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

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<tr>
<td>Keywords:</td>
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Intergenerational changes in knee height among Maya mothers and their adult daughters from Merida, Mexico

Hugo Azcorra, Luis Rodriguez, Maria Inês Varela-Silva, Sudip Datta Banik and Federico Dickinson

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Abbreviated title: Intergenerational changes in knee height in mother-daughter dyads

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

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d, Luis Rodríguez, Maria Inês Varela-Silva, Sudip Datta Banik and Federico Dickinson

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Running head

Intergenerational changes in knee height in mother-daughter dyads
ABSTRACT

Objectives To analyze differences in knee height (KH) between adult Maya mothers and daughters in the city of Merida, Mexico, and determine if these differences are associated to their childhood socioeconomic conditions. Methods From September 2011 to January 2014, we measured KH and collected data on childhood conditions (place of birth, type of drinking water, family size [FS] and fathers’ occupation) from a sample of 180 Maya mother-daughter dyads. Mean intergenerational difference in KH was calculated and compared for each category of socioeconomic variables and a multiple regression model was adjusted to assess the association between childhood conditions and difference in KH. Results A relative increase of 1.05 cm (SD = 2.3 cm) or 0.45 standard deviations (effect size of difference) was observed in KH between generations. Place of birth and FS were significantly associated to KH. The intergenerational KH difference was 1.6 cm longer when mothers were born outside Merida but daughters were born in the city. Daughters with larger FS than their mothers associated to a decrease in KH difference (1.6 cm) compared to daughters and mothers having the same FS. Conclusions The relative increase in KH between generations represents a portion of the expected change in growth in a group that has experienced few substantial improvements in their living conditions. Slight improvements in childhood living conditions resulting from the intergenerational transition from rural to urban environments seem to be linked to a slight intergenerational increase in KH among Maya women in Merida. Key words: knee height, Yucatan, growth, intergenerational changes.
INTRODUCTION

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

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

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

Intergenerational changes in the length of body segments, such as KH, can be positive or negative in response to the changes in environmental conditions experienced by each generation during sensitive growth periods. Socioeconomic
factors involved in the changes of patterns of growth between generations are specific for each population and depend on the changes on socioeconomic dynamism of the studied region or nation. We suggest that intergenerational differences between parent and offspring (i.e. mothers and daughters) can be explained by differences in socioeconomic circumstances experienced by both generations during childhood.

PARTICIPANTS AND METHODS

The Maya people constitute the largest indigenous group in Mexico. The State of Yucatan in the southern part of Mexico has historically been the home of a great number of Maya people. Since the 1970's, Merida, the capital city of Yucatan, has attracted many Maya peasants who have moved from the rural areas. Since the first European contacts nearly five centuries ago, the Maya people have experienced adverse living conditions. Even, nowadays, as a group, the Maya are still involved in social, economic and cultural transitions resulting from the imposition of government policies related to the national and global economy (Bracamonte, 2007). These adverse environmental conditions have been probably expressed in the poor biological status of the Maya. Previously published studies involving living populations suggest that mean height among Maya women in Yucatan has remained historically very low (<148 cm). Early studies done in Yucatan between 1895 and 1941 found that mean height in Maya women ranged from 141.5 cm to 142.7 cm (Starr, 1902, Williams, 1931; Steggerda, 1932, 1941). More recent studies have reported average mean heights in adult Maya women residing in Merida of 147.2 cm (SD = 5.4) (Varela-Silva et al., 2009), 147.9 cm (SD = 4.8) (Azcorra et al., 2013), and 146.8 cm (SD = 4.6) (Wilson et al., 2014). The objectives of this study are: i) to analyze differences in KH between Maya mothers and their adult daughters in the city of Merida, Mexico, and ii) determine if these differences are associated with socioeconomic circumstances experienced by the mothers and daughters during their childhood.
Ethical clearance The research design was approved by the Bioethics Committee for the Study of Human Beings of the Center for Research and Advanced Studies of the National Polytechnic Institute (Cinvestav-IPN), Mexico, and by the Ethical Advisory Committee of Loughborough University, UK. Mothers and daughters were informed in details about the purpose of the study and their rights as participants. Written informed consent was obtained from literate participants and thumb impressions were asked from illiterate women as proof of their consent.

