RESEARCH ARTICLE

REVISED Do Maya women have the chance to improve their quality of life? [version 2; peer review: 3 approved with reservations]

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Abstract

Background: Maya families suffered greatly during the henequen industry in the Yucatan, but the lives of the Maya women at the time were perhaps worse than anywhere in the world. Changes in Maya body height over the 20th century were assessed in order to show secular changes. The use of the sexual dimorphism index (SDI) allowed for the evaluation of the living conditions prevailing during the existence of the henequen haciendas to the Mexican revolution and a gradual improvement of these conditions by the end of the 20th century.

Methods: In 1994, 364 men and 320 women aged 20-98 years were studied in Merida, Yucatan, Mexico. They were divided into six age groups and by sex: 20-29, 30-39, 40-49, 50-59, 60-69 and 70+ years. Stature for both sexes, and age at menarche for women were considered. SDI in stature was calculated to assess living conditions.

Results: There were smaller (0.25 cm/10 years) changes in height in men than in women (0.9 cm/10 years) and no significant changes in acceleration of maturation. SDI results showed changes from 9.9 to 7.6, and this may indicate a constant, but very small improvement of living conditions. The age at menarche of women did not show statistically significant acceleration with age.

Conclusions: In the colonial period of the late 19th century until the Mexican Revolution, women were worse off than men. Previous research has shown that when living conditions change, men always react faster than women, e.g. by lowering or increasing body height. Our study of the Maya population in the 20th century showed otherwise; female height increased more than male height. This may reflect that the living conditions of Maya men have not changed over the 20th century, but have improved for women.

Keywords

Mayas, sexual dimorphism, secular changes, violence against women

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REVISED Amendments from Version 1

The second version of this article contains minor changes indicated by the reviewer. The fragment repeated in the discussion has been removed from the introduction. Also, the words "gender" were changed to "sex" as the article is based on the sexual dimorphism index.

Any further responses from the reviewers can be found at the end of the article

Introduction

James Tanner wrote that the average height of people in any society is a mirror that "reflects rather accurately the material and moral conditions of that society" (Tanner, 1986). Simply stated, height reflects the quality of life. Maya women of southern Mexico and Guatemala have the shortest stature of all non-Pygmy women and that has been so for at least 100 years (NCD-RisC, 2016).

Mayan life in the late 19th and at the turn of the 20th centuries was closely related to the cultivation of henequen fiber. At that time the daily lives of Maya families had a great impact on their biological status. The description of the relationship between the hacienda workers and the henequen industry, using supporting literature, is important here. This is for evaluation, in both sexes separately, changes in body height with age, changes in sexual dimorphism index (SDI) with age, which describes living conditions and changes in women's age of maturation using age at menarche.

History of henequen industry

With the arrival of the Spaniards in the 16th century, the cultivation of henequen fiber became a mass industry that flourished in the mid-19th century (Rioux, 2014). There were many haciendas (large agricultural estates or plantations) in Spanish-speaking countries, especially in Mexico, and from the mid-18th century these grew in size and economic power for almost a hundred years. In the Yucatan region of Mexico, the haciendas started as maize and sugar plantations, but later they became henequen estates.

The haciendas were independent organizations employing hundreds of workers, arranged according to a certain structure. The most important in the hierarchy were the landowners, then the hacendados (people to whom the land was gifted along with peons - unskilled farm workers), at the bottom there were Maya people (Kumar, 2019). Haciendas were typically composed of a variety of different structures, including a main house, a kitchen, a warehouse, servant quarters, worker housing, stables, a church, a store, a cemetery, a pigsty, roping areas, gardens or fields, and even prisons. It maintained huge fields of henequen, tended by hundreds of men. The main house, or Casa Principal, was usually the largest building, where the hacendado kept his living quarters and where most of the administration occurred (Kumar, 2019; Wells, 1985). Plants had machines to produce henequen fibers and ropes which were shipped worldwide from the port of Sisal (Kumar, 2019).

From the end of the 19th century to the 1920s, for around 40 years, henequen was the basic industry of Yucatán. This resulted in Yucatán becoming the richest state of Mexico (Brannon & Baklanoff, 1987). By this time, the henequen plant was called "green gold". But henequen had been present in the life of Mayan society since pre-conquest times. The plant was often grown outside of houses, along roads and outside of towns (Rejón, 2006). A major use for the henequen fiber was rope to fasten and pull, and as material for sandals, hunting bows and traps, roofing thatch, fishing nets, hammocks, bags to transport different items (e.g. corn seed) or other framing tools to cultivate milpas (fields cleared of forest where farmers plant more than a dozen plants at once, including corn, avocado, many varieties of squash and bean, melon, tomatoes and the like). Henequen fiber was also used to drill teeth, and the sharp spines of henequen leaves were used as needles. In addition, prisoners of war were bound with henequen rope, juices from Agave were used to make wine, and henequen also could be a decoration (Rioux, 2014).

The henequen industry was owned by homogeneous groups called the 'elites'. They were most often white individuals of Spanish origin who came from two categories: either they were born in Creole families and most often they were already wealthy, or they used the export and import of henequen to create new wealth (Rioux, 2014). In 1856, as a result of reform laws, the lands belonging to the villagers were divided, the 'elites' quickly bought land from Mayas and changed that land from subsistence food farming to henequen production. Unfortunately for Maya people, selling their land was the only way to earn some money and support their families (Evans, 2012). However, soon after selling their land most Maya adults became henequen plantation workers. As already mentioned, many 'elites' were successful in the henequen industry, but there were 20 to 30 families known as '*casta divina*' (divine caste), who controlled 80-90% of the henequen industry (Riestra, 1996).

