 55% respectively lower variability in BMI than the same-age males from food-secure households. After about 20 years of age, the difference in coefficient of variation among males from food-secure and food-insecure households is negligible.

c-- Females & males

In food-insecure households, girls ≤ 2 years of age have 15% lower variability in BMI than the same-age boys and in food-secure households girls ≤ 2 years of age have 13% higher variability than the same-age boys (Table 1, columns 12 & 13). Females between 3-5 years and 6-11 years have 17% and 29% higher variability in BMI than the same-age males in food-insecure households (Table 1, column 12). During 12-19 years of age, girls and boys from food-insecure households have the same coefficient of variation in BMI. In food-secure households (Column 13), females 12-19 years of age have 42% lower variability in BMI than the same-age males. Females 20-25 years have 33% and 43% respectively higher variability in BMI than the same-age males in food-insecure (Column 12) and food-secure (Column 13) households. Women aged 26 and above years have 23% higher variability than men irrespective of food-security status of households.

d-- Summary

Girls 3-5 years of age from food-insecure households have more variability than the same-age girls from food-secure households. Boys 3-5 years from food-insecure households have higher variability than the same-age boys from food-secure households. Adult women aged 20+ years of age have more variability in BMI than the same-age males in food-insecure households and in food-secure households.

6.2 Visual Analysis

Figures 2-4 show the coefficient of variation of physical stature, weight, and BMI on the y-axis and the age category on the x-axis for females and males from food-secure and food-insecure households. In figure 2, females ≤ 2 years of age have highest variability in stature. Physical stature clearly shows sharp linear decline in variability over the years irrespective of food-security status of households as males and females grow up. Females 12-19 years of age from food-secure households have higher variability in physical stature than the same-age females from food-secure households.

In figure 3, infant girls ≤ 2 years of age from food-insecure households have highest variability in weight. Weight also shows a declining trend similar to physical stature. In figure 3, variability curves of males and females from food-secure and food-insecure households swing together. The relation between variability in stature and age (Figure 2) and in weight and age (Figure 3) is downward. This indicates children have the highest variability and as individuals, grow variability in physical stature and weight declines along with age. The relation between variability in BMI and age is "inverted U" curve, except an inverted U swing in 12-19 years of age (Figure 4). Figures 2-4 show that after attaining the adulthood (20+ years), anthropometric variability of females from food-secure and food-insecure households converge. In case of males food security as an environmental factor is not critical in determining anthropometric variability. In other words environmental factors have a constant effect or no

effect on the population. Males < 5 years of age from food-insecure households have greater variability in physical stature and weight than the same-age males from food-secure households (Figures 2 & 3). Females 12-19 years of age from food-insecure households have higher variability in physical stature than the same-age females from food-secure households.

6.3 Robustness

Results are also calculated by using standard deviation of the logarithms (Table 2) and Gini-coefficient (Table 3) to ensure the robustness of the results.

6.3.1 Physical Stature

Females 12-19 years of age from food-insecure households have 40% by using standard deviation of the logarithms (Table 2, column 10) and 33% by using Gini-coefficient (Table 3, column 10) higher variability in their physical stature than the same-age females from food-secure households. Standard deviation of the logarithms found females aged 26 and above years of age from food-insecure households have 25% higher physical stature variability than their same-age peers from food-secure households (Table 2, column 10) whereas Gini-coefficient suggests no difference in variability in physical stature among females aged 26 years of age. Young males ≤ 2 and 3-5 years of age from food-insecure households have 7% and 27% respectively higher physical stature variability than the same-age males from food-secure households (Table 2, column 11). Gini-coefficient measures indicate no difference in stature variability among males ≤ 2 years of age. However, males 3-5 years of age from food-insecure households have 33% higher variability in physical stature than the same-age males from food-secure households (Table 3, column 11). Both measures of inequality found both that children ≤ 2 years of age have highest variability in physical stature and that variability goes down as they age.