Sample size The sample included 180 dyads of Maya mothers and their adult biological daughters residing in Merida city. None of daughters included in the sample have the same mother. Maya ethnicity was identified by the presence of both paternal and maternal Maya surnames in mothers and daughters.

Data collection A cross-sectional and intergenerational study was undertaken from September 2011 to January 2014 in neighborhoods from the south, west and east of Merida. Left KH was measured in mothers and daughters with participants seated, barefoot and with the lower leg positioned at a 90-degree angle to the thigh. KH was measured as the distance between the proximal border of the patella and the floor, as suggested by Bogin (2012). Anthropometric measurements were done during home visits by trained female research assistants.

A socioeconomic questionnaire was applied to mothers and daughters addressing childhood living conditions. The questionnaire design was based on similar instruments developed and applied over the last years by two of the co-authors (FD and MIVS) and their research assistants and postgraduate students. Since the questionnaire was designed to obtain retrospective information, based on people’s memory, we gave special care to include in several parts of the questionnaire questions that allowed us to confirm responses provided by participants. Research assistants who applied the questionnaire were attentive to identify inconsistencies in responses obtained from participants and, if necessary, clarify the situation or make observations to allow subsequent interpretation. In
addition, questionnaires were applied during home visits and mothers and
grandmothers helped themselves to answer questions related to their childhood. In
this study we are focusing on four socioeconomic variables collected from both
generations: 1) place of birth, 2) family size, 3) type of drinking water, and 4)
father’s occupation. The rationale for the selection of these variables was based on
our knowledge about social and economic changes occurred in Yucatan in the last
decades. We established two specific criteria for variable selection: 1) variables
that represent plausible links to intergenerational differences in growth, and 2)
variables with enough variability across the two generations.

With reference to socioeconomic parameters, four categorical variables
were built to describe the condition of both generations. Three levels of place of
birth were defined: 1) mother and daughter born out of Merida, 2) mother born out
of Merida and daughter born in Merida, and 3) mother and daughter born in
Merida. Categories of type of drinking water were: 1) mother and daughter drinking
well water, 2) mother drinking well water and daughter drinking piped water, and 3)
mother and daughter drinking piped water. Family size (FS) was treated as follow:
1) mother and daughter having the same FS, 2) mother with a larger FS than her
daughter, and 3) daughter with a larger FS than her mother. Categories of father’s
occupation were: 1) mother and daughter with a peasant father, 2) mother with a
peasant father and daughter with a non-peasant father, and 3) mother and
daughter with a non-peasant father.

**Statistical analysis** Paired Student’s t-test was applied to compare KH between
generations. Student’s t-test (for continuous variables) and Chi-square test (for
categorical variables) were used to compare early socioeconomic conditions
between mothers and daughters. One-way ANOVA was used to compare the
intergenerational differences in KH (KH differences = daughters’ KH – Mothers’
KH) between categories of socioeconomic variables. A multiple regression model
was adjusted to assess the association between socioeconomic variables and
intergenerational differences in KH. Each predictor was introduced into the model
as two dummy variables. The next categories of predictors were used as the
references in the model: mother and daughter born out of Merida, mother and daughter drinking well water, mother and daughter with the same FS, and mother and daughter with a peasant father. All possible interactions between predictors were generated and regressed to the outcome to check its effect. Several diagnostic tests were used to assess the validity of model. Normality of residuals and outcome variable was verified by using Shapiro-Wilk test. Non-collinearity between predictors was confirmed by the calculation of variance inflation factor (VIF) values. Statistical analyses were done using the Stata/IC 11.1 for Windows statistics package (StataCorp LP, 2010). Significance level in all analyses was $\alpha = 0.05$.