Life on haciendas for workers was very hard. Haciendas became the places in which the Mayas lived, worked and shopped. Maya families often spent their lives on the plantations for many generations (Peniche Rivero, 2003). We use the term '*henequeneros*' for individuals (often belonging to 'elites') that supervised the production of a henequen in a given hacienda and oversaw the Maya families working there. The role of *henequeneros* was to encourage workers to remain in the hacienda. Also, marriages outside the hacienda were often forbidden. Everything was done to bring families together in order to control the social life of Maya peasants (Joseph, 1982; Remmers, 1981; Wells, 1985).

Workers were offered loans by *henequeneros* that were part of the so-called 'paternalistic goods' (restriction of the freedom of a person or group of people). This concerned the land of milpa, corn ration, access to water, medical care, and sometimes children's education. For hacendados (persons who own or supervise haciendas), control over the Maya people provided year-round labor. It was also a certain protection for the workers, but the possible benefits amounted to the loss of

autonomy, backbreaking year-round labor, and separation from traditional pueblo life. Thus, henequen workers were essentially slaves as a result of the debt peonage system (an employer compels a worker to pay off a debt with work) (Alston *et al.*, 2009). Even though elites claimed that workers had the right to leave haciendas, realistically, they were accumulating huge debts and were unable to escape. In 1900, rural laborers were spending half to three-quarters of their incomes on basic staples of life, mainly food (Buffington & French, 2000). Their daily food typically consisted of two tortillas, a bowl of beans, and a plate of fish (Sterling, 2012). Although hacienda owners claimed slavery was non-existent, their rules and practices bear strong resemblance to a slave society. The workers were forced to buy food and other things at the hacienda-owned store. The store provided credit, and this indebted the Maya to the hacienda. They were slaves because they could not leave the hacienda until they paid their debt, but they could never do this (Rioux, 2014).

In Yucatán at this time, education was devoted to the expansion and success of the henequen industry, and as a result, laborers were mainly trained in henequen production only. However, other residents in Yucatán experienced an expansion of education, and secondary and professional education did advance. In 1857, there were 21 public primary schools with less than 2,000 students, but by 1883, there were 225 schools with over 8,000 students. Despite all of the increases in education, many people in Yucatán were illiterate and the literacy rate was still low due to the many laborers on haciendas (Remmers, 1981).

Health problems and injuries were prevalent on the haciendas, but workers did not have access to medical treatment (Remmers, 1981). Henequen is a rough, spiny plant, and its continued contact with skin often caused irritation and eczema among laborers. The challenging manual labor led to many fractured or broken arms and legs. In addition, carrying henequen leaves in the sun and the heat in Yucatán was especially grueling (Remmers, 1981). Additionally, public health agents ignored hacienda conditions and doctors were rarely present. Despite the modernization efforts in society, health-care on haciendas was virtually non-existent, so modernity was mainly limited to spaces outside of the hacienda system. Conditions were unsanitary, and diarrhea was the leading cause of death, especially among infants. Poor diets and the lack of sufficient food led to starvation for many laborers, and suicide was not uncommon. Doctors and medicines were only present on larger haciendas, and even then, they were not sufficient to treat the quantity of health issues faced by laborers (Ransom Carty, 2006; Remmers, 1981; Wells, 1985).

Laborers were required to wear specific types of clothing and they were not allowed to wear foreign styles. Also, workers and their families were required to cut their hair a certain way (Moseley, 1980).

There are many factors that contributed to the decline of the henequen industry, but the changes brought about by the

Mexican Revolution were crucial in causing the era of poverty in Yucatán (Evans, 2012; Rioux, 2014). The Mexican Revolution arrived in Yucatán in 1915, five years after it had begun in Mexico City. Laborers experienced slave conditions, and the revolutionaries sought to give them more rights. Between August 1915 and February 1917, the cost of production of henequen fiber increased by more than double due to the increase in wages for workers. These changes were positive for laborers, but *henequeneros* were forced to pay higher wages and provide more services to the workers. The only reason henequen continued to prosper was the massive demand created by World War I. The further instability in Yucatán and increased prices of henequen encouraged the United States to continue seeking different sources of fiber. However, elites in Yucatán continued to invest only in henequen, which led to an increase in poverty, because *henequeneros* could no longer pay the workers' debts. After the 1920s, the henequen industry faced continued challenges. The Great Depression continued to affect society, which reduced the demand for wheat and henequen. During the 1930s, adverse weather changes, such as drought, windstorms, cold winters, hot summers, as well as grasshoppers, caused further damage to the wheat industry. Between 1934 and 1940, large areas of land were redistributed, which resulted in the confiscation of 61% of henequen fields. Yucatán became one of the poorest states in Mexico and could not survive without the help of Mexico City (Evans, 2012; Rioux, 2014). During the 1960s, there was an attempt to revive the henequen industry, but hard fiber industries had already been established in other areas, and it would have been very challenging for Yucatán to become competitive in the market again (Carrillo, 2013). However, it should be mentioned here that the Mexican Revolution also brought many positive changes to Yucatán as it ended the slave work conditions and gave more rights to laborers. It also created thousands of schools, health reforms, and sanitation services (Rioux, 2014).

Maya in the Yucatán from the end of Mexican Revolution to the end of the 20th century

The literature contains much information about Maya life in the second half of the 20th century, including their population size, households, work, income, crops, culture and education (Lutz *et al.*, 2000). It is worth noting that the life of the Maya has not changed significantly since the fall of the henequen economy. However, they were somewhat independent in this time, able to cultivate milpa (corn, beans and squash), usually in small fields, and leave their place of residence looking for work anywhere, e.g. in the nearby holiday resorts of Cancun or Mérida.

The authors of the present paper spent 13 years in Yucatán, mainly at the end of the 20th century, taking part in various research projects which took place in Mérida (the capital city of Yucatán), Progreso, Sotuta, Yaxcabá Municipality, and villages near Chichenitza, such as Pisté where the Steggerda research took place (Steggerda, 1932; Steggerda, 1941; Steggerda, 1977). Observations of these communities by the authors has led to the following reflections about living conditions:

The households (farms) are different, depending on the size of the family and its wealth. Every nuclear family, consisting of parents and at least one child, has its own home. Such a family also has its own or shared garden, kitchen, storage area, and sometimes manufacturing area. The number of shared buildings in a household depends on how many families are living there.