6.3.2 Weight

Table 2, column 10 suggests that females ≤ 2 and 3-5 years of age from food-insecure households have 50% and 22% more variability in weight than the same-age females from food-secure households. Whereas table 3, column 10 measures females from food-insecure households age ≤ 2 years have 14% lower and age between 3 and 5 years have 20% higher variability in weight than the same-age females from food-secure households. Table 2 column 11 suggests males ≤ 2 and 3-5 years of age from food-insecure households have 17% lower and 14% higher variability than the same-age males from food-secure households. Table 3, column 11 confirms that males ≤ 2 and 3-5 years of age from food-insecure households have 13% and 25% respectively higher variability in weight than the same-age males from food-secure households. Both measures of inequality (Tables 2 & 3, columns 12 & 13) suggest that females aged 26 and above years of age have higher variability in weight than the same-age males from food-secure and food-insecure households.

6.3.3 *Body-mass Index (BMI)*

Females ≤ 2 years of age from food-insecure households have 11% by using standard deviation of the logarithms (Table 2, column 10) and 12% by using Gini-coefficient (Table 3, column 10) higher variability in their BMI than the same-age females from food-secure households. Standard deviation of the logarithms and Gini-coefficient suggest that females 12-19 years of age from food-insecure households have 11% higher variability in BMI than the same-age females from food-secure households. Standard deviation of the logarithms suggest that males ≤ 2 and 3-5 years of age from food-insecure households have 7% and 39% respectively higher variability in BMI than the same-age males from food-secure households (Table 2, column 11). Gini-coefficient calculations found males ≤ 2 and 3-5 years of age from food-insecure households have 1% and 38% respectively higher variability in BMI than the same-age males from food-secure households (Table 3, column 11). Both measures of inequality (Tables 2 & 3, columns 12 & 13) suggest that females aged 26 and above years of age have higher variability in BMI than the same-age males from food-secure and food-insecure households.

7.0 Discussion

The results expand our present understanding of the trend of anthropometric variability over the life course in a foraging society. They also help to make comparisons of variability in anthropometrics of food-secure and food-insecure individuals by sex and age, which helps to identify the more marginalized groups among Tsimane'.

The anthropometric variability comparisons between food-insecure and food-secure individuals over the life course reveal some notable patterns of effect of malnutrition on the normal growth pattern. High variability at early childhood was found in both males and females from food-secure and food-insecure households. Similar patterns in variability in physical stature are noticed in children from developing countries (Harrison and Schmitt, 1988). Especially, young males 0-5 years of age from food-insecure households have high variability in physical stature and weight than the same-age males from food-secure households. This finding identifies young males in Tsimane' as the most vulnerable or marginalized group.

Prevalence of malnutrition among Tsimane' is making young children, particularly male, susceptible to environmental influences. Having high variability in physical stature in weight in early childhood ≤ 2 years of age is governed more by environmental factors than by genes. Poor environmental conditions are making it harder for young children to achieve homeostasis or allostasis. High variability in young males indicates the failure of canalization of growth process or homeostasis among young males from food-insecure households. The findings confirm the results of several earlier research studies that females are stronger than males and males are more likely to detour from the normal growth path due

to adverse environmental conditions (Tanner, 1966; Bielicki and Charzewski, 1977).

Similarly, teenage females 12-19 years of age from the food-insecure households have higher variability in physical stature, weight, and BMI than the same-age females from food-secure households. This is the crucial age when 50% of bone mass forms among females during this phase. Lack of food at this stage disturbs the hormonal growth function or homeostasis and hinders in ability to “catch up” in terms of growth. Variability in anthropometrics indicates the negative imprints of adverse environmental stress like food-scarcity on the growth of the females.

What is the relation between food-insecurity and health variability? Why are young males and adolescent females from food-insecure households thrown away from their normal growth paths and unable to “catch up” (Tanner 1988)? It is well known that inferior environmental factors contribute to increasing the stress load on individuals and that body responses to such factors through physiological and behavioral changes tries to maintain stability or homeostasis. The concept of allostasis (Sterling and Eyer, 1988) or homeostasis explains the neurohormonal and autonomic responses of the body to adverse environmental conditions and how the body tends to maintain its stability. Allostasis literally means “maintaining stability” like homeostasis. In the short-run, every system of the body takes adaptive measures (allostasis) to maintain the stability and in long-run if adverse environmental conditions persist (allostatic load), it will damage the functions of body. Allostatic load hinders body normal growth functions. Dynamic physiological and behavioral changes occur in the body due to high allostatic load. The allostasis and allostatic load explains the cause and effect relationship between adverse environmental factors and variability in physical stature and in weight and in BMI. If children continue to face high allostatic loads, they might not be able to catch up in future.

