Intergenerational factors that shape the nutritional status of urban Maya households in Merida, Mexico. A 3-generations study

By

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Abstract

Background. The Maya are one of the largest Mesoamerican groups. The decline of the classic Maya society, the subsequent Colonial domination and the current national economic policies has had a severe biological and social impact on the Maya across several generations. Accumulated evidence suggests that conditions and environments experienced by one generation can affect the health, growth and development of the next generation (Emanuel, 1986). Historical evidence of political, educational and socioeconomic deprivation suffered by the Maya from Yucatan, Mexico, provides us with the opportunity to test the intergenerational influence hypothesis and ascertain the impact of the biosocial background of urban Maya grandmothers (first generation) and mothers (second generation) on the growth and nutritional status of their children (third generation).

Aims. The main objective is to assess the impact of socioeconomic and intergenerational factors on the growth of Maya children, in a sample of children, their mothers and maternal grandmothers. The specific objectives are: 1) to assess the nutritional status and nutritional dual burden prevalence in participants, 2) to identify the pre and postnatal biosocial and economic factors that relate to the nutritional status of the children, and 3) to assess the intergenerational influences on the growth of participants: from grandmothers to mothers and from grandmothers and mothers to children.

Methods. The sample is composed of 109 triads of Maya children (6-8 years old), their mothers and their maternal grandmothers from the city of Merida, Yucatan, Mexico. From September 2011 to June 2012 we collected anthropometric, body composition and socioeconomic data on the three generations. We also assessed parameters about living conditions of maternal and grand-maternal childhood. Nutritional status was assessed by comparing the participants against the Comprehensive Growth References published by Frisancho (2008) and based on the NHANES III. Pre and postnatal biosocial and economic factors were analysed through multiple regression models.

Intergenerational influences were assessed through: 1) bivariate and partial correlations in anthropometric and derived variables between participants, 2) path analysis to identify the direction and magnitude of direct and indirect causal effects between the three generations, and 3) multiple regression models to identify the effect of anthropometric and socioeconomic intergenerational factors on the growth of mothers and children.

Results. Eleven percent of the children were categorized as stunted and 36% met the criteria of risk for abdominal obesity. Only 1% of children exhibited the combination of stunting and abdominal obesity. Mothers and grandmothers showed very low average heights and high levels of abdominal obesity. The combination of maternal abdominal obesity and child stunting was present in the 6% of mother-child dyads. It was found that preeclampsia and cigarette smoke exposure during pregnancy and household overcrowding impacted negatively the linear growth of the children. Maternal education and the presence of grandmothers at home predicted healthier values of BMI, waist circumference, body fat and body lean mass percentages on children. Maternal height and leg length (LL = height – sitting height) were positively associated with the linear growth of children. These associations were not modified by the grand-maternal size, in terms of very short stature. In contrast, associations in weight, body mass index, sum of skinfolds and fat mass were stronger in grandmother-child pairs than in mother-child pairs. The birth weight of the children was positively associated with maternal head circumference and negatively associated with the absence of a toilet at home during maternal childhood (i.e. when the mother was growing up). Grand-maternal intergenerational predictors of children's height, leg length, body mass index, waist circumference and skinfolds were: index of household characteristics, family size and school attendance during childhood. Family size and paternal job loss during maternal childhood were the maternal intergenerational factors that influenced significantly the body mass index, waist circumference and skinfolds of children.

Conclusions. Growth and nutritional status of the children, mothers and grandmothers reflect the effects of chronic deprivation and poverty that are a constant among the Maya in the Yucatan. Under–and-overnutrition coexisted in this sample of three generations. Pre-and-postnatal biosocial and economic factors impacted the growth and nutritional status of children. Harsh living conditions experienced by mothers and grandmothers during their childhood influenced the prenatal and postnatal growth of children. We suggest that disadvantaged conditions experienced by mothers and grandmothers during their first years of life impacted their own growth and this in turn is influencing the growth of children of the third generation. Substantial reductions in poverty levels and increase educational levels of the mothers are required to overcome the intergenerational traces on the future generations.

Key Words: Maya, growth, intergenerational influences, nutritional dual burden.

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...we all carry with us biological tattoos
that tell life stories of our ancestors.

I really hope that the Maya (my people)
can wash their intergenerational traces
and become a group rich not only
in culture but also in vitality and wellbeing.

Publications

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Abbreviations

AGEB	Basic geo-statistical area
ANC	Antenatal care
AO	Abdominal obesity
BIA	Bioelectric impedance analysis
BMI	Body mass index
CDC	Centers for Disease Control and Prevention
CI	Confidence interval
CINVESTAV	Research and Advanced Studies Center of the National Polytechnic Institute of Mexico
CONACYT	National Council of Science and Technology of Mexico
CONCIYTEY	Council for Science, Innovation and Technology of the State of Yucatan
CONEVAL	National Council for the Evaluation of Social Development Policy of Mexico
EMPIMAYA	Marginalization, Poverty and Identity of the Maya Population Survey
ENMIMERIDA	Permanent Maya Migrants in the City of Merida Survey
ENSANUT	National Survey of Health and Nutrition of Mexico
F_1	Grandmothers (1st generation)
F_2	Mothers (2nd generation)
F_3	Children (3rd generation)
FM	Fat mass
FFM	Fat free mass
HC	Hip circumference

INCAP	Institute of Nutrition of Central America and Panama
INEGI	Statistic and Geography National Institute of Mexico
INSP	National Institute of Public Health of Mexico
IOTF	International Obesity Task Force
IS	Iliac skinfold
KH	Knee height
KHR	Knee height ratio
LL	Leg length
MXN	Mexican currency
NCEP-ATP III	National Cholesterol Education Program Adult Treatment Panel III
NHANES	National Health and Nutrition Examination Survey
NCHS	National Center for Health Statistics
NDB	Nutritional dual burden
OECD	Organization for Economic Co-Operation and Development
OW	Overweight
OB	Obesity
OR	Odds ratio
RLLI	Relative leg length index
SD	Standard deviation
SE	Standard error of measurement
SH	Sitting height
SHR	Sitting height ratio
SS	Subscapular skinfold
SSP	Health Secretary of Mexico

SumSkf	Sum of tricipital and subscapular skinfold
TS	Tricipital skinfold
UNICEF	United Nations Children's Fund
WC	Waist circumference
WHO	World Health Organization
WHR	Waist-to-hip ratio
%BF	Percentage of body fat
%LBM	Percentage of lean body mass

INTRODUCTION

The Maya are one of the largest and most important ethnic groups in Mesoamerica (Kirchhoff, 2009). Historically, during the Classic Period prior to the Spanish Conquest they have been widely recognized and valued by their astonishing advances in mathematics, astronomy, literature and architecture (Thompson, 1973). The current Maya descendants are nowadays distributed in the nations of Mexico, Guatemala, El Salvador, Belize and Honduras. The Yucatan Peninsula, in Mexico, is the home of a great number of Maya people resident in urban and rural communities.

The colonial period (1535-1821) had great implications for Maya people. During the European domination the Maya lived under a system of subjugation and oppression which brought them to experience very hard living conditions. These conditions did not change substantially after the independence process that occurred officially in 1821. The political and economic system of Mexico has kept the Maya in very precarious conditions (Bracamonte, 2007; Bracamonte and Lizama, 2006). These historical and more recent facts have impacted tremendously the biosocial status of the Maya. Even today the Maya are one of the shortest people in the world, as a result of adverse socioeconomic and political conditions. Poverty and lack of opportunities for social and economic development have led to the migration of thousands of Maya families to urban centres within the Yucatan Peninsula. Among these urban centres, the city of Merida, the capital of the Yucatan state, has historically been the home of rural-to-urban Maya migrants. In Merida, most of Maya people work in the informal economy (street vendors, domestic workers, and other non-skilled jobs that are out of the regulatory fiscal framework) or got low skilled jobs with the lowest incomes (Lizama et al., 2008). In addition, they have poor access to high quality services of health and education.

The Maya provide a good example that physical growth of our species is a good indicator of the quality of current and historical living conditions experienced by individuals of a group. Many factors have been identified that impact the variation in growth and health status; the complex relationship between genes and the endocrine system, and the wide number of ecological, socioeconomic and cultural factors that produce human epifenotypes. Studying growth at early ages of life give us relevant information at different levels. Firstly, it provides information not only about the nutritional or genetic condition of a given population, but also about the quality of environmental conditions that surround a population. Secondly, in the epidemiological context the study of growth tells us about health conditions of a population and their implications for morbidity and mortality. At another level of analysis, the awareness about the growth status of a given population gives us valued information about the positive or negative results of social policies implemented in groups belonging to developing countries.

The Maya from Merida give us the opportunity to study how biology responds to chronic biosocial stress. Several biological traits distinguish the Maya, one of them is the paradoxical coexistence of both extremes of malnutrition: undernutrition and overnutrition, commonly called nutritional dual burden. The nutritional dual burden is commonly present among the Maya at different levels (Varela-Silva et al., 2012). Of great interest for this research is the analysis of the coexistence of stunting (chronic malnutrition) and overweight/obesity in the same person (children and adults), population or sample and the coexistence of maternal overweight/obesity and child stunting. The presence of nutritional dual burden (at different levels) has relevant implications not only for health risk but also for the design and planning of interventions of nutrition, health and educational programs. Nutritional dual burden has also relevant economic implications because stunted adults have diminished work capacity, and because overweight/obese adults will load the society with the economic cost of medical care for this chronic disease and other related diseases (Spurr, 1983).

The Maya give also us the opportunity to study how biology reacts when in the presence of adverse environmental conditions along several generations. Previous and more recent studies show that Maya from Yucatan exhibit high rates of undernutrition (mainly short stature) along the growing period (Kelley, 1991; Wolanski et al., 1993; Siniarska and Wolanski, 1999; Azcorra et al., 2009; Varela-Silva et al., 2009; Varela-Silva et al., 2012) and some other research reports suggest that the presence of a positive secular change in stature since the end of the colonial period has been almost non-existent (McCollough, 1982; Siniarska and Wolanski, 1999). In 1986, Irving Emanuel suggested that conditions experienced by one generation can influence the health, growth and development of the next generation (Emanuel, 1986). Recent theoretical contributions suggest that growth trajectories of children are also influenced by factors that trace the chronic nutritional history of matrilineal ancestors, including their nutrition during prenatal stage and fist years of postnatal life (Kuzawa, 2005).

Most of the studies focusing on intergenerational effects have been done analysing only the effects of one generation to the next one (mothers and children). By including a third generation (of grandmothers) in the research design allow us a better and deeper understanding of how collective nutritional experiences of recent matrilineal ancestors shape the nutritional and growth status of children of the current generation. Therefore, the main aim of this research is to analyse in which ways the biosocial background of the maternal Maya ancestors (mothers and grandmothers) is associated with the nutritional status of the children of the third generation. The specific objectives of this research are:

1. To assess the nutritional status and the prevalence of nutritional dual burden in children, mothers and grandmothers.
2. To identify antenatal and socioeconomic factors that shape nutritional status of children of the third generation.
3. To assess the intergenerational influences on the growth of the mothers and children as follow:

    3.1 To assess the intergenerational influences on growth from grandmothers to mothers.

    3.2 To assess the intergenerational influences on growth from grandmothers and mothers to the children.

The main contributions of this research are: 1) the multi-generational analysis of the growth and nutritional status of a sample of Maya children, their mothers and their maternal grandmothers who have experienced chronic adverse living conditions, and 2) the identification of socioeconomic and biological inter-generational factors that are associated with the prenatal and postnatal growth of the children of the third generation and the growth status of the mothers of the second generation. This research contributes to the knowledge about continuity of historical and current living conditions on the biological well-being of the Maya – the largest indigenous ethnic group of the Americas.

SECTION 1

THEORETICAL FRAMEWORK

CHAPTER 1

The Maya: health, nutrition and living conditions among urban groups in Merida, Mexico

1. The Maya: health, nutrition and living conditions among urban groups in Merida, Mexico

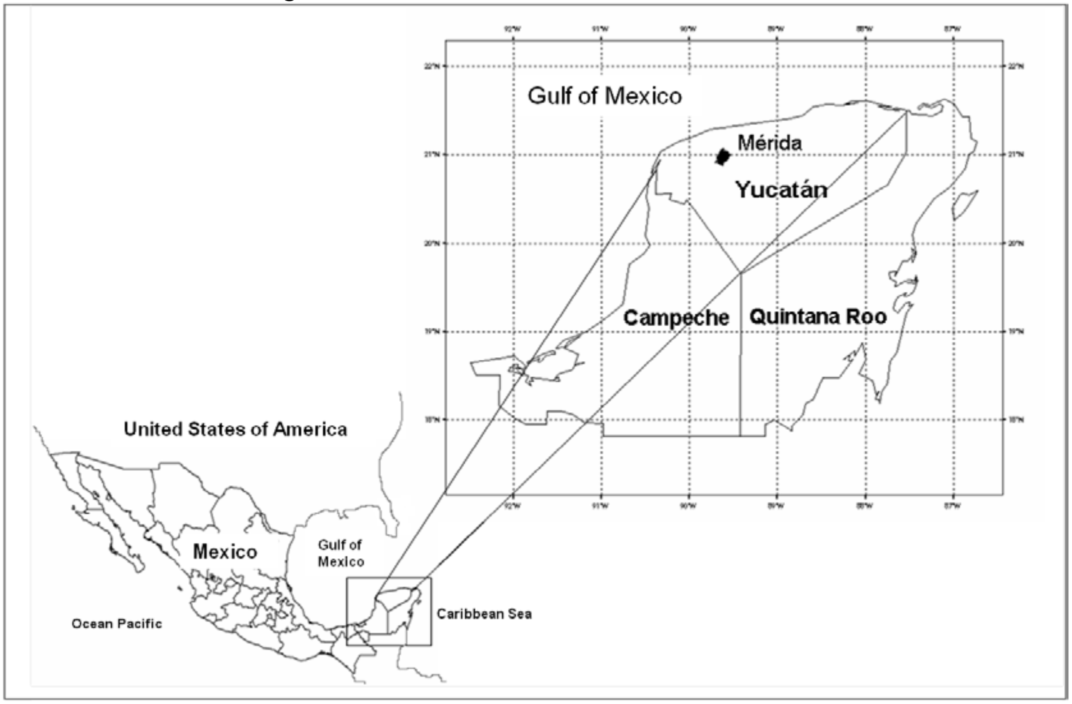
1.1 Introduction

The Maya are a Mesoamerican ethnic group with thousands of years of history, conflict and change in political power. The location of the Maya groups goes from the south-eastern part of Mexico (including the state of Yucatan, in the peninsula of the same name) to the northern Central America, in the current nations of Guatemala, Belize, El Salvador (Northern part) and Honduras (Western part).

This research project took place in Merida, the capital city of the Yucatan state (Figure 1). Based on its historic economic activities, Yucatan is divided into six zones (Figure 2): a) the metropolitan area, which includes the city of Merida, b) the former sisal zone in the central and northern areas of the state, c) the fishery area in the coast, d) the Indian maize zone that include communities from the southeast, e) the cattle farming zone in the northeast, and 6) the cash crop area in the southern zone (Villanueva, 1990; García et al., 1999). Even when the Maya are distributed in these six regions, their presence is less visible on the coast and northwest, (except for Merida), and increases gradually towards the south and east of Yucatan (Bracamonte and Lizama, 2006).

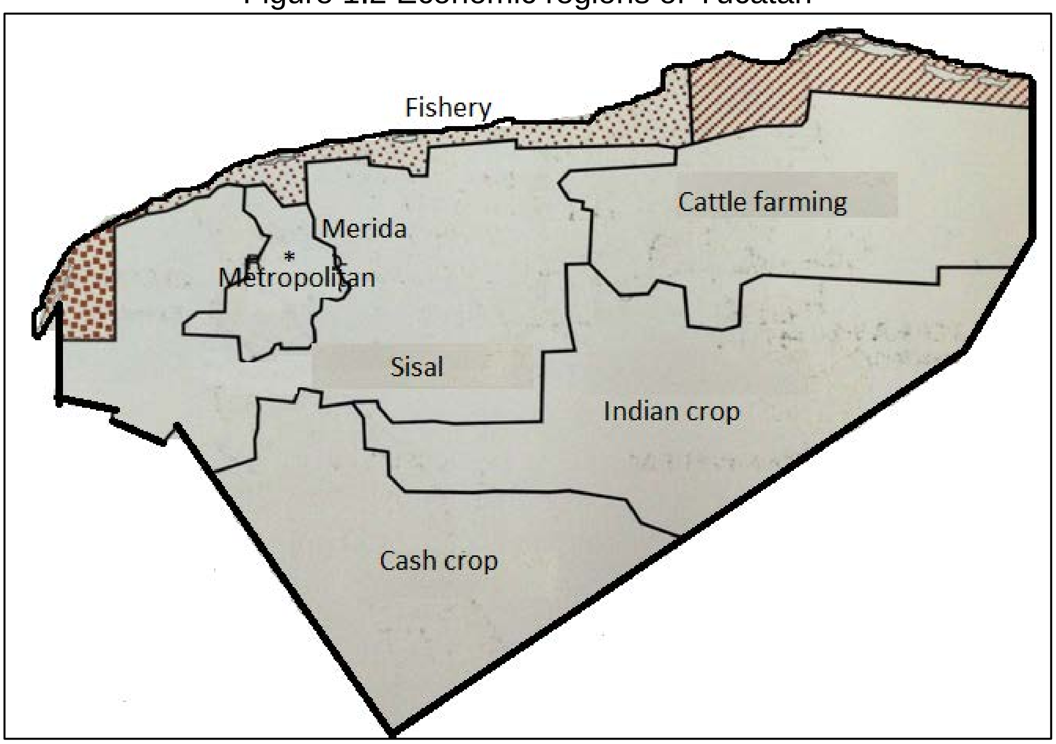
It is commonly assumed that the Maya live in small communities, but nowadays many of the Maya people live in urban settings, among which Merida is the most important (Bracamonte, 2007). According to the Statistic and Geography National Institute of Mexico, in 2010 the Maya speaking population in Yucatan amounted to 537,516, or 27% of the population (INEGI, 2012a).

Figure 1.1 Location of Merida, Yucatan



Source: own design.

Figure 1.2 Economic regions of Yucatan



Source: own design.

1.2 Historical background and oppression

Between 250 and 1200 AD, the Maya achieved state-level societies, with monumental architecture, advanced systems of food production, and sophisticated mathematical, astronomical, and literary skills which allowed the formation of urban-like city-states (Thompson, 1973). These city-states were organized on the basis of a marked social stratification, in which, the nobility, attributed to governors, priests, and traders exerted control and power over the rest of the people. Warfare (Webster, 2000) and environmental degradation (Kennett et al., 2012), caused by both human and natural phenomena have been identified as the initial main factors that contributed to the decline of the Maya states. The Spanish conquest did not initiate the process of the Maya Civilization decline, but it contributed extensively for its almost total annihilation. However, the Maya people did not disappear; the survivors, mainly common peasants, kept working the *milpa* (the traditional farm plot), on a very small scale or moved to the highland regions of Central America. The Maya *milpa* is a complex slash and burn agricultural system involving about 40 vegetal species, from Pre Columbian origin.

The European conquest after the year 1500 AD killed about 90% of the Maya people and destroyed much of the Maya culture. European colonization was followed by the rise of local political domination by descendants of the colonists. Between the beginning of the European colonization and the mid-eighteenth century, the domination functioned on the basis on a slave-like payment tribute system and forced labor. Maya people were forced to work for long journeys with very meager salaries that were barely enough to pay the tribute to the landlord. The colonial exploitation included that men were usually forced to work in the construction of roads, churches and in the properties of Spaniards. Women used to work in the manufacture of cotton fabrics under abusive conditions. This situation led to the rapid deterioration of the living conditions and health of Maya people (Bracamonte, 2007).

During the 19th century, after the consummation of the Mexican Independence (1821), the elite social group (government and rich families) changed its system of appropriation of wealth with the establishment of the *hacienda* system. The Maya population passed then from the forced labor system to the wage labor system. A large number of Maya people were employed in the production of sugar cane, livestock and, subsequently, the sisal agro-industry. However, the living conditions of Maya people did not improve.

Since 1980s, factors such as the fall of the sisal industry, the lack of economic support for agricultural activities and the imposition of government policies relating to the national and global economy have led to the Maya people to move into very low paid jobs in urban centers. This poor development and lack of progress that are reflected on their low level of education have prevented the Maya from improvement their living standards in relation to rest of the people in Yucatan (Bracamonte, 2007).

In summary, the Maya population of Yucatan has lived, from the Colonial times to the present, in conditions of extreme social subjugation, deprivation and oppression. This situation has caused a state of chronic poverty and marginalization.

1.3 Being Maya

Different cultural features distinguish the Maya groups; the most common are language, surnames, traditions, beliefs, clothing, housing characteristics, among others. In the Yucatec sociocultural context the patronymics designate group belonging and are indicative of forms of social organization (Bracamonte, 2007). Particularly in the Yucatan, the patronymics have been preserved and connect individuals with a set of characteristics belonging to the Mayan culture. In the biological context, surnames can be used as a genetic proxy and allow to differentiate ethnic groups (Chakraborty et al., 1989; Relethford, 1995; Colantonio et al., 2003). In Mexico, each person has a patronymic and a matronymic. Particularly, in the case of Yucatan, Maya surnames are preserved despite the colonial cultural impositions.

For this research, Maya people are described as a set of individuals identified as the descendants of the Mesoamerican people inhabiting the Yucatan Peninsula from long time ago and who have had an adverse socioeconomic history along several generations that is different to the rest of Mexican people.

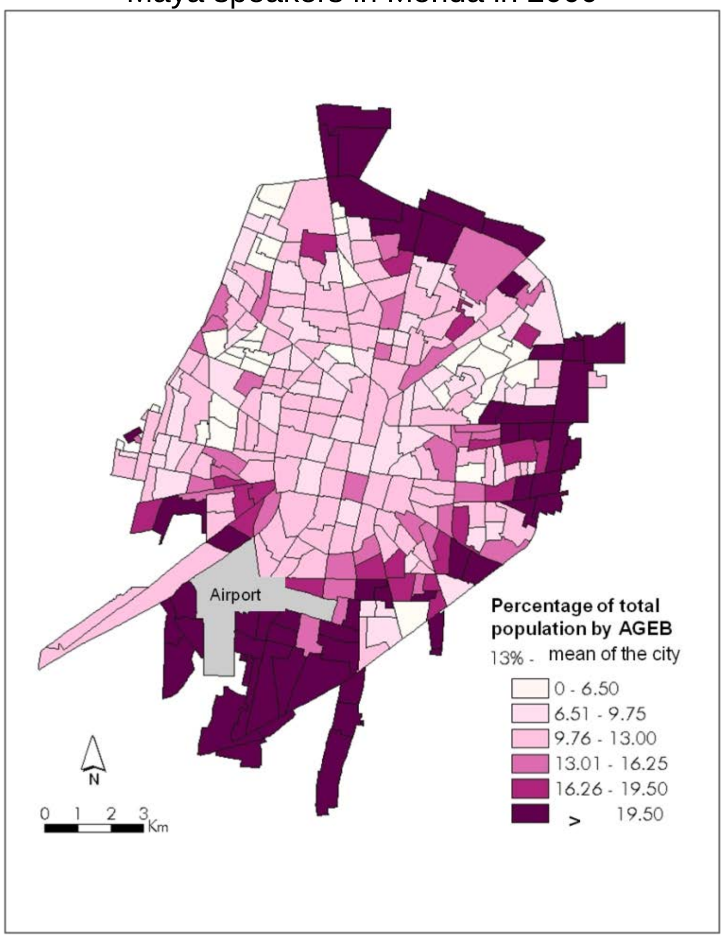
1.4 The urban Maya: poor families in the south of Merida

Merida City became, during the last decades, an important destination for rural-to-urban Maya migrants. The growth of industry, commerce, construction, manufacturing and services in Merida is a source of employment and has attracted the Maya population into the region (Bracamonte and Lizama, 2006). According to the Marginalization, Poverty and Identity of the Maya Population Survey of 2004 (*EMPIMAYA* by its acronym in Spanish) (Bracamonte and Lizama, 2006), sixty-six percent of Maya household heads living in Merida in 2004 were born in another place.

Maya immigrants do not settle uniformly within Merida; the south of the city has historically been their site of settlement. Figure 3 shows the distribution and concentration of Maya speakers in Merida and clearly highlights the regions where the Maya are more concentrated.

Merida is a socioeconomically segregated city. The northern area is the home of the population with the highest levels of income and, in general, this area shows more advanced infrastructure and services. In contrast, the south is the home of the lowest income levels population and endures the lack of proper infrastructures in terms of education, health and recreation services. The south of Merida has historically been marginalized from economic development (Fuentes, 2005). According to the Permanent Maya Migrants in the City of Merida Survey of 2008 (*ENMIMERIDA* by its acronym in Spanish) (Lizama et al., 2008) the Maya work mostly in construction, manufacturing, domestic, commercial, transport and other service jobs, as low-wage employees. Sixty percent of household heads reported an income equivalent to between 1 and 7.5 pounds per day, only six percent reported a higher income than 7.5 pounds per day and thirty-one percent reported not earning a wage in the week preceding the survey. Forty-four percent of household heads did not finish their primary education and twenty-five percent reported not having any level of formal education. It was also found that 11% of the households were built with non-permanent or perishable materials (cardboard, metal and tarp), 39% have only one bedroom for sleeping, 23% do not have an exclusive space for cooking, and 24% have no toilet. In addition, 26% and 23% of households have no refrigerator and stove respectively and the utilization of wood for cooking is common.

Figure 1.3 Location and concentration of Maya speakers in Merida in 2000



Source: Falfán, 2008; *AGEB*: basic geo-statistical area, each *AGEB* contain one or more neighbourhoods.

1.5 Bio-cultural conditions of the Maya from Yucatan and Merida

Historical and current events, briefly described above, have shaped the contemporary biological status of the Maya population from Yucatan, including children and adults. In general, Dickinson (1997) argues, on the base of the then available evidence, that a substantial portion of the Maya population from Yucatan experiences undernutrition in the first years of life and then overnutrition in adulthood.