The Yucatán Peninsula has year-round warm weather and is often hot and the style of home offers a cool place to live. The shape of the houses has been similar from generation to generation. The differences between houses are the size and the materials used to build them. The appearance of the houses also vary depending on the village in which they were located. Many houses are built of wooden stakes (Figure 1 and Figure 2), but there are also houses with a more solid construction. Most houses are about the same size. Often the front door is lined up with a backdoor or window to create cross ventilation, which keeps the home cool. The floors are often concrete and keep the house fresher since the slabs are on the ground. The houses are oval in shape with thatched rooves, which are waterproof when laid in a continuous pattern. Some houses consist of mud and stone walls with thatched roofs, and some are also covered with concrete, grass, or palm leaves (which is very expensive). A thatched roof does not absorb the heat like concrete, so that makes it cooler. Backyards are often full of fruit trees, vegetables, herbs and useful things for the family's meals. There are also chickens, pigs, ducks, or turkeys.

Most people have two houses. One is for living and the other is for cooking. This prevents the living space from getting smoky or catching fire. The fire is low, surrounded by stones, or against a concrete wall. Most of the cooking is done on a *comal* for making tortillas or pots for cooking in (Figure 3). Every house contains some type of pottery. The ancient Maya used pottery for cooking, eating, and storing water. The interior furnishing of houses for living is limited mainly to the space needed to hang hammocks used

for sleeping. It is not common to store a lot of food in the home. The staple food of corn is mainly kept in the field. Also, Maya houses have no furniture. Necessary items are hung in plastic bags, including food. In recent times, however, refrigerators, TV's and other conveniences have been found there; for example, the authors have often seen a poorly constructed house where there were at least two TV's, a car with an incomplete body and a huge refrigerator.

Women spend the majority of time not only at home taking care of the children, but also are in charge of gardening and sometimes help men in farm work. Maya women's dress is very specific and they try to wear it on every occasion (Figure 4). The men take care of the family by mainly cultivating the milpa, hunting and providing other food for the family.

Biological status

As previously mentioned, the 20th century included many economic crises, but overall socio-economic conditions improved. These changes are especially interesting when we relate them to the biological status of the Maya Indian

Figure 2. Maya cottage, Yaxcaba, photo taken by Napoleon Wolański in 1986.

Figure 1. Maya cottage, Dzeal, photo taken by Napoleon Wolański in 2001.

Figure 3. The comal, set over a wood fire on the ground. Photo by Travel, "Eat, Drink, Swim, then Eat, Drink Again," April 03, 2012.

Figure 4. Maya Women's Dress - photo taken by Napoleon Wolański in 2001.

populations before the collapse of their high civilization which took place between the 8th or 9th centuries and was probably caused by a combination of deforestation and drought (Stromberg, 2012). The retardation in growth and maturation of Yucatecan populations during the 19th and 20th centuries has been observed (McCullough, 1982; Saul, 1972; Starr, 1902; Steggerda, 1941). There are only two publications on secular changes of body height in the Yucatán. The first one describes the lack of changes in men born between 1860 and 1933 (McCullough, 1982), the second one describes small changes between 1933 and 1956 (Wolański *et al.*, 1994). It should be added that based on skeletal measurements from archaeological excavations from preclassic (2500 BCE-250 CE), classic (250-900 CE) and postclassic (900-1521) periods, and then based on measurements on living people, it can be concluded that Maya Indians experienced a decrease in body height. From the second half of the 19th century to the first half of the 20th century, stabilization of body height was observed. In the last 60 years a slight increase in body height has been observed in children, which affects the final height in adults (Wolański & Siniarska, 1999).

Globally, Maya people have one of the shortest statures. The average height of contemporary, rural-living Maya men and women in Mexico and Guatemala is 160 cm and 148 cm, respectively (Bogin *et al.*, 2014). Maya adults and children measured in the early to mid-20th century were usually thin, with very low body fat. Short stature and thinness were probably associated with an inadequate diet (Bermudez *et al.*, 2008; Bogin, 2013). Their diet lacked nutrients needed for growth and they also suffered from respiratory and gastrointestinal infections (Bogin, 2013).

Objectives of study

On the basis of the presented characteristics of the Maya living conditions in Yucatan from the beginning of the 20th

century to almost the end of the 20th century, the aim of this study is to assess the direction and the level of living condition changes.

This assessment is built on a comparison of changes in height with age in both sexes, changes in SDI, and changes in women's age of maturation. Changes in height (secular trend) with the age of the studied individuals indicate how each sex reacts to the living conditions existing in a given period of time. Changes in SDI indicate what are the differences in body height between men and women for each age cohort, which is considered a manifestation of specific living conditions. This index is used in the absence of information on the living conditions of adults at the time of the interview. In addition, one of the many indicators of changes in biological status is the age of maturation. Data on age at menarche will therefore also be considered.

Methods

Ethical considerations

Permission to conduct the study was sought and given by CONACyT (Consejo Nacional de Ciencia y Tecnología). Verbal informed consent was obtained from all participants to participate in the project. Before taking part in the project, the participants were informed of what would be required of them, that participation was voluntary, and that they could withdraw at any time. Verbal consent was obtained over written consent because not all participants taking part in the project were literate. Verbal consent was documented by the project team, and the number of participants that took part or were excluded for various reasons was recorded. The original project protocol included that verbal consent would be obtained, and this mode of consent was therefore permitted by CONACyT.

Study design and population

A cross-sectional study including Merida and vicinity residents (Yucatán, Mexico) was performed.

The sample included 364 men and 320 women between 20–98 years of age and the study took place from February to November 1994.