The decline in variability in stature, weight, and BMI along the age over the course of life indicates improvement in canalization or homeostasis when Tsimane' reach to adulthood. Physical stature does not grow after 20 so it is expected to have less variance. However, weight, a short-run nutritional measure, depicts the current stress of nutritional deficiency on people. In adults aged 20+ years, there is no difference in variability in weight and BMI among males and females from food-secure and food-insecure households. However, gender-based differences in variability of weight and BMI exist in adult Tsimane'. While men (except males between 12-19 years of age from food-secure households) have lower variability in BMI than women, mean weight and physical stature has a stronger positive correlation in men than in women (Godoy et al. 2005).

In Conclusion, young males 0-5 years of age and teenage females 12-19 years of age from food-insecure households have higher anthropometric variability than

the same-age peers from food-secure households. This finding characterizes young males and teenage females as most marginalized groups among Tsimane'. In adulthood, no difference in anthropometric variability of individuals from food-secure and food-insecure households is found. Hence in adulthood, individuals catch up in meeting their nutritional requirements. However, gender base-differences in variability in BMI and weight exist. Females for example, have higher variability in BMI and weight than the same-age males. This difference is quite evident in adulthood.

8.0 Policy or Practice Implications

To reduce the overall food-insecurity among Tsimane' requires context specific strategies that take local variations into account. However, in light of the limitations identified above, the findings of this paper suggest the following policy recommendations.

8.1 Supplement Dietary Intake Program

The findings of this paper highlight that children have higher anthropometric variability in physical stature, in weight, and in BMI. Specifically, males 0-5 years of age from food-insecure households have higher anthropometric variability than the same-age males from food-secure households. High variability among children indicates the underlining problem of malnutrition in poor, foraging-farming communities in developing countries. Various studies suggest that 2-5 years of age is a critical in the physiological and emotional growth of an individual. If there is a lag at this age, the chance of catching up is very rare if the status quo remains same. In general, children need supplemental nutritious food to catch up their normal growth cycles. This situation can be worse in case of natural shocks (Dercon, 2005). A supplementary dietary program can provide free meals to children 0-10 years of age to save the children from starvation. In India, programs like mid-day meals and Akshaya Patra are implemented by the government agencies and NGOs to reduce child hunger at large scale. Similar models can be replicated in the Bolivian Amazon to provide nutritious food to the children. Special focus should be on targeting the children below the poverty line.

8.2 Children Public Health Policy

Child development in primitive societies such as Tsimane' and rural poor areas of developing countries is largely neglected. Several studies mention that high worm infections (Tanner 2005) and high disease loads (McDade 2005) among young Tsimane' children. A single program recommendation would be a short-sighted suggestion as most of the children suffer from diseases like diarrhea and worm infections on regular basis. As a result, a comprehensive child health policy for primitive communities is should be implemented. Policy without programs does not make any sense. Health infrastructure should be built in remote areas and local paramedical workers should be trained to serve the people at grassroots levels. Doctors would be unwilling to be posted in remote areas and local para-health professionals can be the good alternative. Local paramedical

workers can also be used to spread preventative health practices in remote areas. Specifically, health interventions like immunization program for children and regular de-worming programs should be started in Bolivia through schools, churches, NGOs and other local institutions.

8.3 Nutrition Program for Adolescent Girls

Adolescent girls 12-19 years of age from the food-insecure households also have a higher variation in physical stature and weight than the same-age girls from food-secure households. 25 kg of staple grain per adult per day should be allocated to every poor family as long as they are below national poverty line.

8.4 Poverty Reduction Programs

A nutritional program is a short-term solution to the prevalence nutritional deficiency among children and women in Tsimane'. Government and developmental agencies should focus on the improvement of agriculture production and livestock rearing to reduce the incidence of food-insecurity. Livelihood promotion programs would increase the buying capacity of individuals and availability of food in households. The following proven programs might be of benefit to the Tsimane':

- a. Techniques like SRI (Systematic Rice Intensification) can help to increase rice cultivation through management practice and can solve the issue of lack of availability of staple food in the Bolivian Amazon. SRI does not require any extra material inputs and has the capacity to increase production of rice by 2-3 times.
- b. Introduction of pulse crops like the pigeon pea, chick-pea, and cow pea can not only enrich protein intakes but such crops also fetch higher prices in the market.
- c. Promotion of small lift irrigation program so farmers can lift water from tributaries of the Amazon. This would prevent delays in the arrival of rain from affecting production allowing farmers to diversify their crops and reduce their dependency on rain.

