

---

This item was submitted to [Loughborough's Research Repository](#) by the author.  
Items in Figshare are protected by copyright, with all rights reserved, unless otherwise indicated.

## Intergenerational changes in knee height among Maya mothers and their adult daughters from Merida, Mexico

PLEASE CITE THE PUBLISHED VERSION

<http://dx.doi.org/10.1002/ajhb.22752>

PUBLISHER

© Wiley Periodicals Inc.

VERSION

SMUR (Submitted Manuscript Under Review)

PUBLISHER STATEMENT

This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) licence. Full details of this licence are available at: <https://creativecommons.org/licenses/by-nc-nd/4.0/>

LICENCE

CC BY-NC-ND 4.0

REPOSITORY RECORD

Azcorra, Hugo, Luis Rodrigues, Maria Ines Varela Silva, Sudip D. Banik, and Federico Dickinson. 2019. "Intergenerational Changes in Knee Height Among Maya Mothers and Their Adult Daughters from Merida, Mexico". figshare. <https://hdl.handle.net/2134/17219>.



**Intergenerational changes in knee height among Maya mothers and their adult daughters from Merida, Mexico**

Journal:	<i>American Journal of Human Biology</i>
Manuscript ID:	AJHB-14-0291.R1
Wiley - Manuscript type:	Original Research Article
Date Submitted by the Author:	n/a
Complete List of Authors:	Azcorra, Hugo; Centro de Investigación y de Estudios Avanzados del Instituto Politecnico Nacional, Departamento de Ecología Humana Rodriguez, Luis; Universidad Autonoma de Yucatan, Facultad de Matematicas Varela-Silva, Maria; Loughborough University, Human Sciences Datta Banik, Sudip; Cinvestav-Merida, Department of Human Ecology Dickinson, Federico; Cinvestav-Merida, Department of Human Ecology
Keywords:	knee height, growth, Yucatan, intergenerational changes

SCHOLARONE™  
Manuscripts

Review

1  
2  
3  
4  
5 Intergenerational changes in knee height among Maya mothers and their adult  
6 daughters from Merida, Mexico  
7  
8

9  
10  
11  
12 Hugo Azcorra, Luis Rodriguez, Maria Inês Varela-Silva, Sudip Datta Banik and  
13 Federico Dickinson  
14

15  
16  
17 Departamento de Ecología Humana  
18 Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional  
19 Mérida, Yucatán, México  
20  
21 Km 6 Antigua carretera a Progreso, C.P. 97310  
22  
23 Phone +52(1) 999 9429413  
24  
25  
26  
27

28 Abbreviated title: Intergenerational changes in knee height in mother-daughter  
29 dyads  
30  
31

32  
33 Corresponding author:

34 Hugo Azcorra

35 Departamento de Ecología Humana

36 Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional  
37 Mérida, Yucatán, México

38 Km 6, Antigua carretera a Progresos, C.P. 97310

39 Phone +52(1) 999 9429413

40 E-mail address: [hugoazpe@hotmail.com](mailto:hugoazpe@hotmail.com)  
41  
42  
43  
44  
45  
46  
47

48  
49 The data reported here were obtained thanks the financial support of the Consejo  
50 Nacional de Ciencia y Tecnologia de Mexico (Conacyt-Ciencia Basica 168047).  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 1 Intergenerational changes in knee height among Maya mothers and their adult  
4 daughters from Merida, Mexico  
5  
6  
7 3

8  
9 4 Hugo Azcorra<sup>1§</sup>, Luis Rodríguez<sup>2</sup>, Maria Inês Varela-Silva<sup>3</sup>, Sudip Datta Banik<sup>1</sup> and  
10 Federico Dickinson<sup>1</sup>  
11  
12 6

13  
14 7 1: Department of Human Ecology, Centro de Investigación y de Estudios  
15 Avanzados del Instituto Politécnico Nacional (Cinvestav)-Unidad Mérida, 97310  
16 Merida, Yucatan, Mexico; 2: Facultad de Matemáticas, Universidad Autónoma de  
17 Yucatán, Mérida, Yucatán, México; 3: Centre for Global Health and Human  
18 Yucatán, Mérida, Yucatán, México; 3: Centre for Global Health and Human  
19 Development, School of Sports, Exercise and Health Sciences, Loughborough  
20 University, Loughborough, LE11 3TU United Kingdom; §: corresponding author.  
21  
22 13

23  
24  
25  
26 14 [hugoazpe@hotmail.com](mailto:hugoazpe@hotmail.com)  
27  
28 15

29  
30 16 This research was funded by the National Council of Science and Technology of  
31 Mexico (Conacyt grant no. 168047).  
32  
33 18

34  
35 19 Running head  
36  
37 20

38 21 Intergenerational changes in knee height in mother-daughter dyads  
39  
40 22  
41 23  
42 24  
43 25  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 26 **ABSTRACT**  
4

5 27 **Objectives** To analyze differences in knee height (KH) between adult Maya  
6 mothers and daughters in the city of Merida, Mexico, and determine if these  
7 differences are associated to their childhood socioeconomic conditions. **Methods**  
8 From September 2011 to January 2014, we measured KH and collected data on  
9 childhood conditions (place of birth, type of drinking water, family size [FS] and  
10 fathers' occupation) from a sample of 180 Maya mother-daughter dyads. Mean  
11 intergenerational difference in KH was calculated and compared for each category  
12 of socioeconomic variables and a multiple regression model was adjusted to  
13 assess the association between childhood conditions and difference in KH.  
14 **Results** A relative increase of 1.05 cm (SD = 2.3 cm) or 0.45 standard deviations  
15 (effect size of difference) was observed in KH between generations. Place of birth  
16 and FS were significantly associated to KH. The intergenerational KH difference  
17 was 1.6 cm longer when mothers were born outside Merida but daughters were  
18 born in the city. Daughters with larger FS than their mothers associated to a  
19 decrease in KH difference (1.6 cm) compared to daughters and mothers having the  
20 same FS. **Conclusions** The relative increase in KH between generations  
21 represents a portion of the expected change in growth in a group that has  
22 experienced few substantial improvements in their living conditions. Slight  
23 improvements in childhood living conditions resulting from the intergenerational  
24 transition from rural to urban environments seem to be linked to a slight  
25 intergenerational increase in KH among Maya women in Merida.  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48