Estimating the number of samples was needed to optimize costs of the project. The research was sponsored by CONACyT, the Mexican government agency, and the funds allocated for this purpose were sufficient for the measurements of all volunteers from a given region who agreed to the research. The research was population based and no *a priori* hypotheses were formulated. It was more about examining the variation of data parameters with age among the Maya. Independently, we tried to have at least 30 people in each study cohort (for each 10-year-old age range and for each sex), which allows us to freely use different statistical tests.

The research was carried out in 1994, i.e. 27 years ago. Most of the research results have never been published due to the lack of available literature (as in the case of

this article). Only the publication of the work by Rioux, 2014 - Honors Theses, allowed the authors to find the relevant literature. Unfortunately, there is no such research in later years in Merida or Yucatan. Some of the existing studies (Bogin, 2013; Bogin *et al.*, 2014), approaching biological status in many aspects, are mainly based on nutritional status, and still do not bring significant changes in the improvement of the living conditions of the Maya group. Why this situation affects Maya is the main goal of this work.

The concept of this study was to measure people from the most numerous ethnic group of the Merida population. Most of the sample (about 80%) was identified as Maya. The assessment of belonging to the Maya ethnic group was based both on their surnames (two Maya surnames or one Maya surname, as well as on their appearance: short stature, corpulent body structure). Younger individuals worked in different kinds of factories localized in Merida city and vicinity, producing different brands of soft drinks and food products. People surveyed belonged partly to blue-collar workers and were employed to do moderate to heavy physical work (lifting, raising, carrying), while some worked directly on the production line, where the work was monotonous and required a lot of attention. Not only men worked there, but also women. Many women worked in garment factories, built by Americans and for the needs of the American market, which were located in the vicinity of Merida.

Older people, not working, generally parents or grandparents of people working in factories, were measured in their homes. This research was conducted in two, rather poor, districts of Merida (Chuburna and Cordemex), where many individuals as Maya resided. People of very old age, often living in great poverty, were measured in nursing homes.

When examining more educated people who held an executive position or supervised the work of other people, these data were not included in the final research material.

Education level varied from illiterate to those who had not completed secondary school. Income levels varied between 900 NP (new pesos/month) for younger people to 300 NP/Mo for older people at a time before the economic crisis at the end of 1994 when the value of the peso was 1US\$ = 3.4 P.

The sample was divided into six age groups by sex: 20–29, 30–39, 40–49, 50–59, 60–69 and 70+ years.

Data collection

Body height of both men and women were collected, as well as age at menarche for women. The height measurement was performed by persons trained and employed to carry out this research. The same was true for age of maturation questions.

Three phenomena were considered: secular trend in height observed in the cohorts of men and women, sexual dimorphism in height which was useful for the assessment

of living conditions for the population studied, and age at menarche.

Data analysis

The secular trend of body height was presented and adjusted for age-associated stature loss after the age of 30 years (0.06 cm / yr) according to Trotter & Gleser (1951).

Sexual dimorphism in height was interpreted using the SDI, which was calculated by the following formula: $(\bar{X} \text{ Males} - \bar{X} \text{ Females} / \bar{X} \text{ Females}) * 100$. It has been widely described in earlier publications (Antoszewska & Wolański, 1992; Siniarska, 1996; Wolański, 2012; Wolański & Kasprzak, 1976).

Age at menarche changes between 10-year-old women's cohorts were assessed using the Kruskal-Wallis Test.

All calculations were done in Statistica 13.0 (Dell Inc, 2016).

Results

Our results showed that the body height of men and women declines with increasing age (Table 1). The effect of age and secular trend on body height of adults was assessed using regression analysis of height and height corrected for the effect of aging after 30 years of age on the year of birth (Trotter & Gleser (1951) prediction of the aging process (0.06 cm per year) was used). The results indicate that height adjustment for the effect of aging does not show significant secular trend in men, but these changes are significant in women (Table 2). However, the large difference in height between the 75 and 55 age cohorts (almost 14 and 13 cm, respectively) may be due to osteoporosis in women. These findings emphasize that secular trend in Merida sample is lower in men than in women.

Considering the SDI results for each of the age group, significant changes in the index values from 9.9 to 7.6 were observed. This may indicate a constant, but very small improvement of living conditions, in the time interval examined (Table 3).

The age at menarche of women did not show statistically significant acceleration with age (Table 4, Figure 5).

Discussion

The results of these studies are based on the height data for female and male cohorts analyzed at 10-year intervals, on SDI data assessing living conditions, and also taking into account the age of women maturation evaluated by age at menarche.

The found secular trend in height (younger 10-year cohorts are slightly taller than the older ones) and the applied correction for changes related to aging indicate that among female differences in height between age cohorts are much more pronounced than among men. If age related changes are eliminated, the secular trend of 0.25 cm per decade in men in Merida, which is not statistically significant, is seen. In

Table 1. Body height of Mayas and sexual dimorphism index (SDI) calculated for each age group (10-year intervals).

Age group	Height of men (M)			Height of women (W)			Difference in height in cm	SDI $(\bar{x}M - \bar{x}W / \bar{x}W) * 100$
	N	Mean	SD	N	Mean	SD		
25.00	85	159.80	5.92	57	148.48	5.64	11.32	7.62
35.00	68	158.47	5.86	59	147.64	5.26	10.83	7.34
45.00	58	158.83	5.32	54	147.40	6.20	11.43	7.75
55.00	56	158.45	5.05	48	146.80	6.54	11.65	7.94
65.00	50	157.13	6.29	49	144.13	5.55	13.00	9.02
75.00	47	154.44	5.38	53	140.58	6.15	13.86	9.86

Table 2. Regression of height and adjusted height with year of birth in Merida adults.