8.5 Developmental Paradox

It is a paradox for me to make recommendations which try to mainstream Tsimane', an indigenous community. Primitive societies have their own culture and practices and any programs that target development in local areas can highly influence the way of life and culture of Tsimane'. Modern developmental strategies can often have negative impacts on indigenous peoples. Are rural roads, electrification, harnessing natural resources, hydropower, and industrial scale production sustainable suggestions for indigenous communities? Any integration and assimilation process of indigenous people with market and mainstream institution results in conflict and threatens the very existence of indigenous people. Instead of imposing prototypes of development strategies on

indigenous people, I would recommend a participatory development approach not only in execution of developmental programs but also on developmental consultation of what kind of development they would like to pursue.

8.6 Research Suggestions

Further research studies can be designed to look into factors responsible in having similar variability in BMI and weight among females and males from food-secure and food-insecure households. It will be interesting to use panel data set and look at dynamism of variability among Tsimane'. Research should also investigate the relationship between factors like social capital, common property ownership, modern human capital and market with variability in anthropometric.

Tables & Figures

Table 1: Difference in coefficient of variation (Standard Deviation/Mean) between females and males from food-insecure and food-secure households among Tsimane', Bolivia, 2005

Coefficient of variation of:	Age groups (in years)	Females				Males				Percentage differences between			
		Insecure		Secure		Insecure		Secure		(2-4)/2 (10)	(6-8)/6 (11)	(2-6)/2 (12)	(4-8)/4 (13)
		n (1)	CV (2)	N (3)	CV (4)	n (5)	CV (6)	n (7)	CV (8)				
Physical Stature (cm)	<=2	53	0.16	43	0.16	53	0.13	50	0.12	0	8	19	25
	3—5	52	0.07	51	0.08	42	0.11	50	0.08	-6	32	-55	0
	6—11	67	0.09	78	0.09	83	0.10	97	0.10	1	-2	-9	-13
	12—19	51	0.05	79	0.03	60	0.08	80	0.09	33	-10	-65	-170
	20—25	43	0.03	30	0.04	42	0.03	40	0.03	-29	13	-3	30
	26+	82	0.04	113	0.03	88	0.03	117	0.03	17	0	17	0
Weight (kg)	<=2	53	0.37	42	0.29	52	0.26	50	0.25	22	5	29	14
	3—5	51	0.12	51	0.16	42	0.25	50	0.14	-33	44	-108	13
	6—11	67	0.23	78	0.23	83	0.22	97	0.25	0	-14	4	-9
	12—19	51	0.17	79	0.15	60	0.24	80	0.25	12	-4	-41	-67
	20—25	43	0.14	30	0.12	42	0.10	40	0.08	14	22	26	33
	26+	82	0.16	113	0.15	88	0.11	117	0.12	6	-9	31	20
BMI (kg/m ²)	<=2	52	0.13	42	0.16	52	0.15	50	0.14	-23	7	-15	13
	3—5	51	0.09	51	0.07	42	0.07	50	0.06	17	21	17	21
	6—11	67	0.09	78	0.08	83	0.06	97	0.08	11	-30	29	-4
	12—19	51	0.11	79	0.12	60	0.11	80	0.17	-9	-55	0	-42
	20—25	43	0.11	30	0.12	42	0.07	40	0.07	-9	7	33	43
	26+	82	0.13	113	0.13	88	0.10	117	0.10	0	0	23	23

Note: n is the number of observations in a. Some of the coefficients of variation look the same in the table as they are rounded to two decimal digits; whereas the percentage difference is calculated to three decimal points. Physical stature is not adjusted for age- related shrinkage.