49 **Key words:** knee height, Yucatan, growth, intergenerational changes.  
50  
51

## 52 INTRODUCTION

53 Intergenerational changes in human growth are usually assessed using the total  
54 height of population; however some studies suggest that positive changes in adult  
55 stature between populations are mainly explained by increases in lower body  
56 segments (Himes, 1979; Moore, 1970; Tanner et al., 1982; Garn, 1987, Hauspie et  
57 al., 1997; Bogin et al., 2002, Cole, 2003; Bogin, 2013). Specifically, lower limb  
58 distal segments may be more sensitive than lower limb upper segments during pre-  
59 pubertal growth periods (Lampl et al., 2003; Bailey et al., 2007; Pomeroy et al.,  
60 2012). In addition, distal limb segments, especially the tibia, tend to exhibit more  
61 variation than the proximal segments (femur) within and between populations  
62 (Holliday and Ruff, 2001; Auerbach and Sylvester, 2011). Tibia length is a  
63 notoriously difficult parameter to measure in living people, but knee height (KH)  
64 can be used as a proxy for this segment (Bogin et al., 2014).

65 Knee height is particularly useful in the evaluation of intergenerational (i.e.  
66 parents-offspring) differences in growth attained in adult population. It has been  
67 estimated that the cumulative height reduction from 30 to 70 years of age is, on  
68 average, 3 cm for men and 5 cm for women, and further accelerates afterwards  
69 (Sorkin et al., 1999). However, loss in adult height is less pronounced in lower  
70 body segments than in trunk (Chumlea et al., 1985). The KH tends to be relatively  
71 stable from early adulthood to senescence and some studies report that this  
72 segment is the most closely associated to total height in adults from different  
73 populations (Prothro and Rosenbloom, 1993; Bermudez et al., 1999; Duyar and  
74 Pelin, 2003; Palloni and Guend, 2005).

75 Intergenerational studies show that infancy and childhood are the stages of  
76 life when the largest proportion of increase in linear growth occurs (Hauspie et al.,  
77 1997; Cole, 2003; Bogin, 2013). This suggests that nutrition and other  
78 environmental factors experienced during the first years of life may partially explain  
79 intergenerational differences in lower body segments such as KH.

80 Intergenerational changes in the length of body segments, such as KH, can  
81 be positive or negative in response to the changes in environmental conditions  
82 experienced by each generation during sensitive growth periods. Socioeconomic

1  
2  
3 83 factors involved in the changes of patterns of growth between generations are  
4  
5 84 specific for each population and depend on the changes on socioeconomic  
6  
7 85 dynamism of the studied region or nation. We suggest that intergenerational  
8  
9 86 differences between parent and offspring (i.e. mothers and daughters) can be  
10  
11 87 explained by differences in socioeconomic circumstances experienced by both  
12  
13 88 generations during childhood.  
14

89

## 90 **PARTICIPANTS AND METHODS**

91 The Maya people constitute the largest indigenous group in Mexico. The State of  
92 Yucatan in the southern part of Mexico has historically been the home of a great  
93 number of Maya people. Since the 1970's, Merida, the capital city of Yucatan, has  
94 attracted many Maya peasants who have moved from the rural areas. Since the  
95 first European contacts nearly five centuries ago, the Maya people have  
96 experienced adverse living conditions. Even, nowadays, as a group, the Maya are  
97 still involved in social, economic and cultural transitions resulting from the  
98 imposition of government policies related to the national and global economy  
99 (Bracamonte, 2007). These adverse environmental conditions have been probably  
100 expressed in the poor biological status of the Maya. Previously published studies  
101 involving living populations suggest that mean height among Maya women in  
102 Yucatan has remained historically very low (<148 cm). Early studies done in  
103 Yucatan between 1895 and 1941 found that mean height in Maya women ranged  
104 from 141.5 cm to 142.7 cm (Starr, 1902, Williams, 1931; Steggerda, 1932, 1941).  
105 More recent studies have reported average mean heights in adult Maya women  
106 residing in Merida of 147.2 cm (SD = 5.4) (Varela-Silva et al., 2009), 147.9 cm (SD  
107 = 4.8) (Azcorra et al., 2013), and 146.8 cm (SD = 4.6) (Wilson et al., 2014). The  
108 objectives of this study are: i) to analyze differences in KH between Maya mothers  
109 and their adult daughters in the city of Merida, Mexico, and ii) determine if these  
110 differences are associated with socioeconomic circumstances experienced by the  
111 mothers and daughters during their childhood.

112

1  
2  
3 113 **Ethical clearance** The research design was approved by the Bioethics Committee  
4  
5 114 for the Study of Human Beings of the Center for Research and Advanced Studies  
6  
7 115 of the National Polytechnic Institute (Cinvestav-IPN), Mexico, and by the Ethical  
8  
9 116 Advisory Committee of Loughborough University, UK. Mothers and daughters were  
10  
11 117 informed in details about the purpose of the study and their rights as participants.  
12  
13 118 Written informed consent was obtained from literate participants and thumb  
14  
15 119 impressions were asked from illiterate women as proof of their consent.  
16

17  
18 121 **Sample size** The sample included 180 dyads of Maya mothers and their adult  
19  
20 122 biological daughters residing in Merida city. None of daughters included in the  
21  
22 123 sample have the same mother. Maya ethnicity was identified by the presence of  
23  
24 124 both paternal and maternal Maya surnames in mothers and daughters.  
25

26  
27 126 **Data collection** A cross-sectional and intergenerational study was undertaken  
28  
29 127 from September 2011 to January 2014 in neighborhoods from the south, west and  
30  
31 128 east of Merida. Left KH was measured in mothers and daughters with participants  
32  
33 129 seated, barefoot and with the lower leg positioned at a 90-degree angle to the  
34  
35 130 thigh. KH was measured as the distance between the proximal border of the  
36  
37 131 patella and the floor, as suggested by Bogin (2012). Anthropometric  
38  
39 132 measurements were done during home visits by trained female research  
40  
41 133 assistants.