Sample studied	r	Regression coefficient $(b) \pm SE_b$	t	p
Merida adults				
Men (n=364)				
Height	0.24	0.080±0.017 cm/yr	4.77	p<0.01
Adjusted height ¹	0.08	0.025±0.017 cm/yr	1.49	NS
Women (n=320)				
Height	0.42	0.146±0.018 cm/yr	8.28	p<0.01
Adjusted height ¹	0.28	0.090±0.018 cm/yr	5.12	p<0.01

¹ Adjusted for age-associated stature loss after the age of 30 years (0.06 cm/yr) after Trotter & Gleser (1951)

Table 3. Values of Sexual Dimorphism Index (SDI) and their interpretation (based on data of Wolański, 2012).

SDI values in %	Interpretation
4.5 – 5.5	In both sexes there is a strong growth retardation in very poor living conditions
6.0 – 7.0	Intensive growth of girls, compensating for earlier developmental inhibition. This usually takes place in the second phase of improving living conditions.
7.0 – 7.5	Moderately severe growth failure in boys, or growth acceleration in girls. This can occur in populations in transition from good to worse, or from worse to better living conditions.
7.5 – 8.5	Normal growth in both sexes takes place, especially in boys. This SDI of height usually occurs in economically and socially stable populations, or in the first phase of improvement of living conditions, after a previous unfavorable situation.
9.0 – 10.0	Girls show moderately severe growth failure, usually with the onset of very poor living conditions.
10.0 – 11.0	Growth is intensified in boys, but stunted in girls. This can occur in populations that are in a state of disturbance or socioeconomic instability.

Merida women, it is 0.90 cm per decade, which is statistically significant. These findings emphasize that age changes in height in Merida are lower in men and greater in women.

To understand this phenomenon, the SDI was calculated, and its magnitude explains the prevailing life conditions at the time of each six intervals. The calculation of sexual dimorphism, in the absence of socio-economic data, is still used in the assessment of the prevailing living conditions. Here, we describe a second model, which is based on an approach published by [Bogin *et al.* \(2017\)](#) and assesses sexual dimorphism of height in relation to three economic predictors: (1) gross domestic product; (2) gross national income per capita adjusted for personal purchasing power; and (3) the relative degree of income distribution adjusted for health inequalities within a nation and calculated by the Wagstaff method (Gini coefficient). In the previous study by [Bogin *et al.* \(2017\)](#), sexual dimorphism in adult height

was calculated for 169 countries and its average value was 11.8 cm (sd 2.0). The variation is considerable and there is a significant positive association for greater sexual dimorphism with increasing height for both men and women. Therefore, it could be concluded that sexual dimorphism in adult height is more affected by its changes in males than females ([Bogin *et al.*, 2017](#)). [Table 5](#) shows the interpretation of sexual dimorphism based on three predictors in Bogin *et al.*'s study.

This second model could not be applied on our studied Mayan population, due to the lack of detailed information on the three economic predictors. However, the two models (SDI as used by the authors and the model proposed by [Bogin *et al.*, 2017](#)) of the assessment of the impact of living conditions on the body height of Maya men and women show that low or high values of sexual dimorphism may indicate improvement or worsening of living conditions ([Bogin *et al.*, 2017](#); [Wolański & Kasprzak, 1976](#)).

What are the changes in height if we compare both sexes? Body height has increased dramatically during the 20th century in many populations across the world with only few exceptions. This visible trend started at least in the mid-19th century ([Cole, 2003](#)). These changes are also related to body weight and their direction depends on environmental conditions (including mainly living conditions), which can deteriorate or improve. It should be noted, however, that changes in body height occurs first in men and then in women and are slightly weaker in women. This is due to greater sensitivity to environmental factors of men than women ([Bogin, 1999](#); [Cole, 2003](#); [Kaczmarek & Wolański, 2018](#); [Mamidi *et al.*, 2011](#); [Özer, 2007](#); [Singh-Manoux *et al.*, 2010](#); [Tutkuvienė, 2005](#); [Wolański, 2012](#)). In addition, previous studies also

Table 4. Age at menarche in Maya women from Merida, Yucatán, Mexico.

Agegroup	N	Mean	SD	Kruskal-Wallis Test
25.00	52	12.42	1.53	Chi-Square = 3.494 Sig. = 0.624
35.00	59	12.15	1.59	
45.00	50	12.66	1.49	
55.00	45	12.53	1.71	
65.00	43	12.40	1.45	
75.00	40	12.47	1.66

Figure 5. SDI scatter chart for age (square polynomial). $SDI = 9.1013 \times x + 0.0015 \times x^2$.

Table 5. Sexual dimorphism (SD) as a difference between mean height of men and women for 169 countries in terms of the three economic predictors. Data from [Bogin et al., 2017](#); permission to republish this data provided by [Bogin et al.](#)

Mean height	Predictors	Interpretation
Men: 171.23; SD = 5.43 Women: 159.44; SD = 4.43	GDP - gross domestic product	Not a significant predictor of height
Difference = 11.79; SD = 2.02; min = 4.47; max = 18.55	GNI_PPP - gross national income per capita adjusted for personal purchasing power	A significant predictor of height. Greater GNI_PPP greater height
	Giniw - income distribution adjusted for health inequalities	A significant predictor of height. Lower Giniw greater height

looked at some physiological variables, including respiratory variables, and showed a greater relationship between these variables in women than in men, which confirms that women are less sensitive to environmental factors ([Siniarska, 2000](#)).

Despite the improvement in living conditions among Maya women, there were no changes in the age of menarche over the 20th century. However, the most recent study, conducted in 2011–2014, showed that in a 33-year-old Maya women menarche occurred at 12.05 years ([Azcorra et al., 2018](#)), which is much earlier than observed in a 25-year-old Maya women examined in 1994 (12.42 years; in our study). This may indicate a recent improvement in the living conditions of Maya women in Yucatán but it may also depend on the female cohort taken for the study, which is not as numerous as in the case of this material, as well as may relate to another socio-economic group.