Figure 2: Variability in physical stature by sex, food-security, and age among Tsimane', Bolivia, 2005

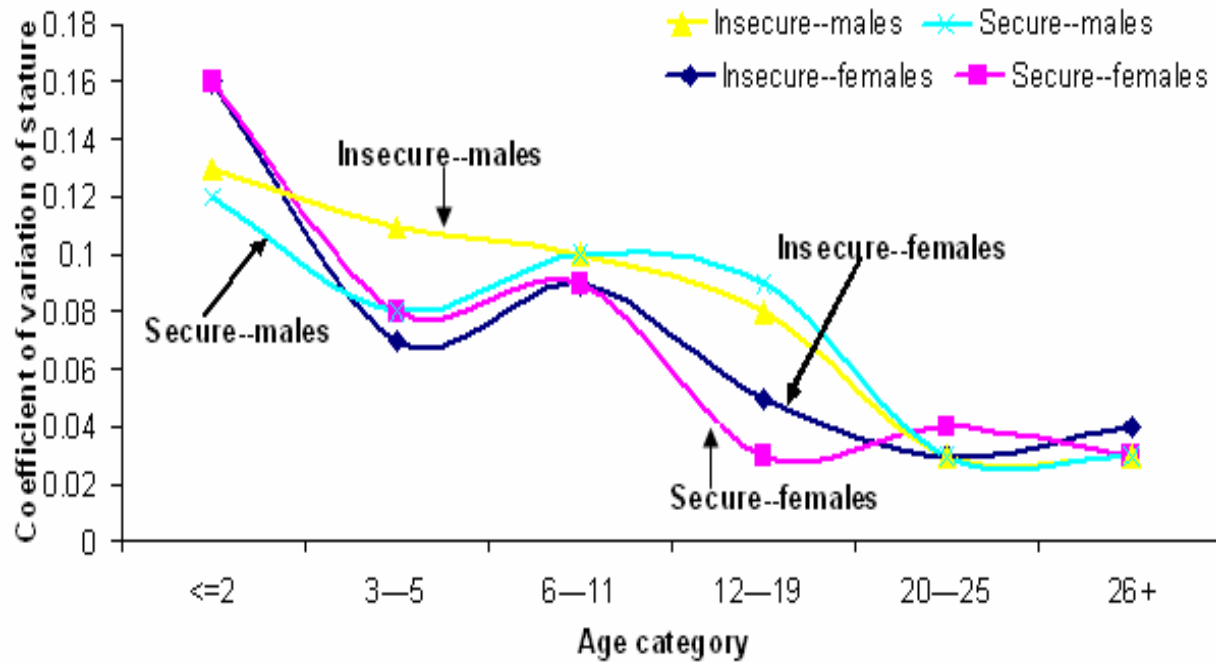


Figure 3: Variability in weight by sex, food-security, and age among Tsimane', Bolivia, 2005