42  
43 134 A socioeconomic questionnaire was applied to mothers and daughters  
44  
45 135 addressing childhood living conditions. The questionnaire design was based on  
46  
47 136 similar instruments developed and applied over the last years by two of the co-  
48  
49 137 authors (FD and MIVS) and their research assistants and postgraduate students.  
50  
51 138 Since the questionnaire was designed to obtain retrospective information, based  
52  
53 139 on people's memory, we gave special care to include in several parts of the  
54  
55 140 questionnaire questions that allowed us to confirm responses provided by  
56  
57 141 participants. Research assistants who applied the questionnaire were attentive to  
58  
59 142 identify inconsistencies in responses obtained from participants and, if necessary,  
60  
143 clarify the situation or make observations to allow subsequent interpretation. In



1  
2  
3 144 addition, questionnaires were applied during home visits and mothers and  
4  
5 145 grandmothers helped themselves to answer questions related to their childhood. In  
6  
7 146 this study we are focusing on four socioeconomic variables collected from both  
8  
9 147 generations: 1) place of birth, 2) family size, 3) type of drinking water, and 4)  
10  
11 148 father's occupation. The rationale for the selection of these variables was based on  
12  
13 149 our knowledge about social and economic changes occurred in Yucatan in the last  
14  
15 150 decades. We established two specific criteria for variable selection: 1) variables  
16  
17 151 that represent plausible links to intergenerational differences in growth, and 2)  
18  
19 152 variables with enough variability across the two generations.

20  
21 153 With reference to socioeconomic parameters, four categorical variables  
22  
23 154 were built to describe the condition of both generations. Three levels of place of  
24  
25 155 birth were defined: 1) mother and daughter born out of Merida, 2) mother born out  
26  
27 156 of Merida and daughter born in Merida, and 3) mother and daughter born in  
28  
29 157 Merida. Categories of type of drinking water were: 1) mother and daughter drinking  
30  
31 158 well water, 2) mother drinking well water and daughter drinking piped water, and 3)  
32  
33 159 mother and daughter drinking piped water. Family size (FS) was treated as follow:  
34  
35 160 1) mother and daughter having the same FS, 2) mother with a larger FS than her  
36  
37 161 daughter, and 3) daughter with a larger FS than her mother. Categories of father's  
38  
39 162 occupation were: 1) mother and daughter with a peasant father, 2) mother with a  
40  
41 163 peasant father and daughter with a non-peasant father, and 3) mother and  
42  
43 164 daughter with a non-peasant father.

44  
45 165  
46  
47 166 **Statistical analysis** Paired Student's t-test was applied to compare KH between  
48  
49 167 generations. Student's t-test (for continuous variables) and Chi-square test (for  
50  
51 168 categorical variables) were used to compare early socioeconomic conditions  
52  
53 169 between mothers and daughters. One-way ANOVA was used to compare the  
54  
55 170 intergenerational differences in KH (KH differences = daughters' KH – Mothers'  
56  
57 171 KH) between categories of socioeconomic variables. A multiple regression model  
58  
59 172 was adjusted to assess the association between socioeconomic variables and  
60  
173 intergenerational differences in KH. Each predictor was introduced into the model  
174  
as two dummy variables. The next categories of predictors were used as the

1  
2  
3 175 references in the model: mother and daughter born out of Merida, mother and  
4  
5 176 daughter drinking well water, mother and daughter with the same FS, and mother  
6  
7 177 and daughter with a peasant father. All possible interactions between predictors  
8  
9 178 were generated and regressed to the outcome to check its effect. Several  
10  
11 179 diagnostic tests were used to assess the validity of model. Normality of residuals  
12  
13 180 and outcome variable was verified by using Shapiro-Wilk test. Non-collinearity  
14  
15 181 between predictors was confirmed by the calculation of variance inflation factor  
16  
17 182 (VIF) values. Statistical analyses were done using the Stata/IC 11.1 for Windows  
18  
19 183 statistics package (StataCorp LP, 2010). Significance level in all analyses was  $\alpha =$   
20  
21 184 0.05.

## 22 186 **RESULTS**

23  
24 187 Mothers (mean age = 60.16 yrs, Standard Deviation or SD = 8.93) were on  
25  
26 188 average 27.05 (SD = 7.18) yrs older than their daughters (mean age = 33.11 yrs,  
27  
28 189 SD = 5.63), and daughters showed higher mean values of KH than their mothers  
29  
30 190 (45.53 cm [SD = 2.03] vs. 44.48 cm [SD = 1.90],  $P < 0.001$ ; mean difference = 1.05  
31  
32 191 cm [SD = 2.33]).

33  
34 192 Differences in socioeconomic conditions experienced in childhood between  
35  
36 193 mothers and daughters are presented in Table 1. Only 8% of mothers were born in  
37  
38 194 Merida, compared to 42% of their daughters. As a group, daughters grew up in  
39  
40 195 families slightly smaller than their mothers and the proportion of women that  
41  
42 196 consumed well water during childhood was greater in mothers than in daughters  
43  
44 197 (93% vs. 28%). Compared to their daughters, most of mothers reported that their  
45  
46 198 father was peasant (77% vs. 23%).