The Maya social and living conditions are also evaluated through research on children and youth in Merida (the capital of the Yucatán state), carried out in 1996–99 ([Siniarska et al., 2019](#)). It is assumed that there are three ethnic groups in the Yucatán: the Maya, the Mestizo and the Creole. Ethnic groups were established using two surnames of children from the father's and mother's side. Maya (two Maya surnames), Mestizo (one Maya and one Creole surnames), and Creole (two Creole surnames) ([Siniarska, 1999](#); [Wolański & Siniarska, 1999](#)). Because there were not statistically significant differences between children from Maya and Mestizo groups in most somatic measurements, those two ethnic groups were joined together and the final comparison was done between Creole and Maya / Mestizo groups. The results of these studies indicate that Maya / Mestizo children and youth are shorter, with shorter legs and are characterized by relatively longer upper limbs than legs and relatively (to height) wider shoulders as compared to their peers from the Creole group. Ethnicity was the main effect factor for leg length both in boys and girls, and for the body proportions: upper-to-lower limb in girls and shoulder-to-body height in boys. It may be stated that variation in body physique and body proportions during the postnatal growth in different ethnic groups is under the influence of complex interaction between genetic and environmental factors ([Siniarska et al., 2019](#)). This work was

continued using the same type of three-ethnic division by [Azcorra et al., 2013](#).

However, further research, especially that carried out by [Fernández del Valle \(2011\)](#) from 1986 to 2000, showed a different relationship between the Maya and the Creoles. The question arose as to whether researchers were paying careful attention to the ethnic division based on surnames. Is the division that two Spanish surnames mean Creoles, two Maya surnames mean- Mayas, and mixed surnames -mean Mestizos, correct? As it turns out, this division is not fully correct. We have to remember that in the turn of the century (the 19th and 20th) in some places of Maya land (especially in Yucatán), Maya inhabiting communities were under supervision of owners of sisal or other plantations' haciendas and Maya people received the surname of the owner (as a gift). It is the case of a small Maya community Dzeal located near Pisté (Yucatán Peninsula) investigated in 1986 and 2000 ([Fernández del Valle, 2011](#)). The people of Merida, participating in various types of research within ethnic groups, distinguish the Maya mainly by their appearance.

Returning to the results of this work, which includes adults, the observed differences in the secular changes of men and women in the Maya population since the beginning of the 20th century are most likely caused by living conditions. The very poor living conditions of Mayas began in the colonial period (19th century), where large haciendas (mostly sisal plantations) existed in the Yucatán Peninsula ([EY, 1980](#); [González Navarro, 1979](#)) and continued until the end of the Mexican Revolution (around 1940), when the living conditions of Mayas slightly improved ([Evans, 2012](#); [Rioux, 2014](#)). At that time the mortality rate for women was higher than that for men. Men who physically worked on the plantations were under health care by the hacienda owners, but women's health was not a priority. This fact could have worked as a selection mechanism within the cohort of women. There was a high mortality rate of women and men often had a series of wives (personal communication with Dr Gilberto Balam-Pereira, Cinvestav Mérida, 2000).

Women on henequen haciendas had very few rights and were under the control of both their husbands and their husbands'

overseers. It is not uncommon for workers to beat their wives because of failures at work. While laborers were treated like slaves, it has been reported that their wives often experienced the effects of their anger and frustration in the form of violence (Wells, 2006). Women had less mobility than their husbands and remained mainly in the home performing many household chores (food preparation, retrieving water and firewood, making hammocks etc.). It was also very rare for women to work with the henequen crop, but if there was a need, they were not paid for their work (Wells, 1998). They were also expected to reproduce to create another generation. Women were also subject to the sexual impulses of men: there was the so-called “ritual of the first night”, in which henequenero or overseers violate a wife or daughter of a laborer to show who has the greatest power in the hacienda (Wells, 2006).

A question can be asked what Maya women themselves think about the changes in their lives. The authors of this work, during a long stay in Yucatán in 1992-2005, had many contacts with various families, especially in the villages of Yaxcabá Municipality. Many research projects took place in these villages, which involved renting apartments and ordering food from the local families. The authors were in close contact with certain families, which made it possible to have very personal conversations. We made a few observations: the Mayas did not want to open bank accounts, and even in the case of significant savings, they did not want to modernize their homes; money was collected in case of the husband or son's illness (illness in daughters was not alluded to); modern appliances were not required, e.g. buckets of water were used for washing and showers were not regarded as needed. Of course, it is a matter of time when they will change their lifestyle, especially due to younger generations.

Against the background of the characteristics of the life of Maya women at the turn of the 19th and 20th centuries, it can be seen that their situation has improved over the years. Maya women from the end of the 20th century are treated much better. However, the life of men was better than women at the beginning of 20th century. It is expected that the living conditions of Maya men did not improve significantly in the 20th century. This could be the most important reason showing the observed secular trend of increasing height is less in men compared to women.

Conclusion

The Maya living conditions throughout the late 19th century and the first half of the 20th century were very bad. This was due to the cultivation of henequen fiber, which was led by ‘elites’, primarily white individuals of Spanish origin, named henequeneros. They bought land belonging to Mayas and turned it into haciendas (large agricultural estates or plantations) producing henequen. After selling their land, most Maya adults became henequen plantation laborers. Haciendas became the places in which Mayas lived, worked and did shopping. Laborers were offered loans by henequeneros as part of the so-called ‘paternalistic goods’ relating to the land of milpa,

corn ration, access to water, medical care, and sometimes children's education. Even though the ‘elites’ claimed that workers had the right to leave haciendas, realistically, they were accumulating huge debts and were unable to escape. In other words, henequen workers were essentially slaves as a result of the debt peonage system. Finally, Mayas became strongly associated with working on henequen in haciendas and because the loans could not be repaid, they had to stay with entire families in the workplace. All members of the Maya families suffered, but women were particularly affected. The production of henequen in haciendas was based on the labor of men. Poor diets and the lack of sufficient food led to starvation for many laborers, and suicide was not uncommon. In case of the laborer's disease, it happened that the owner of the hacienda looked after him in his home, but the sick women were not looked after. If women had to replace men in henequen production, they were not paid for it. The main role of Maya women was to run the house and give birth to children. They suffered physically not only from their husbands who were reported to be violent towards their wives, but also from the owners of haciendas who were reported to humiliate and rape both the wives and daughters of their workers on various occasions. After the Mexican Revolution, the whole industry related to the production of henequen, which ceased to be “Yucatán gold”, collapsed, but the living conditions of Mayas have since improved.