Evidence of socioeconomic marginalization comes from the biological context of Maya physical growth and health. One indicator is stunting (chronic undernutrition), defined as a height-for-age below 2.0 standard deviations from the median reference value (i.e. the WHO cut-off points) or a stature-for-age that falls below the 5th percentile of the references (i.e. the CDC cut-off points). By 2006 the national prevalence of stunting in Mexican school children (5-to-11 years old) was 9.9%. However, Yucatan showed a prevalence of 23.6%, one of the highest in the country (INSP-SSP, 2007).

The Mexican health surveys do not provide specific prevalence values for Maya children, but past and recent studies show that the rate of undernutrition in Maya children is even higher than the values for the state of Yucatan as a whole. Available evidence suggests that biological conditions are worse in the Indian maize zone in comparison to those found in the sisal, cash-crop and coastal zones. The rates of chronic undernutrition (< -2 SD of height-for-age) in the Indian maize zone range from 37.7% to 82.1% in children under ten years of age (Balam, 1988; Gurri and Balam, 1992; Balam et al., 1994; Balam and Gurri, 1994; Cervera, 1994; Cuanalo et al., 2007).

Despite the improvement in living conditions registered in the last decades, the Maya from the Indian maize zone continue showing conditions of severe poverty and marginalization, reflected in the highest incidence of undernutrition and infectious diseases (Cervera and Mendez, 1999; Fernández, 2003). In this context, Leatherman et al. (2010) compared anthropometric data of children (7-13 years old) and adults from 1938, 1987 and 1998 in *Yalcobá*, a rural Maya community of the maize region. They found that between 1938 and 1987 the height increased in boys on average 1 cm and decreased 0.5 cm in girls. Between 1987 and 1998 the height of boys and girls increased by 2.6 cm and 2.7 cm respectively. In 1998, 65.6% of children were classified as stunted (< -2 SD of height-for-age). The increments on weight between 1987 and 1998 were on average 2.0 kg for boys and 1.8 kg for girls. In addition, 32.1% and 44.7% of adult males and females respectively were overweight (BMI $\geq$ 25 - $\leq$ 30) and 10.3% of males and 20.6% of females were obese (BMI > 30) in 1998. These data show a clear pattern of child stunting and adult overweight.

The migrant population has not been exempt from the effect of the socioeconomic conditions in the destination place. Working in two coastal communities from Yucatan, Dickinson et al. (1990) found that migrant boys (11-13 years) from sisal and cattle zones had significantly lower values in weight, humerus width, arm fat area, and arm muscle area than coastal native boys.

Studies with urban populations have been carried out to a lesser extent and more recently. Wolanski et al. (1993) found, in Merida, that Maya girls (two Maya surnames) were on average 4.7 cm and 2.3 cm shorter than non-Maya (none Maya surname) and mixed (with at least one Maya surname) girls respectively (Table 1.1). Compared with other populations from Yucatan, the non-Maya girls from Merida were the tallest, followed by girls of mixed families from Merida and girls from the cattle area, these last studied by Murguia et al. (1991). They were followed by the girls from the fishery area and urban Maya girls from northern and southern Merida (Kelley, 1991; Wolanski et al., 1993) and by girls from the sisal area (Murguia et al., 1991). The lowest stature was observed in girls from the maize area of Yucatan. Subsequently, Siniarska and Wolanski (1999) studied the anthropometric status of a sample of boys from Merida. Again, Maya boys were on average 4.84 cm and 2.3 cm shorter than non-Maya and mixed boys respectively. Similarly, when comparing these results with other studies, the boys from the maize area of Yucatan were the shortest (Table 1.1).

Table 1.1 Height (means ±SD) of Maya, non-Maya and mixed children of two studies conducted in Merida City

Sample	Population	Sex		Source
		Boys Mean (SD)	Girls Mean (SD)	
522 girls (11-20 years old)	Maya	-	145.06 (5.97)	Wolanski et al., 1993
	Non-Maya	-	149.78 (8.50)	
	Mixed	-	147.41 (6.38)	
493 boys (11-20 years old)	Maya	152.23 (8.50)	-	Siniarska and Wolanski, 1999
	Non-Maya	157.07 (9.70)	-	
	Mixed	154.53 (9.20)	-	

Means and standard deviations given in centimetres.

Overweight (OW) and obesity (OB) are the opposite biological conditions to undernutrition, experienced by the Maya. Table 1.2 summarizes results of some studies performed in Yucatan, including rural and urban areas. As can be seen in Table 1.2, using the cut-off points suggested by the WHO the prevalence of overweight ranged from 31% to 57% and for obesity from 16% to 49%.

Table 1.2 Prevalence of overweight and obesity in Maya population according to some studies

Author & year	Region of Yucatan	Sample	Results
Dickinson et al. 1993	Sisal and coastal	216 women >30 yrs	OW= 35% OB= 49%
Arroyo et al. 1997	Rural	119 women (20-49 yrs)	OW= 38% OB= 41%
		38 women (>50 yrs)	OW= 37% OB= 45%
		63 men (20-49 yrs)	OW= 57% OB= 22%
		51 men (>50 yrs)	OW= 31% OB= 31%
	Urban	96 women (20-49 yrs)	OW= 35% OB= 35%
		89 women (>50 yrs)	OW= 42% OB= 48%
		58 men (20-49 yrs)	OW= 40% OB= 16%
		70 men (>50 yrs)	OW= 27% OB= 27%
Arroyo et al. 1999		226 women (20-75 yrs)	OW= 45%
		231 men (20-75 yrs)	OW= 73%

Cut-off points for overweight and obesity used in Dickinson et al. 1993 and Arroyo et al. 1997 were BMI of 25.0 – 29.9 kg/m^2 and BMI of $\geq$ 30 kg/m^2 respectively; cut-off points used in Arroyo et al. 1999 for overweight were BMI of $\geq$ 27.3 kg/m^2 in women and BMI $\geq$ 27.8 kg/m^2 in men.

According to the results of the National Survey of Health and Nutrition of Mexico 2006 (INSP-SSP, 2007) (*ENSANUT* by its acronym in Spanish), OW and OB are public health problems in Yucatan (Table 1.3). Although this survey does not differentiate by ethnic background, its results are useful since the Maya population is distributed in urban and rural contexts of Yucatan.

In general, familial and intergenerational approaches in the study of urban Maya groups are scarce. A previous study on the nutritional status of 206 Maya children (120 girls) 4-6 years of age and their mothers living in the south of Merida (Varela-Silva et al., 2009) found a 22% prevalence of stunting (*z*-score of height-for-age (HAZ) $\leq$ -1.650), 33% prevalence of overweight (*z*-score of BMI (BMIZ) between +1.036 and +1.640) and 2.4% showed the combination of these conditions (dual burden individuals) using NHANES III references. Among both boys and girls the mean of HAZs were significantly lower ($p<0.001$) than the reference (i.e. 50th centile). In contrast BMIZ was significantly higher ($p<0.001$) than the reference in boys and girls at all ages. The mean of HAZs of the mothers was -2.13 ($\pm$0.84), significantly lower ($p<0.001$) than the reference and almost 70% of them were shorter than 150 cm. This situation reflects the result of chronic malnutrition across two generations and lifestyles characterized possibly by a diet high in energy but low in micronutrients.

Table 1.3 Percentages of overweight and obesity in Yucatan, Mexico, in 2006

Condition	Preschoolers (<5 yrs)	Scholars (5-11 yrs)	Adolescents (12-19 yrs)	Adults (>20 yrs)
		Yucatan		
Overweight	10.0%	21.3%	27.0%	39.5%
Obesity	-	15.0%	11.1%	35.0%
Overweight+Obesity	-	36.3%	38.2%	74.4%
		Urban		
Overweight	10.6%	20.9%	28.4%	38.4%
Obesity	-	16.9%	12.0%	35.7%
Overweight+Obesity	-	37.8%	40.5%	74.2%
		Rural		
Overweight	6.1%	23.2%	18.9%	46.5%
Obesity	-	4.5%	5.7%	29.8%
Overweight+Obesity	-	27.8%	24.6%	76.3%

Preschoolers: Overweight = *z*-score weight-for-height $\geq$ 2SD of WHO/NCHS/CDC. Scholars/Adolescents: overweight and obesity = BMI using International Task Force (IOTF) criteria. Adults: overweight= BMI 25.0 – 29.9 kg/m^2; obesity = BMI $\geq$ 30kg/m^2. Source: *ENSANUT*, 2006.

In a semi-longitudinal study conducted in Merida (Unpublished results from the Laboratory of Somatology at the Department of Human Ecology, *CINVESTAV*, Merida, Mexico), we collected anthropometric data in a sample of 841 children and youth (9-17 years old) and their mothers from low, medium and high socioeconomic levels. Comparing the data with reference published by Frisancho (2008), we found that 16% of children were classified as stunted (below 5^{th} of reference of height-for-age). When the data were split according to the number of Maya surnames the prevalence of stunting among children with one and two Maya surnames increased to 24% and 30% respectively. In contrast, just 10% of children without any Maya surname met the criteria for stunting. The prevalence of OW/OB (> 85^{th} percentile of BMI-for-age) in children without Maya surnames was 27% and increased to 35% and 30% in children with one and two Maya surnames, respectively. The risk for abdominal obesity (> 85^{th} percentile of waist circumference-for-age) was present in 20% of studied children and no differences according to the number of Maya surnames were found. The combination of stunting and OW/OB in children was present in 2.97% of sample. However, the prevalence of nutritional dual burden in children with one Maya surname was higher than in children without Maya surnames (4.34%). We were able to measure 201 of children's mothers. In general, 52% of them exhibited short stature (below 5^{th} percentile of height-for-age). We also found that the prevalence of short stature increased according to the number of Maya surnames. Thirty-three percent of mothers without Maya surnames met the criteria for short stature and 65% and 72% of mothers with one and two Maya surnames respectively were classified with this condition. The combination of short stature and high BMI (BMI > 25) was present in 73% of women and the prevalence increased to 92% and 83% in women with one and two Maya surnames respectively.

More recently we found very similar results studying a different sample of 58 Maya mother-child dyads from the south of Merida (Varela-Silva et al., 2012). In this study we found that 27.5% of children were overweight or obese (OW/OB) and 31% stunted (height-for-age below 5^{th} percentile of reference). Maternal stunting prevalence was 81% (height-for-age below 5^{th} percentile of reference) and 91% of them were overweight, exceeding the BMI cut-off point of 25 kg/m^2. Nutritional dual-burden conditions were found for 74% of mothers, and the combination of maternal overweight and stunted child was present in 27.6% of the mother-child dyads.

1.6 Summary

In summary, the Maya is a Mesoamerican ethnic group very rich in history and culture. The Spanish and Mexican domination maintained the subordinate position of the Maya. More recently factors such as the collapse of sisal industry, the lack of economic support to agricultural activities and global economic policies have led to the Maya to move into low paid employment in urban centres. At least, since the Colonial period to the current time, the Maya have lived under socioeconomic deprivation and political subjugation. This situation has had a severe biological impact on the population. The city of Merida, in Yucatan, became during decades an important place of destination of Maya migrants from rural communities. Specifically neighbourhoods of the south of Merida are home to Maya families. The Maya population from Merida have low salaries and education level, limited access to health, education and recreation services. Studies consistently show the coexistence of undernutrition and overnutrition among the Maya. Evidence suggests that Maya people experience chronic undernutrition during childhood and adolescence and overweight/obesity during adulthood and senescence.

CHAPTER 2

Nutritional dual burden: the paradox of under-and-over nutrition

2. Nutritional dual burden: the paradox of under-and-over nutrition

2.1 Definitions and general considerations

Overweight or obesity is defined as an abnormal or excessive fat accumulation that presents a risk for health (WHO, 2011). In contrast, undernutrition is defined as the outcome of insufficient food intake and repeated infectious diseases, including underweight and stunting (based, respectively on weight-for-age and height-for-age values) and wasting or acute malnutrition defined as low weight-for-height (UNICEF, 2011).

From a nutritional perspective, under and overnutrition are conditions that have been considered as opposites and commonly found in environments that differ in several aspects of welfare. Among these are, for example, the differences in the availability and access to food, to health and education systems, and in the incidence of illnesses.

However, recent evidence clearly shows the coexistence of these two conditions. Nutritional dual burden (NDB) can be defined as the coexistence of undernutrition (mostly stunting) and OW/OB. This dual condition has been observed at different levels: individual, mother-child pairs and household (Varela-Silva et al., 2012). Individual NDB is present when chronic undernutrition and OW/OB coexist in the same individual, being these children or adults. NDB in the mother-child pairs exist when the combination stunting in children and OW/OB in mothers is present. Households can be classified as NDB when stunting is present in at least one member of the family and OW/OB is present in at least one other family member. NDB in mother-child pairs can be also considered as a type of household NDB. For the purposes of this chapter we present evidence of NDB at individual, mother-child dyad and household levels.

2.2 Nutritional dual burden at individual level

Maybe the first documented evidence of individual NDB comes from Adrianzen's et al. (1973) longitudinal research, who studied 115 families living in extreme poverty from the city of Lima, Peru. The sample consisted of 444 children (212 females) from 0 to 18 years of age who had at least one sibling who had been hospitalized for severe malnutrition. Participants were measured every 6 months over 5 years after the sibling was discharged from the hospital. It was found that since the second and third semester both boys and girls drop and run parallel in length or height-for-age to the 3rd percentile of the United States reference. In contrast, the mean weight for girls was increasing from age of 10 years and by age of 13.5 years it approached the 50th percentile of the reference. The authors highlight the fact that at almost all ages, both girls and boys could be classified as overweight for their height.

More recently, using representative data samples of the child population from China, Russia, South Africa and Brazil, Popkin et al. (1996) examined the relative risk of overweight among stunted children between 3 and 9 years of age. Stunting and OW were assessed using height-for-age and weight-for-height z-scores values (NCHS/WHO 1986). Children with height-for-age below two z-scores were considered stunted and those with weight-for-height above two z-scores as overweight. After controlling for income, the relative risk ratio for overweight among stunted children was 7.8 in Russia, and 4.4 and 3.5 in China in 1991 and 1993 respectively, 2.6 in South Africa and 1.7 in Brazil. However family income had a significant function as a confounder in Brazil. The analysis also revealed a U-shaped relationship between weight-for-height and height-for-age categories in all countries, that is, low and high heights were at increased risk for overweight.

Analysing anthropometric and socioeconomic data from the Central Region of Limpopo Province, South Africa (162 children at 3 years old) and Yaounde in Cameroon (169 preschool children), Mamabolo et al. (2005) and Said-Mohamed et al. (2009) respectively have identified some determinants of the stunting-overweight relationship.

In the first case, researchers found that 19% of children were both stunted and overweight. The risks for individual NDB were having an increased weight (OR 8.97, CI 95% 1.09-13.51) and shorter length (OR 0.14, CI 95% 0.02-0.87) at 1 year, having more than nine persons in the household (OR 5.72, CI 95% 2.70-12.10), and having a working (OR 10.97, CI 95% 1.41-14.89) and student (OR 7.45, CI 95% 3.20-17.34) mother. Stunting was defined when the height-for-age was below -2 SD (NCHS 2000). Overweight/obesity was defined using International Obesity Task Force guideline. For the Cameroon the coexistence of stunting and overweight was present in 27% of the sample. Living in a household with low economic level (OR 3.81, CI 95% 1.08-13.32) and having a mother with low educational level (OR 2.90, CI 95% 1.07-7.82) were factors that predicted NDB in children. Stunting and overweight were defined when height-for-age was $\leq 3^{rd}$ percentile and when BMI-for-age was greater $\geq 85^{th}$ percentile according to CDC/NCHS 2000 reference. Stunted and NDB children had significantly (p<0.01) shorter mothers than overweight and non-stunted-non-overweight groups. Additionally, siblings of stunted and NDB tend to be overweight (p<0.01).

However, the association between stunting and overweight in the same individual is not always present. Cross-sectional studies from the North West Province of South Africa (10-15 years old children) (Mukuddem-Petersen and Kruger, 2004) and indigenous *Tarahumara* from northern Mexico (6-14 years old children) (Peña-Reyes et al., 2009) show no significant associations between these two conditions. Few longitudinal studies have paid attention to this topic. Importantly, Cameron et al. (2005) found that children who were stunted at 2 years of age were significantly shorter and lighter than non-stunted children at ages of 7 and 9 years. Authors highlight the fact that stunting at 2 years of age was not a significant predictor of overweight at the older ages.

The individual NDB is particularly important for Latin America and the Caribbean. Using the WHO Global Database on Child Growth and Malnutrition, Duran et al. (2006) analysed the association between stunting and overweight in Latin American and Caribbean preschool children. The overall prevalence of stunting (< -2 SD of height-for-age) and overweight (> 2 SD of weight-for-age) in the Latin America and the Caribbean was 13.7% (CI 95% 9.1-18.4) and 4.3% (CI 95% 3.5-5.2) respectively. The highest prevalence of stunting was found in Central America (20.4%) followed by South America (11.3%) and the Caribbean (7.4%). The prevalence of overweight by sub-regions ranged from 3.9% in Central America to 4.5% in South America. An inverse and significant correlation ($r = -0.3$, $p<0.05$) between stunting and overweight was found in the three regions. In addition, performing a regression analysis of prevalence of overweight against prevalence of stunting according to the prevalence of stunting ($\pm$20% of stunting), a significant correlation ($p<0.05$) was observed in the three sub-regions when the prevalence of stunting was higher than 20%, with stunted children being more likely to be overweight.

The coexistence of stunting and overweight has also been evident in offspring of immigrant families (Martorell et al., 1987; Bogin and Loucky, 1998; Smith et al., 2002; Markowitz and Cosminsky, 2005). Socioeconomic deprivation has led to the migration of thousands of Mexican and Central American (Guatemala, El Salvador, and Honduras) families to the United States. In the particular case of Maya immigrants from Guatemala, their family members have been undernourished for generations; as a result their children still show high rates of stunting even when living in more wealthy environments like the US (Bogin and Loucky, 1998). However, as a result of the exposure to some unhealthy patterns of American lifestyle, Maya immigrants exhibit equal or higher levels of overweight than their counterparts in the USA (Smith et al., 2002).

The combination of overweight ($\geq 85^{th}$ to $< 95^{th}$ percentile of BMI-for-age) or obesity ($\geq 95^{th}$ percentile of BMI-for-age) and stunting (< -2 SD of height-for-age) in Mexican indigenous children from rural and low income communities had been found, according to their age range, at a prevalence of 10.3% in children aged 24 to 36 months, 12.1% in children aged 37 to 48 months, 10.4% in children aged 49 to 60 months and 5.9% in 61 to 72 months age children. Nutritional dual burden in the studied children was significantly associated with lower maternal variables: age, shorter height, and lower education, as well as lower socioeconomic status and larger household size (Fernald and Neufeld, 2007). Studies concerned with NDB in adult people are scarce. In this sense, studying a sample of 116 Mexican adults of around 27 years of age (78 women), López-Alvarenga et al. (2003) found that adults with short stature, defined as height $\leq$ 150 cm in women and height $\leq$ 160 cm in men, had higher body fat percentage than adults with higher stature (29.7% $\pm$9.5 vs. 28.3% $\pm$8.9, p = 0.04).

Documented data of individual NDB in the Maya population are scarce. As we noted in the previous chapter we found that the combination of being stunted and overweight in a sample of 206 Maya children (4-6 years old) from the south of Merida city in Mexico was 2.4% (z-score of height-for-age < -1.645 plus >85th percentile of BMI-for-age using NHANES III) (Varela-Silva et al., 2009). More recently, studying a different sample from the same region of Merida (58 mother-child dyads, children 6 to 9 years old and mothers 22 to 49 years old), we found that the prevalence of individual NDB was 1.7% in children and 50% in mothers using the same criteria as in the previous research (Varela-Silva et al., 2012).

2.3 Nutritional dual burden among mother-child pairs

Recent studies reveal the coexistence of overweight or obesity in mothers and undernutrition in offspring in the same household, with stunting the most common type of undernutrition found among children. As in the case of individual NDB, the coexistence of stunted children and overweight mother (SCOWT) is also relevant in Latin America. Using a data set from the Demographic and Health Surveys for 36 countries (23 in Africa, 8 in Latin America and 5 in Asia), Garret and Ruel (2003) quantified the global prevalence of SCOWT and explored its association with global factors of economic development and urbanization. Children between 6 and 60 months of age and mothers of 18 years or older were included in the analysis. Child stunting and maternal overweight were defined as height-for-age below -2 SD of the WHO/NCHS/CDC 1979 reference and as BMI above 25 kg/m^2 respectively. The SCOWT was generally more prevalent in Latin America compared to Africa and Asia. Guatemala showed the highest prevalence (13.4%) followed by Bolivia (11%) and Nicaragua (9.8%). Egypt (14%) showed the highest prevalence in Africa and Kyrgyz

Republic (4.6%) in Asia. It was also found that urbanization and economic development (measured through Gross Domestic Product) were significantly and positively associated with the prevalence of SCOWT in Latin America. In fact, economic development was associated with SCOWT in all regions, but urbanization was only significant in Latin America. According to the authors SCOWT is not only common in urban areas, especially because stunting rates are still high in rural areas and adult overweight rates are high in both urban and rural areas.

According to the analysis of Garret and Ruel's (2003), the national prevalence for SCOWT in Haiti was 2%. However, when the phenomenon is studied in poor urban areas the prevalence increased to 11% and reached 14% when child undernutrition as reflected by both wasting and stunting rates is taken into account (Raphael and Delisle, 2005). Although the SCOWT condition is more common in Latin America, this phenomenon has been also documented in poor urban areas of Benin, West Africa (Deleuze Ntandou Bouzitou et al., 2005). In this case the condition was associated with low food diversity score and a relatively high socioeconomic level.

More recently, Jehn and Brewis (2009) aimed to identify individual and household-level risk factors for the presence of different combinations of NDB. The analysis included data from 18 countries with low and middle income of four regions: Northern Africa (2), Sub-Saharan Africa (9), South Asia (1) and the Americas (6). Independent variables (all binary) included were: mother's occupation and education, child's breastfeeding history, urban residence, maternal age, number of siblings in the household, child's age and sex, and country. Dependent variables were defined as: 1) overweight mother/stunted children pairs, 2) overweight mother/underweight child pairs and, 3) overweight mother/wasted child pairs. The prevalence of NDB pairs ranges from 1% in Bangladesh to 23% in Guatemala when undernutrition was defined by stunting, from 0.3% to 3.5% defining by wasting, and from 0.3% to 5.3% defining by underweight. Significant risk factors for overweight mother/stunted child were mother's age (>30 years) and education (less than primary school), and having more than 2 young siblings.

Significant risk factors for overweight mother/underweight or wasted child were the same as the previous definition but also living in an urban area.

Guatemala has consistently shown the highest prevalence of SCOWT in Latin America, 13.4% in 2003, 16% in 2005 and 23% in 2009 (Garret and Ruel, 2003, 2005, Jehn and Brewis, 2009). Due to this situation, Lee et al. (2010) analysed the maternal and household predictors for several combinations of NDB in mother-child pairs in Guatemala. The final data set consisted of 2261 mother-child pairs. Children were classified in two groups: stunted group (< -2 SD of height-for-age) and non-stunted group (> -2 SD of height-for-age) using WHO child growth guidelines. Mothers were classified as normal weight (BMI between 18 and 25) and overweight (BMI $\geq$ 25). Mother-child pairs were classified into four categories: stunted child and overweight mother (SCOWT), stunted child and normal weight mother (SCNM), non-stunted child and overweight mother (NCOM), and non-stunted child and normal weight mother (NCNM). The SCNM combination was the most prevalent category (33.8%) and SCOWT was prevalent in 18.2% of households. Comparing SCOWT with NCMN, it was found that SCOWT pairs were more likely to have short mothers (< 145 cm, OR 3.12, CI 95% 2.08-4.69), higher parity (OR 1.20, CI 95% 1.09-1.31), indigenous mother (OR 1.98, CI 95% 1.25-3.12) and working mother (OR 1.67, CI 95% 1.08-2.57). Additionally, average per capita total household consumption was lower in SCOWT pairs than in NCNM counterparts.

Maternal central adiposity and child stunting (MCACS) have been found to be associated in Mexican mother-child pairs. Studying 6225 child-mother pairs from the second Mexican Nutrition Survey of 1999, Barquera et al. (2007) analysed the coexistence of child stunting (< -2 SD of height-for-age of WHO reference) and maternal overweight (BMI > 25 kg/m^2), obesity (BMI > 29.9 kg/m^2), high WC ($\geq$ 88 cm) and central adiposity (WHR > 0.85). WHR, not BMI, was significantly and positively associated to child stunting. The national prevalence of maternal overweight and child stunting was 6.1% and 14.4% among indigenous families. The prevalence of MCACS was 6.2% at national level, but increased to 23.9% in indigenous pairs. After controlling for child's age and maternal BMI, maternal central adiposity increased the likelihood of child stunting by 78% (CI 95% 1.53 – 2.1) but after controlling for maternal height decreased it to 33% (CI 95% 1.13 – 1.57). The prevalence of MCACS was higher in rural than in urban areas (14.5% vs. 2.8%), higher in the south region of Mexico than in north (12.5% vs. 2.2%) and higher in individuals with indigenous background (23.9% vs. 4.2%). These results reflect the presence of NDB in mother-child dyads in groups with the worse socioeconomic conditions.

In a different combination of NDB among mothers and offspring, short stature in mothers has been found associated to child stunting, but not to overweight (Ferreira et al., 2009).

2.4 Nutritional dual burden at household level

The coexistence of under-and-overnutrition is also relevant among family members in the same household. Using nationally representative surveys from Brazil (1989), China (1993) and Russia (1996), Doak et al. (2000) estimated the prevalence of under/overweight households (dual burden households). Adults were classified as overweight having a BMI > 25 kg/m^2 and as underweight having a BMI < 18.5 kg/m^2. The IOTF guidelines were used to classify children as underweight or overweight. Four types of households were defined: 1) under/over households (with at least one underweight and one overweight member), 2) under/normal households (with underweight and normal weight members), 3) over/normal (with overweight and normal weight members), and 4) normal/normal (with normal weight members only). In general the proportion of dual burden households was 8% in Russia, 8% in China and 11% in Brazil. Urban residence was significantly associated with being a dual burden household in China and Brazil. Income showed an inconsistent pattern of association with the four types of households across countries.