RESULTS

Mothers (mean age = 60.16 yrs, Standard Deviation or SD = 8.93) were on average 27.05 (SD = 7.18) yrs older than their daughters (mean age = 33.11 yrs, SD = 5.63), and daughters showed higher mean values of KH than their mothers (45.53 cm [SD = 2.03] vs. 44.48 cm [SD = 1.90], $P<0.001$; mean difference = 1.05 cm [SD = 2.33]). Differences in socioeconomic conditions experienced in childhood between mothers and daughters are presented in Table 1. Only 8% of mothers were born in Merida, compared to 42% of their daughters. As a group, daughters grew up in families slightly smaller than their mothers and the proportion of women that consumed well water during childhood was greater in mothers than in daughters (93% vs. 28%). Compared to their daughters, most of mothers reported that their father was peasant (77% vs. 23%).

Table 2 shows the mean intergenerational differences in KH for each category of socioeconomic variables. Place of birth was the only variable that significantly differed between generations; being the greatest difference in the category of mothers born outside Merida and daughters born in Merida. The
Bonferroni multiple comparison tests revealed that significant differences were found between the category of mother and daughter born out of Merida and the category of mother born outside Merida and daughter born in the city. Regarding the type of drinking water, it was observed that when both generations consumed piped water during their childhood the difference in KH increased 1.6 cm compared to the category of mother and daughter drinking well water and 1.3 cm compared to the category of mother drinking well water and daughter drinking piped water.

The analysis of FS showed that the greatest difference in KH (~2 cm) was found when mothers and daughters lived during childhood in families with the same size followed by the category of mothers with a bigger FS than their daughters (1 cm). The difference in the category of daughters with a greater FS than their mothers was reduced to 0.8 cm. Compared to the category of mothers and daughters having a peasant father during childhood, the differences in KH increased around 0.6 cm with the presence of a non-peasant father in daughters' generation and around 1 cm with non-peasant fathers in both generations. Difference of KH was the highest (1.63 cm) case of non-peasant fathers in both generations.

Multiple regression model for intergenerational differences in KH is presented in Table 3. Place of birth and family size (FS) were significantly related to the outcome variable (KH). Compared to the reference category (mother and daughter born outside Merida), the circumstance of mother born outside Merida and daughter born in the city was significantly associated to an increase of 1.6 cm in mothers-daughters KH difference. Our model predicted that when daughters' FS was higher than mothers' FS, the difference in KH decreased significantly around 1.6 cm compared to that dyads in which mother and daughter had the same FS. Consumption of piped water during childhood by both mothers and daughters was associated with an increase in KH difference (1.5 cm) compared to those mothers and daughters who consumed well water ($p = 0.065$). Paternal occupation was not significantly associated to intergenerational differences of KH. None of interactions
between predictors showed a significant association to intergenerational differences in KH.

DISCUSSION

Our results suggest that the Maya daughters of our sample experienced slightly better childhood living conditions than their mothers, which is consistent with their relative increase of 1.05 cm in KH. Given the variation of mean intergenerational difference in KH (SD = 2.3 cm), it is possible to estimate the effect size of difference around 0.45 standard deviations. This positive change may be associated to the investment made by the Mexican government during the last 3-4 decades to reduce poverty levels in the region. Government investment has been focused on improvements in basic households’ infrastructure and health care system (Levy, 2006; OECD, 2007). Poor families have been supplied with better access to clean drinking water, cement floors and toilets. Improvements in the health care system have included the increase in the number of health care units in urban and rural areas and an expansion in the vaccination and vitamin doses coverage in infants. However, we suggest that the conditions experienced by previous generations of the Maya in Yucatan were so precarious that these material improvements observed in the last years have been not enough to be reflected in anthropometric traits such as KH.

The study of Maya migrants in the United States of America by Bogin et al. (2002) provides a useful initial point of comparison for our results. In their study Bogin and his colleagues found that Guatemalan Maya children 5 to 12 years of age living in a poor setting in the United States were 11.54 cm taller than their peers living in Guatemala and that 60% of the mean height increase was explained by the differences in leg length (leg length = height – sitting height). Differences between groups were attributed to remarkable improvements in sanitary conditions and food support programs of schools in the United States. Compared to these findings we may suggest that the 1.05 cm of relative increase in KH between
mothers and daughters of our study represent only a portion of the expected increase in growth between generations in a social group that have showed few substantial improvements in their living conditions.