We showed that the changes in living conditions were not as significant for men as for women. Until the end of the 20th century, height of men increased a little, but the changes are not statistically significant, while it increased statistically in the case of women. There has been no change in the maturation time of Maya women throughout the 20th century, but recent research in the early 21st century shows that there has been little progress (earlier maturation assessed by age at menarche). The way of thinking of Maya women, with whom there was direct contact in the late 20th century, was focused mainly on taking care of their husbands and sons, they did not respond to questions about the future of their daughters. They still accepted ‘superiority’ and better health care for their husbands and sons compared to them and their daughters. This may be a result of the mistreatment of women over many generations. However, it is to be hoped that the quality of life of Maya women will quickly improve significantly due to the widespread fight for women's rights and the protection of these rights.

Data availability

Underlying data

Figshare: Merida1994-95.csv, <https://doi.org/10.6084/m9.figshare.16447350.v1> (Siniarska & Wolański, 2021).

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

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This article discusses the secular trend of height, sexual dimorphism and female sexual maturation in a fairly large sample of Maya population aged 20-98 years and living in Merida, Yucatan, Mexico. The trend is discussed in relation to historic economic and cultural changes, which have affected men and women differently. The topic is interesting and the article presents valuable data, collected by the same authors three decades ago. However, in my opinion the results are not enough explained or discussed, and the overall structure needs some adjustment.

Abstract

Please note that the acceleration of maturation is mentioned twice within the results. Please also eliminate the term 'constant' because the study only analyses the difference of sexual dimorphism between the first and the last estimate.

Introduction

The sentence "This is for evaluation [...] using age at menarche." is not necessary and interrupts the reasoning. I suggest deleting it.

The description of the historical context is long, but very clear and useful. I would like to congratulate the authors for writing it. To fully explain the scenario of the study, I suggest inserting here the description of the peculiar condition of Maya women ("At that time...", p. 10, until "... the greatest power in the hacienda (Wells, 2006)", page 11).

Furthermore, the commentary on the collapse of Maya civilization between the 8th and 9th centuries (page 6) would be better placed in the same section on history.

Page 6 – the comment "which affects the final height in adults" can be deleted.

Objectives of study

A brief comment on why age at menarche can be indicative of living conditions, such as done for

changes in height and sexual dimorphism, should be added. Indeed, the sentence “one of the many indicators of changes in biological status is the age of maturation” is not very informative.

Study design and population

Page 6. I suggest changing the sentence “Most of the research results have never been published due to the lack of available literature”, because the lack of available literature cannot be considered a valid motivation.

Page 7. Please rephrase the sentence “Some of the existing studies (Bogin, 2013; Bogin *et al.*, 2014), approaching biological status in many aspects, are mainly based on nutritional status, and still do not bring significant changes in the improvement [...] of the living conditions of the Maya group”, that is unclear to me. Also the subsequent sentence “Why this situation affects Maya is the main goal of this work” refers to the research objective and appears slightly redundant and confusing in this position.

Data collection

Please provide more information and reference on the methods used to collect measurements (height, weight, and, especially, age at menarche).

The sentence “Three phenomena were considered [...] and age at menarche.” could be eliminated, or moved within the objective of the study, or the study design.

Results

The method used to adjust age (“after 30 years of age on the year of birth (Trotter & Gleaser (1951) prediction of the aging process (0.06 cm per year) was used”) has already been explained within the methods and should not be repeated here.

The terms “height adjustment” in the sentence “The results indicate that height adjustment for the effect of aging does not show”, should be replaced with “height adjusted” (thus referring to measures rather than methods).

The sentence “This may indicate a constant, but very small improvement of living conditions, in time interval examined” is a comment that would be better placed within the discussion. Here the link between the already commented changes of height with the change of sexual dimorphism could be emphasised.

Discussion

Please check the results of table 2, where the coefficient is 0.09 (please substitute the comma with a dot), while in the text it is 0.9.

Table 3 is not very clear because the increase of sexual dimorphism does not appear to be related to the improvement of living conditions (very poor conditions are mentioned in case of both low and high sexual dimorphism). Please explain better and show a summary consistent with the discussion.

The results of Bogin *et al* (2017) are relevant and appropriate for this study. However: Figure 5 is not correctly cited in the text (it is cited in relation to the menarche) and the results therein (increase of sexual dimorphism with age) are not discussed; table 5 refers to changes in

height; the relationship of these changes to sexual dimorphism should be explained; the two sentences “The variation [...] for both men and women” and the subsequent one “Therefore [...] more affected by its changes in males than females” are not logically related, unless the stronger increase among men is mentioned; the sentence “low or high values of sexual dimorphism may indicate improvement or worsening of living conditions” is misleading and should be changed to “low or high values of sexual dimorphism may indicate worse or better living conditions” (or similar).

The paragraph on the research on children carried out in 1996–99 (Siniarska *et al.*, 2019) does not appear to be related to the results of this study. Please explain how these findings may add information to the discussion on secular trend of height/sexual dimorphism/age at menarche in adults, or delete this part.

Page 11- the text “...increased statistically in the case of women” should be “... increased significantly in the case of women”.