47 199

48 200 INSERT TABLE 1 HERE

49 201

50  
51 202 Table 2 shows the mean intergenerational differences in KH for each  
52  
53 203 category of socioeconomic variables. Place of birth was the only variable that  
54  
55 204 significantly differed between generations; being the greatest difference in the  
56  
57 205 category of mothers born outside Merida and daughters born in Merida. The

1  
2  
3 206 Bonferroni multiple comparison tests revealed that significant differences were  
4  
5 207 found between the category of mother and daughter born out of Merida and the  
6  
7 208 category of mother born outside Merida and daughter born in the city. Regarding  
8  
9 209 the type of drinking water, it was observed that when both generations consumed  
10  
11 210 piped water during their childhood the difference in KH increased 1.6 cm compared  
12  
13 211 to the category of mother and daughter drinking well water and 1.3 cm compared  
14  
15 212 to the category of mother drinking well water and daughter drinking piped water.  
16  
17 213 The analysis of FS showed that the greatest difference in KH (~2 cm) was found  
18  
19 214 when mothers and daughters lived during childhood in families with the same size  
20  
21 215 followed by the category of mothers with a bigger FS than their daughters (1 cm).  
22  
23 216 The difference in the category of daughters with a greater FS than their mothers  
24  
25 217 was reduced to 0.8 cm. Compared to the category of mothers and daughters  
26  
27 218 having a peasant father during childhood, the differences in KH increased around  
28  
29 219 0.6 cm with the presence of a non-peasant father in daughters' generation and  
30  
31 220 around 1 cm with non-peasant fathers in both generations. Difference of KH was  
32  
33 221 the highest (1.63 cm) case of non-peasant fathers in both generations.

34  
35 222  
36  
37 223 INSERT TABLE 2 HERE  
38  
39 224

40  
41 225 Multiple regression model for intergenerational differences in KH is  
42  
43 226 presented in Table 3. Place of birth and family size (FS) were significantly related  
44  
45 227 to the outcome variable (KH). Compared to the reference category (mother and  
46  
47 228 daughter born outside Merida), the circumstance of mother born outside Merida  
48  
49 229 and daughter born in the city was significantly associated to an increase of 1.6 cm  
50  
51 230 in mothers-daughters KH difference. Our model predicted that when daughters' FS  
52  
53 231 was higher than mothers' FS, the difference in KH decreased significantly around  
54  
55 232 1.6 cm compared to that dyads in which mother and daughter had the same FS.  
56  
57 233 Consumption of piped water during childhood by both mothers and daughters was  
58  
59 234 associated with an increase in KH difference (1.5 cm) compared to those mothers  
60  
235 and daughters who consumed well water ( $p = 0.065$ ). Paternal occupation was not  
236  
significantly associated to intergenerational differences of KH. None of interactions

1  
2  
3 237 between predictors showed a significant association to intergenerational  
4  
5 238 differences in KH.

6  
7 239

8  
9 240 INSERT TABLE 3 HERE

10  
11 241

## 12 242 **DISCUSSION**

13  
14 243 Our results suggest that the Maya daughters of our sample experienced slightly  
15  
16 244 better childhood living conditions than their mothers, which is consistent with their  
17  
18 245 relative increase of 1.05 cm in KH. Given the variation of mean intergenerational  
19  
20 246 difference in KH (SD = 2.3 cm), it is possible to estimate the effect size of  
21  
22 247 difference around 0.45 standard deviations. This positive change may be  
23  
24 248 associated to the investment made by the Mexican government during the last 3-4  
25  
26 249 decades to reduce poverty levels in the region. Government investment has been  
27  
28 250 focused on improvements in basic households' infrastructure and health care  
29  
30 251 system (Levy, 2006; OECD, 2007). Poor families have been supplied with better  
31  
32 252 access to clean drinking water, cement floors and toilets. Improvements in the  
33  
34 253 health care system have included the increase in the number of health care units in  
35  
36 254 urban and rural areas and an expansion in the vaccination and vitamin doses  
37  
38 255 coverage in infants. However, we suggest that the conditions experienced by  
39  
40 256 previous generations of the Maya in Yucatan were so precarious that these  
41  
42 257 material improvements observed in the last years have been not enough to be  
43  
44 258 reflected in anthropometric traits such as KH.

45  
46 259 The study of Maya migrants in the United States of America by Bogin et al.  
47  
48 260 (2002) provides a useful initial point of comparison for our results. In their study  
49  
50 261 Bogin and his colleagues found that Guatemalan Maya children 5 to 12 years of  
51  
52 262 age living in a poor setting in the United States were 11.54 cm taller than their  
53  
54 263 peers living in Guatemala and that 60% of the mean height increase was explained  
55  
56 264 by the differences in leg length (leg length = height – sitting height). Differences  
57  
58 265 between groups were attributed to remarkable improvements in sanitary conditions  
59  
60 266 and food support programs of schools in the United States. Compared to these  
267 findings we may suggest that the 1.05 cm of relative increase in KH between

1  
2  
3 268 mothers and daughters of our study represent only a portion of the expected  
4  
5 269 increase in growth between generations in a social group that have showed few  
6  
7 270 substantial improvements in their living conditions.

8  
9 271 Place of birth of mothers and daughters was significantly associated with  
10  
11 272 differences in KH. A brief historical review indicates that until the mid-20th century,  
12  
13 273 most of the population from Yucatan inhabited in small towns and villages with  
14  
15 274 rural characteristics (Baños, 1996). Two distinct agricultural areas were easily  
16  
17 275 identifiable since the early 20<sup>th</sup> century: 1) the Indian maize zone in the south and  
18  
19 276 west of the state, where the traditional maize farm plot (*milpa* system) was the  
20  
21 277 base not only for food production but also for the social relationships and beliefs,  
22  
23 278 and 2) the former sisal zone in the northwestern area of the state (Villanueva,  
24  
25 279 1990; García et al., 1999). The sisal production (*Agave sisalana* sp.) was framed  
26  
27 280 under the establishment of the *hacienda* system (land holding) during the 19<sup>th</sup>  
28  
29 281 century. In this system, the elite social group (rich families and government)  
30  
31 282 controlled the production and processing of sisal fiber for their exportation  
32  
33 283 (Bracamonte, 2007). A large number of Maya people were employed in the sisal  
34  
35 284 agroindustry under very disadvantaged socioeconomic conditions.