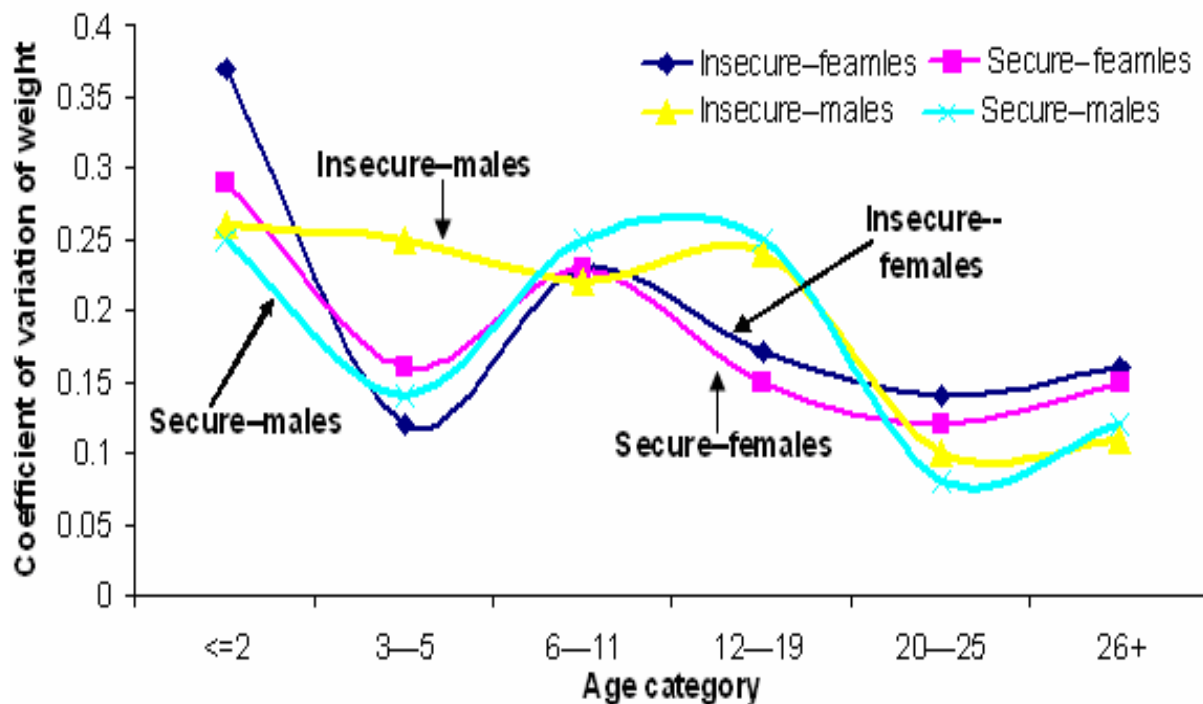


Figure 4: Variability in BMI by sex, food security, and age among Tsimane', Bolivia, 2005

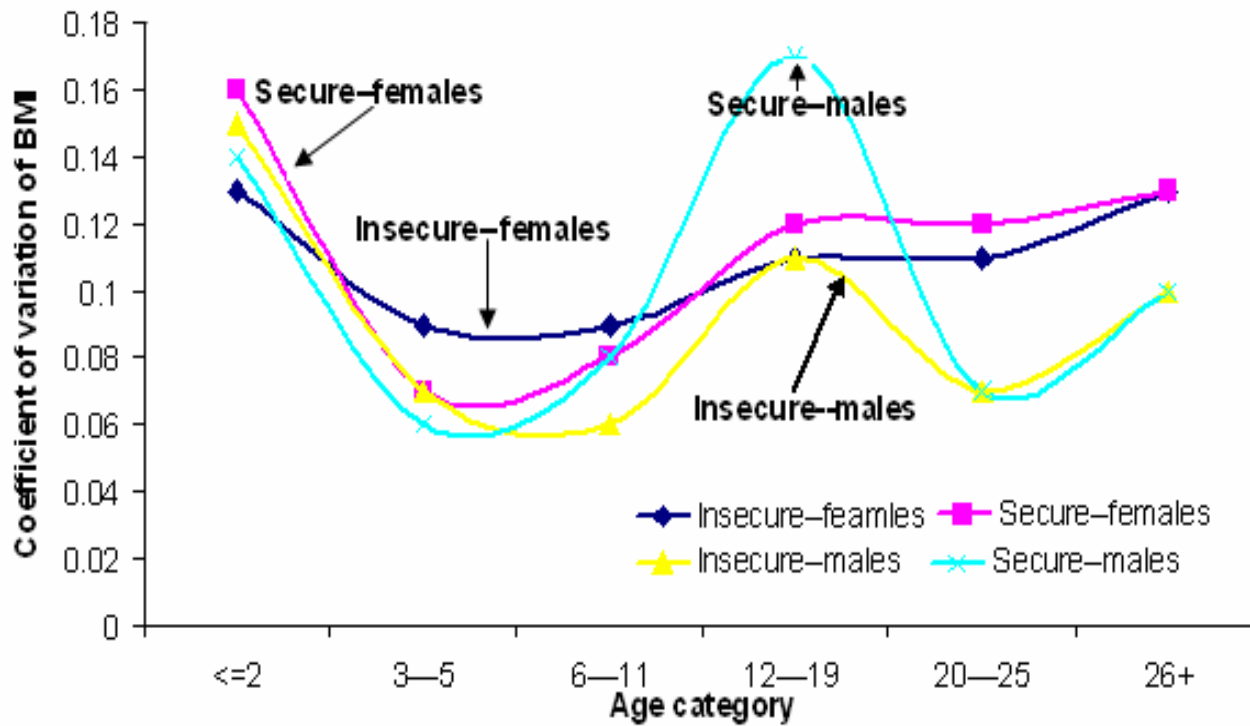


Table 2: Difference in standard deviation of the logarithm between females and males from food-insecure and food-secure households among Tsimane', Bolivia, 2005