Conclusions

I suggest reducing the summary of the introductory remarks on the historical context and limiting the text to the main findings of the research.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Physical Anthropology, Human biology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 05 April 2022

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This paper attempts to use height and sex dimorphism to evaluate changes in the quality of life of Maya women. The background information is extensive and informed by the authors' extensive experience with the Maya people. It may be more extensive than required for the scientific objectives of the study, but I found it interesting and engaging, essentially an ethnography of the population. It provides a complete picture of the circumstances under which the Mayans were living.

I have some concerns about the methods employed. What the authors have attempted is laudable but tricky because secular change and age changes are confounded to some extent. Trotter's correction for stature loss due to aging is problematic for at least three reasons; 1) it assumes stature loss begins at age 30; 2) it assumes stature loss is linear; 3) it assumes stature loss is the same for the sexes. Research since Trotter's proposed adjustment suggests that none of these assumptions is likely to be the case. See references at end of review (Cline *et al.*, 1989¹ and Giles, 1991²). These papers show that stature loss with age begins later than Trotter's 30, more likely in the 40s. It also accelerates with advancing age, rather than proceeding at a constant rate as Trotter's method would have it. Essentially Trotter's method will over adjust in the 30s, and under adjust in advanced ages. It is likely the case that stature loss with age has some population specificity, but in the absence of data specific to the Maya, the authors would be better using the Cline *et al.* method.

Next to last paragraph under Results, the authors say there are significant changes in the SDI, but there is no explicit reference to a statistical test. Perhaps they mean the quadratic equation graphed in Figure 5. Note that Figure 5 is incorrectly mentioned in relation to changes in menarcheal age in the last paragraph under Results. The quadratic equation given in the caption to Figure 5 appears incomplete, lacking an intercept. The equation I get using the data from Table 1 is:

$$SDI = 9.17304 + (-0.10091 * age) + (0.00148 * age^2)$$

It produces a plot identical to that shown in Figure 5. Comparing my equation to Figure 5, it appears that what is actually missing is the linear term.

References

1. Cline MG, Meredith KE, Boyer JT, Burrows B: Decline of height with age in adults in a general population sample: estimating maximum height and distinguishing birth cohort effects from actual loss of stature with aging. *Hum Biol.* 1989; **61** (3): 415-25 [PubMed Abstract](#)
2. Giles E: Corrections for age in estimating older adults' stature from long bones. *J Forensic Sci.* 1991; **36** (3): 898-901 [PubMed Abstract](#)

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Biological anthropology, skeletal biology, human variation, quantitative methods.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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This paper presents valuable data on Maya people. The introduction, though historically interesting, is too long for a paper exploring just two biological characteristics. Many human

biologists today may not know what the henequen is. A sentence explaining that it is a source of industrially useful fibre would be useful. The Discussion repeats one paragraph from the Introduction. The Conclusion, that is actually an extensive Summary of the whole paper, instead of a short statement of what is the new addition to knowledge, repeats a lot of Introduction. Too much history, compared to biology.

The main problem regards data collection and analysis. In the description of how data were collected the authors state that membership of the Mayan group was established, among other criteria, also on the physical appearance of being short. This, in a study of stature changes, leads to the circular reasoning. Please explain more precisely your "ethnic" classification. The authors correctly state that stature loss with age must be corrected for before comparing body heights of people born in different years in order to draw conclusions about secular trends. They use a linear correction for loss of stature with age of some 0.6 mm per year. This, however published by Trotter and Gleser in 1951, has been superseded by the findings that, as most biological processes do, decline of stature with age is curvilinear, described by the second order polynomial regression (see examples of papers cited below). This means the decline speeds up with age. My perusal of numbers contained in the Table 1 indicates that such curvilinear decline is the case among Mayans. Secular trends in stature, and other biological characteristics, do not follow straight lines, either. Therefore linear regressions of stature on age shown in Table 2 may be an insufficient approximation of actual trends, especially if corrections for age were too simplistic.

Finding no secular increase of stature, at least in Mayan males, is not surprising to I who found no increase on two different continents of the Southern Hemisphere. The lack of secular trends is more common than expressed in the literature because of the tendency not to publish "negative" results.

The lack of change of the menarcheal age disagrees with the significant trend in Mayan females' stature. I understand, of course, that the method of establishing the menarcheal age of these women was a recall rather than probit analysis. The recall method, though I defended its accuracy in some of my research situations, is prone to subjective memory and status errors that may vary with age. Menarcheal ages in Table 4, though consistent with some published menarcheal age, are fairly young, especially for women who lived in poor conditions. For instance, girls in families of rural labourers (situation similar to henequen plantation workers) in Africa in 1990s had probit menarcheal age a bit over 14 years. Young menarcheal age of Mayans needs an explanation in the Discussion.

There are a few minor grammatical errors in the text. These can be easily eliminated by careful editing. One common problem we all have these days is sex as the English expression evolves. The authors study **gender** differences by calculating the **sexual** dimorphism index and in the text use both "gender" and "sex". The standard understanding in human biology is that "sex" is what is given by XY chromosomes and expressed anatomically, while "gender" is what a person chooses to be socially. "Political correctness" pressures authors into use of "more polite" expressions. Sex, of course seems to be less polite. I respect the authors' right to be politically correct, but then they should use the Gender Dimorphism Index and remove all mentions of sex from the text.

Table 5 can easily be reduced to a few lines of text.

References

1. Chandler PJ, Bock RD: Age changes in adult stature: trend estimation from mixed longitudinal data. *Ann Hum Biol.* **18** (5): 433-40 [PubMed Abstract](#) | [Publisher Full Text](#)
2. Morgan S: Adjustment of age-related height decline for Chinese: a 'natural experiment' of longitudinal survey using archival data. *Economic History Society.* 2010. [Reference Source](#)

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Reviewer Expertise: Science, Biology, Anatomy, Biological Anthropology, Applied Mathematics

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