36  
37 285 The vast majority (92%) of mothers in our sample, born in the sisal zone  
38  
39 286 between 1940 and 1960 and their families experienced the crisis of sisal agro-  
40  
41 287 industry, characterized by low wages, unemployment and migration. Between 1940  
42  
43 288 and 1960, most the inhabitants of Yucatan sisal zone belonged to large families in  
44  
45 289 which the father, with little or no formal education, worked in the plantations or sisal  
46  
47 290 shredders with very low wages and the mother, besides housework (including  
48  
49 291 fuelwood collection), used to weave hammocks and clothes to sell to intermediate  
50  
51 292 traders at very low prices. Those families usually lived in a house with one  
52  
53 293 bedroom, had only well water for drinking, cooking with firewood and had no  
54  
55 294 electricity and drainage system. The latter generated health problems as most  
56  
57 295 people had no toilet in their households (Katz, 1980; Lugo Pérez, 1996; Baños,  
58  
59 296 1996; Nickel, 1997; Benitez, 1962).

60  
297 Several factors including the fall of the sisal industry led that, since late  
298  
sixties, a great number of Maya people started moving to the growing urban

1  
2  
3 299 centers such as Merida, Yucatan and Cancun in the state of Quintana Roo in  
4  
5 300 search of better job opportunities (Lizama Quijano, 2012). Merida city became an  
6  
7 301 important destination for rural-to-urban Maya migrants; from 1970 to 2000 its  
8  
9 302 population increased from 212,097 to 777,615 inhabitants, which corresponded to  
10  
11 303 an increase of 351% in 30 years, basically due to migration (INEGI 1971, 2001).  
12  
13 304 The immigrants (most from sisal zone) had very low education and poor job  
14  
15 305 training so they were typically employed as masons in construction works,  
16  
17 306 unskilled labourers and multiple informal activities such as sale of goods in the  
18  
19 307 street corners of downtown. These immigrants settled in the south of the city of  
20  
21 308 Merida, an area with precarious urbanization, limited access to electricity, drinking  
22  
23 309 water, transport, schools and public markets (Dickinson et al., 1999; Fuentes,  
24  
25 310 2005; Pérez Medina, 2010). Our results suggest that migration to Merida city  
26  
27 311 produced some improvements in the living conditions of daughters' families, but  
28  
29 312 also indicate that these improvements were not enough to be expressed in greater  
30  
31 313 somatic differences.

30 314 Changes in FS were also associated to intergenerational differences in KH.  
31  
32 315 In general, mothers and daughters reported to have belonged to large families  
33  
34 316 during their childhood [mean mothers = 8.2, (SD = 3.2); mean daughters = 7.2, (SD  
35  
36 317 = 2.4)]; until the decade of 1970s, around 30% of Mexican families had seven or  
37  
38 318 more family members (INEGI, 1971). Our analysis showed that when the FS  
39  
40 319 increased in the daughters' generation, the intergenerational differences in KH  
41  
42 320 reduced to 0.77 cm. When FS is compared between generations in the category of  
43  
44 321 daughters having greater FS than mothers, the difference was around 3 family  
45  
46 322 members [mean mothers = 8.9, (SD = 2.4) vs. mean daughters = 5.8, (SD = 2.2)].  
47  
48 323 An increase in FS, explained mainly by an increase in the number of offspring, may  
49  
50 324 be associated to less individual resources for feeding, lower access to high quality  
51  
52 325 health services and increased crowding in the household. We suggest that these  
53  
54 326 factors and others may be associated to lower values in daughters' KH. Interaction  
55  
56 327 between place of birth and FS was non-significant, which suggest that their  
57  
58 328 influences are independent.

1  
2  
3 329 Our analysis shows that paternal occupation was not significantly associated  
4  
5 330 to differences in KH. However, the greater difference in KH (mean = 1.63 cm [SD =  
6  
7 331 2.8]) was observed when both mothers and their daughters reported to have had a  
8  
9 332 non-peasant father and lesser differences (mean = 0.57 cm, SD = 2) when both  
10  
11 333 generations had a peasant father during their childhood. Most of non-peasant men  
12  
13 334 were employed in Merida and outside the city as salaried workers such as masons,  
14  
15 335 labourers and poorly qualified employees. It is possible that the relative income of  
16  
17 336 non-peasant fathers who had a relatively stable employment allowed better  
18  
19 337 conditions in the studied families and thus the expression of larger differences in  
20  
21 338 KH.

21 339 As far as we know, very few studies have investigated changes in lower  
22  
23 340 body segments between parents and offspring and their associations to childhood  
24  
25 341 conditions (Himes, 1979; Floyd, 2007; Bogin et al., 2014, Sohn, 2015). In their  
26  
27 342 study with Taiwanese families living in Auckland, New Zealand, and Taipei,  
28  
29 343 Taiwan, during 2003, Floyd (2007) found that parent-offspring differences in  
30  
31 344 subsischial leg length tended to be lesser when both generations experienced  
32  
33 345 disadvantaged living conditions in early years of development; more noticeable  
34  
35 346 changes were observed when conditions lived by parents were relatively more  
36  
37 347 unprivileged than their offspring and differences were less evident when parents  
38  
39 348 and offspring experienced relatively well-off circumstances in childhood. Our  
40  
41 349 results are consistent with findings reported by Floyd (2007) in the sense that  
42  
43 350 greater differences in KH were observed when: 1) daughters experienced better  
44  
45 351 conditions than their mothers, as is the case of place of birth, and 2) when mothers  
46  
47 352 and daughters lived under relative well-off or similar conditions, as assessed by the  
48  
49 353 type of drinking water, FS and paternal occupation.

48 354 In their study with Bangladeshi mothers and daughters living in Bangladesh  
49  
50 355 (BD) and in the UK, Bogin et al. (2014) found that daughters born and living in the  
51  
52 356 UK were 3.8 cm taller than daughters living in the UK but born in BD, with KH  
53  
54 357 values accounting for 53% (2 cm) of the total difference in height. The authors  
55  
56 358 suggest that these differences are due to 1) that living conditions experienced by  
57  
58 359 women in BD were worse than in the UK during childhood, and 2) the daughters

1  
2  
3 360 born in BD experienced more emotional stress due to the migration, including the  
4  
5 361 fact that fathers usually migrated first, leaving mothers and children behind for  
6  
7 362 some months or years. In our study, Maya daughters born in Merida were around  
8  
9 363 1.5 cm taller than daughters born out of Merida; being the differences in KH around  
10  
11 364 0.6 cm. The magnitude of our differences compared to differences reported by  
12  
13 365 Bogin and collaborators with Bangladeshi women are consistent with differences in  
14  
15 366 the amounts of change in developmental settings. We suggest that circumstances  
16  
17 367 lived in the UK by Bangladeshi women after migration were substantially better  
18  
19 368 than circumstances experienced by Maya women in the city of Merida.