Place of birth of mothers and daughters was significantly associated with differences in KH. A brief historical review indicates that until the mid-20th century, most of the population from Yucatan inhabited in small towns and villages with rural characteristics (Baños, 1996). Two distinct agricultural areas were easily identifiable since the early 20th century: 1) the Indian maize zone in the south and west of the state, where the traditional maize farm plot (milpa system) was the base not only for food production but also for the social relationships and beliefs, and 2) the former sisal zone in the northwestern area of the state (Villanueva, 1990; García et al., 1999). The sisal production (Agave sisalana sp.) was framed under the establishment of the hacienda system (land holding) during the 19th century. In this system, the elite social group (rich families and government) controlled the production and processing of sisal fiber for their exportation (Bracamonte, 2007). A large number of Maya people were employed in the sisal agroindustry under very disadvantaged socioeconomic conditions.

The vast majority (92%) of mothers in our sample, born in the sisal zone between 1940 and 1960 and their families experienced the crisis of sisal agroindustry, characterized by low wages, unemployment and migration. Between 1940 and 1960, most the inhabitants of Yucatan sisal zone belonged to large families in which the father, with little or no formal education, worked in the plantations or sisal shredders with very low wages and the mother, besides housework (including fuelwood collection), used to weave hammocks and clothes to sell to intermediate traders at very low prices. Those families usually lived in a house with one bedroom, had only well water for drinking, cooking with firewood and had no electricity and drainage system. The latter generated health problems as most people had no toilet in their households (Katz, 1980; Lugo Pérez, 1996; Baños, 1996; Nickel, 1997; Benitez, 1962).

Several factors including the fall of the sisal industry led that, since late sixties, a great number of Maya people started moving to the growing urban
centers such as Merida, Yucatan and Cancun in the state of Quintana Roo in search of better job opportunities (Lizama Quijano, 2012). Merida city became an important destination for rural-to-urban Maya migrants; from 1970 to 2000 its population increased from 212,097 to 777,615 inhabitants, which corresponded to an increase of 351% in 30 years, basically due to migration (INEGI 1971, 2001). The immigrants (most from sisal zone) had very low education and poor job training so they were typically employed as masons in construction works, unskilled labourers and multiple informal activities such as sale of goods in the street corners of downtown. These immigrants settled in the south of the city of Merida, an area with precarious urbanization, limited access to electricity, drinking water, transport, schools and public markets (Dickinson et al., 1999; Fuentes, 2005; Pérez Medina, 2010). Our results suggest that migration to Merida city produced some improvements in the living conditions of daughters' families, but also indicate that these improvements were not enough to be expressed in greater somatic differences.

Changes in FS were also associated to intergenerational differences in KH. In general, mothers and daughters reported to have belonged to large families during their childhood [mean mothers = 8.2, (SD = 3.2); mean daughters = 7.2, (SD = 2.4)]; until the decade of 1970s, around 30% of Mexican families had seven or more family members (INEGI, 1971). Our analysis showed that when the FS increased in the daughters' generation, the intergenerational differences in KH reduced to 0.77 cm. When FS is compared between generations in the category of daughters having greater FS than mothers, the difference was around 3 family members [mean mothers = 8.9, (SD = 2.4) vs. mean daughters = 5.8, (SD = 2.2)]. An increase in FS, explained mainly by an increase in the number of offspring, may be associated to less individual resources for feeding, lower access to high quality health services and increased crowding in the household. We suggest that these factors and others may be associated to lower values in daughters’ KH. Interaction between place of birth and FS was non-significant, which suggest that their influences are independent.
Our analysis shows that paternal occupation was not significantly associated to differences in KH. However, the greater difference in KH (mean = 1.63 cm [SD = 2.8]) was observed when both mothers and their daughters reported to have had a non-peasant father and lesser differences (mean = 0.57 cm, SD = 2) when both generations had a peasant father during their childhood. Most of non-peasant men were employed in Merida and outside the city as salaried workers such as masons, labourers and poorly qualified employees. It is possible that the relative income of non-peasant fathers who had a relatively stable employment allowed better conditions in the studied families and thus the expression of larger differences in KH.