In a subsequent study Doak et al. (2005) documented the prevalence of dual burden households (under/overweight) in Brazil (10.9%), China (8.3%), Indonesia (11%), the Kyrgyz Republic (15.5%), Russia (7.8%), Vietnam (3.7%) and the United States (5.4%) examining representative data sets. Households were classified according to the BMI of their family members. After controlling for family size, it was found that the lowest prevalence of dual burden households were in countries with low and high GNP and highest prevalence in countries in the middle range of GNP, showing clearly an inverted U-shape curve.

More specifically, comparing dual burden households against underweight, overweight and normal households, Doak et al. (2002) found previously that urban residence and high income were significantly associated (OR 2.0, CI 95% 1.5-2.8; OR 1.7, CI 95% 1.2-2.4 respectively) with being a dual burden household in China. However, among low income households the urban association was also significant (OR 3.1, CI 95% 1.7-5.6), which suggests an interaction between income and urban residence. Additionally, compared to underweight and overweight households, dual burden households were significantly associated with owning a television, motor vehicle or washing machine, having a household head with a high energy demand occupation, and having a household diet with a high percentage of energy from fat or carbohydrates.

Few studies have addressed the study of dual burden household in very poor communities. In this context Toledo Florencio et al. (2001) studied the nutritional status of 1247 individuals (children, adolescents and adults) belonging to 315 families from the city of Maceio, Alagoas, Brazil. It was found that low weight and overweight-obese members coexist in 30% of the families. These results highlight the emergence of nutritional dual burden even in contexts of extreme socioeconomic deprivation.

2.5 Biological factors associated with the nutritional dual burden

The coexistence of under and overnutrition in the same individual, child-mother pair and the household level suggest that environmental conditions during early stages of human development increase the risk for obesity in later life. Observational and prospective studies have shown the impact of early nutrition during gestation (Ravelli et al., 1976;

Law et al., 1992; Fall et al., 1995; Curhan et al., 1996; Barker, 1998; Ravelli et al., 1999; Martorell et al., 2001) and the first years of life (Schroeder et al., 1999) on the development of adiposity in adulthood. Stunted juvenile and early adolescents (10 to 14 years of age) have shown prospectively to have a greater central adiposity than normal-height children. Hoffman et al. (2007) found that stunted children had more truncal fat mass, in both absolute (kg) and proportional (%) terms and increased gain of truncal fat mass. Additionally, it has been found that stunted boys accumulated more body fat and gain less lean mass (kg and %) than non-stunted boys when they reach puberty (Martins et al., 2004).

Some physiological processes have been proposed to explain how early malnutrition increases the risk for obesity in later life. Most of these processes occur at a metabolic level. The four possible processes are: 1) impaired fat oxidation, 2) changes in the resting metabolic rate (RMR), 3) alterations in the metabolism of cortisol and insulin, and 4) changes in appetite regulation.

1) Impaired fat oxidation. It is suggested that individuals who suffered undernutrition during gestation or early stages of the life tend to satisfy their energetic requirements through the preferential oxidation of carbohydrates rather than fat, increasing the risk for adiposity storage (Frisancho, 2003). The most plausible explanation for this process is that the use of carbohydrates requires less metabolic steps than stored fat and because carbohydrate oxidation results in more ATP generation than iso-energetic amounts of fat or protein (Shetty, 1999). Through indirect calorimetry is it possible to obtain the respiratory quotient (RQ), which is the ratio between the volume of CO_2 produced and the volume of oxygen consumed. Indirectly, the RQ assesses the proportion of carbohydrate and fat that is being metabolized. Measurements of RQ range from 0.70 to 1.0. A RQ near or greater than 1.0 indicates that carbohydrates are being used; whereas an RQ close to 0.70 indicates that fat is being metabolized.

In this context, Hoffman et al. (2000a) tested the hypothesis that stunting is associated with impaired fat oxidation comparing 28 stunted pre-pubertal children (height-for-age < -1.50 z-score) with 30 non-stunted children (height-for-age > -1.50 z-score) all of them of 7 to 11 years old. All subjects had normal weight-for-height z-score (-2.0 to 1.5). RQ was measured under specific conditions by indirect calorimetry and body fat and lean body was obtained with dual-energy X-ray absorptiometry. After excluding those children who had a RQ > 1.00 (n = 5) and examining the effect of confounding variables, the fasting RQ was significantly higher ($p<0.05$) in the stunted group than in the control group. The stunted group also oxidized a significantly ($p<0.01$) higher percentage of carbohydrates and a significantly ($p<0.01$) lower percentage of fat than did the control group. This result suggests that stunted children preferentially use carbohydrates as fuel and store the fat that comes from diet. Previous studies developed with Indians a Pima population identified the RQ as a good predictor of body fat gained (Zurlo et al., 1990). Using measurements of 24-hour RQ in a subsample of 111 subjects (49 females and 62 male) 18 to 42 years old and fed a weight maintenance diet, the researchers found that the 24-hour RQ was correlated with subsequent body weight change ($r = 0.27$, $p<0.01$) and body fat mass change ($r = 0.19$, $p = 0.04$). Additionally, the 24-hour RQ was an independent predictor of body weight gain and rate of body fat mass gain.

2) Changes in the resting metabolic rate (RMR). Reduction in the resting energy expenditure (REE) in undernourished individuals has been suggested as another possible process to explain the increased risk for adiposity. Well-nourished adults have shown consistent reductions in REE after semi-starvation periods in experimental studies (Sawaya and Roberts, 2003). However, studies in chronically undernourished children are scarce and their results do not confirm this hypothesis (Hoffman et al., 2000a; Hoffman et al., 2000b; Wren et al., 1997). In this context Hoffman et al. (2000b) tested the hypothesis that stunted pre-pubertal children have different energy expenditure than non-stunted children (8 to 11 years of age) in a shantytown from Sao Paulo, Brazil. This study was conducted during 7 days; anthropometrics, food intake and total energy expenditure (using doubly labelled water technique) were measured in

households during the 7 days and REE and body composition (using dual-energy X-ray absorptiometry) in laboratory conditions during three days. After adjusting for weight and fat-free mass there was no difference between stunted and non-stunted group in REE, total energy expenditure and energy expenditure for physical activity.

3) Alterations in the metabolism of cortisol and insulin. Besides this, Sawaya et al. (2004) suggest a model in which a decrease in insulin-like growth factor (IGF-1) is a result of chronic low energy intake lead to high rates of cortisol to insulin hormones. High levels of cortisol have been associated to central obesity. Previously, Sawaya et al. (1998) demonstrated that girls with lower levels of IGF-1 show less linear growth in a 22 months follow-up than girls with high levels of IGF-1.

4) Changes in appetite regulation. Impaired regulation of food intake is another factor suggested to explain the fat accumulation in stunted children. In this sense, through a 3 days residence study Hoffman et al. (2000c) compared the energy intake of 27 stunted and 29 non-stunted children (8 to 11 years). They found that stunted children had a significantly higher energy intake per kilogram body weight (333 $\pm$67 kJ/kg vs. 278 $\pm$89 kJ/kg, $p<0.05$), which suggest that stunted children have decreased ability to regulate their energy intake increasing risk for excess weight gain over time. Additionally it has been found that mild-stunting is associated with higher susceptibility to the effects of high fat diets. In a 22-month prospective study conducted in 1994 and 1995, Sawaya et al. (1998) examined obesity risk factors of normal height (n = 15) and mild stunting (n = 15) 7 to 11 years old girls (height-for-age < -1.4 z-score) from shantytowns of Sao Paulo. The study was conducted during 8 days, resting metabolic rate and anthropometric measurements were taken in days 1 and 8 and the food intake of participants was weighted during consecutive days. In general, stunted girls had significantly higher waist-to-hip ratios than non-stunted girls ($p<0.05$). In the follow-up component of the study there was a difference between the groups in trends in weight-for-age. However, the mild-stunted girls showed a greater susceptibility to the effects of high fat diets compared with non-stunted girls. This susceptibility was evident in the

significant association observed ($p = 0.048$) between dietary fat (percentage of energy intake) and increase on weight over the study period.

It is also possible that the reason for the presence of NDB at individual or household levels is less complex. In this sense the quality of the diet is factor that can play an important role. If the diet of any individual or group during the first years of life is poor in important nutrients such as proteins, vitamins and minerals, is quite possible that linear growth (trunk and leg length) would be compromised. If this type of diet continue after the growth period is likely that individual tend to accumulate adipose tissue chronically. The common dietary pattern of some poor social groups such as the Maya is a diet high in carbohydrates (most of them low in fibre) and saturated fat and low in vitamins and minerals.

Additionally, the presence of continuous infectious diseases, the lack of a good quality health service, the poor knowledge in health and cultural beliefs are factors that can contribute to the coexistence of under and overnutrition. In the case of rural and urban areas in the Yucatan is still present the belief that beauty and health are present in a corporal image that excess the normal values of body weight, body mass index and body fat.

Social groups in socioeconomic disadvantage have, in general, access to a low cost diet. Very often this diet is high in energy, which satisfies primary necessity of family member’s but low in nutrients and has a negative long term impact.

2.6 Summary

Under and overnutrition are both extremes of malnutrition. However, paradoxically these conditions can coexist (NDB) at individual, mother-child pairs and household levels. Individual NDB is defined when under and overnutrition are present in the same individual, being stunting and OW/OB the main studied conditions. Mother-child pairs are commonly defined as NDB when OW/OB is present in mothers and stunting in children. Households are defined as NDB when at least one family member shows undernutrition (stunting or underweight) and at least one family member shows OW/OB. Individual NDB has been studied in low and middle income countries in regions such as Africa and Latin America. The most common predictors for this condition are a big family size, low level of maternal education and stunted mothers. Individual NDB is more common among indigenous groups in Mexico and data from Maya population are still scarce. NDB in mother-child pairs is particularly relevant in countries from Latin America. Predictors of this condition are: 1) the process of urbanization in poor areas, 2) older mothers, 3) low maternal stature 4) low maternal education level and 5) belonging to an indigenous group. NDB at household level has been mostly studied at the national level. The available evidence suggests that urban areas of low and middle income countries show the highest prevalence of this condition. Some physiological processes have been related to the presence of NDB at individual level. These processes included metabolic changes in subjects who have experienced chronic undernutrition, such as, impaired fat oxidation, changes in the resting metabolic rate, and alterations in the metabolism of some hormones and changes in the appetite regulation. It is also possible that poor diets during first years of life and then in adulthood contribute to the presence of NDB. Social groups in socioeconomic disadvantaged conditions are continuously exposed to diets high in energy but poor in important micronutrients.

CHAPTER 3

Intergenerational influences and health outcomes

3. Intergenerational influences and health outcomes

3.1 Definitions and general considerations

The physical growth of our species is the result of a complex interaction between genes and environment (Tanner, 1978). In this sense the nutritional status of a group or generation reflects the genetic load and the quality of past and current living conditions. Particularly, some measures of linear growth such as height, leg length, and knee height are the result of cumulative experiences such as nutrition and infectious diseases during the growth period (Bogin, 2012).

During the last decades cumulative evidence suggests that living conditions experienced by one generation (during its growth period) can have biological effects upon the next generation. It is argued that intergenerational influences contribute to shape the nutritional status of newborns, children and adolescents. By 1986, Emanuel (1986, p 27) defined intergenerational factors *"as those factors, conditions, exposures, and environments experienced by one generation that relate to the health, growth, and development of the next generation"*. In this thesis we focussed on the effects that one generation may have over the physical growth of the next two generations.

Emanuel's hypothesis was initially proposed to explain the persistence of low birth weight across generations in some populations. Early and recent studies show the positive association between maternal and grand-maternal birth weight and the offspring's birth weight (Emanuel, 1986; Ounsted et al., 1986; Klebanoff and Yip, 1987; Emanuel et al., 1992; Emanuel et al., 1999; Emmanuel et al., 2004; Hypponen et al., 2004; Martin et al., 2004). A review of 14 studies showed that per each 100 g of maternal birth weight, the offspring's birth weight was, on average, 10 – 20 g heavier (Ramakrishnan et al., 1999). The offspring's birth weight is not only explained by the maternal and grand-maternal birth weight, but also by their height during their childhood

(Hypponen et al., 2004; Martin et al., 2004) and adulthood (Emanuel et al., 1992; Hypponen et al., 2004). In particular, Martin et al. (2004) found that maternal leg length, but not trunk length was associated with offspring's birth weight, specifically they found that for each unit increase in z-score of maternal leg length during childhood the offspring's birth weight increased by 96 g (CI 95% 6 – 186). Leg length seems to be a good marker of early life nutrition (Bogin, 2012). Similarly Hypponen et al. (2004) found that the birth weight of children increase 93 g (CI 95% 77 – 108) per each standard deviation change in maternal height at age of 7 and also show that the effect of maternal height during adulthood is biologically important on the offspring's birth weight (90 g per each standard deviation change, CI 95% 74 – 105), however its effect is clearly diminished when grandparental and maternal birth weight is controlled (25 g, CI 95% 2 – 48). These results suggest that maternal growth status during childhood is more relevant for offspring birth weight than maternal height during adulthood. This is partially supported by the results from the Institute of Nutrition of Central America and Panama (INCAP) supplementation trial in Guatemala. In this research it was found that those offspring whose mothers received a high-quality supplementation during childhood were taller and grow faster during the first 36 months of life than those children whose mothers received low-quality supplementation (Stein et al., 2003).

3.2 Intergenerational influences on postnatal growth

The intergenerational effects on postnatal growth have been less studied. Some studies provide results about the association between parental and offspring height (Table 3.1). In all cases parental height was measured during adulthood and offspring's height was taken during childhood or adultness. In general, correlation coefficients show three results: 1) associations between mothers and offspring are stronger than associations between fathers and offspring in all ages, 2) associations between parents and offspring at adult ages are stronger than association between parents and offspring during childhood and, 3) associations between offspring and mid-parental height are stronger than association between offspring and mothers and fathers analysed separately. Emanuel et al. (2004) reported associations in four different groups of North America, in this study the daughters were measured at adult age. Associations in Hispanic mother-daughter pairs were the strongest compared with white, African American and Native American pairs. All these studies come from developed countries. Results of studies from developing countries, particularly from Latin America, are scarce.

Table 3.1 Association between parental and offspring height in some studies

	Comparisons	r	Source
Mid-parental	Adult males & females	0.510	1946 Cohort of MRC National Survey of Health and Development. Population from England, Wales and Scotland (Kuh and Wadsworth, 1989).
Mothers	Daughters at 23 years	0.469	1958 British National Birth Cohort. Population from England, Wales and Scotland (Alberman, 1991).
	Sons at 23 years	0.451	
Fathers	Daughters at 23 years	0.420	
	Sons at 23 years	0.424	
Mid-parental	Daughters and sons	0.560	
Mothers	Daughters at 7 years	0.370	1958 British National Birth Cohort. Population from England, Wales and Scotland (Hypponen et al., 2004).
	Sons at 7 years	0.390	
Fathers	Daughters at 7 years	0.350	
	Sons at 7 years	0.360	
Mothers	Daughters at 33 years	0.450	
	Sons at 33 years	0.470	
Fathers	Daughters at 33 years	0.420	
	Mothers at 33 years	0.430	
Mother	Daughters (White)	0.436	Washington State Intergenerational Cohort. Mothers born 1949 – 1979 and daughters 1987 – 1995. (Emanuel et al., 2004).
	Daughters (African American)	0.398	
	Daughters (Native American)	0.369	
	Daughters (Hispanic)	0.465	

Even when the associations between parents and offspring in height are, due in part, to a genetic load, they also reflect the effects of living conditions experienced by the immediate ancestors. The final linear growth attained by mothers and other previous ancestors (i.e. grandmothers) reflects the quality of the environment experienced both in utero and during postnatal growth.

Some other studies report the implications of maternal growth status on the offspring nutritional status. Ozaltin et al. (2010) examined the association between maternal height and child stunting in the first five years of life analysing 109 Demographic and Health Surveys from 54 low- to middle-income countries. The sample included a total of 558,347 children born to 234,604 mothers. Stunting in children was defined using the WHO cut-off points. Maternal height was used both as a continuous and as categorical variable: 1) less than 145 cm, 2) 145 to 149.9 cm, 3) 150 to 154.9 cm, 4) 155 to 159.9 cm, and 5) 160 cm and more. The results showed that the increase of 1 cm in maternal height was significantly associated with a decreased risk in stunting (Relative Risk 0.968; CI 95% 0.967 - 0.969). Compared with the tallest category of maternal height, each lower category had higher risk of stunting. Another study conducted in Nepal found that maternal height was negatively associated with stunting (Adjusted OR 0.90, CI 95% 0.87 – 0.93) and underweight (Adjusted OR 0.92, CI 95% 0.89 – 0.93) (Christian, 2009). Studying 4663 mother-child pairs from the 1988 Mexican National Nutrition Survey, Hernández-Díaz et al. (1999) found that mothers with short stature (< 145 cm) were significantly more likely to have stunted children (OR 4.0, CI 95% 3.2 - 4.8). However after controlling for region, urban/rural residence, SES, household size, child age, presence of infectious diseases in past 14 days and maternal age and BMI the association was substantially attenuated but remained significant (OR 2.0, CI 95% 1.6 – 2.6). Using data derived from the 1997-2006 Demographic and Health Survey of 42 low-and-middle income countries, Monden and Smiths (2009) found that maternal height was negatively associated with child mortality. Specifically the authors found that children whose mothers were 135 cm tall were 1.40 times more likely to die before the age of 5 when compared to children whose mother were 155 cm tall on average. In contrast, children from mothers with an average height of 170 cm were 20% less likely to die before the age of 5 than children whose mothers were of average height (155 cm).

Martorell and Zongrone (2012) propose a conceptual framework for intergenerational relationships on linear growth (Figure 3.1). This framework postulates that the environment experienced by mothers during their development in utero and during their postnatal growing years, shapes the maternal constitution (height, fat free mass and pelvic inlet) and organ size (i.e. uterus, placenta). The mother gives birth to one or more offsprings whose characteristics at birth (size, weight, and head circumference) have implications on the first years of postnatal growth of her child. Nutrition during pregnancy is influenced by maternal constitution and in turn influences the characteristics of the new-born. As a result, the child characteristics during postnatal growth (length/height, head circumference) will reflect the quality of the pre-and-postnatal maternal environment. Intermediate factors, such as breastfeeding, act as covariate factors that may or may not buffer the intergenerational influences and shape the growth during first years of life.

Figure 3.1 Intergenerational relationships on linear growth

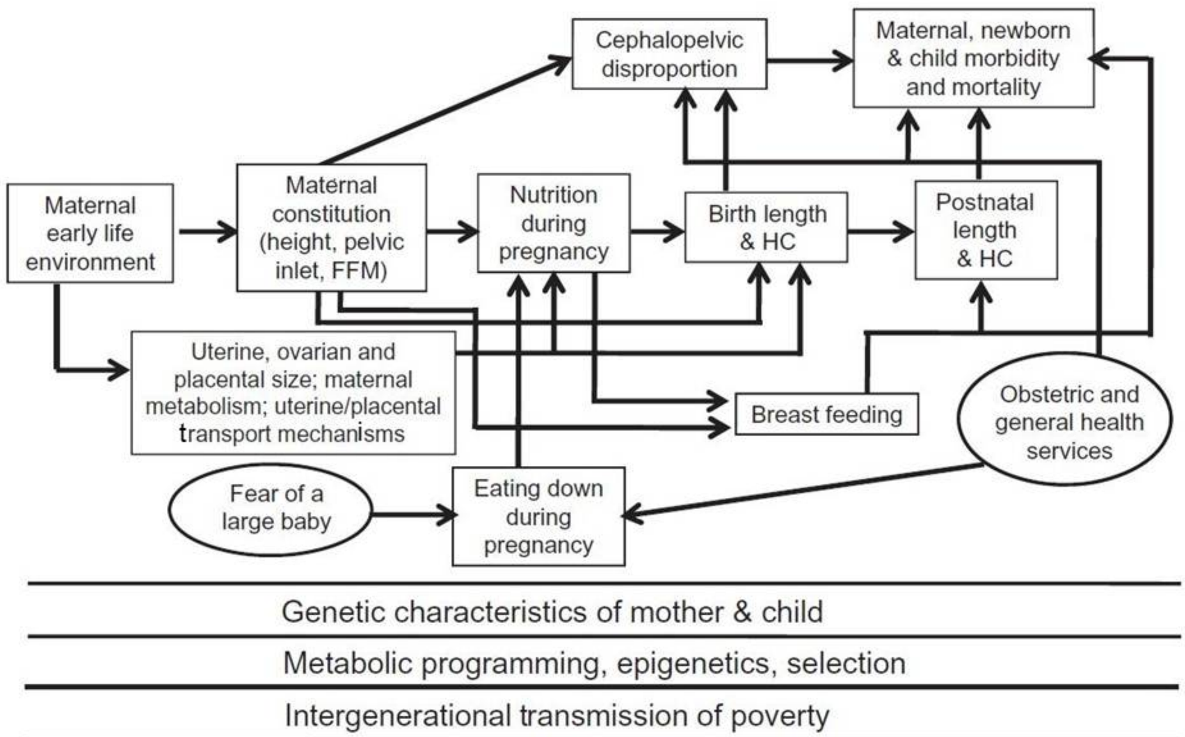


Figure 1. Intergenerational influences on child nutrition. FFM, fat free mass; HC, head circumference.

Source: Martorell and Zongrone, 2012.

At broader level the authors suggest that the genetic endowment, the metabolic programming, epigenetics factors, and the intergenerational transmission of poverty are the basis for potential explanations for intergenerational effects on growth. However, the model proposed does not provide a possible explanation about how these mechanisms (at macro-level) interact in environments that differ in their conditions to produce different trajectories of growth and development. Genetic load, metabolic programming, epigenetic expression and transmission of poverty have been widely described in the scientific literature on the intergenerational influences, but few advances have been reached in determining the specific contribution of each factor.

Evidence from studies on birth weight suggest that the intergenerational influences occur through a maternal line and can span across several generations (Ounsted et al., 1986; Emanuel et al., 2004). In the case of linear growth it has been proposed that *"young girls who grow poorly become stunted women and more likely to give birth to low-birth weight babies. If those infants are girls, they are likely to continue the cycle by being stunted in adulthood and so on…*" (UNICEF 1998, cited by Ramakrishnan et al., 1999 p 544S).

For purposes of this thesis it is convenient to review theoretical contributions of Gluckman and collaborators, Kuzawa and Wells in the context of intergenerational influences.

In order to explain variations in phenotypic characteristics and disease during adulthood, Gluckman and collaborators have proposed the **predictive adaptive responses** (PAR's) hypothesis. PAR's is defined by their proponents "*as a form of developmental plasticity that evolved as adaptive responses to environmental cues acting early in life cycle, but where the advantage of the induced phenotype is primarily in a later phase of life cycle" (*Gluckman et al., 2005*)*. This hypothesis is based upon the idea that the embryo/fetus receives information from the mother about environmental quality that it will experience during its mature stage. In this context, the levels of nutrients and hormones act as coded messages about the external environment. In response, the developing organism utilises these cues to make adaptive adjustments for future ecological conditions. These adjustments could lead to permanent changes in the physiology or structure of the organism to survive and reach reproductive success (Gluckman and Hanson, 2004). A crucial point in the PAR´s hypothesis is the connection between prediction and disease; if the prediction is accurate a healthy phenotype is expected and if the prediction is incorrect then disease or disadvantage should be observed. The proponents of this model suggest that the changed postnatal nutritional environment is responsible for the mismatch between the actual and predicted postnatal environments. The current high energy environment of many human populations has significantly contributed to the appearance and increase of chronic disease such as obesity, type 2 diabetes mellitus, hypertension and cardiovascular diseases. Following the logic of PAR's hypothesis, prenatal growth restriction (frequently characterised by low birthweight) is a response to signals or cues of a poor external environment and a preparation for a thrifty adult phenotype. The common phenotype as a result of PAR's is characterised by a compact body shape, predisposition to central fat accumulation, reduced muscle mass and insulin resistance, fundamental traits for chronic diseases. In the context of intergenerational influences the authors suggest that we can expect the transmission of PAR's through maternal effects to continue beyond the immediate generation.

Wells proposes a model that differs from Gluckman and collaborators in several aspects (Wells, 2012a, 2011). In the first instance, Wells' model differs from the PAR's hypothesis on the meaning of signals or cues that a developing organism receives during the prenatal stage. Specifically, Wells suggests that *"the maternal phenotype may itself not relate strongly to current ecological conditions, but may reflect the mother's own developmental experience, and hence grand-maternal phenotype"* (Wells, 2003). Therefore, Wells suggests that rather than choose physiological or structural adjustments for predicted future conditions, the embryo/fetus adapts to the maternal phenotype which is the primary environmental component.

Wells also differs on the idea that an offspring can predict its long term future; instead he argues that the baby is exposed in the womb to **maternal capital**, defined *as any aspect of maternal phenotype, whether somatic or behavioural, which enables differential investment in offspring* (Wells, 2010). This maternal investment is composed of two factors: 1) the maternal nutritional status at the time of conception and, 2) the maternal nutritional resources available during pregnancy and lactation. The first of these relates more to extensive periods of time or nutritional history and the second relates to short-term periods which might not be indicative of longer term trends. The exposition of each offspring to such maternal capital variability results in different developmental trajectories (Wells, 2003). A crucial point in Wells’ model is the idea that the maternal phenotype acts a buffer to protect the offspring from external ecological variability.