20  
21 369 We acknowledge the fact that daughters' fathers may be also contributing to  
22  
23 370 daughters' growth and therefore to intergenerational changes in KH, however they  
24  
25 371 were not included in the study because they spend the most of day on work  
26  
27 372 activities outside home including the weekends.

28  
29 373 In summary, childhood living conditions experienced by Maya daughters  
30  
31 374 were somewhat better than that their mothers experienced, which is consistent with  
32  
33 375 their positive difference in KH (mean = 1.05 cm [SD = 2.33]). Our analysis  
34  
35 376 suggests that differences are associated with rural-to-urban migration experienced  
36  
37 377 by mothers as a result of the sisal agroindustry crisis of Yucatan during the 1960's  
38  
39 378 and 1970's and by differences in family size between generations due to official  
40  
41 379 policies of birth control. Our results suggest that present living conditions of Maya  
42  
43 380 women remain generally unfavorable, constituting a continuation of those  
44  
45 381 experienced by their ancestors since, at least, the 19th Century in the sisal zone, a  
46  
47 382 period of time known locally as The Slavery Time, as one informant reported to one  
48  
49 383 of us (FD) in 1978.

50 384

## 51 385 **ACKNOWLEDGMENTS**

52 386 The authors thank two anonymous reviewers for their criticism and suggestions.  
53  
54 387 The authors also thank Ms. Graciela Valentín and Ms. Adriana Vázquez-Vázquez  
55  
56 388 for assisting with somatic measurements, questionnaire application and field work  
57  
58 389 organization, and Ms. Frida Gutierrez, Ms. Paulina Cauich and Ms. Samantha  
59  
60 390 Sánchez for collaborating in the field work. Ms. Ina Susana Falfán-Lopez and Ms.



1  
2  
3 391 Adriana Vázquez-Vázquez developed the dataset and took part in participant  
4  
5 392 recruitment design. We also thank the mothers and daughters who agreed to  
6  
7 393 participate in the study. Mr. John Lindsay improved our written English.  
8  
9 394

10 395 **LITERATURE CITED**  
11

12  
13 396 Auerbach BM, Sylvester AD. 2011. Allometry and apparent paradoxes in human  
14  
15 397 limb proportions: implications for scaling factors. *Am J Phys Anthropol* 144:382-  
16  
17 398 391.  
18

19 399  
20 400 Azcorra H, Varela-Silva MI, Rodriguez L, Bogin B, Dickinson F. 2013. Nutritional  
21  
22 401 status of Maya children, their mothers, and their grandmothers residing in the city  
23  
24 402 of Merida, Mexico: revisiting the leg-length hypothesis. *Am J Hum Biol* 25:659-665.  
25

26 403

27 404 Bailey SM, Xu J, Feng JH, Hu X, Zhang C, Qui S. 2007. Trade-offs between  
28  
29 405 oxygen and energy in tibial growth at high altitude. *Am J Hum Biol* 19:662-668.  
30

31 406

32 407 Baños O. 1996. Neoliberalismo, reorganización y subsistencia rural. El caso de la  
33  
34 408 zona henequenera de Yucatán: 1980-1992. Mérida: Universidad Autónoma de  
35  
36 409 Yucatán.  
37

38 410

39 411 Benítez F. 1962. El drama de un pueblo y una planta. México, D. F.: Fondo de  
40  
41 412 Cultura Económica.  
42

43 413

44  
45 414 Bermudez OI, Becker EK, Tucker KL. 1999. Development of sex-specific equations  
46  
47 415 for estimating stature of frail elderly Hispanic living in the north-eastern United  
48  
49 416 States. *Am J Clin Nutr* 69:992-998.  
50

51 417

52 418 Bogin B. 2012. Leg length, body proportion, health and beauty. In: Cameron N and  
53  
54 419 Bogin B, editors. *Human growth and development*. London: Elsevier. p 343-373.  
55

56 420  
57  
58  
59  
60

- 1  
2  
3 421 Bogin B. 2013. Secular changes in childhood, adolescent and adult stature. In:  
4  
5 422 Gillman MW, Gluckman PD, Rosenfeld RG, editors. Recent advances in growth  
6  
7 423 research: nutritional molecular and endocrine perspectives. Nestle Nutr Inst  
8  
9 424 Workshop Ser, 71:115-126.  
10  
11 425  
12 426 Bogin B, Smith P, Orden AB, Varela-Silva MI, Loucky J. 2002. Rapid change in  
13  
14 427 height and body proportions of Maya American children. Am J Hum Biol 14:753-  
15  
16 428 761.  
17  
18 429  
19 430 Bogin B, Harper D, Merrel J, Chowdhury J, Heinrich M, Garaj V, Molik B,  
20  
21 431 Thompson JL. 2014. Influence of adult knee height, age at first birth, migration, and  
22  
23 432 current age on adult physical function of Bangladeshi mothers and daughters in the  
24  
25 433 United Kingdom and Bangladesh. J Anthropol, Article ID 808634, 14 pages.  
26  
27 434 doi:10.1155/2014/808634.  
28  
29 435  
30 436 Bracamonte P. 2007. Una deuda histórica. Ensayo sobre las causas de pobreza  
31  
32 437 secular de los mayas yucatecos. México, D. F.: CIESAS-Porrúa-ICY. 346 p.  
33  
34 438  
35 439 Chumlea WC, Roche AF, Steinbaugh ML. 1985. Estimating stature from knee  
36  
37 440 height for persons 60 to 90 years of age. J Am Geriatr Soc 33:116-120.  
38  
39 441 Cole TJ. 2003. The secular trend in human physical growth: a biological view. Econ  
40  
41 442 Hum Biol 1:161-168.  
42  
43 443  
44 444 Cole TJ. 2003. The secular trend in human physical growth: a biological view. Econ  
45  
46 445 Hum Biol 1:161-168.  
47  
48 446  
49 447 Dickinson FA, García A, Pérez S. 1999. Social differentiation and urban  
50  
51 448 segregation in a Mexican regional metropolis. In: Aguilar and Escamilla editors,  
52  
53 449 Problems on megacities: social inequalities, environmental risk and urban  
54  
55 450 governance. Mexico, D.F., Universidad Nacional Autonoma de México: 345-58.  
56  
57 451