As far as we know, very few studies have investigated changes in lower body segments between parents and offspring and their associations to childhood conditions (Himes, 1979; Floyd, 2007; Bogin et al., 2014, Sohn, 2015). In their study with Taiwanese families living in Auckland, New Zealand, and Taipei, Taiwan, during 2003, Floyd (2007) found that parent-offspring differences in subischial leg length tended to be lesser when both generations experienced disadvantaged living conditions in early years of development; more noticeable changes were observed when conditions lived by parents were relatively more unprivileged than their offspring and differences were less evident when parents and offspring experienced relatively well-off circumstances in childhood. Our results are consistent with findings reported by Floyd (2007) in the sense that greater differences in KH were observed when: 1) daughters experienced better conditions than their mothers, as is the case of place of birth, and 2) when mothers and daughters lived under relative well-off or similar conditions, as assessed by the type of drinking water, FS and paternal occupation.

In their study with Bangladeshi mothers and daughters living in Bangladesh (BD) and in the UK, Bogin et al. (2014) found that daughters born and living in the UK were 3.8 cm taller than daughters living in the UK but born in BD, with KH values accounting for 53% (2 cm) of the total difference in height. The authors suggest that these differences are due to 1) that living conditions experienced by women in BD were worse than in the UK during childhood, and 2) the daughters
born in BD experienced more emotional stress due to the migration, including the
fact that fathers usually migrated first, leaving mothers and children behind for
some months or years. In our study, Maya daughters born in Merida were around
1.5 cm taller than daughters born out of Merida; being the differences in KH around
0.6 cm. The magnitude of our differences compared to differences reported by
Bogin and collaborators with Bangladeshi women are consistent with differences in
the amounts of change in developmental settings. We suggest that circumstances
lived in the UK by Bangladeshi women after migration were substantially better
than circumstances experienced by Maya women in the city of Merida.

We acknowledge the fact that daughters’ fathers may be also contributing to
daughters’ growth and therefore to intergenerational changes in KH, however they
were not included in the study because they spend the most of day on work
activities outside home including the weekends.

In summary, childhood living conditions experienced by Maya daughters
were somewhat better than that their mothers experienced, which is consistent with
their positive difference in KH (mean = 1.05 cm [SD = 2.33]). Our analysis
suggests that differences are associated with rural-to-urban migration experienced
by mothers as a result of the sisal agroindustry crisis of Yucatan during the 1960's
and 1970's and by differences in family size between generations due to official
policies of birth control. Our results suggest that present living conditions of Maya
women remain generally unfavorable, constituting a continuation of those
experienced by their ancestors since, at least, the 19th Century in the sisal zone, a
period of time known locally as The Slavery Time, as one informant reported to one
of us (FD) in 1978.

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Sánchez for collaborating in the field work. Ms. Ina Susana Falfán-Lopez and Ms.
Adriana Vázquez-Vázquez developed the dataset and took part in participant recruitment design. We also thank the mothers and daughters who agreed to participate in the study. Mr. John Lindsay improved our written English.

LITERATURE CITED


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

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<th>Mothers</th>
<th>p-value</th>
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<tr>
<td>Family size</td>
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<td>8.2 (SD = 3.2)</td>
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<td>Drinking water access:</td>
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<tr>
<td>Well</td>
<td>28%</td>
<td>93%</td>
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<tr>
<td>Piped</td>
<td>72%</td>
<td>7%</td>
<td></td>
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<tr>
<td>Father’s occupation</td>
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<td></td>
<td></td>
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<tr>
<td>Peasant</td>
<td>23%</td>
<td>77%</td>
<td>P&lt;0.001</td>
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<tr>
<td>Non-peasant</td>
<td>20%</td>
<td>3%</td>
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Table 2 Mean and standard deviations of intergenerational differences of KH according to socioeconomic conditions

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<td>Place of birth</td>
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<td>Type of water to drink</td>
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<td>Mother &amp; daughter non-peasant, n = 34</td>
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Table 3 Multiple regression model of socioeconomic parameters experienced by mothers and daughters in childhood for intergenerational differences in KH

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

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.