Wells also proposes that maternal capital can be transferred to subsequent generations leading to complex associations between linear growth trajectories and body composition. In this context, sexual maturation and reproductive strategy play important roles in the intergenerational transmission of phenotypes. Both poor and rapid growth during the prenatal stage are associated with early age of menarche in girls, and this in turn is associated with reduced birth weight, rapid infant growth, high levels of central adiposity and early puberty in the offspring of the next generation. The possible explanation for this outcome is that girls entering puberty earlier will complete their growth earlier, resulting in reduced adult stature. Under these circumstances it is expected that maternal phenotype will be replicated across generations. Wells also points out that increased investment in adipose tissue by females in one generation can provide an opportunity to recover negative trends in growth (Wells, 2011).

Kuzawa (2008) agrees with Gluckman’s model in the sense that the developing organism is provided with signals or cues during gestation through nutrients and hormones. However, Kuzawa argues that what offspring “see” is an average of nutritional conditions experienced by matrilineal ancestors. Part of this argument suggests that offspring establish a filtering process of short-term “noise” to discern long term signals about environmental conditions (Kuzawa, 2008).

Specifically, Kuzawa (2005) suggested two arguments that might be useful to understand the intergenerational influences on the postnatal growth of our species.

1) the growth of a child depends not only on the conditions experienced *in utero*, but it is also influenced by factors that trace the chronic nutritional history of the mother, including her nutrition *in utero* and during her early years of life and,

2) the uterine nutritional conditions the mother provides to her offspring depend also on the uterine conditions that the mother has received during her own fetal stage. The growth of a current generation is thereby influenced by the nutritional experiences not only from the mother but also from the maternal grandmother.

In this way it is suggested that those traits acquired in the past through non-genomic information and accumulated in the phenotype along multiple generations of matrilineal ancestors are conveyed to the soma of the current generation. Kuzawa coins the concept **phenotypic inertia** to describe the gradual intergenerational response to change (Kuzawa, 2005, 2008). This argument suggests that the phenotypic characteristics of a growing individual whose matrilineal ancestors have had adverse nutritional histories might improve little even if the environmental conditions improve substantially. Kuzawa point out that this phenotypic inertia can improve the reliability of early signals and promote a recalibration to more stable ecological conditions by ignoring short-term changes.

Kuzawa differs from Gluckman et al's hypothesis in terms of the offspring's developmental strategies. Gluckman's model is clearly forward-looking in the sense that the developing organism responds to signals making a prediction for long-term future. In contrast, Kuzawa's model is backward-looking, in which the developing organism predicts its future based on past nutritional experiences of recent ancestors.

The mechanisms through which intergenerational influences operate are not entirely clear. However, accumulated evidence strongly suggests that epigenetic mechanisms are involved. Epigenetic changes are defined as "*chemical modifications that change the pattern of gene expression in a specific tissue or organ without changing the DNA" (*Kuzawa, 2012 p 329*)*. Epigenetic regulation includes three specific molecular mechanisms: 1) DNA methylation, 2) histone modifications and, 3) DNA-binding proteins (Waterland and Michels, 2007). Several experimental studies using animal models show that changes in the nutritional environment during prenatal and postnatal stages can produce durable epigenetic changes and subsequently impact the biology of animals increasing their risk for disease. Epigenetic processes provide rational explanations about how pre-and postnatal environmental conditions experienced by one generation can affect the phenotypic variation of the following generation(s).

3.3 Summary

Intergenerational influences are defined as those factors, conditions, and exposures experienced by one generation that relate with the health, growth and development of the next generation(s). Most of literature on intergenerational influences focuses on birth weight. The intergenerational effects on postnatal growth have been less studied. Some studies provide simple associations in anthropometric parameters between parents and offspring. Even when these associations inform about genetic load, they also reflect the effect of the conditions experienced by maternal ancestors on the nutritional status of offspring. The results of these studies suggest that associations between mothers and offspring are stronger than the associations between fathers and offspring. Other studies show evidence that maternal height is negatively associated with the presence of stunting in children. Theoretical contributions originally formulated in the context of birth weight might be useful in the context of intergenerational influences on postnatal growth. This theoretical framework suggests that postnatal growth is influenced by factors that trace the chronic nutritional history of matrilineal ancestors. The concept of Intergenerational Phenotypic Inertia (Kuzawa, 2005) is useful to understand the persistence of chronic undernutrition in children and adults in developing countries. Even when the mechanisms through which intergenerational influences operate are not yet entirely clear, accumulated evidence suggests that epigenetic mechanisms are involved.

SECTION 2

RESEARCH PROCEDURE

CHAPTER 4

Research questions and objectives

4. Research questions and objectives

4.1 Research questions

4.1.1 General research question

With this research we are mainly interested in knowing whether the biosocial background of Maya children is associated not only with their own nutritional status but also with the nutritional status of their mothers and their maternal grandmothers. More specifically we aim to identify and measure the impact of the intergenerational influences on the growth of children. Therefore our general research question is:

- Is the biosocial background of the maternal Maya grandmothers (F_1), and mothers (F_2) associated with the nutritional status of their children (F_3)?

Even when we are particularly interested in understanding the effect of intergenerational factors on the nutritional status of children (F_3), we consider necessary to determine firstly the nutritional status of children (F_3), mothers (F_2) and grandmothers (F_1). Additionally we aim to identify and measure the effect of some antenatal and socioeconomic factors that shape the nutritional status of children.

4.1.2 Specific research questions

Our specific research questions were:

1. What is the nutritional status of children, mothers and grandmothers and the nutritional dual burden prevalence among the participants?
   1.1 What is the prevalence of stunting, short trunk, short legs and underweight among the participants?
   1.2 What is the prevalence of overnutrition (overweight, obesity, abdominal obesity) among the participants?

1.3 What is the prevalence of the nutritional dual burden at individual and household level?

2. What are the antenatal and socioeconomic factors that shape nutritional status of the children (F_3)?
   2.1 What are the antenatal and socioeconomic factors that shape the linear growth of children?
   2.2 What are the antenatal and socioeconomic factors that shape the body mass and body composition of children?

3. What is the impact of intergenerational factors on the growth of participants?
   3.1 What is the impact of intergenerational influences from grandmothers (F_1) to mothers (F_2)?
   3.2 What is the impact of intergenerational influences from grandmothers (F_1) and mothers (F_2) to children (F_3)?

4.2 Research aims

4.2.1 Main objective

To assess the impact of socioeconomic and intergenerational factors on the growth of Maya children, in a sample of three generations: children, their mothers and their maternal grandmothers.

4.2.2 Specific objectives

1. To assess the nutritional status and nutritional dual burden prevalence in participants.
2. To identify the antenatal and socioeconomic factors that shape nutritional status of children (F_3).
3. To assess the intergenerational influences on the growth of participants

3.1 To assess the intergenerational influences from grandmothers (F_1) on the growth of mothers (F_2).
3.2 To assess the intergenerational influences from grandmothers (F_2) and mothers (F_2) on the growth of children (F_3).

4.3 Research approach

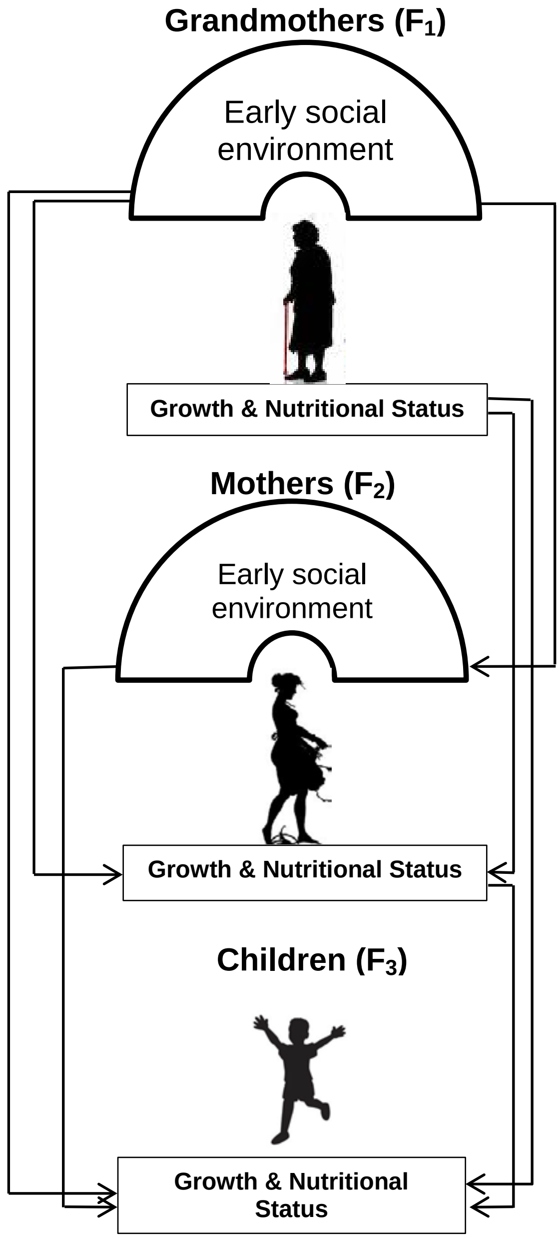
Most of the studies on intergenerational influences on postnatal growth include two generations: the mother and the child. In this study we are including three generations (adding the maternal grandmothers) to help us understand how the collective nutritional experiences of recent matrilineal ancestors (grandmothers and mothers) shape the growth and nutritional status of children (Kuzawa, 2005).

We hypothesize that social living conditions experienced by grandmothers (F_1) and mothers (F_2) during their childhood and adolescence might shape the growth and nutritional status of children (F_3) (Figure 4.1). Intergenerational influences of living conditions are also present from grandmothers (F_1) to mothers (F_2). We also propose that intergenerational influences of grandmothers and mothers are contained in their somatic traits at the current time. We are particularly interested in linear growth measures as they reflect the cumulative effect of environment during early life.

The effect of early social environment is analysed through a set of socio-demographic variables experienced by mothers and grandmothers during childhood. The model allows us to analyse the effect of social environment and biological factors (anthropometric data) separately and collectively.

Our model suggests the presence of direct and indirect effects among the three generations. Direct effects can be found from grandmothers to mothers and children and from mothers to children. Indirect effects from grandmothers to children can occur through maternal effects.

Figure 4.1 Graphic representation of our research approach



CHAPTER 5

Methods

5. Methods

This chapter aims to describe in detail the methods used throughout the research, and includes six sections. Section 5.1 is a brief description of the place of research. Section 5.2 details the characteristics of the participants, including the definition of the unit of analysis, the inclusion criteria, the sample size calculation and the participants' recruitment process. Section 5.3 concerns the procedures for data collection. Section 5.4 deals with ethical considerations of research, and Section 5.5 and 5.6 describe the data handling and data analysis procedures, respectively.

5.1 Place of research

This research took place in the Merida City, capital of the current Mexican state of Yucatan (Figure 5.1). Yucatan is located in the southeast of Mexico and in the north of the Yucatan peninsula. The city of Merida is located in the north-western part of the state within 40 kilometres of the Gulf of Mexico. Merida is characterized by a flat topography, low altitude over sea level and a tropical climate. By 2010, the population size of Merida was 777,615 inhabitants (INEGI, 2012b). Currently Merida is one of the most important cities in the region, with a remarkable offer of services, among these, business, education and health, and is a major tourist destination.

The south of Merida has been historically the main site of residence of the Maya population. This area is characterized by housing the families with the highest poverty levels in the city. As we will explain in detail, studied children were recruited through primary schools. In Mexico, like in many other countries, children who attend public schools belong to families that live around the schools. According to the Urban Development Program of Merida, the city is divided into eight districts (Fuentes, 2005). The schools where children were recruited are located in districts D-V (south), D-VI, D-VII (west), and D-II and DIII (east) (Figure 5.2). The studied families in the south were located in around 30 neighbourhoods and the families of the west and east were found in 15 and 10 neighbourhoods respectively (Figure 5.3). Most of the selected schools

(60%) are distributed in the south of the city, the rest are located in the west (30%) and east (10%).

Figure 5.1 Place of research

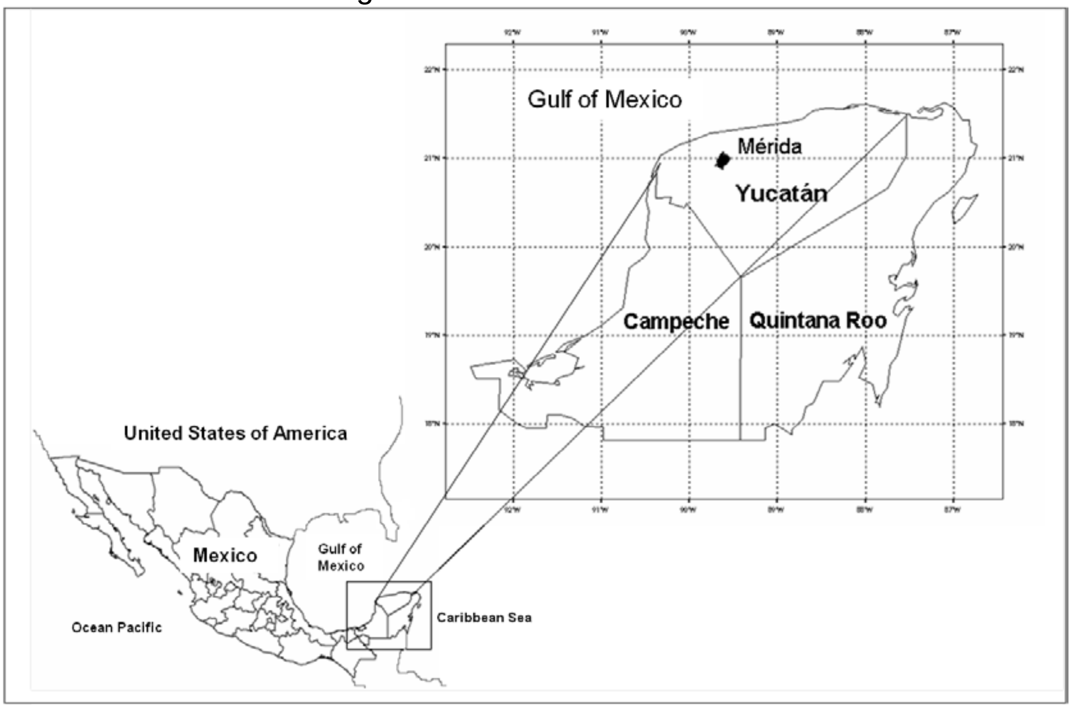
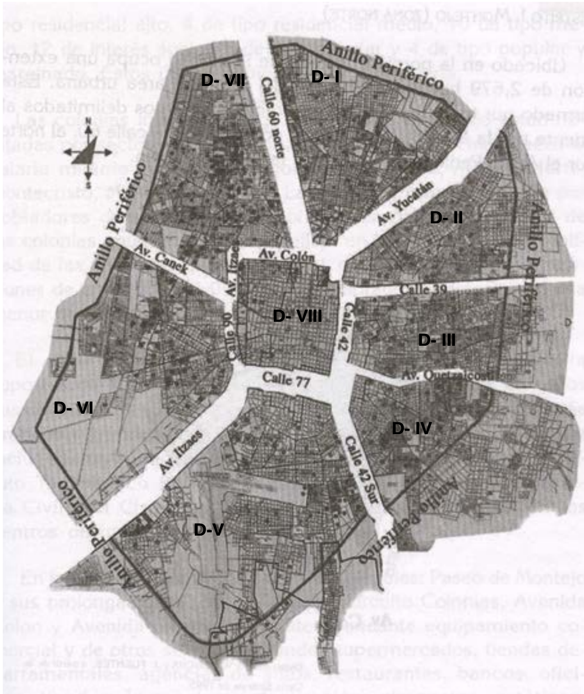


Figure 5.2 Urban districts of Merida



Source: Fuentes, 2005.

Figure 5.3 Places of research in the city

5.2 Participants

We studied 6-to-8 year old children who attended public schools, their mothers and their maternal grandmothers. We focused on 6-to-8 year old children because in terms of height and weight gain this age-range corresponds to the late childhood and early juvenile stages of growth which are characterised by a stable or decelerating growth rate relative to the rapid accelerating growth rate of the adolescent stage (Bogin, 1999). Previous research shows that by late childhood and early juvenile stages it is relatively easy to detect environmental influences on human height, weight and body proportions (Bogin and MacVean, 1982; Bogin et al., 2002). Because we also intend to conduct this study focusing on intergenerational factors that explain health and nutritional status outcomes, we also focused on biological mothers and grandmothers of the children.

5.2.1 Unit of analysis

Even when we focused on children, mothers and grandmothers, our unit of analysis was the household. This was for two reasons; the first is because the main social and cultural environment of the children is the household, and second because many socioeconomic factors –such as paternal income, education and occupation, related to human growth can be studied using the household as a unit of analysis. For this purpose we got demographic and socioeconomic information of all people who live in the house, whether they were family members or not.

5.2.2 Inclusion criteria

5.2.2.1 Maya identification

We used the presence of Maya surnames as a proxy to Maya ancestry. Surnames can be used as a genetic proxy and as a means to identify ethnic groups (Chakraborty et al., 1989; Relethford, 1995; Colantonio et al., 2003). Research reports suggest that Maya groups from Yucatan show a high degree of genetic homogeneity (González-Martínez et al., 1993; Serrano-Sánchez, 1997; Ibarra-Rivera, 2008; Hunley and Healy, 2011). In Mexico, each person inherits and formally uses a patronymic and a matronymic. In Yucatan, Mayan surnames remain in wide use despite the colonial cultural impositions and can be readily distinguished from non-Maya surnames.

Our inclusion criterion was:

- Maya children aged 6-8 years old attending public schools and their biological and non-pregnant mothers and grandmothers. Additionally it was required that each member of a triad (child-mother-grandmother) had to have at least a maternal Maya surname, as opposed to a Spanish or other non-Maya surname.

5.2.3 Power analysis calculation to determine the sample size

The number of triads (sample size) was calculated through a power analysis calculation. Setting the significance level at $\alpha = 0.05$, the power at 0.80, and expecting a medium size error of 0.15, we found that a sample of 107 children, including their mothers and grandmothers was required. Furthermore, eight independent variables in a multiple regression model were considered. For our analysis a triad was considered complete when all variables were available for each child, mother, and grandmother.

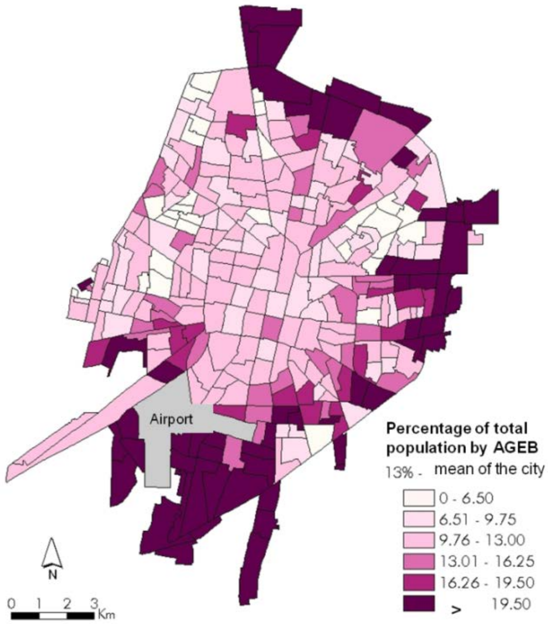
5.2.4. Participants recruitment

5.2.4.1 Rationale for selection of the schools

In Mexico, information about location and distribution of people according to their surnames is not available. Therefore, the selection of the schools was done following two indicators: 1) the location and concentration of Mayan speakers in the city, from official census sources and 2) the location and concentration of people with the lowest level of income in the city. Maya language use and low income characterize urban people with Mayan ancestry.

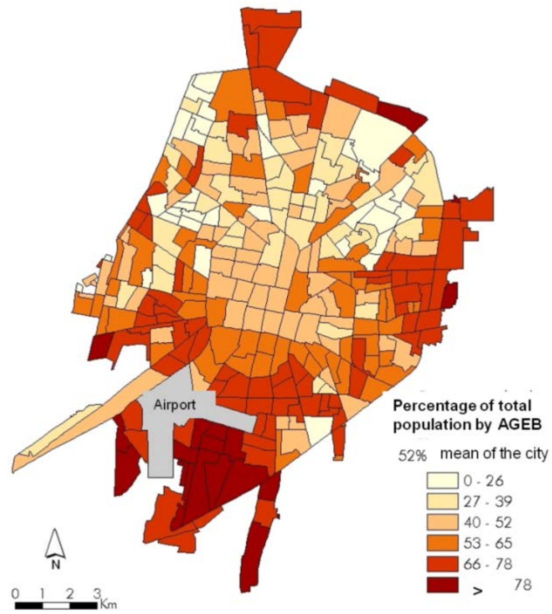
Figure 5.4 shows the location and concentration of Yucatec Mayan speakers in the city. Figure 5.5 shows the location and concentration of people with an income below 2 minimum wages. As can be seen, both maps show significantly similarity, meaning that Maya speakers and people with very low income are located and concentrated in the same areas of the city.

Figure 5.4 Location and concentration of Maya speakers in Merida in 2000



Source: López-Falfán, 2008. *AGEB*: basic geo-statistical area, each *AGEB* can contain one or more neighbourhoods.

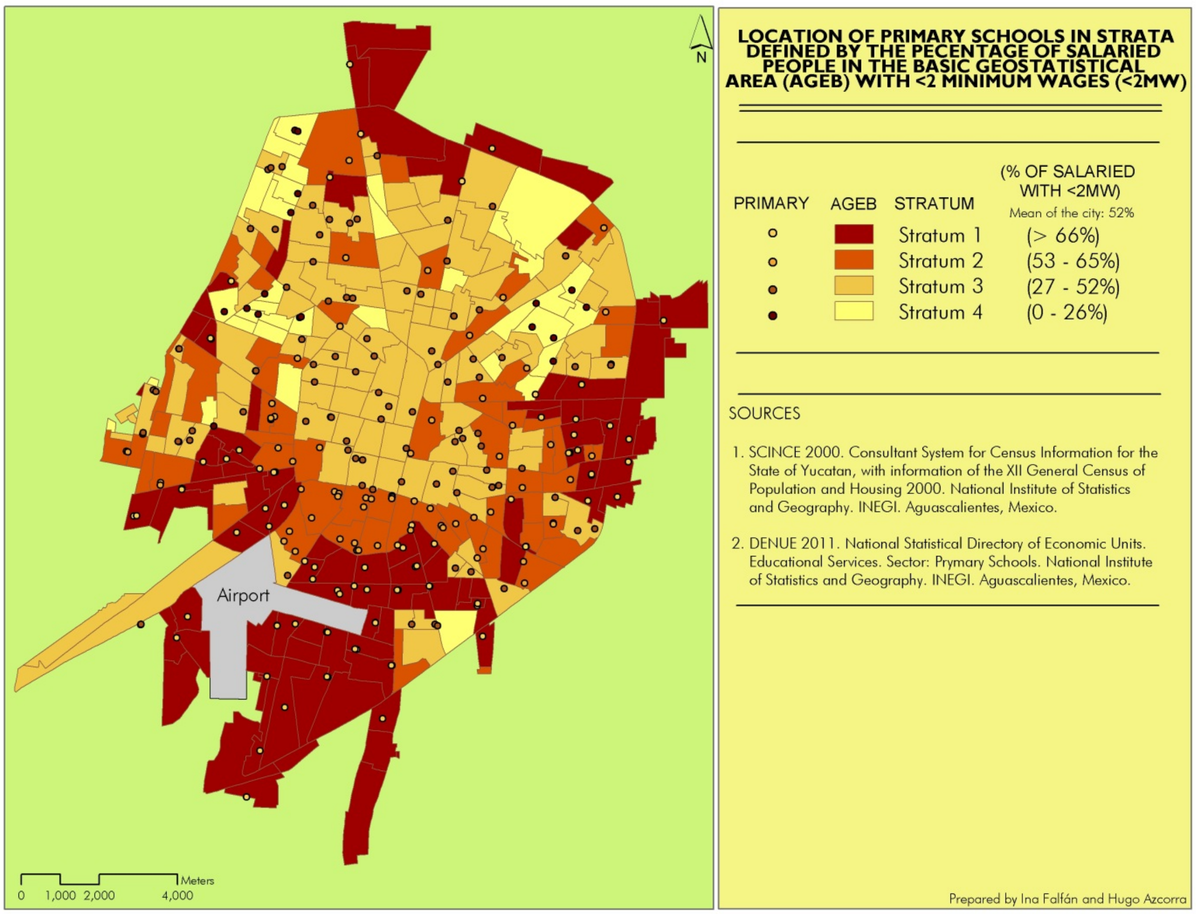
Figure 5.5 Location and concentration of people with ≤2 minimum wages in Merida in 2000



Source: López-Falfán, 2008. *AGEB*: basic geo-statistical area, each *AGEB* can contain one or more neighbourhoods. In 2002 1 minimum wage was equivalent to £ 3.

Since maps of Figures 5.4 and 5.5 were very similar, we used the map of income to produce a new map (Figure 5.6) dividing the city into four strata according to the percentage of people that receive up to two minimum wages per month (1 minimum wage was equivalent to £ 3). We reduced the numbers of strata for operational purposes of the research. Dividing the study area into a smaller number of strata allowed us to organize the data collection more effectively while maintaining the representativeness of the sample under study. Using datasets from the Ministry of Education and the National Institute of Statistics and Geography of Mexico we introduced into the new map all existing primary schools in the four strata (Figure 5.6). The strata 1 included the schools where we expected to find the largest number of children with Mayan surnames and parents with low income. We expected that as we move to the strata 2 and 3 we would find fewer children with Maya surnames belonging to families with relatively higher incomes. We decided to include, in strata 4, only private schools that in Merida are concentrated in the north and people who attend them tend to come from families of very high income and of non-Maya ancestry. Unpublished results (Laboratory of Somatology at the Department of Human Ecology, *CINVESTAV*, Merida, Mexico) of a study completed in 2011 showed that in a sample of 993 students of public and private schools in Merida, there was not a single case of a child with two Maya surnames attending private schools.

Figure 5.6 Location of primary schools in Merida



The strata were defined according to the percentage of people receiving two minimum wages per month. In 2002, 1 minimum wage was equivalent to £ 3.