Standard deviation of logs of:	Age groups (in years)	Females				Males				Percentage Differences between			
		Insecure		Secure		Insecure		Secure		(2-4)/2 (10)	(6-8)/6 (11)	(2-6)/2 (12)	(4-8)/4 (13)
		n (1)	CV (2)	n (3)	CV (4)	n (5)	CV (6)	n (7)	CV (8)				
Physical Stature (cm)	<=2	53	0.15	43	0.16	53	0.14	50	0.13	-7	7	7	19
	3—5	52	0.07	51	0.08	42	0.11	50	0.08	-6	27	-55	-7
	6—11	67	0.09	78	0.09	83	0.10	97	0.10	0	0	-11	-11
	12—19	51	0.05	79	0.03	60	0.08	80	0.10	40	-25	-60	-233
	20—25	43	0.03	30	0.04	42	0.03	40	0.03	-33	0	0	25
	26+	82	0.04	113	0.03	88	0.03	117	0.03	25	0	25	0
Weight (kg)	<=2	53	0.14	42	0.07	52	0.12	50	0.14	50	-17	14	-100
	3—5	51	0.09	51	0.07	42	0.07	50	0.06	22	14	22	14
	6—11	67	0.09	78	0.08	83	0.06	97	0.08	11	-33	33	0
	12—19	51	0.12	79	0.13	60	0.11	80	0.14	-8	-27	8	-8
	20—25	43	0.11	30	0.11	42	0.07	40	0.07	0	0	36	36
	26+	82	0.13	113	0.13	88	0.10	117	0.10	0	0	23	23
BMI (kg/m²)	<=2	52	0.36	42	0.32	52	0.29	50	0.27	11	7	19	16
	3—5	51	0.12	51	0.16	42	0.23	50	0.14	-33	39	-92	13
	6—11	67	0.21	78	0.21	83	0.22	97	0.25	0	-14	-5	-19
	12—19	51	0.18	79	0.16	60	0.26	80	0.29	11	-12	-44	-81
	20—25	43	0.13	30	0.11	42	0.11	40	0.09	15	18	15	18
	26+	82	0.16	113	0.15	88	0.12	117	0.12	6	0	25	20

Table 3: Difference in Gini-coefficient between females and males from food-insecure and food-secure households among Tsimane', Bolivia, 2005

Gini Coefficient of:	Age groups (in years)	Females				Males				Percentage Differences between			
		Insecure		Secure		Insecure		Secure		(2-4)/2 (10)	(6-8)/6 (11)	(2-6)/2 (12)	(4-8)/4 (13)
		n (1)	CV (2)	n (3)	CV (4)	n (5)	CV (6)	n (7)	CV (8)				
Physical Stature (cm)	<=2	53	0.08	43	0.08	53	0.07	50	0.07	0	0	13	13
	3—5	52	0.04	51	0.04	42	0.06	50	0.04	0	33	-50	0
	6—11	67	0.05	78	0.05	83	0.05	97	0.06	0	-20	0	-20
	12—19	51	0.03	79	0.02	60	0.04	80	0.05	33	-25	-33	-150
	20—25	43	0.02	30	0.02	42	0.02	40	0.02	-24	0	-18	5
	26+	82	0.02	113	0.02	88	0.02	117	0.02	0	0	0	0
Weight (kg)	<=2	53	0.07	42	0.08	52	0.08	50	0.07	-14	13	-14	13
	3—5	51	0.05	51	0.04	42	0.04	50	0.03	20	25	20	25
	6—11	67	0.04	78	0.04	83	0.04	97	0.04	0	0	0	0
	12—19	51	0.06	79	0.07	60	0.06	80	0.07	-17	-17	0	0
	20—25	43	0.06	30	0.06	42	0.04	40	0.04	0	0	33	33
	26+	82	0.07	113	0.07	88	0.05	117	0.05	0	0	29	29
BMI (kg/m ²)	<=2	52	0.17	42	0.15	52	0.14	50	0.14	12	1	17	7
	3—5	51	0.07	51	0.09	42	0.13	50	0.08	-29	38	-86	11
	6—11	67	0.12	78	0.12	83	0.13	97	0.13	0	0	-8	-8
	12—19	51	0.09	79	0.08	60	0.13	80	0.13	11	0	-44	-63
	20—25	43	0.07	30	0.06	42	0.05	40	0.04	14	20	29	33
	26+	82	0.09	113	0.08	88	0.06	117	0.06	11	0	33	25

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