- 1  
2  
3 452 Duyar I, Pelin C. 2003. Body height estimation based on tibia length in different  
4 453 stature groups. *Am J Phys Anthropol* 122: 23-27.  
5  
6 454  
7  
8 455 Floyd B. 2007. Focused life history data and linear enamel hypoplasia to help  
9 456 explain intergenerational variation in relative leg length within Taiwanese families.  
10 457 *Am J Hum Biol* 19:358-375.  
11  
12 458  
13  
14 459 Fuentes J H. 2005. Espacios, actores, prácticas e imaginarios urbanos en Mérida,  
15 460 Yucatán, México. Mérida: Universidad Autónoma de Yucatán.  
16  
17 461  
18  
19 462 García A, Chico P, Córdoba J. 1999. Atlas de procesos territoriales de Yucatán.  
20 463 México, D.F.: Universidad Autónoma de Yucatán.  
21  
22 464  
23  
24 465 Garn SM. 1987. The secular trend in size and maturational timing and its  
25 466 implications for nutritional assessment. *J Nutr* 117:817-823.  
26  
27 467  
28  
29 468 Hauspie RC, Vercauteren M, Susanne C. 1997. Secular changes in growth and  
30 469 maturation: an update. *Acta Paediatr* 424:20-27.  
31  
32 470  
33  
34 471 Himes JH. 1979. Secular trends in human growth, maturation, and development.  
35 472 *Mon Soc Res Child Devel* 44:28-58.  
36  
37 473  
38  
39 474 Holliday TW, Ruff CB. 2001. Relative variation in human proximal and distal limb  
40 475 segment lengths. *Am J Phys Anthropol* 116:26-33.  
41  
42 476  
43  
44 477 INEGI. 1971. IX Censo General de población 1970. Aguascalientes: Instituto  
45 478 Nacional Estadística, Geografía e Informática.  
46  
47 479  
48  
49 480 INEGI. 2001. XII Censo General de Población y Vivienda 2000. Aguascalientes:  
50 481 Instituto Nacional de Estadística, Geografía e Informática.  
51  
52 482  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 483 Katz F. 1980. La servidumbre agraria en México en la época porfiriana. México,  
4 D.F.: Ediciones Era.  
5 484  
6 485  
7  
8 486 Lampl M, Kuzawa CW, Jeanty P. 2003. Prenatal smoke exposure alters growth in  
9 limb proportions and head shape in the midgestation human fetus. Am J Hum Biol  
10 487 15:533-546.  
11 488  
12 489  
13 490 Levy, S. 2006. Progress Against poverty – Sustaining Mexico’s PROGRESA-  
14 Oportunidades Program. Washington DC: Brookings Institution Press.  
15 491  
16 492  
17 493 Lizama Quijano J. 2012. El perfil maya de la blanca Mérida. México D.F.: CIESAS.  
18 494  
19 495 Lugo Pérez, JA. 1996. Desarrollo citrícola y reorganización familiar. In: Krotz E,  
20 editor. Cambio cultural y resocialización en Yucatán. Mérida: Universidad  
21 Autónoma de Yucatán. p 97-116  
22 496  
23 497  
24 498  
25 499 Moore WM. 1970. The secular trend in physical growth of urban North American  
26 Negro Schoolchildren. Mon Soc Res Child Devel 35:62-73.  
27 500  
28 501  
29 502 Nickel HJ. 1997. El peonaje en las haciendas mexicanas. Interpretaciones,  
30 fuentes, hallazgos. México, D.F.: Universidad Iberoamericana.  
31 503  
32 504  
33 505 OECD, 2007. OECD Economic Survey Mexico, Organization for Economic Co-  
34 Operation and Development. Volume 2007/18 Available at: [http://www.oecd-](http://www.oecd-ilibrary.org/docserver/download/1007181e.pdf?expires=1368521031&id=id&accname=ocid43013083&checksum=B05933F38B7C24F708E1BAA4DFB485A5)  
35 [ilibrary.org/docserver/download/1007181e.pdf?expires=1368521031&id=id&accna](http://www.oecd-ilibrary.org/docserver/download/1007181e.pdf?expires=1368521031&id=id&accname=ocid43013083&checksum=B05933F38B7C24F708E1BAA4DFB485A5)  
36 [me=ocid43013083&checksum=B05933F38B7C24F708E1BAA4DFB485A5](http://www.oecd-ilibrary.org/docserver/download/1007181e.pdf?expires=1368521031&id=id&accname=ocid43013083&checksum=B05933F38B7C24F708E1BAA4DFB485A5)  
37 507  
38 508  
39 509 consulted on Feb 2015.  
40 510  
41 511 Palloni A, Guend A. 2005. Stature prediction equations for elderly Hispanics in  
42 Latin American countries by sex and ethnic background. J Gerontol 60A:804-810.  
43 512  
44 513  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 514 Pérez Medina S. 2010. Segregación, recreación y calidad de vida en Mérida.  
4 515 México, D.F.: Universidad Nacional Autónoma de México.  
5  
6 516  
7  
8 517 Pomeroy E, Stock JT, Stanojevic S, Miranda J, Cole T, Wells JCK. 2012. Trade-  
9 518 offs in relative limb length among Peruvian children: extending the thrifty  
10 519 phenotype hypothesis to limb proportions. PLoS ONE 7(12).  
11  
12 520  
13  
14 521 Prothro JW, Rosenbloom CA. 1993. Physical measurements in an elderly black  
15 522 population: knee height as the dominant indicator of stature. J Gerontol 48:M15-  
16 523 M18.  
17  
18 524  
19  
20 525 Sohn K. 2015. Is leg length a biomarker of early life conditions? Evidence from a  
21 526 historically short population. Am J Hum Biol In Early View, consulted Feb 12<sup>th</sup>  
22 527 2015. DOI: 10.1002/ajhb.22682  
23  
24 528  
25  
26 529 Sorkin JD, Muller DC, Andres R. 1999. Longitudinal change in height of men and  
27 530 women: implications of the body mass index. The Baltimore Longitudinal Study of  
28 531 Aging. Am J Epidemiol 150:969-977.  
29  
30 532  
31  
32 533 Starr F. 1902. The physical characters of the Indians of southern Mexico.  
33 534 University of Chicago Press.  
34  
35 535  
36  
37 536 Steggerda M. 1932. Anthropometry of adult Maya Indians. A study of their physical  
38 537 and physiological characteristics. Carnegie Institution of Washington, Publication  
39 538 No. 434.  
40  
41 539  
42  
43 540 Steggerda M. 1941. Maya Indians of Yucatan. Washington D.C. Carnegie Institute  
44 541 of Washington.  
45  
46 542  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 543 Tanner JM, Hayashi T, Preece MA, Cameron N. 1982. Increase in length of leg  
4 relative to trunk in Japanese children and adults from 1957 to 1977: comparison  
5 544  
6 with British and with Japanese Americans. *Ann Hum Biol* 9:411-423.  
7 545  
8 546  
9  
10 547 Varela-Silva MI, Azcorra H, Dickinson F, Bogin B, Frisancho AR. 2009. Influence of  
11 548 maternal stature, pregnancy age, and infant birth weight on growth during  
12 549 childhood in Yucatan, Mexico: A test of intergenerational effects hypothesis. *Am J*  
13 550 *Hum Biol* 21:657-663.  
14  
15 551  
16  
17 552 Villanueva E. 1990. La formación de las regiones de Yucatán. In: Baños O, editor.  
18 553 Sociedad, estructura agraria y Estado en Yucatán. Mérida: Universidad Autónoma  
19 554 de Yucatán. p 167-203.  
20  
21 555  
22  
23 556 Williams GD. 1931. Maya-Spanish crosses in Yucatan. Cambridge: Peabody  
24 557 Museum of American Archaeology and Ethnology.  
25  
26 558  
27  
28 559 Wilson HJ, Dickinson F, Griffiths PL, Bogin B, Hobbs M, Varela-Silva MI. 2014.  
29 560 Maternal short stature does not predict their children's fatness indicators in  
30 561 a nutritional dual-burden sample of urban Mexican Maya. *Am J Phys Anthropol*  
31 562 153:627-634.  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Table 1 Differences in socioeconomic indicators  
between daughters and mothers by childhood living conditions variables