Table 5.1 shows the number of schools located in each stratum. For this research we decided to focus only in the schools of the strata 1. Of the 91 schools located in the strata 1, we randomly selected 20 of them (25%). In order to include a larger number of schools and give more socioeconomic variability to the sample, we decided to include in the study no more than 10 children per school. In those schools where more than this number of children met the inclusion criteria, just 10 children were randomly selected. Apparently 12 schools would be sufficient to cover the required sample size. However, according to our research experience in Merida, several situations could reduce the possibilities to get participants in schools. For example, some directors of schools could refuse to participate in the research, even if we have the permission of authorities of the Ministry of Education. Another situation is that in some circumstances only 50% of mothers attended to the informative meetings in schools. Maybe the most important situation is that it was a volunteer study, in which the participants could refuse to participate even if they began their participation. Therefore we visited all 20 schools to recruit participants. The 20 randomly selected schools are geographically distributed in the south, west and east of Merida, although as we previously noted the most of them (60%) were concentrated in the south of the city.

Table 5.1 Number of schools by strata and type

Strata	Type of schools	Number of schools
1		91
2	Public	61
3		89
4	Private	116
Total		357

It is important to state that this research is part of an on-going research project (*Doble carga nutricional e influencias intergeneracionales en familias mayas urbanas de Mérida, Yucatán*) funded by the National Council of Science and Technology of Mexico. Colleagues from *CINVESTAV*-Merida are currently recruiting participants in strata 2 and 3.

5.2.4.2 Procedure for participants' recruitment

Participant's recruitment was made at the selected primary schools. In Mexico the primary education is compulsory. According to the Ministry of Education of Yucatan 97% of the children attend the primary school, and the percentage for urban settings, like

Merida, is higher. Given this data we are sure that all children that meet with inclusion criteria and live in selected zones of Merida had the same chance to be included in the study.

As a first step we submitted the research protocol to the Ministry of Education of Yucatan to get approval to carry out the study in selected schools. Once we received the approval we visited each school and explained to each director the purposes of the research. Most directors asked us to corroborate the authenticity of the permission letter that we showed. We noticed that directors showed a very cautious attitude to our work especially at the first schools. The common reason of directors was the security of the children. After one or two weeks, most directors allowed us to check the birth certificates of all children between 6 and 8 years of age. In Mexico the birth certificates have the full name of children and parents and we used them to identify those children and their mothers with at least the maternal Maya surname, and then invited their mothers to an informative meeting in the school. We designed formal invitations (Appendix 1) to the mothers. Teachers of schools gave the invitations to the mothers a week before the meeting. The invitations described briefly who we are and explained that their child was selected to participate in a research study related to physical growth during childhood. During the meetings we explained to the mothers the purpose of the study and obtained information about maternal grandmothers of children. In all cases the mothers gave us the required information, which was recorded on a specially designed format (Appendix 2). In most of the meetings mothers asked specific questions related with their participation. All questions were clearly answered aiming to reassure the mothers. Finally, we asked the mothers if they would like to participate in the study. In some cases it was necessary to talk individually to each mother trying to create an atmosphere of trust and to stimulate them to take part in the study. The women that agreed to participate were asked for their address and phone number to make an appointment to begin the process of obtaining information. The time period between the first contact with a school director and the informative meeting with mothers lasted between 2 and 3 weeks.

5.3 Data collection

5.3.1 Community introduction

The research was carried out in conjunction with the Human Ecology Department of the Research and Advanced Studies Center of the National Polytechnic Institute of Mexico (*CINVESTAV*-Merida). The data collection was carried out with research assistants of *CINVESTAV*-Merida and students of nutrition from local universities. The author of this thesis has extensive experience in research in the south of Merida. This experience has allowed him to have a broad knowledge of the social dynamics of the area, the cultural practices and the main services available, such as schools, health and communitarian centres.

The assistance of research colleagues and other students was very important. The daily organization of the fieldwork included several activities: 1) to phone the mothers and grandmothers who accepted to participate in the study and make appointments with them, 2) to organize the questionnaires used to obtain information, 3) to make anthropometric measurements in schools and homes, 4) to apply questionnaires in homes, and 5) to organize the feedback of results to the mothers and grandmothers about nutritional status of participants.

5.3.2 Physical measures

5.3.2.1 Anthropometry

Nutritional status of children, mothers and grandmothers was assessed by anthropometry. Table 5.2 shows the measures taken, by generation.

Table 5.2 Anthropometric measurements taken in children, mothers and grandmothers

Measurements	Children	Mothers	Grandmothers
Weight	✓	✓	✓
Height	✓	✓	✓
Sitting height (SH)	✓	✓	✓
Knee height (KH)	✓	✓	✓
Upper arm length	✓	✓	✓
Mid-arm circumference	✓	✓	✓
Waist circumference (WC)	✓	✓	✓
Hip circumference (HC)	✓	✓	✓
Tricipital skinfold (TS)	✓	✓	✓
Subscapular skinfold (SS)	✓	✓	✓
Iliac skinfold (IS)	✓	✗	✗

Training and reliability

The anthropometric measurements in children were taken by Hugo Azcorra (HA), Graciela Valentin (GV) and Frida Gutierrez (FG). For ethical reasons adult women (mothers and grandmothers) and girls were measured just by women (GV and FG). HA and GV have extensive experience in taking anthropometric measurements in research. FG was trained in anthropometry by GV and HA. Anthropometric standardization was made in *CINVESTAV*-Merida. During August 2011 we measured 10 non-participants children and 10 non-participants adult women to measure the inter-observer variation. Inter-observer variation was considered appropriate if it was within the technical error of measurement ± 5%.

Measures and anthropometric techniques used

With the exception of knee height (KH), all the anthropometric measurements were taken following the manual reference of Lohman et al. (1988). Measurements were taken by the measurer in the left side of the body and recorded by an assistant. During measurements the measurer said aloud the measurement and the assistant repeated and recorded it in the anthropometric sheet (Appendix 3). The assistant also helped the measurer giving her or him the anthropometric equipment and verifying the correct application of anthropometric technique. Children were measured at schools in bare feet and wearing shorts and sleeveless shirts. Mothers and grandmothers were measured at homes using thin cloth shorts and sleeveless shirts provided by the research team. Except for skinfolds, all other measurements were taken in centimetres.

Weight

Any added object to the body such as watches, bracelets, necklaces and others were removed from the participants before starting the measurement. The subjects were asked then to step on the middle of the scale (SECA, model 881, with 0.05 kg of precision and an error of $\pm$0.25%) in bare feet, look straight ahead and keep this position. The reading was taken approximately three seconds after the display was stabilized. The scale was calibrated with a tare of known weight before the start of each anthropometric measurement.

Height

The measurement was taken using a moveable Martin type anthropometer. The participants were asked to stand on a flat surface in bare feet with their heels together and toes slightly pointed. In those cases where the subjects had knock knees, they were asked to separate their feet so that the medial borders of the knees were in contact but not overlapping. The subjects were asked to keep the arms hanging freely by the sides of the trunk, with the palms facing the thighs. The measurer positioned the head's subject in the Frankfort Horizontal Plane and ensured that the subject stands straight. The anthropometer was held behind participant's left heel and the arm aligned with the sagittal crest. The participants were asked then to inhale deeply and keep a fully erect position. Standing in front of the participant, the assistant ensured the correct alignment of the anthropometer. The measurement was taken during inhalation moving the arm onto the most superior point of the head.

Sitting height (SH)

The participants were asked to sit on a table, located on a flat surface, with the legs hanging freely and the hands resting on the thighs. The back of the knees were kept near to the edge of the table but not in contact with it. The measurer positioned the head's subject in the Frankfort Horizontal Plane and kept it placing his left hand under the participant's chin. The measurer also ensured that the subject sits erect by applying gentle pressure over the lumbar area of the back. The anthropometer was placed on the table just behind the participant, slightly to the left side of the body to align the arm of the anthropometer with the sagittal crest. The participants were asked to inhale deeply and keep an erect position. Just after the assistant ensured the correct alignment of the anthropometer, the measurement was taken during inhalation moving the arm onto the most superior point of the head. The measurement was taken with the same anthropometer used in height measurement.

Knee height (KH)

Participants were asked to sit on a chair in bare feet; the leg was oriented to ensure a 90º angle in the left knee. The chair was placed on a flat surface. The KH was measured as the distance between the superior edge of the patella and the floor. The anthropometer was located on the ground on one side of the heel and the arm over the superior edge of the patella. To ensure the location of superior edge of the patella the measurer was placed facing the left knee of the participant and asked her to bend and straighten the knee two or three times. Located in front of the subject and behind the measurer, the assistant ensured that the lower leg and anthropometer were straight.

Upper arm length

Participants were asked to stand on flat surface and flex to 90º the left arm. The measurer stood behind the subjects and located the lateral tip of the acromion with the left hand. The assistant then made a small mark with a pen just over the point indicated by the measurer. The distance between the acromial process and the mark was taken using large callipers. Subsequently, keeping one jaw of the calliper over the acromion, the inferior jaw of the calliper was moved to the half of the segment and a mark was made by the assistant to identify the half upper arm length.

Mid-arm circumference

The participants were asked to stand on flat surface with left arm relaxed, the elbow extended and the palm facing the thigh. The measurer stood facing the left side of the trunk. The subjects were asked to separate slightly the arm from the trunk and the measurer placed the tape in a horizontal plane around the arm just over the mark of the half upper arm length. The tape was placed touching the skin of participant but not compressing the soft tissues. The assistant ensured that the tape was placed in a horizontal plane around the arm. The measurement was taken using a fiberglass tape Seca®. The tapes were replaced two times during fieldwork due to loss of firmness.

Waist circumference (WC)

The participants were asked to stand on a flat surface with their heels together and toes slightly pointed. The measurer stood in front of the subject and located the upper ridge of the left iliac crest with the ring finger and the last non-floating left rib with the index finger. The assistant made a mark with a pen on the skin at the midpoint of these bony structures. The measurer then placed the tape around the body exactly over the mark. The assistant helped to ensure the tape be in a horizontal plane around the body. In both children and adult women WC was taken directly on the skin.

Hip circumference (HC)

The participants were asked to stand erect on a flat surface with their heels together, toes slightly pointed and the arms crossed with the hands touching the shoulders. The measurer stood in the left side of the subject and placed the tape in a horizontal plane just over at the maximum extension of the buttocks. The assistant helped to keep the tape in the horizontal plane. HC was measured over thin cloth shorts.

Skinfolds

Triceps skinfold (TS), subscapular skinfold (SS) and suprailiac skinfold (IS) were taken in children and TS and SS were taken in mothers and grandmothers. For all skinfold measurements the measurer held the caliper with the right hand; the thumb and index finger of the left hand were used to grasp and elevate a fold of skin and subcutaneous fat approximately 1 cm proximal to the site of measurement. The thumb and index finger were placed, during skin elevation, about 8 cm apart on a perpendicular axis to the skinfold to be measured. Once the skinfold was elevated, the caliper was placed on the skinfold releasing the jaws very gently and maintaining the grasp of the skinfold. The measurement was taken four seconds after the pressure of the caliper was released and finally the caliper was removed carefully. Each measurement was taken three times and the average was used for calculations.

In order to take TS, the posterior half upper arm length was identified and marked. To make that, the measurer placed the tape in a horizontal plane just over the mark of the mid-arm circumference and a mark was then made by the assistant over the midline of the posterior portion of the arm. Standing behind participant the measurer elevated the fold vertically and placed the jaws of caliper so that the thickness of the fold was measured perpendicular to its long axis when the pressure of the caliper was released. During measurement the participants remained stood with the arms relaxed.

For SS measurement the participant was asked to stand with the arms relaxed at the sides of the trunk. Standing behind the participant, the measurer firstly located the inferior angle of the left scapula. In some cases, especially in obese people, it was necessary to ask the participants to bend the elbow and place the arm behind the back. The fold was taken by the measurer diagonally inclined approximately at 45º to the horizontal plane. The clothes provided to mothers allowed taking easily this measurement directly on the skin.

For IS the participant was asked to keep an erect position with the feet together and the left hand crossed on the right shoulder. The fold was taken in the midaxillary line obliquely approximately at 45º just over the iliac crest.

5.3.2.2 Bioelectric impedance

Bioelectric impedance analysis (BIA) was used in children and adults to estimate fat mass and fat free mass. Bioelectric impedance was applied, after the anthropometry was done, using a Bodystat 1500 MDD Body Composition Monitoring Unit, Bodystat Ltd. During BIA children and adult women were asked to lie on a movable bed in bare feet without any metal jewellery in the body. The assistant ensured that the participant's legs were slightly apart and the arms were not touching the trunk. The electrode pads were attached in the right hand just behind the knuckle of the middle finger and on the wrist next to ulna head. On the right foot, the electrodes were attached behind the second toe next to the big toe and on the ankle between the medial and lateral malleoli (Figures 5.7 and 5.8). In order to get more reliability on BIA measurements, children were measured during mornings in schools two hours after they ate the breakfast and before they take breaks and exercise sessions. In so far as during menstrual period women very frequently experience edema, pre-menopausal mothers and grandmothers were measured seven days before or seven days after their menstrual period. Mothers and grandmothers were visited in homes mainly during mornings before they start daily activities out of home.

Figure 5.7 Bioelectrical impedance applied to a child

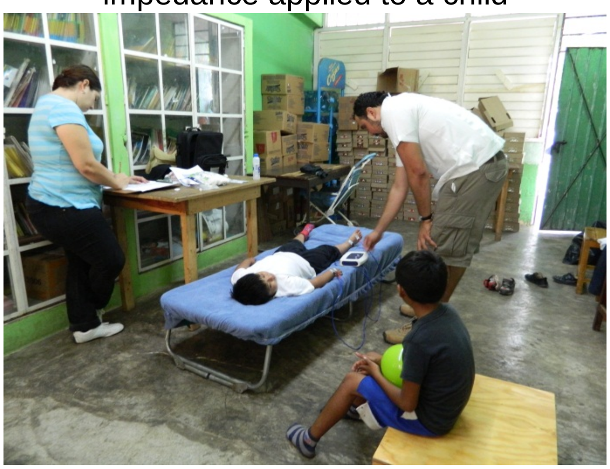


Figure 5.8 Bioelectrical impedance applied to a mother

5.3.3 Interviews

5.3.3.1 Design and content

The interview was designed and refined between January and July 2011. The content of the interview was discussed in several meetings with supervisor Dr. Maria Ines Varela-Silva from Loughborough University, and with research colleagues of *CINVESTAV*-Merida before to initiate the fieldwork. Dr. Federico Dickinson (researcher of Human

Ecology Department) and his research assistant Biol. Graciela Valentin (GV), M Sc. Ina Lopez and nutritionist Ana Andrade of *CINVESTAV* contributed significantly. The interview was initially written in English and then translated into Spanish by Hugo Azcorra, being the latter his native language.

The interview was designed so that the questions were answered by the children's mothers and grandmothers. The interview was organized in four sections (Appendix 3). The first section was concerned with the socioeconomic conditions of the family, and included questions about the living conditions of participants, among these, family size, number of rooms used to sleep, type of water to drink, availability of a toilet at home, type of construction materials of the household and household assets. Additionally, we included questions about the age, schooling, occupation, and income of each family member.

The second section focused on children´s biology, and included two groups of questions. The first addressed some relevant antenatal events, such as age at pregnancy, length of gestation and antenatal care. Additionally, questions about the presence of preeclampsia, eclampsia, diabetes and infectious diseases during pregnancy were made. The second group of questions addressed specific postnatal events of the child, including type of delivery, birth weight, number of siblings, birth order and inter-birth period. Birth certificates were used to corroborate the birth weight and length of gestation. Additionally, information about length of breastfeeding, age of weaning, and health conditions during the first years of life was obtained. Information about the type of medical service and grandparents' participation in the children's care was also asked.

The third section of the interview, aimed to obtain data about the mother (F_2), was divided into two groups of questions. The first one asked information about living conditions during mother's childhood (place of birth and growing up, family size, number of rooms used to sleep, type of water to drink, availability of a toilet at home, constructions materials of the house, household assets, and parents' occupation). The second group of questions regarded the current situation of the mother, such as marital status, presence of illnesses and questions about empowering. Maternal empowerment was explored by asking them who used to make decisions in the household, such as how much money is spent, what will be eaten during the day and how much money is spent on medical service and drugs.

The fourth section addressed to obtain information about the grandmothers (F_1). In general, we asked the same questions of grandmothers as mothers. Additionally grandmothers were asked about their schooling, number of offspring, age at first pregnancy and age at which she was pregnant with the studied child's mother.

Into the third and fourth section, both mothers and grandmothers were asked about whether, during childhood and adolescence, they experienced situations such as: serious illness or death of parents, divorce or separation of parents, job loss of parents, and alcoholism in the immediate family. Women were asked whether any of these situations affected them and if the effect was in each case economic, emotional or in their health.

5.3.3.2 Interviewer training and reliability

Four trained interviewers collected data during the fieldwork. All of them had had previous experience applying similar kind of interviews in Merida. The procedure of application was discussed by interviewers during several meetings. During the pilot phase of the project each interviewer applied five interviews with non-participants families from the research place. After the pilot project the interviewers discussed and made necessary adjustments to the questionnaires.

5.3.3.3 Interview procedure

After obtaining the addresses and phone numbers of participants, we contacted the mothers in order to make an appointment to visit them. However it was not easy, especially because many working mothers could only be contacted after several phone calls. In some cases it was necessary to make direct visits because telephone numbers provided by mothers were incorrect or unavailable. Once we contacted the mothers, they decided the day and hour of the visit. Most of the mothers gave us an appointment during the next 3-5 days. During call phones mothers provided also information about their menstrual cycle. As it was written before, bioelectric impedance was only applied in mothers and grandmothers seven days before or seven days after their menstrual period. Only 6% of the grandmothers were still having menses during research. Visits to the grandmothers were made through several strategies. In most cases mothers gave us the address of the grandmothers and then we visited them. Occasionally we visited the mother and grandmother when they were together. Sometimes the mothers went with us to their mother’s house. This strategy was particularly useful when grandmothers lived outside the city. We encouraged the mothers and grandmothers to be visited together. However it was not always possible due to the distance between mothers and grandmothers houses. Some grandmothers, who lived outside Merida, preferred to come to the city to be measured and interviewed. In those cases we refunded transportation expenses. On average, it took one or two weeks to gather information following initial contact with the mother.

The interviews were conducted in the homes of the mothers’ and grandmothers’ most of them (72/109) by HA. In general, women were not uncomfortable to be interviewed by a man. The rest of the interviews were conducted by GV (22/109) and FG (15/109).

In order to establish a rapport during the interview the questions were made by the interviewer using fluid, informal conversation. Each interviewer had his/her own style and pace. On average, interviews with the mothers lasted between 20 and 30 minutes and between 15 and 20 minutes with the grandmothers. In some cases mothers helped the interviewer to ask questions of the grandmother. This situation was only necessary when grandmothers were not fluent in Spanish. However, almost all grandmothers could easily understand the questions of the interview.

5.4 Ethical considerations

The research was approved by the Ethical Advisory Committee of Loughborough University (R11-P133) and by the *Comité de Bioética para el Estudio con Seres Humanos* (Bioethics Committee for the Study of Human Beings) of CINVESTAV. Additionally, we obtained authorization from the Ministry of Education of Yucatan to recruit children in selected schools. In the next lines we describe the ethics care developed during each stage of the research.

5.4.1 Participants' recruitment

During the information sessions mothers and grandmothers were informed in detail about the purposes of the study and their rights as participants. It was explained to them that the study would involve gathering anthropometric measures and socioeconomic information from children, mothers and grandmothers. It was emphasized that their participation was strictly voluntary and that they could choose to stop participating at any stage of the study. Mothers and grandmothers were invited to discuss with their husbands their decision to participate in the study. In such cases women were contacted 2 or 3 days later by telephone to know their decision. In some cases, husbands were also informed about the purposes of the study and all the implications of participation.

Additionally, during these meetings mothers were informed that, after the collection of data, they would receive the anthropometric diagnostic of their children. In Mexico, nutritionists are trained and legally qualified to give nutritional diagnosis. Most of the research team members, including myself (Ph.D. student), are nutritionists. The nutritional diagnosis included the examination of children's height and BMI and mothers and grandmothers BMI and recommended healthy weight (Appendix 4). During feedback meetings we also organized a talk about Nutrition on the family, in which mothers and grandmothers received recommendations about nutrition.

5.4.2 Participants measurement

5.4.2.1 Children measurement

All mothers signed the consent forms before their children were measured. Additionally mothers were invited to attend the anthropometric measurements at schools. During these sessions the purpose of each anthropometric measurement taken was explained to mothers and children. All mothers agreed that their children were measured using shorts and sleeveless shirts, provided by the research team.

In order to maintain the privacy of children during measuring, the directors of schools assigned us a room where the measurements were taken. The research team ensured that the door and windows of the room were closed during measurements. Beside research team members and mothers, no other person was allowed to remain during measurements. Mothers were informed that they could withdraw their children if they were uncomfortable with any measurement.

5.4.2.2 Adult women measurement

All adult women signed the consent forms before they were measured at homes. For ethical and cultural reasons, all mothers and grandmothers were only measured by women (GV and FG). Measurer and recorder ensured the privacy of women during measurements. All mothers and grandmothers agreed to be measured using shorts and sleeveless shirts, even the grandmothers who were visited in rural communities where the traditional dress is different. For cultural reasons no man was present during measurement of women but fortunately no husband disapproved of his wife being measured.

5.4.3 Interviews

We provided the mothers and grandmothers with a general explanation about the purposes of the interview. They were also informed during the meetings and home visits that they could refuse to answer any question if they felt uncomfortable. Mothers and grandmothers were interviewed separately. However in some cases mothers and grandmothers helped themselves to answer questions related to their childhood. Only participant and interviewer were present during interview application.

5.5 Data handling

5.5.1 Data input and cleaning

After completing a case, each questionnaire was reviewed to identify any mistake or missing data. In those cases where a mistake or missing data was found, the research team obtained the correct information in the field. Then the completed and reviewed interviews were stored for capture. The dataset template was created before starting the fieldwork. Anthropometric and socioeconomic data were fully captured by Ina Falfán (IF), who has an extensive experience in data management and analyses. The data were initially captured in Microsoft Office Excel 2003 software and then exported to Stata 12 for analyses. For security reasons the data set was only stored in a computer without internet access. After each day of data capture the dataset was also stored in two external memory disks. Only IF and HA had access to the computer and the external disks.

Dataset cleaning consisted basically on verifying the matching between dataset and questionnaires in all the participants. This process was made by HA and FG during three weeks. Fifteen mistakes of capture in 5450 observations (0.28%) were found in anthropometry, and four mistakes of capture in 654 observations (0.92%) were found in the bioimpedance data. We found 43 mistakes of capture in 25,724 (0.17%) observations in all socioeconomic data. All of these mistakes were corrected.

5.5.2 Derived variables

5.5.2.1 Anthropometry

Table 5.3 shows the anthropometric derived variables in children, mothers and grandmothers. Percentiles and z-scores of height, SH, SHR and LL and skinfolds were calculated in children and adult women using the growth reference values published by Frisancho (2008). For this research we used the sex and age specific comprehensive reference which use data from the National Health and Nutrition Examination Survey III (1994-1998). The comprehensive reference allows determining the percentile and z-score values of children and adults ranging from 2 months to 90 years of age, and is the only reference chart that includes Mexican children, which it makes more appropriate to use in this research. Percentiles and z-scores of weight and WC were only calculated in children. Equations of SHR, LL, RLLI, KHR, BMI and WHR were:

- SHR (sitting height ratio) = (sitting height / height) * 100
- LL (leg length) = height – sitting height
- RLLI (relative leg length index) = leg length x 100 / height
- KHR (knee height ratio) = (knee height / height) * 100
- BMI (body mass index) = weight (kg) / height (m) ^{2}
- WHR (waist-to-hip ratio) = (waist circumference / hip circumference) * 100

Leg length was calculated indirectly by subtracting the sitting height to the total height. Skinfold measurements were taken three times; mean was calculated to each of these. Sum of skinfolds was also calculated in each generation.

Table 5.3 Derived variables using anthropometric techniques

Variables	Children	Mothers	Grandmothers
Height-for-age percentiles/z-scores	✓	✓	✓
SH-for-age percentiles/z-scores	✓	✓	✓
SHR (%)	✓	✓	✓
SHR percentiles/z-scores	✓	✓	✓
KHR (%)	✓	✓	✓
LL (cm)	✓	✓	✓
LL-for-age percentiles/z-scores	✓	✓	✓
RLLI (%)	✓	✓	✓
Weight-for-age percentiles/z-scores	✓	-	-
BMI (kg/m^2)	✓	✓	✓
BMI-for-age percentiles/z-scores	✓	-	-
WC-for-age percentiles/z-score	✓	-	-
WHR	-	✓	✓
Mean of TS (mm)	✓	✓	✓
TS-for-age percentiles/z-score	✓	✓	✓
Mean of SS (mm)	✓	✓	✓
SS-for-age percentiles/z-score	✓	✓	✓
Mean of IS (mm)	✓	-	-
IS-for-age percentiles/z-score	✓	-	-
Sum of skinfolds (SumSkf) (mm)	✓	✓	✓
SumSkf-for-age percentiles/z-scores	✓	✓	✓

SH: Sitting height; SHR: Sitting height ratio; KHR: Knee height ratio; LL: Leg length; RLLI: Relative leg length index; BMI: Body mass index; WC: Waist circumference; WHR: Waist-to-hip-ratio, TS: Tricipital skinfold; SS: Suprailiac skinfold; IS: Iliac skinfold.

5.5.2.2 Bioelectric impedance

Children's fat-free mass was estimated using an equation recently developed by Ramírez et al. (2012). The equation was developed in a sample of 336 Mexican school children (6-to-14 years of age) of different geographical regions (Northern, Central and Southern) and ethnicity based on deuterium oxide dilution technique. Forty-three percent of them belong to six major indigenous groups, including the Maya from Yucatan. Fat-free mass (FFM) was calculated using resistance, stature, and weight (Equation 1), and then converted to fat mass (FM), %BF (percentage of body fat) and %LBM (lean body mass percentage). The equation had a bias of 0.095 kg and a precision of 1.43 kg.

Equation 1:

Children's fat-free mass (kg) = 0.661 x stature $(cm)^2$ / resistance (Ω) + 0.200 x weight (kg) – 0.320

Since there is no specific equation for Mexican adult women, we used Equation 2 calculated for North American Indian women from the southwest of the United States (Stolarczyk et al., 1994). This equation was used in mothers and grandmothers to estimate FFM. The study that allowed the development of this equation included 151 women (18-60 years of age) from six indigenous tribes of Arizona, South Dakota and New Mexico in the United States. The equation was compared to three other bioelectric impedance predictive equations to determine the most accurate equation. The developed predictive equation was also highly correlated (R^2 = 0.803) with the hydrodensitometry measurement with a standard estimate of error of 2.63 kg for fat-free mass.

Equation 2:

Women's fat-free mass = 0.001254 x stature (cm^2) – 0.04904 x resistance (Ω) + 0.1555 x weight (kg) + 0.1417 x reactance (Ω) – 0.0833 x age (years) + 20.05

Among both children and adult women (mothers and grandmothers) equations of FM, %BF and %LBM were:

FM = weight (kg) – fat-free mass (kg)

%BF = fat mass (kg) x 100 / weight (kg)

%LBM = fat free mas x 100 / weight (kg)

5.5.2.3 Socioeconomic data

Table 5.4 shows the socioeconomic derived variables. These variables were used both for descriptive and inferential purposes.

Table 5.4 Socioeconomic derived variables

Derived variables	Type of variable
If the child's father live with the family (yes/no)	Dichotomous
If the grandmother (F_1) live with the child's family (yes/no)	Dichotomous
Overcrowding index in the child's family*	Continuous
Family income (child's family) in pesos	Continuous
Familial contribution to living expenses in Mexican pesos	Continuous
Percentage of father's income addressed to living expenses	Continuous
Percentage of mother's income addressed to living expenses	Continuous
Inter-birth interval of studied child in months	Continuous
If the mother (F_2) was born in Merida city (yes/no)	Dichotomous
If the mother (F_2) grew up in Mérida city (yes/no)	Dichotomous
Overcrowding index in the mother's house during her childhood*	Continuous
If the mother (F_2) is currently working (yes/no)	Dichotomous
If the grandmother (F_3) was born in Merida city (yes/no)	Dichotomous
If the grandmother (F_3) grew up in Mérida city (yes/no)	Dichotomous
Overcrowding index in the grandmother's house during her childhood*	Continuous
If the grandmother is currently working (yes/no)	Dichotomous

*Overcrowding index was calculated dividing the number of person at home by the number of rooms used to sleep.

5.6 Data analysis

Analysis of the first and second result chapters (living conditions and nutritional status participants) are described in this section. The analysis used in the third and fourth result chapters (socioeconomic and biological factors that shape the physical growth of children and intergenerational influences on the growth of participants) are described at the beginning of each result chapter.

5.6.1 General living conditions of the families

Living conditions of the participants were described using descriptive statistics. Frequencies and percentages were calculated to define socio-demographic data of family members and characteristics of the housing and household sanitation, such as family size, number of offspring, parental education and occupation, number of rooms used to sleep, type of water to drink, construction materials of the households, toilet availability at home and household assets. Dispersion statistics (median, interquartile range and minimum/maximum values) were calculated for some data, such as parental income, monetary contribution and familial expenditures.

Similarly, percentages and descriptive statistics (means and standard deviations) were generated to describe relevant antenatal and postnatal data of children, among these, mothers' age at pregnancy, antenatal care, child birth weight, length of gestation, inter-birth period, and illnesses in children.

5.6.2 Nutritional status and nutritional dual burden in participants

Nutritional status of participants was determined by comparing the studied participants' anthropometric values with reference values from Frisancho (2008). This comparison allowed us to anthropometrically classify the children, mothers and grandmothers.

Frisancho (2008) proposes five categories of anthropometric nutritional status based on percentiles and z-scores (Table 5.5).

Table 5.5 Nutritional status categories according to percentiles and z-score values proposed by Frisancho

Categories of nutritional status	Percentiles	z-score values
Low	below the 5th percentile	less than -1.650
Below range	5 to 15th percentile	between -1.645 and -1.040
Healthy range	15.1 to 85th percentile	between -1.036 and +1.030
Above average	85.1 to 95th percentile	between +1.036 and +1.640
Excessive	above the 95.1th percentile	greater than +1.645

5.6.2.1 Nutritional status of children

Descriptive statistics (mean and standard deviations) for most of anthropometric variables (raw and derived variables) are presented in tables according to children's age and sex. The prevalence of nutritional status categories (stunting, short trunk, short legs, overweight, obesity and abdominal obesity) were included in some of tables. In addition, tables with the proportion of children into the categories of anthropometric status (low, below range, healthy range, above average, and excessive) are also presented for height-for-age, SH-for-age, LL-for-age, weight-for-age, BMI-for-age and WC-for-age.

Children were classified as stunted, short trunk and short leg if they were below the 5th percentile (or z-score less than -1.650) of the reference for height-for-age, SH-for-age and LL-for-age indicators, respectively. BMI-for-age was used to determine under-and-overnutrition in children. Risk for overweight and obesity was determined when children were above 85th and 95th percentile of reference respectively. In contrast children were classified as underweight if they were below the 5th percentile for BMI. Even when waist circumference is more relevant in adult population as a health indicator, risk for abdominal obesity was determined in children when they were above the 85th percentile of reference for WC-for-age.

Since the centile curves proposed by the International Obesity Task Force – IOTF (Cole et al., 2000; Cole et al., 2007) are one of the most commonly references used to assess nutritional status of children, we additionally decided to classify the children with this references, as well. Overweight and obesity were defined when sex-and-age adjusted centile curves passed through the BMI cut-off points of 25 and 30 at 18 years old, respectively. In contrast, thinness was determined when sex-and-age adjusted centile curves were below the BMI cut-off point of 17 at 18 years of age.

Since there is no available reference for %BF specific for Mexican children, the values of %BF were used just for descriptive purposes in the results shown in chapters 8 and 9.

Unpaired t-test and Wilcoxon rank sum test were used to compare continuous variables between boys and girls. Chi-square analysis was used to compare the proportion of boys and girls between nutritional status categories.

5.6.2.2 Nutritional status of mothers and grandmothers

Since significant biological changes occur with aging, mothers and grandmothers were grouped in age categories. Descriptive statistics (mean and standard deviations) for linear growth and body mass and body composition variables (raw and derived variables) are presented in tables by age groups.

The classification of short stature in adults is controversial. Some authors (Lara-Esqueda et al., 2004; Lopez-Alvarenga et al., 2003) propose to use the cut-off of 150 cm in women, which correspond to the 4.6th percentile and -1.69 z-score of Frisancho's Comprehensive reference. The cut-off of 150 cm corresponds to the nearest whole centimetre of -1.65 z-score and 5th percentile of the Comprehensive reference. Therefore, in order to be consistent with children, mothers and grandmothers were classified as short stature (height-for-age), short trunk (SH-for-age) and legs (LL-for-age) when they were below the 5th percentile of reference.

The assessment of nutritional status of the adult Maya population according to body mass indicators is challenging. The accuracy of BMI in assessing nutritional status in adult population with high levels of stunting has been questioned in studies made in several populations (Norgan 1994; Deurenberg et al., 1999; Asao et al., 2006; Bogin and Beydoun, 2007). Stunting experienced during childhood and adolescence may result in an altered body proportion phenotype, with short legs and long trunk (Gunnell et al., 1998). In addition, a reduction of stature in BMI equation will lead to an increase of BMI. We recently found that SHR and stunting significantly alter the predictive power of BMI on body fat percentages and waist circumference in a small sample of adult Maya women from Merida, Mexico (Wilson et al., 2011).

The assessment of nutritional status of older people brings several difficulties, mainly because body composition changes significantly with age. The loss of muscle mass and the gain of fat tissue are the main processes that accompany the transition from adulthood to the elderly (Elia, 2001; Kennedy et al., 2008). The selection of nutritional indicators for old people is a matter under debate. However, some research shows the limitations of BMI as a measure of adiposity in geriatric subjects (McTigue et al., 2006; Donini et al., 2012). Some evidence suggests that older people show a greater proportion of fat mass than younger people having the same BMI (Baumgarter et al., 1995). Of relevance is the fact that ageing implies a redistribution of fat tissue in which abdominal fat tends to increase significantly (Horber et al., 1997; Zamboni et al., 1997; Baufrere and Morio, 2000). Waist circumference seems to be a stronger predictor of body fat and health-risk factors than BMI in old subjects (McTigue et al., 2006; Donini et al., 2012). In fact there is some agreement in the use of WC as a measure of abdominal obesity when adults during elderly are studied (Gutiérrez-Fisac et al., 2004; Alemán-Mateo et al., 2009; Wyka et al., 2010; Rosas-Carrasco et al., 2012).

Taking into account this fact we decided to use values of WC in this research to determine the risk of abdominal obesity in mothers and grandmothers. We chose the cut-off point of 88 cm proposed by The National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III). This cut-off point is the most commonly used by the Mexican Health authorities.

One-way Anova and Kruskal-Wallis tests were used to compare continuous anthropometric variables between age groups in mothers and grandmothers. Unpaired t-test and Wilcoxon rank sum were applied to compare anthropometry indicators between women with low and high WC values.

5.6.2.3 Nutritional dual burden

The combination of nutritional status categories already mentioned was used to determine the NDB at individual and at household level.

Nutritional dual burden at individual level

Children were classified as NDB when they showed the coexistence of stunting (< 5th percentile of reference for height-for-age) and overweight (> 85th percentile of reference for BMI-for-age). Mothers and grandmothers were classified as NDB if they showed the coexistence of short stature (< 5th percentile of reference for height-for-age) and abdominal obesity (WC > 88 cm). Since WC is a good indicator of risk for current and future health we also determined the prevalence of the coexistence of stunting and abdominal obesity (> 85^{th} percentile of reference for WC-for-age) in children.

Nutritional dual burden at household level

Household NDB was determined at two levels: in mother-child dyads and grandmother-mother-child triads. Mother-child dyads were classified as NDB when they had the combination of abdominal obesity in mothers (WC > 88 cm) and stunting in children (< 5^{th} percentile of reference for height-for-age). Since the combination of maternal abdominal obesity and underweight children (< 5^{th} percentile of reference for BMI-for-age) is relevant in terms of public health we also explored its prevalence in the participants.

Grandmother-mother-child triads were classified as NDB when they had the combination of abdominal obesity in grandmothers and mothers and stunting in children. Since the risks for health on children are also duplicated, the prevalence of the combination of abdominal obesity in children and stunting in grandmothers and mothers was also determined.

SECTION 3

RESULTS

General description of the sample

Recruitment final results

Fieldwork was launched on the first week of September 2011 visiting directors of the first selected schools. In June 2012, 109 cases had been collected and the fieldwork season that gave data for this Ph. D. thesis ended. The fieldwork was only interrupted during Christmas (18-31 of December 2011) and Easter (1-14 of April 2012) holidays. The fieldwork lasted one scholar period (September 2011 to June 2012), in which a total of 20 primary schools were visited and 109 triads of children, mothers and grandmothers were recruited (Table 6.a).

Table 6.a Cases by schools

School	F_3-F_2 dyads with Maya surnames	Mothers who attended the recruitment sessions		F_3-F_2-F_1 triads with Maya surnames	Full cases	
	n	n	%	n	n	%
1	30	19	63	15	9	60
2	60	32	53	16	10	62
3	63	36	57	24	10	42
4	27	19	71	13	7	54
5	51	20	39	13	8	62
6	32	20	62	14	6	43
7	39	18	46	13	7	54
8	13	9	69	6	2	33
9	20	3	15	2	0	0
10	10	6	60	3	1	33
11	29	13	45	11	5	45
12	29	18	62	15	9	60
13	21	6	29	4	1	25
14	22	7	32	3	1	33
15	29	8	28	6	3	50
16	24	17	71	6	3	50
17	44	18	41	13	7	54
18	69	37	54	24	11	46
19	28	10	36	3	3	100
20	36	11	31	8	6	75
Total	676	327	48	212	109	49

F_3: children; F_2: mothers; F_1: grandmothers.

Overall, 676 child-mother dyads with maternal Maya surnames were identified through birth certificates. Birth certificates were available in 100% of children who participated in the selection process. On average, 48% (n = 327) of the mothers attended the recruitment sessions conducted in schools. We believe that the reasons why 52% of mothers did not attended the sessions were due to work commitments. As we will show later, 52% of mothers work inside or outside the home. Given this situation, we decided to implement some strategies, such as to carry out the sessions at different times and send informative letters to the parents explaining the importance of the participation in the research. However, the percentage of attendance to the meetings did not change. On the other hand, the types of occupation of many mothers impeded them from attending their children’s school activities without monetary or labor implications.

We could not include most of the above mentioned cases mainly because the grandmothers did not meet the inclusion criteria (maternal Maya surname) and also because of the presence of non-biological mothers and because the maternal grandmother was dead. In general we found that mothers were comfortable to give us information about the presence of adopted children and non-biological grandmothers. After the recruitment sessions we were able to identify 212 triads (children, mothers and grandmothers) with maternal Maya surnames. Of these, 49% (n = 109) agreed to participate in the study. Unfortunately, about 20 additional mothers were never located in their homes or by telephone even when they agreed to participate in the research. It is important to note that the research team spent several days trying to locate these families through several strategies.

Most (60%) of cases were recruited in schools located in the south of Merida. As we noted in Chapter 1, the Maya population from Merida city is concentrated in this area of the city. However, in order to give more socioeconomic variation to the studied sample we decided to recruit triads in others areas of the city. According to several indicators, the families who inhabit these areas could have a better socioeconomic status. In this sense, 30% of the cases were recruited in the west and 10% in the east of the city.

The distribution of children by sex and age is shown in Table 6.b. There were no significant differences in ages between girls and boys (z = 0.815, p>0.05, Wilcoxon rank sum). In addition, after Chi-square analysis we found no significant differences in the proportion of boys and girls by age group (X^2 = 0.22, p = 0.897). In general we got a good balance in the number of children by sex and age groups. However, during recruitment we noticed some difficulty in identifying 8 year old children. We also identified that most of the women who did not attend the informative meetings were mothers of a child in that group of age.

In general, mothers of children were young (median = 31.96 years), most (63%) of them between 25 and 35 years of age and only 12% were older than 40 years old. The ages of grandmothers ranged from 43 to 78 years (median = 58.89 years) with 85% of them between 45 and 69 years (Table 6.c).

Table 6.b Age and sex distribution of children

Age groups (years)	Boys			Girls			All		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
6.00 – 6.99	17	6.59	0.23	20	6.54	0.21	37	6.56	0.22
7.00 – 7.99	21	7.40	0.28	20	7.41	0.30	41	7.40	0.29
8.00 – 8.99	15	8.65	0.25	16	8.38	0.26	31	8.51	0.29
Total	53	7.49	0.85	56	7.39	0.78	109	7.43	0.81

SD: standard deviation.

Table 6.c Distribution of mothers and grandmothers by age groups

Age groups (years)	Mothers		Grandmothers	
	n	%	n	%
20.0 – 24.9	7	7		
25.0 – 29.9	36	33		
30.0 – 34.9	33	30		
35.0 – 39.9	20	18		
40.0 – 44.9	11	10	3	3
45.0 – 49.9	2	2	13	12
50.0 – 54.9			20	18
55.0 – 59.9			24	22
60.0 – 64.9			19	17
65.0 – 69.9			17	16
70.0 – 74.9			10	9
75.0 – 79.9			3	3
Total	109	100	109	100

Mothers: min = 22.37, p25 = 28.32, p50 = 31.96, p75 = 36.74, max = 49.88; Grandmothers: min = 43.42, p25 = 52.36, p50 = 58.89, p75 = 65.80, max = 77.98.

CHAPTER 6

Results

General living conditions of the families

6. General living conditions of the families

The general aim of this chapter is to describe the living conditions of the families participating in this research. Specifically, in this chapter is described:

a) socio-demographic data of family members,
b) income and expenditures in the household,
c) characteristics of the housing and household sanitation, and
d) biological and socioeconomic variables that shape the physical growth of children.

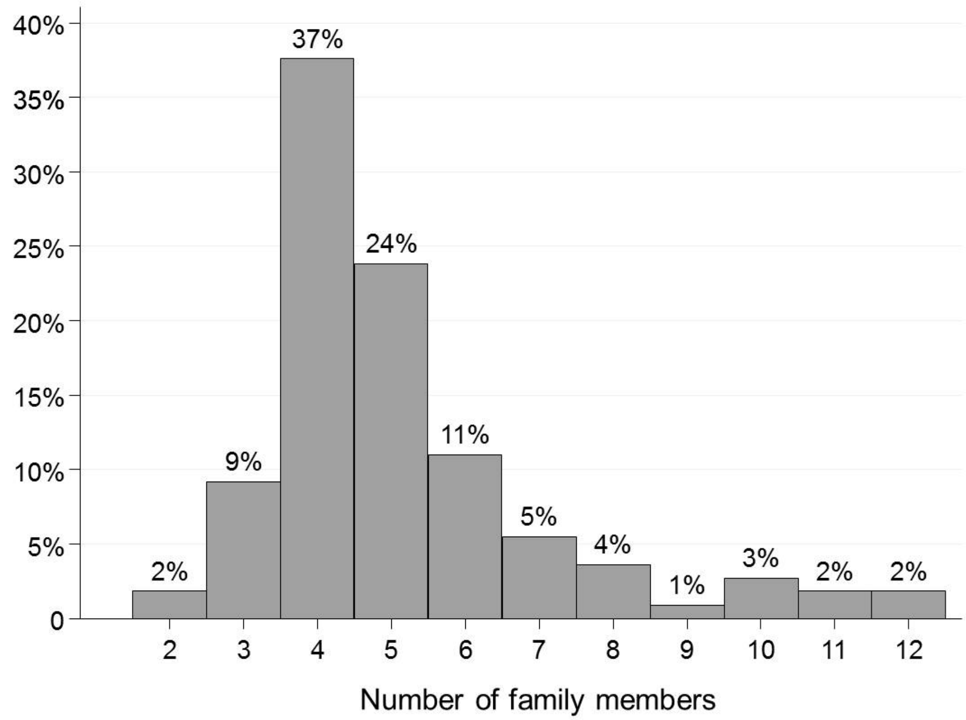
6.1 Living conditions of the families

6.1.1 General demographic data of the families

Our final sample consisted of 109 families, most of them nuclear (74% vs. 26%); 88% of studied families consisted in parents (fathers and mothers) and offspring, all other families were headed by women.

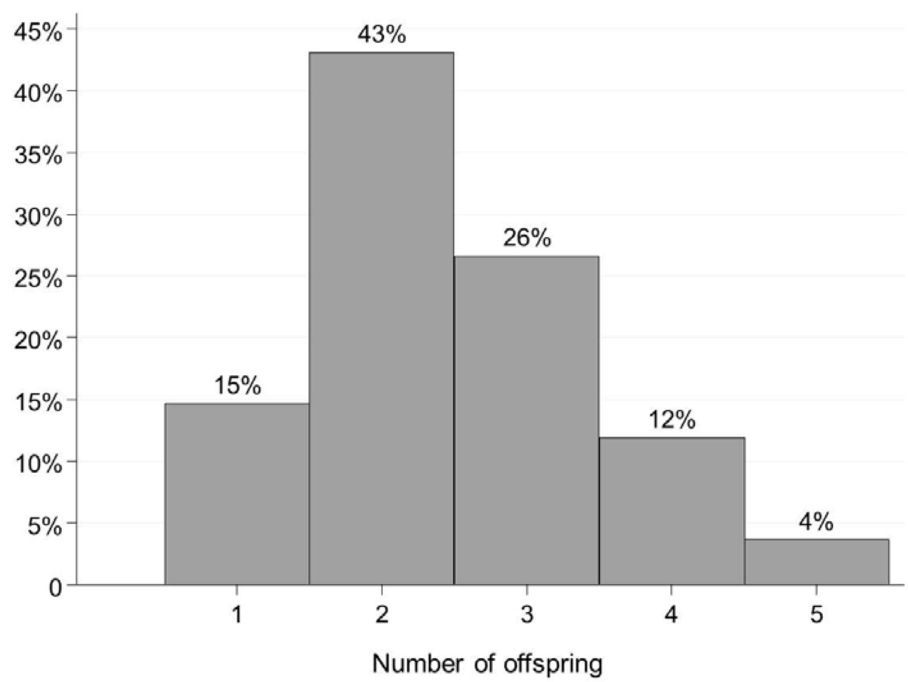
In relation to family size, we found that 11% of families consisted of 2-3 members, 72% of 4-6 members and the remaining 17% of 7-12 members (Figure 6.1). According to the National Institute of Statistic and Geography of Mexico (*INEGI* by its acronym in Spanish), in 2010, the average family size in Mexico and in Yucatan State was 3.9 members (INEGI, 2012a). In the case of our sample the average was 5.1, 1.2 members more than the state and country average. Regarding the number of offspring, 69% of the families had 2-3 children (Figure 6.2). The mean for the total sample was 2.5 (SD = 1), which is very similar to the national and state average in 2010 (2.3) (INEGI, 2012a).

Figure 6.1 Family size



Dispersion: p25 = 4, p50 = 5, p75 = 6.

Figure 6.2 Number of offspring



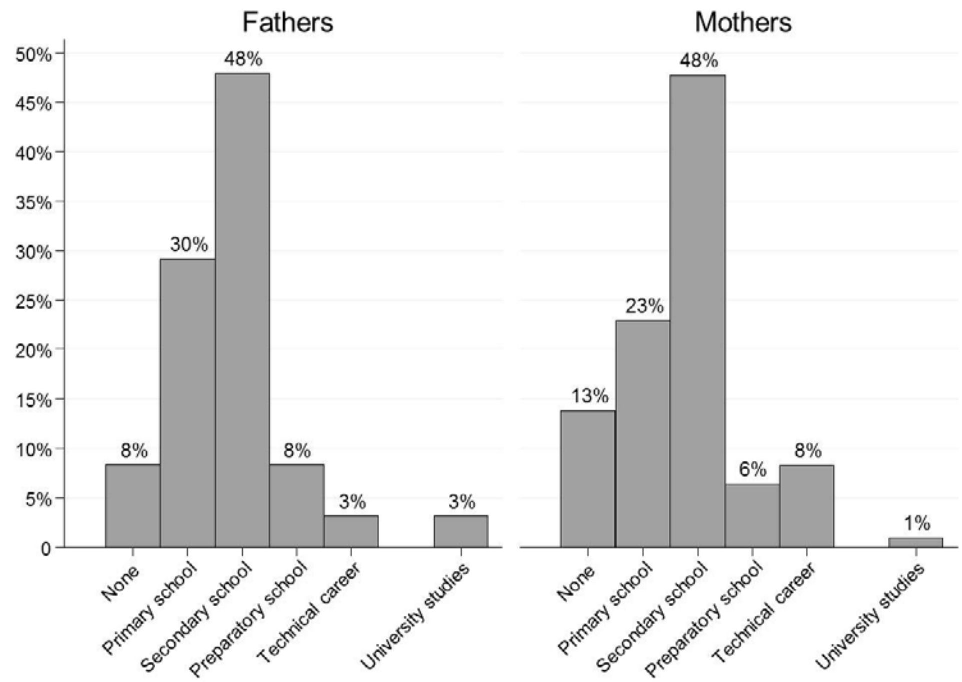
Dispersion: p25 = 2, p75 = 3.

Eighteen percent (n = 20) of grandmothers (F_1) lived with their daughter (F_2) and grandchild (F_3). The proportion of grandmothers who lived with the family is higher in the households where the father is absent (46% vs. 15%). Spanish language was used in most (94%) of the households and 5% reported to speak the combination of Spanish and Yucatec Maya language.

6.1.2 Sociodemographic data of children, parents and grandmothers

In Mexico, the formal education system is organized as follows: 6 years of primary education, 3 years of secondary education, 3 years of preparatory education and, finally, a course of professional studies, which could be technical or short careers and university studies. The median of total years of maternal education in our sample is 9. We found that 48% of women completed their secondary studies (Figure 6.3). However, the proportion of mothers with studies of primary school or less is still high (36%). In addition, 13% of children's mothers did not finish any level of formal education. The educational level of fathers is quite similar to the mothers (Figure 6.3). The median of the total years of education for them is also 9. In addition, after Chi square analysis, we found no significant differences in the proportions of mothers and fathers by level of education attained ($X^2 = 5.93$, $p = 0.31$).

Figure 6.3 Parental education level



Education is highly associated with occupation. Fifty-two percent of mothers perform a paid job, 60% of which are self-employed and 40% employees of small trades. For participants' description purposes we followed the classification of occupations used in the Population and Housing Census of Mexico 2012 (INEGI, 2012b). Twenty-three percent of women perform domestic works for other people between 1 and 3 days per week receiving around £7.50 per day[1] (Table 6.1). These women are not officially employees because they do not sign any contract and receive their pay after each working day.

Seventeen percent of the mothers run small sales of different products, such as snacks and candies outside schools and others do catalog sales including clothes and perfumes. These mothers receive small monetary earnings from these sales. Eleven percent of mothers are employees in small business, such as food establishments, laundries and pharmacies. Most of these businesses are located in the same

[1] Rate of exchange on July 31th 2012 according to the Bank of Mexico £1 = 20.77 MXN (Mexican pesos). Source: Banco de México, 2012.

neighbourhood of the families' households. Another 11% of women are owners of small convenience stores. Seventeen percent of mothers work at home as seamstresses, hairdressers and bakers. Another 5% work in clothing factories as labor workers. Eight percent of women work as support workers in administrative activities. In general, the income of administrative workers is better than the previous occupations. Only 4% of mothers have professional occupations. It is important to note that most of the reported occupations by mothers involve important physical demand.