Variables	Daughters	Mothers	p-value
Born in Merida	42%	8%	P<0.001
Family size	7.2 (SD = 2.4)	8.2 (SD = 3.2)	P<0.001
Drinking water access:			
Well	28%	93%	P<0.001
Piped	72%	7%	
Father's occupation			
Peasant	23%	77%	P<0.001
Non-peasant	20%	3%	

Table 2 Mean and standard deviations of intergenerational  
differences of KH according to socioeconomic conditions

Socioeconomic parameter	KH difference		ANOVA p-value
	Mean (cm)	SD	
Place of birth			
Mother & daughter out of Merida, n = 106	0.53	2.00	F = 8.16 P<0.001
Mother out of Merida/daughter in Merida, n = 61	1.98	2.44	
Mother & daughter in Merida, n = 13	0.88	2.13	
Type of water to drink			
Mother & daughter well, n = 51	0.81	2.30	F = 2.05 P = 0.132
Mother well/daughter piped, n = 118	1.03	2.33	
Mother & daughter piped, n = 11	2.36	2.29	
Family size (FS)			
Mother & daughter with same FS, n = 24	1.97	2.32	F = 2.36 P = 0.097
Mother > daughter, n = 95	1.00	2.32	
Daughter > mother, n = 61	0.77	2.31	
Father's occupation			
Mother & daughter peasant, n = 36	0.57	2.00	F = 1.69 P = 0.170
Mother peasant/daughter non-peasant, n = 95	1.04	2.29	
Mother & daughter non-peasant, n = 34	1.63	2.78	

Table 3 Multiple regression model of socioeconomic parameters experienced by mothers and daughters in childhood for intergenerational differences in KH

Variable	Coefficient	S. E.	t	p	CI 95%	
Place of birth						
Ref = Mother & daughter out of Merida						
Mother out of Merida/Daughter in Merida	1.58	0.41	3.85	<0.001	0.77	2.39
Mother & daughter in Merida	0.23	0.77	0.30	0.766	-1.28	1.74
Type of water to drink						
Ref = Mother & daughter well						
Mother well /daughter piped	0.09	0.41	0.23	0.822	-0.71	0.89
Mother & daughter piped	1.48	0.79	1.86	0.065	-0.09	3.05
Family size (FS)						
Ref = Mother & daughter with same FS						
Mother's FS > Daughters FS	-0.98	0.53	-1.85	0.166	-2.02	0.07
Daughter's FS > Mother's FS	-1.58	0.55	-2.87	0.005	-2.66	-0.49
Father's occupation						
Ref = Mother & daughter peasant						
Mother peasant & daughter non-peasant	-0.02	0.48	-0.05	0.959	-0.96	0.91
Mother & daughter non-peasant	0.36	0.60	0.60	0.552	-0.83	1.54
Constant	1.38	0.60	2.30	0.023	0.195	2.56

S.E.: standard error;  $R^2 = 0.16$ , Shapiro-Wilk residual normality test  $p = 0.897$ ; Breusch-Pagan/Cook-Weisberg homoscedasticity test  $p = 0.292$ ; mean variance inflation factor = 1.68.