We also gathered information about fathers' occupation in 87% of the cases. Twelve percent of fathers do not live with the family. Eighty-three percent of fathers are employees and 17% are self-employed. Twenty-nine percent of the fathers are craft workers (Table 6.1). Masonry is the most common occupation in this group. Nine percent of men included in the "crafts" category are labor workers, most of them in the industry of production of materials for construction and manufacture.

Nineteen percent of men are employees in different kind of business, mainly in those related with sales. Only three percent are owners of small convenience stores located in the household. Professional and public workers represent only six percent of all fathers. Ten percent of men have occupations with very high levels of physical demand. Among these, the most commons are the chargers of construction materials. These workers are mostly employees of business of sales and receive very low salaries. The group of self-employed workers consists mainly of technicians in mechanics and electricity, smiths and welders, gardeners and bakers.

Table 6.1 Parental occupation

Occupations	Mothers %	Fathers %
Workers in agricultural activities	-	1
Workers in elementary and support activities		
Domestic workers and cleaning workers	27	-
Charger and porters	-	10
Small traders and sales workers		
Owners of informal trades (food, perfumery and others)	17	-
Owners of formal trades (small convenience stores)	11	3
Employees in trades (food, laundries and pharmacies)	11	19
Sales promoters (supermarkets)	5	-
Craft workers		
Seamstresses (5%), hairdressers (5%), bakers (2%)	12	-
Masons (11%), labor workers in industry (9%), smiths & welders (6%), bakers (2%), others (1%)	-	29
Labor workers in manufacture	5	-
Operators of transport machinery		13
Personal service workers		
Soldiers, police, guards, gardeners, cooks	-	7
Support workers in administrative activities		
Secretaries and administrative assistants	8	2
Collectors	2	
Professionals & technicians		
Nurse and accountant	4	
Accountants, engineers, teachers, musicians, others	-	7
Technicians in mechanics and electricity	-	7
Public functionaries of low level	-	2
Total	100	100

The level of grand-maternal education was very low. More than one third of them (37%) never attended the school; the rest (63%) attended school during their childhood but only 10% of them finished the primary school. Data about the occupation of grandmothers was obtained only for the grandmothers who lived with their families (18%). Of them, two thirds (67%) do not perform any paid job; the rest (33%) work as maids or as employees of small business. In general the number of offspring of grandmothers was high. Only 8% of grandmothers had less than 4 children. Sixty-three percent had between 5 and 10 offspring and 12% had more than 10 offspring (min = 2, p25 = 5, median = 6, p75 = 8, max = 14).

6.1.3 Household sanitation

The following information describes the sanitary infrastructure of the households. All families had piped water in their households. However, in the local context, this water is not safe to drink and 97% of families used purified water to drink[2]. By 2010, according to official reports (INEGI, 2012a), 89% of Mexican families overall and 94% of families in Yucatan (including urban and rural areas) had piped water in their houses. Based on this national data, our families are in relative better conditions.

In relation to the number of rooms to sleep we found that 82% of the families used 1 to 2 rooms and 34% use only one. We use the concept “room” and not bedroom because in many cases these rooms are also commonly used for other activities (dining and living). National statistics show that, in Mexico, 75% of the families use 1 to 2 rooms to sleep and 23% of families use 3 to 4 rooms. However, the national average of the number of persons in the house is 3.9, which is lower than in our sample (median = 5). The average of occupants per room in our sample was 3.1, which is higher compared to the national (2.0) and Yucatan (1.1) values (INEGI, 2012a). More specifically, in our sample, we found the following values for bedroom sharing: i) in 57% of the households there were between 1.3 and 2.8 individuals per room; ii) in 30% of the households there were between 3.0-4.5 individuals per room and, iii) in 15% of the households there were between 5 and 10 individuals per room.

According to the National Council for the Evaluation of Social Development Policy of Mexico (*CONEVAL*, by its acronym in Spanish), overcrowding is defined when the number of occupants per room is equal or greater than 2.5 (CONEVAL, 2012). Therefore, 62% of studied families were considered “overcrowded” at the moment of the research.

[2] Purified water refers to water that has been mechanically filtered or processed to be cleaned for consumption. In the local context purified water is commonly sold in plastic jugs in convenience stores or by delivery trucks. The most common brands of purified water are produced by The Coca Cola Company and PepsiCo. The cost of a 20 litres jug of purified water is around £1.25.

Seventy-three percent of the households had a kitchen (a room inside the house only used to prepare and cook food). According to the last National Census of Population and Households of 2010 (INEGI 2012a), in Mexico and Yucatan 88% and 77% of the houses respectively had a kitchen. Therefore, regarding this indicator, our sample is very similar to the general population. Twenty-one percent of the families use a room as a kitchen that is also used for other activities such as to sleep. These kinds of “kitchens” have limitations about basic infrastructure, mainly a reduced space to store, clean and cook the food. Six percent of the families use a small space outdoors, in the backyard, to cook. These “kitchens” are built many times with perishable materials and meals are daily exposed to wind, dust, bugs and high temperatures. In addition, half of families with a kitchen in the backyard use wood to cook, which increases the risk of smoke inhalation and burns for family, but mainly for mothers and grandmothers who are mainly involved in the kitchen activities.

Ninety-one percent of mothers had a stove at home. However, when we asked them what kind of fuel is used to cook at home, we found that only 84% effectively cook with a stove. Thirteen percent of families use wood in an open fire to cook. Sometimes even when the family has a kitchen inside the house, the meals are cooked in the yard using wood. Finally, three percent of families use an electric grill to cook. Eighty-seven percent of the households have a refrigerator. But because 24% do not have a kitchen, the refrigerator is placed elsewhere in the house and forces the families to reduce other spaces of the house. The remaining 20% of the families without refrigerator have to buy food every day. Six percent of the families do not have either a refrigerator or a stove at home.

By 2010, in Mexico, 96% of households had a toilet; this percentage was lower for the Yucatan State (87%). This makes Yucatan the Mexican State with the highest percentage of households without a toilet (23%) (INEGI, 2012a). In our sample, 85% of the houses have a toilet, and this value is slightly lower than the State value. Almost 10%

of families dispose their excreta directly in their backyards and 6% use latrines[3] which are also built in their backyards. The sanitary situation of these families is compromised, not only because their members are exposed to infectious agents but also because of their exposure to odors. This problem gets more severe with the presence of high temperatures, wind and rain.

6.1.4 General characteristics of the housing

This section describes briefly the characteristics of the households. All houses were visited by the research team during the fieldwork. Most of the people who participate in the fieldwork had the opportunity to get inside the houses and corroborate most of information given by mothers.

In relation to the tenure of the house, we found that 82% of the families are the owners of their houses. In this group are included those families that live in the house of any grandparent; 13% of families live in a borrowed house; most of the homeowners of these houses are any relative of the mother or father and only 4% of the families pay a monthly rent.

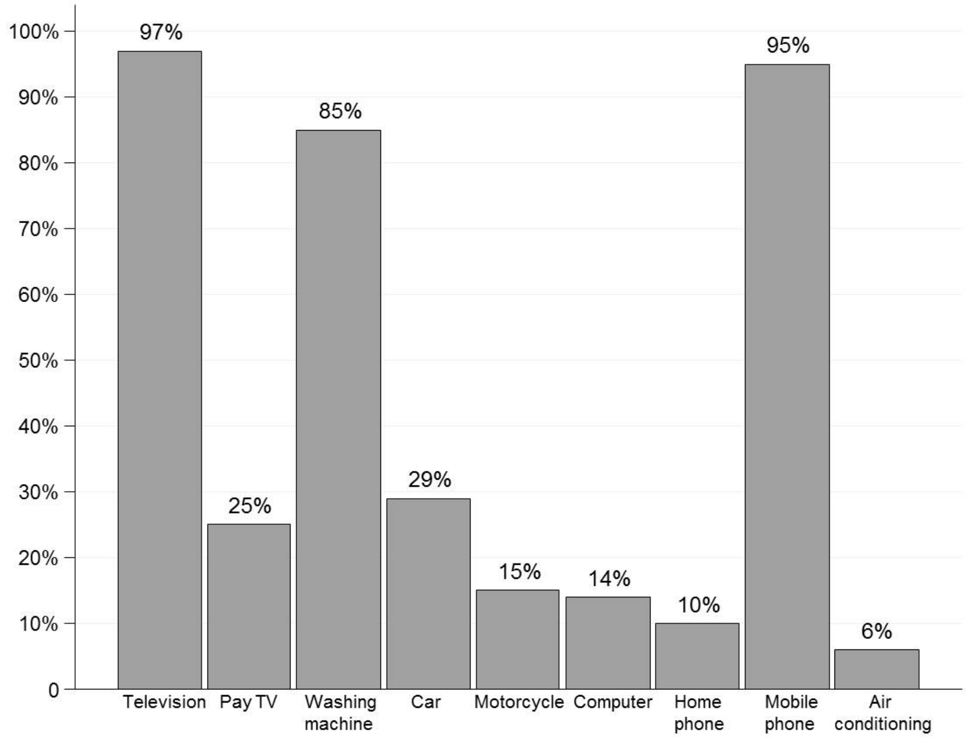
The type and quality of construction materials of the houses are very important for the well-being of the families. High temperatures and rain are perhaps the most important environmental factors that should be taken into account in tropical regions as Yucatan. Regarding the floors, 49% of the houses are built of cement and a similar percentage (51%) of cement and tile. We did not found any house with a ground (dirt) floor. According to the INEGI (2012a) in Yucatan only 3% of households have ground (dirt) floors. The great majority (82%) of the houses have ceilings made with building blocks and concrete. However, 14% are made with only building blocks (without concrete). The four percent remaining have ceilings made with sheets of metal and asbestos. Regarding the materials for walls, 76% of the houses are made with construction blocks and concrete and 22% with only construction blocks. In the case of

[3] Latrine refers to a facility used as a toilet, generally a trench (without a bowl) made in the backyard for familial use.

ceilings and walls, the main difference between construction blocks with concrete and construction blocks without concrete is that the first are more resistant to water and humidity.

Even when parents reported low incomes, almost all mothers reported owning a television and a mobile phone (Fig. 6.4). However, compared with some other countries, in Mexico the people do not need to pay any kind of rent or right for use a television at home. Only 25% of families who have a television reported paying for a private TV system. On the other hand, even when 95% of mothers have a mobile phone, they do not have any kind of contract that includes some monthly payment for the use of the system. Air conditioners, home phones and computers are household assets with low percentages of possession at home. Almost 30% of families have a car. Most of the family members use the public transportation system for their daily activities. Eighty-five percent of mothers have a washing machine. However, in the most of the cases mothers combine the use of washing machine with hand washing. For cultural reasons very few mothers exclusively use washing machine.

Figure 6.4 Percentages of possession of households' assets



6.1.5 Income and expenditures in the households

Table 6.2 shows the number of people in the household who earn an income. Thirty-nine percent of families have only one person with income; 88% of them are the fathers and 12% the mothers. Thirty-eight percent of the families have two people earning an income; of these, 83% are the fathers and mothers. Grandparents and uncles were the most common family members who also reported to have an income in those families with more than two people with an income.

Table 6.2 Number of people with income in the household

Number of persons with monetary income in the household	n	%
1	42	39
2	41	38
3	12	11
≥4	14	12
Total	109	100

Min = 1, p25 = 1, p50 = 2, p75 = 2, Max = 7.

Regarding the mothers, 58% (n = 64) reported earning an income. Of them, 37% (n = 24) receive a salary by its work and the rest (53%; n = 34) are self-employed. The remaining 10% (n = 6) correspond mostly to those mothers who received money from the welfare program called *Oportunidades* (Opportunities, in English). *Oportunidades* is a program promoted by the Mexican government that aims to foster the human development of population in extreme poverty. The program provides support to families in education, health, nutrition and income (SEDESOL, 2012). Beneficiaries of the program, and the type of support, are selected according to the socioeconomic conditions of the families. One of the main indicators to allocate the economic support to each family is the number of offspring in the family. On average, beneficiary families in this research received from *Oportunidades* £33 per month. Most (82%) of fathers are wage earners, 17% are self-employed and the 1% remaining corresponds to a father who is a student that receives a scholarship.

Table 6.3 shows descriptive statistics of parents' income. Sixty-four (59%) mothers were reported to have an income; two of them chose not to report to their income. Fathers' income data was reported by mothers on 86 cases. As we noted previously, 96 fathers live with their families. Paternal income was significantly higher than maternal income (median = £186 vs. median = £116; z = 5.89, p<0.001 Wilcoxon rank-sum test). We also calculated the monthly family income (Table 6.3), which is defined, for purposes of this research, as the sum of incomes of all family members who reported to have an income within the household. We found that 10% of the mothers did not know the income of their husbands.

Table 6.3 Descriptive statistic of monthly parents' and familial income

Family Member	n	Min £	p25 £	Median £	p75 £	Max £	Diff †
Mother	*62	10	58	116	160	626	z = 5.89 p<0.001
Father	**86	43	144	186	231	481	
Family	***96	89	173	265	404	1102	-

† Wilcoxon rank-sum test.
*64 mothers reported to have income, but 62 of them give us information about this data; **96 fathers live with the studied families; however informant mothers gave us information about 86 fathers; ***number of families in which familial income could be calculated.
£1 = 20.77 Mexican pesos. Rate of exchange on July 31th 2012 according to the Bank of Mexico.

In addition to the income, we also collected information about monetary contribution to the familial living expenses of each family member who reported to have an income. Monetary contribution includes money for food, services (water, electricity, and telephone), clothes, education and health. Table 6.4 shows descriptive statistics about monthly parent's contribution. Paternal contribution was again significantly higher than maternal contribution (median = £144 vs. median = £96; $z = 3.93$, $p<0.001$ Wilcoxon rank-sum test). As in the case of income, we also calculated the monthly familial contribution (Table 6.4 with descriptive statistic data).

Table 6.4 Descriptive statistics of monthly parents' and familial contribution

Family member	n	Min £	p25 £	Median £	p75 £	Max £	Diff †
Mother	*63	10	48	96	154	626	$z = 3.93$
Father	**93	39	96	144	183	433	$p<0.001$
Family	***104	77	137	202	308	899	

† Wilcoxon rank-sum test.
*64 mothers reported to have income and contribute to the familial expenses, but 63 of them give us information about their contribution; **96 fathers live with the studied families, however informant mothers gave us information about 93 fathers; ***number of families in which familial income could be calculated.
£1 = 20.77 Mexican pesos. Rate of exchange on July 31th 2012 according to the Bank of Mexico.

Importantly, we found that even when mothers have a lower income and contribution than fathers, they addressed a higher percentage of their income to the familial living expenses than fathers (median = 100% vs. median 80%).

We got information about daily monetary expenditure in food. We only focused in food cooked at home. For descriptive purposes of this research we calculated familial expenditure in food per month (Table 6.5). We found that 31% of families expend from £39 to £135, 65% expend from £144 to £217 and only 11% expend $\geq$ £246. Using monthly expenditure in food and familial income we also calculated the percentage of familial income addressed to buy food to be cooked at home. On average the families used 60% of their income to buy food. However, 35% of families spend more than 70% of their income to satisfy basic food needs. Those families who address less than 30% of their income consist basically of families who spend very little money on food. In some cases families spend very few money in food because their children eat in the home of some relative as grandparents or uncles. This is a very common strategy among families with low income. Seventy-three percent of families do not buy food outside home; this result is consistent with family income. Of the families who just buy food cooked outside home, 72% expend less than £50 per month.

Information about family spent on medical services and medicines is provided in Table 6.5. In Mexico people can access four types of medical services. The first is that available for workers whose employers pay fees for the medical service to the Mexican Institute of Social Security or to the Institute for Security and Social Services of the State (*IMSS* and *ISSSTE* respectively by theirs acronyms in Spanish). The second type of medical service is available for all population; it means public medical service given by the Secretary of Health of each state of Mexico. The third type of medical service is the private sector. It is important to note that the quality range of this type of medical services in Mexico is wide. The fourth type of service is that given by support programs to populations in poverty. The program *Oportunidades* is the service with more coverage of this type. We asked the mothers how much they expended in medical services and medicines during the previous month to the interview. Thirty-seven percent of them reported not having spent anything during the previous month. We found that 76% of mothers reported to spend less than £24 during last month and only 6% reported to expend more than £50 during the same period. Descriptive statistics of expenditure in medical services are given in Table 6.5.

Table 6.5 Descriptive statistics of monthly familial expenditure in food and medical services (MS)

	*n	Min	p25	Median	p75	Max
		£	£	£	£	£
Food	107	39	116	144	217	361
MS	68	1	10	18	24	72

*Number of families in which information was available.
£1 = 20.77 Mexican pesos. Rate of exchange on July 31th 2012 according to the Bank of Mexico.

6.2 Description of biological and socioeconomic variables that relate to the health, nutritional and growth status of children

This section aims to describe some of the biological and socioeconomic variables that shape the health, nutrition and growth status of children. The variables are presented in chronological order, from pregnancy to the main postnatal events during the first years of life of children.

On average mothers (F_2) of the studied children (F_3) got pregnant at 24.6 ($\pm$5.7) years of age. Regarding the birth order, we found that 50%, 28% and 14% of children were the first, second and third offspring, respectively. For those children whose birth order was second and up, we found that the first pregnancy of mothers was on average, at 21.2 ($\pm$4.6) years of age. Seventeen percent of the mothers reported having had at least one abortion before the birth of the studied children.

For those children whose birth order was not the first, we estimated the inter-birth interval, defined in this research as the time (in months) between the birth of the child immediately older than the studied child and the birth of the studied child. It was not possible to estimate the inter-genesic interval (i.e. the interval of time between the last menstrual period of the mother and the birth of the studied child) because we lack data about the start date of pregnancy of older offspring. We found that in 50% (interquartile range) of the cases the inter-birth interval was between 33 to 80 months (2.75 to 6.7 years). The median for all children was 48 months (4 years).

Eighty-five percent of the mothers reported having a partner when they got pregnant and 59% had intentions to become pregnant. We also asked the mothers about whether the family saved money for the childbirth and for how long. We found that 54%[4] (n = 57) reported having saved money. Of them, 37% (n = 21) saved money from 1 to 4 months and 56% (n = 32) saved money from 5 to 9 months. All these savings

[4] Time of saving was obtained in 105 cases.

were made during pregnancy and only 7% of mothers saved money 12 months before the birth of their children.

Information about antenatal care (ANC) was also obtained. Specifically, we asked the mothers if they went to the hospital for assessment during the first, second and third trimester of pregnancy. In general, we found that 84% of mothers attended ANC assessments during the entire pregnancy (Table 6.6). We also found that the highest percentage of absence of ANC occurred during the first trimester of pregnancy. Ninety-six percent of mothers also reported having received at least one ultrasound during the pregnancy. However, 58% of them received only 1 to 2 ultrasounds during all pregnancy. Ninety-two percent and 95% of mothers reported having consumed iron and folic acid during pregnancy, respectively. Finally, 17% of the mothers mentioned that they cohabited with smokers during pregnancy. No mother reported having smoked during pregnancy.

Table 6.6 Antenatal care by trimester of pregnancy in mothers

Answer	1st trimester		2nd trimester		3rd trimester		All pregnancy	
	%	(n)	%	(n)	%	(n)	%	(n)
Yes	84%	(92)	98%	(107)	99%	(108)	84%	(92)
No	16%	(17)	2%	(2)	1%	(1)	16%	(17)
Total	100%	(109)	100%	(109)	100%	(109)	100%	(109)

We also asked about the occurrence of maternal health problems during the pregnancy. Seven percent of the mothers reported having experienced hyperglycemia during pregnancy. Nineteen percent were diagnosed with preeclampsia and 16% suffered from eclampsia. However, infection diseases were the most common health problems reported during the pregnancy of mothers, the prevalence of these was 29%. Urinary tract infections represented 72% of the cases, followed by vaginal infections (19%).

All children were born in hospitals. Fifty-one percent were born in the Mexican Institute of Social Security, which provides health services for workers of private companies and business. Forty-three percent were born in public hospitals of the

Secretary of Health and only 6% in private hospitals. Sixty-seven percent of birth child were delivered vaginally and 33% by caesarean.

Ninety-four percent of children were breastfed. However, 72% were breastfed six months or less, and more than 32% of children were only breastfed for a few days after birth (Table 6.7). The median age of weaning among the children was 10 months (interquartile range = 6 – 12 months). Infant formula was introduced on average at 3 months of age and 41% of children received it during the first month of life.

Table 6.7 Percentages of breastfed children by time periods

Period (months)	n	%
0 – 1	33	32
1 – 6	41	40
7 – 12	19	19
12 – 24	8	8
>24	1	1
Total	102	100

Children's birth weight was gathered in two ways. Firstly, we asked the mothers to report on the birth weight of the child as they remembered. Ninety-eight percent of the mothers provided us with a value; only 2 mothers did not remember the birth weight of their child. Secondly, we asked the mothers to show us the child' birth certificate; birth weights and ages of gestation were obtained from these. Forty-six percent of the mothers provided us the birth certificates with the required data. The remaining 54% did not keep this document. Based on the available data we did not find significant differences between birth weights reported by mothers and gathered in certificates. Therefore we decided, as in previous works (Azcorra et al., 2009; Varela-Silva et al., 2009), to combine these two sources to generate a new variable with birth weights. In this variable, birth weights gathered in certificates were kept and reported values were used in those cases where birth certificates were not available. According to this criterion, 11% of children weighted <2500 g at birth. The median of birth weight of children was 3150 kg (Min = 1590 g, interquartile range = 2800 g – 3400 g, Max = 4000 g).

We also asked the opinion of the mothers about the health status of their children during the first years of life. More specifically, we asked the mothers to take into account the occurrence and frequency of infectious diseases on their children and state if they consider their children as: 1) very healthy, 2) healthy, 3) sickly, or 4) very sickly. This question was used to identify specific periods of life: a) during the1st year of life, b) between 1 and 3 years of age, c) between 3 and 5 years of age, and d) above 5 years of age. A range of frequencies was used to classify the children. The classification of "very healthy" was used if the child got ill one time or less every three months; "healthy" if the child was ill once every 2 months; "sickly" if the child was ill once or twice a month; and "very sickly" if the child was reported to be ill more than two times per month with the same or a different disease. We found that the number of children classified by their mothers as healthy increased with age and the number of children classified as very sickly also decreased with age (Table 6.8). This result could be expected if we take into account that the maturation of the immunological system is a natural process that takes place during the first years of life. Forty-one percent of the children were classified by their mothers as healthy or very healthy during all life stages.

Table 6.8 Mothers opinion of children's health status during first years of life, in percentages

Period (years)	Very healthy	Healthy	Sickly	Very sickly	Total
1st	22	31	25	22	100
1 - 3	16	44	27	13	100
3 - 5	20	53	19	8	100
>5	28	62	5	5	100

Very healthy: if the child got sick 1 time each $\geq$ 3 months; Healthy: if the child got sick 1 time every 2 months; Sickly: if the child got sick 1 to 2 times per month; Very sickly: if the child got sick > 2 times per month with the same or different illnesses.

In addition it was found that 43% of the mothers reported that their children got sick of any infectious disease during the previous month of the survey. Of them, 79% (n = 37) got sick one time and 21% (n = 10) receded in a couple of times. Respiratory infections were the most common illness (83%), followed by intestinal infections (9%). According to information given by mothers, 17% (n = 19) of children were sick during the survey application and again respiratory infections were the most common cause (84%). Of them, 32% (n = 6) of children was not receiving pharmacological treatment.

We also asked about the presence of chronic diseases in children. Twenty-five percent (n = 27) of them were reported with the presence of any chronic disease, 74% of them with the presence of an allergy (all of them with respiratory symptoms). Only 30% of these children were receiving any pharmacological treatment.

Even when almost 50% of children are treated in private services, some of these services consist of pharmacies that offer medical consultations at very low cost (approx. £2), in other words, they are not formal hospitals or doctor's offices. Public service and medical service provided by *Oportunidades* y *Seguro Popular* programs are given by the Secretary of Health of Mexico, where, according to the mothers' opinion people have to wait a long time to be treated and the medication is not always available (Table 6.9).

Table 6.9 Medical services where children are treated

Medical service	n	%
None	2	2
Mexican Institute of Social Security	22	20
Public service	10	9
Welfare programs	24	22
Private service	51	47
Total	109	100

We also inquired about the participation of grandmothers in the care of the children. We found that 50% of the children were cared very often by their grandmothers, especially before they started primary school (6 years of age). In general this result is consistent with the percentage of working mothers in the studied sample (52%). Additionally, we looked at the participation of grandmothers during specific years of the children lives. Table 6.10 shows the percentage of grandmothers who participated in child caring during three specific periods and if was the maternal or paternal grandmother who participated.

Table 6.10 Maternal and paternal grandmothers who participate in the care of their grandchildren during specific periods

Period (years)	No	Yes	Maternal grandmother	Paternal grandmother	Both
	% (n)	**%** (n)	**%** (n)	**%** (n)	**%** (n)
1^{st}	59 (64)	41 (45)	73 (33)	24 (11)	3 (1)
1 - 3	62 (68)	38 (41)	78 (32)	20 (8)	2 (1)
3 - 5	63 (69)	37 (40)	80 (32)	18 (7)	2 (1)
At present	70 (76)	30 (33)	91 (30)	3 (1)	6 (2)

In general, we found that the participation of grandmothers (maternal or paternal) decreased with the increase of children's age. However, even at the current age of children, the participation of grandmothers is important (30%). In all periods the participation of maternal grandmothers was higher than paternal grandmothers. Very few children were cared by their grandmothers during all studied periods. In addition, we found that on average 73% of grandmothers are responsible, during some time of the day, of caring and provide food for their grandchildren. Finally, we found that 21% of children were cared by their grandmothers during all reported periods.

In summary, our results show that the studied families belong to an overall disadvantaged socioeconomic group. Low income and high physical demand jobs are traits that characterized the children's parents. Our findings of low paternal levels of formal education and unskilled jobs are consistent with the current situation of the urban Maya population from Yucatan State. The current state of poverty is also evident in the high levels of household overcrowding, lack of sanitation and on the high percentage of households with reduced spaces to live. The living conditions described in this chapter suggest the existence of an adverse environment for a healthy, physical growth process of the children from our sample.

CHAPTER 7

RESULTS

Nutritional status and nutritional dual burden in participants

7. Nutritional status and nutritional dual burden in participants

The first aim of this chapter is to describe the nutritional status of children, mothers and grandmothers. Descriptive statistics of anthropometric and derived variables are presented for each generation. Z-scores values of relevant anthropometric variables were calculated to give the reader a more accurate idea of how the participants compare to a reference group. Prevalence of nutritional status categories (stunting, short trunk and legs, underweight, overweight, obesity and abdominal obesity) are presented for each generation.

The second aim of this chapter is to document the prevalence of nutritional dual burden at individual level, mother-child dyads' level, and grandmother-mother-child triads' level.

7.1 Nutritional status of children

7.1.1 Nutritional status of children according to linear growth variables

Descriptive statistics of height, SH (sitting height), SHR (sitting height ratio), leg length (LL), and relative leg length index (RLLI) of children are given in Table 7.1. There were no significant differences by sex, even within age group. However, boys showed higher SHR at ages 6 and 7 and girls had higher RLLI at the same ages, which means that the proportion of the trunk in relation to total height was higher in boys and the proportion of the legs in relation to the total height was higher in girls, although the differences are not statistically significant. From a biological point of view this indicator may suggest that boys are in worse biological condition than girls.

Descriptive statistics of z-score values for height-for-age (HAZ), SH-for-age (SHZ) and LL-for-age (LLZ) and percentages of stunting, short trunk and short legs are presented in Table 7.2. The HAZ values ranged from -2.66 to 1.10 with a mean of -0.66 (0.79). Eleven percent of the children met the criteria for stunting. The SHZ and LLZ values range from -2.01 to 1.44 (mean = -0.38 $\pm$0.81) and from -3.91 to -1.12 (mean = -1.12 $\pm$0.89) respectively. Only 7% of the sample showed short trunk but 29% showed short LL for their age. There were no significant differences in HAZ by sex and Chi square analysis did not show significant differences in the proportions of stunted children by sex. However, girls, as a group, showed significant higher values of SHZ (-0.09 vs. -0.68 $p<0.05$, Student t- test) and LLZ (-0.80 vs. -1.47 $p<0.05$, Student t-test) than boys and the proportion of boys and girls with short legs was significantly different (X^2 = 9.80, p = 0.02), with boys being more leg stunted than girls. These results are consistent with the fact that girls, as a group, show lower values of SHR than boys (53.47 vs. 53.74), although this is non significant. Values of SHR ranged from 53.20 to 53.91 in girls and from 53.04 to 54.07 in boys (Table 7.1). It is to be noted that the lower the SHR, the higher the length of the legs in proportion to the total stature.

We also calculated the knee-height-ratio (KHR) in all participants. Girls revealed higher values of KHR than boys (30.67 vs. 30.40 p = 0.06, Student t-test). This means that the proportion of the KH in relation to the total height is higher in girls than in boys, which confirms that girls are growing physically in better conditions than boys, although the differences are not statistically significant.

Even the non-stunted children showed low values of HAZ, SHZ, LLZ and high values of SHR. Twenty eight percent of children were below the 15^{th} percentile for height-for-age and 23% of the children were below 15^{th} percentile for SH-for-age (Table 7.3). Of relevance was the fact that the deficit on growth is more evident on LL because 48% of children fell below 15^{th} percentile of LL-for-age. In contrast, 66% of children were between 15^{th} and 85^{th} percentile of SHR-for-age and 33% were above 85^{th} percentile, which confirms that the deficit of growth is located in legs.

Table 7.1 Descriptive statistics (mean $\pm$SD) for body length measures and indices (height, SH, SHR, LL, and RLLI) of children

Age groups	n	Height		SH		SHR		LL		RLLI	
		Mean (cm)	SD	Mean (cm)	SD	Mean (%)	SD	Mean (cm)	SD	Mean (%)	SD
Boys	53	119.71	6.30	64.29	2.89	53.74	1.35	55.42	4.00	46.26	1.35
6	17	116.01	5.55	62.71	2.92	54.07	1.37	53.30	3.38	45.93	1.37
7	21	118.30	4.25	63.83	2.35	53.98	1.32	54.46	2.85	46.02	1.33
8	15	125.91	5.08	66.74	1.90	53.04	1.16	59.17	3.57	46.96	1.16
Girls	56	119.08	5.49	63.64	2.73	53.47	1.28	55.43	3.43	46.53	1.28
6	20	115.05	3.60	61.99	1.52	53.91	1.50	53.06	3.11	46.09	1.50
7	20	119.44	4.30	63.55	2.49	53.20	1.13	55.90	2.59	46.80	1.13
8	16	123.66	5.12	65.84	2.79	53.35	1.06	57.83	2.92	46.75	1.06
Total	109	119.39	5.88	63.96	2.82	53.60	1.31	55.43	3.70	46.40	1.31

SH: Sitting height; SHR: Sitting height ratio (SH x 100/height); LL: Leg length (height – SH); RLLI: Relative leg length index (LL x 100/height).

Table 7.2 Descriptive statistics (mean ±SD) of z-score values of height-for-age, SH-for-age and LL-for-age and percentages of stunting, short trunk and legs

Age groups (years)	n	Height-for-age z-scores		Stunting z-score <-1.650		SH-for-age z-scores		Short trunk z-score <-1.650		LL-for-age z-scores		Short legs z-score <-1.650	
		Mean	SD	Fr	%	Mean	SD	Fr	%	Mean	SD	Fr	%
Boys	53	-0.78	0.66	8	15	-0.68*	0.79	6	11	-1.47*	0.89	23	43
6	17	-0.56	0.99	3	18	-0.38	0.92	1	6	-1.18	0.94	5	29
7	21	-0.97	0.75	3	14	-0.76	0.74	3	14	-1.68	0.79	13	62
8	15	-0.78	0.82	2	13	-0.91	0.62	2	13	-1.49	0.92	5	33
Girls	56	-0.55	0.72	4	7	-0.09*	0.82	2	4	-0.80*	0.77	9	16
6	20	-0.37	0.63	1	5	0.12	0.55	-	-	-0.69	0.87	3	15
7	20	-0.49	0.78	2	10	-0.12	0.85	1	5	-0.68	0.75	3	15
8	16	-0.86	0.67	1	6	-0.33	0.74	1	6	-1.08	0.64	3	19
Total	109	-0.66	0.79	12	11	-0.38	0.81	8	7	-1.12	0.89	32	29

SH: Sitting height; LL: Leg length (height – SH); Stunting, short trunk and short legs: z-score less than -1.650 for height-for-age, SH-for-age and LL-for-age respectively (Frisancho AR. 2008. Anthropometric standards: an interactive nutritional reference of body size and body composition for children and adults. Ann Arbor, MI: The University of Michigan Press. 335 p).
*Differences by sex p<0.05, Student t-test.

Table 7.3 Distribution of children (%, n) according to their height-for-age, SH-for-age, LL-for-age and SHR-for-age categories

Indicator	Low $<5^{th}$		Below average $5.0 – 15^{th}$		Healthy range $15.1 – 85^{th}$		Above average $85.1 – 95^{th}$		Excessive $>95^{th}$	
Height-for-age	11	(12)	17	(19)	71	(77)	1	(1)	-	-
SH-for-age	7	(8)	16	(17)	72	(79)	5	(5)	-	-
LL-for-age	29	(32)	19	(21)	50	(55)	1	(1)	-	-
SHR-for-age	1	(1)	-	-	66	(72)	21	(23)	12	(13)

SH: Sitting height; LL: Leg length; SHR: Sitting height ratio; Classification proposed by Frisancho (Frisancho AR. 2008. Anthropometric standards: an interactive nutritional reference of body size and body composition for children and adults. Ann Arbor, MI: The University of Michigan Press. 335 p).

7.1.2 Nutritional status of children according to body mass variables

The descriptive statistics for weight, body mass index (BMI), waist circumference (WC) and hip circumference (HC) are given in Table 7.4. Significant differences by sex were only found in WC at age of 8 (z = 2.06 p<0.05, Wilcoxon rank sum test).

Table 7.4 Descriptive statistics (mean ±SD) for body mass measurements and indices (weight, BMI, WC and HC) of children

Age groups	N	Weight		BMI		WC		HC	
		Mean (kg)	SD	Mean (kg/m^2)	SD	Mean (cm)	SD	Mean (cm)	SD
Boys	53	25.56	5.46	17.69	2.81	59.94	7.43	66.87	6.62
6	17	23.57	4.88	17.40	2.78	58.70	7.28	64.89	5.79
7	21	24.65	5.44	17.50	3.10	58.51	7.71	65.82	7.05
8	15	29.09	4.68	18.30	2.48	63.33*	6.52	70.57	5.70
Girls	56	24.76	4.48	17.40	2.57	58.78	6.42	66.83	5.88
6	20	23.13	3.76	17.43	2.43	57.72	5.94	64.95	5.08
7	20	25.12	4.28	17.52	2.23	60.16	6.26	67.03	5.37
8	16	23.33	5.11	17.21	3.23	58.40*	7.25	68.94	6.94
Total	109	25.15	4.97	17.54	2.68	59.34	6.92	66.85	6.22

BMI: Body mass index (weight/height^2); WC: Waist circumference; HC: Hip circumference;
*z = 2.06 p<0.05, Wilcoxon rank sum test.

Descriptive statistics for subcutaneous body fat (tricipital, subscapular, suprailiac skinfolds and sum of three skinfolds) are shown in Table 7.5. As expected girls, as a group, showed thicker subscapular skinfolds (9.93 vs. 8.55, z = -2.45 p<0.05, Wilcoxon rank sum test) and sum of skinfolds (37.50 vs. 33.16, z = -2.01 p<0.05, Wilcoxon rank sum test) than boys.

Table 7.5 Descriptive statistics (mean $\pm$SD) of children's skinfolds

Age (years)	N	Tricipital		Subscapular		Suprailiac		Sum of 3 skinfolds	
		Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (cm)	SD
Boys	53	11.50	4.69	8.55*	4.44	13.11	7.70	33.16*	16.32
6	17	11.04	4.55	8.16	5.37	12.94	8.45	32.14	17.80
7	21	10.94	4.86	8.26	4.32	11.58	7.68	30.78	16.54
8	15	12.82	4.64	9.39	3.53	15.43	6.70	37.64	14.34
Girls	56	12.75	4.08	9.93*	4.66	14.82	7.03	37.50*	15.12
6	20	11.98	3.97	9.52	4.77	14.01	7.04	35.51	15.15
7	20	13.26	3.53	10.67	4.29	16.08	5.89	40.01	12.91
8	16	13.08	4.89	9.52	5.15	14.26	8.43	36.86	17.95
Total	109	12.14	4.41	9.26	4.59	13.99	7.38	35.39	15.79

* Differences by sex p<0.05, Wilcoxon rank sum test.

Descriptive statistics of z-score values for weight-for-age (WAZ), BMI-for-age (BMIZ), WC-for-age (WCZ) and HC-for-age (HCZ) are given in Table 7.6. The WAZ values ranged from -1.91 to 2.13 (-0.08 $\pm$0.85). Only 3% of the children were classified as underweight being all of them boys and 11% of children were over the 85th percentile. BMIZ ranged from -1.13 to 3.62 with a mean of 0.71 ($\pm$0.97). Thirty-six percent of the children were over the 85th percentile of the references (18% in risk for overweight and 18% in risk for obesity). WCZ and HCZ ranged from -1.10 to 2.88 (0.60 $\pm$0.77) and from -1.20 to 3.07 (0.78 $\pm$0.89) respectively. Thirty-two percent of the children were over the 85th percentile of WC-for-age, showing risk for abdominal obesity. Boys, as a group, showed significant low (-0.28 vs. 0.09, $p<0.05$, Student t-test) values of WAZ and girls significantly higher (0.99 vs. 0.55, $p<0.05$, Student t-test) values of HCZ.

Table 7.6 Descriptive statistics (mean $\pm$SD) of z-score values of weight-for-age, BMI-for-age, WC-for-age and HC-for-age of children

Age(years)	N	Weight-for-age		BMI-for-age		WC-for-age		HC-for-age	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Boys	53	-0.28*	0.89	0.79	1.02	0.49	0.82	0.55*	0.91
6	17	-0.08	1.03	0.89	1.06	0.64	0.91	0.73	0.96
7	21	-0.40	0.91	0.73	1.11	0.34	0.85	0.42	1.01
8	15	-0.33	0.69	0.77	0.88	0.56	0.70	0.52	0.72
Girls	56	0.09*	0.78	0.64	0.92	0.71	0.72	0.99*	0.82
6	20	0.41	0.68	0.86	0.86	0.83	0.69	1.17	0.77
7	20	0.12	0.74	0.70	0.83	0.86	0.68	1.04	0.79
8	16	-0.35	0.76	0.27	1.05	0.37	0.74	0.72	0.89
Total	109	-0.09	0.85	0.71	0.97	0.60	0.77	0.78	0.89

BMI: Body mass index (weight/heigh^2); WC: Waist circumference; HC: Hip circumference;
*Differences by sex p<0.05, Student t-test.

Means and standard deviations of z-score values for tricipital (TSZ), subscapular (SbSZ), suprailiac (SpSZ) and sum of 2 skinfolds (tricipital and subscapular) (SumZ) are given in Table 7.7. The TSZ, SbSZ and SpSZ ranged from -0.95 to 2.13, 0.85 to 2.83 and -0.87 to 4.18 respectively. We only found significant differences in SumZ by sex, having the girls, as a group, higher values than boys (0.65 vs. 0.32, $z = -2.35$ $p<0.05$, Wilcoxon rank sum test).

Table 7.7 Descriptive statistics (mean ±SD) of z-score values of tricipital (TSZ), subscapular (SbSZ), suprailiac (SpSZ) skinfolds and sum of tricipital and subscapular (SumZ) skinfolds of children

Age groups	N	TSZ		SbSZ		SpSZ		SumZ	
		Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (cm)	SD
Boys	53	0.50	0.74	0.61	0.76	1.31	1.17	0.32*	0.84
6	17	0.58	0.80	0.56	0.86	1.39	1.34	0.33	0.93
7	21	0.42	0.74	0.55	0.73	1.07	1.16	0.26	0.85
8	15	0.52	0.71	0.77	0.71	1.57	0.99	0.40	0.76
Girls	56	0.57	0.75	0.65	0.74	1.30	0.97	0.65*	0.72
6	20	0.54	0.80	0.66	0.74	1.44	0.96	0.64	0.75
7	20	0.70	0.63	0.81	0.67	1.52	0.77	0.81	0.61
8	16	0.45	0.86	0.43	0.82	0.85	1.10	0.47	0.82
Total	109	0.54	0.74	0.63	0.75	1.31	1.07	0.49	0.80

Sum of skinfolds: tricipital and subscapular; * Differences by sex p<0.05, Wilcoxon rank sum test.

The centile curves proposed by the International Obesity Task Force – IOTF (Cole et al., 2000; Cole et al., 2007) are one of the most commonly used references to assess nutritional status of children. When children of our sample were compared with the IOTF references we found that the percentage of children (both boys and girls) who exceeded the sex-specific percentile which at age of 18 corresponded to a BMI of 25 was 36%. Twenty-four percent of them were overweight and 12% were obese. Only 3% of the sample met the criteria for thinness. After Chi square analysis we found no significant differences in the proportion of boys and girls, by BMI categories ($X^2 = 0.61$, $p = 0.89$).

Table 7.8 shows the percentages of children divided by the nutritional status categories (weight, BMI and WC) according to the criteria we defined and explained in the Methods section. As we previously noted, percentiles for height, weight, BMI and

WC-for age were produced using growth reference values published by Frisancho (2008). In general, we found very similar percentages of overweight (OW+OB) when BMI and WC percentiles are used. It is possible that using weight-for-age indicator we underestimated the excess of weight in our sample due to the high incidence of overweight in the reference (NHANES III). Results from IOTF centile curves comparison were not included in Table 7.8 because it uses different cut off points (91th percentile for overweight and 99th percentile for obesity) to classify subjects.

Table 7.8 Percentages of nutritional status categories of children

Indicator	Criteria	Low	Normal	OW	OB	OW+OB
Weight-for-age	Centiles (NHANES III)	3	94	10	2	12
BMI-for-age	Centiles (NHANES III)	-	64	24	13	37
WC-for-age	Centiles (NHANES III)	-	74	26	9	35

BMI: Body mass index (weight/height^2); WC: Waist circumference; Low: < 5th percentile (underweight), Normal or Healthy: 5th to $\leq$ 85th percentile, Overweight (OW): > 85th to 95th percentile, Obesity (OB): > 95th percentile, Overweight + Obesity (OW+OB): > 85th percentile.

7.2 Maternal nutritional status

Maternal age ranged from 22.37 to 49.88 years with a mean of 32.75 (5.67) years. For analysis purposes we grouped the mothers into three age groups: 1) 20-29 years, 2) 30-39 years, and 3) 40-49 years.

7.2.1 Maternal nutritional status according to linear growth variables

Descriptive statistics of observed and derived values of maternal linear growth variables are given in Table 7.9. Within the linear growth variables only height differed between age groups ($F = 4.26$, $p<0.05$, one-way Anova). After performing multiple-comparison tests we found that the youngest mothers (20-29 years) were significantly taller than the mothers of group 2 (30-39 years).

Table 7.9 Descriptive statistics of observed and derived values (mean ±SD) of linear growth variables of mothers

Variable	20-29 yrs (1)		30-39 yrs (2)		40-49 yrs (3)		Diff [a, b]
	Mean	SD	Mean	SD	Mean	SD	
n	43 (39%)		53 (49%)		13 (12%)		
Age (years)	27.42	1.87	34.47	2.82	43.30	2.71	X^2 = 88.78, p<0.001[b]
Height (cm)	149.46	5.21	146.64	4.41	147.79	3.96	F = 4.26, p = 0.017[a]
SH (cm)	79.93	2.53	78.81	2.29	79.25	1.43	F = 2.78, p = 0.067[a]
SHR (%)	53.50	1.31	57.76	1.10	53.58	1.23	X^2 = 1.21, p = 0.546[b]
LL (cm)	69.53	3.79	67.83	3.07	68.02	4.67	F = 2.83, p = 0.064[a]
RLLI (%)	46.50	1.31	46.24	1.10	45.93	2.29	X^2 = 1.17, p = 0.557[b]
KH (cm)	45.77	2.14	45.11	1.95	45.95	1.69	F = 1.75, p = 0.179[a]

SH: Sitting height; SHR: Sitting height ratio (SH x 100/height); LL: Leg length: (height – SH); RLLI: Relative leg length index (LL x 100/height); KH: Knee height; [a]One-way Anova; [b]Kruskal-Wallis rank sum test.

In general, the mothers in our sample showed very short statures (Mean = 147.91cm ±4.84). When compared against the references (Frisancho, 2008), 71% of them are below the 5th percentile, therefore being classified as stunted adults. The deficit of growth was very severe in both trunk (54%) and leg lengths (59%) (Table 7.10). We found that, on average, the leg length of the mothers corresponded to the 46.31% (±1.37) of the total height, which correspond to the 5th percentile of the references. In contrast, the mean of SHR was 53.63 (±1.20) which corresponds to the 33th percentile of the reference. Maternal knee height values ranged from 40.1 cm to 51 cm (45.47 ±2.01). The knee height ratio ranged from 29.34% to 32.82% with a mean of 30.74% (±0.70) in all sample.

Table 7.10 Descriptive statistics (mean ±SD) of z-score values of height, SH and LL-for-age, and percentages of stunting and short trunk and legs in studied mothers

Indicator	Mean	SD	Stunting/Short trunk or legs*
			% (n)
Height-for-age	-2.01	0.75	71 (77)
SH-for-age	-1.65	0.74	50 (54)
LL-for-age	-1.70	0.86	54 (59)
SHR-for-age	0.58	0.89	-

SH: Sitting height; LL: Leg length; SHR: Sitting height ratio;
*Cut-off points = z-score of < -1.645 or below 5th centile (Frisancho AR. 2008. Anthropometric standards: an interactive nutritional reference of body size and body composition for children and adults. Ann Arbor, MI: The University of Michigan Press. 335 p).

7.2.2 Maternal nutritional status according to body mass and body composition variables

Descriptive statistics of observed and derived values of maternal body mass and body composition variables are given in Table 7.11. We found that weight, BMI, WC, HC, TS and %BF of the mothers increase significantly with age. After multiple-comparison tests we found that, in all variables, mothers of group 3 (40-49 years) showed significantly higher values than mothers of groups 1 (20-29 years) and 2 (30-39 years). In contrast, %LBM decreased with age and significant differences were found between older mothers (40-49 years) and mothers of age groups 1 (20-29 years) and 2 (30-39 years).

Overnutrition in mothers was assessed through WC. Using the 88 cm cut-off point we found that 55% of the mothers showed risk for abdominal obesity. Also, mothers with high WC show significant higher values of tricipital, subscapular and sum of skinfolds and also %BF (Table 7.12). Additionally, mothers with WC < 88 cm were significantly shorter and lighter than mothers with high WC. Waist-to-hip ratio is another important indicator for health risk. Applying the cut-off point of > 0.88 in WHR, we found that 49% of mothers showed high risk to develop chronic degenerative diseases.

The mothers presented very high levels of BF%. The values ranged from 31.24% to 55.69% with a mean of 44.19% ($\pm$4.52). We found that WC and BMI correlates significantly ($p<0.001$) with %BF at level of $r = 0.68$ and $r = 0.71$ respectively.

Finally, 18% of the mothers reported to have been diagnosed with some sort of chronic disease by a medical doctor. Of them, 20% were diagnosed with hypertension, 15% with type 2 diabetes *mellitus*, 15% with hypercholesterolemia and hypertriglyceridemia and 10% with asthma.

Table 7.11 Descriptive statistics of observed and derived values (mean ±SD) of body mass and body composition variables of mothers

Variable	20-29 yrs (1)		30-39 yrs (2)		40-49 yrs (3)		Diff [a, b]
	Mean	SD	Mean	SD	Mean	SD	
n	43 (39%)		53 (49%)		13 (12%)		
Age (years)	27.42	1.87	34.47	2.82	43.30	2.71	X^2 = 88.78, p<0.001[b]
Weight (kg)	63.80	10.02	64.21	10.61	76.14	14.61	X^2 = 7.30, p = 0.026[b]
BMI (kg/m^2)	28.54	4.11	29.80	4.30	34.71	6.04	X^2 = 10.78, p = 0.005[b]
WC (cm)	88.86	8.85	89.35	9.91	100.21	14.96	X^2 = 6.81, p = 0.033[b]
HC (cm)	102.43	7.25	103.02	8.78	112.94	11.38	X^2 = 8.91, p = 0.012[b]
WHR	0.87	0.05	0.87	0.07	0.88	0.06	X^2 = 1.30, p = 0.522[b]
TS (mm)	24.05	5.61	24.98	5.80	31.80	6.38	F = 9.22, p<0.001[a]
SS (mm)	22.46	5.79	23.72	5.83	27.93	8.49	X^2 = 4.78, p = 0.092[b]
%BF	42.42	3.74	44.39	4.13	49.17	4.74	F = 13.91, p<0.001[a]
%LBM	57.58	3.75	55.61	4.13	50.83	4.74	F = 13.90, p<0.001[a]

BMI: Body mass index (weight/height^2); WC: Waist circumference; HC: Hip circumference; WHR: Waist-to-hip ratio; TS: Tricipital skinfold; SS: Subscapular skinfold; %BF: Body fat percentage; %LBM: Percentage of body lean mass; [a]One-way Anova; [b]Kruskal-Wallis rank sum test.

Table 7.12 Differences in anthropometric variables between mothers with low and high waist circumference

Variable	Low WC (< 88cm)		High WC (≥ 88cm)		Diff [a, b]
	Mean	SD	Mean	SD	
n	49 (45%)		60 (55%)		
Age (years)	31.84	4.26	33.49	6.55	z = -0.96, p = 0.336[b]
Height (cm)	146.82	5.19	148.81	4.37	t = -2.17, p = 0.032[a]
Weight (kg)	57.23	6.98	72.21	10.03	z = -7.48, p<0.001[b]
BMI (kg/m^2)	26.55	2.97	32.61	4.27	z = -7.13, p<0.001[b]
TS (mm)	22.13	4.99	28.12	5.85	t = -5.67, p<0.001[a]
SS (mm)	20.27	3.92	26.54	6.56	z = -5.28, p<0.001[b]
SumSkf (mm)	42.41	7.70	54.66	11.31	z = -5.52, p<0.001[b]
%BF	41.76	4.05	46.17	3.89	t = -5.78, p<0.001[a]

BMI: Body mass index (weight/height^2); TS: Tricipital skinfold, SS: Subscapular skinfold; SumSkf: tricipital and subscapular; %BF: Body fat percentage; [a]Student t-test; [b] Wilcoxon rank sum test.

7.3 Nutritional status of grandmothers

The age of the grandmothers ranged from 43.42 to 77.98 years (mean = 59.39 ±8.41 years). Since significant biological changes occur during aging, grandmothers were grouped in four categories of age: 1) 40-49 years, 2) 50-59 years, 3) 60-69 years, and 4) 70-79 years.

7.3.1 Nutritional status of grandmothers according to linear growth variables

Descriptive statistics of observed and derived values of grand-maternal linear growth variables are given in Table 7.13. The height of the grandmothers ranged from 131.50 to 159.20 cm with a mean of 143.08 cm ($\pm$4.77). The grandmothers show very low z-score values for height, SH and LL (Table 7.14). Eighty-nine percent of them were below the 5th percentile for height-for-age indicator (short stature/adult stunting). The prevalence of short trunk (83%) and short legs (69%) in grandmothers was also very high.

One-way Anova analysis revealed significant differences in SH, SHR and RLLI between age groups. Sitting height and SHR decreased as grandmothers' age increased and RLLI increased with age. After multiple-comparison tests we found that, in the three variables, significant differences were found between group 1 (40-49 years) and group 3 (60-69 years). Our results show, as expected, a significant reduction in the upper trunk of grandmothers with age.

Table 7.13 Descriptive statistics of observed and derived values (mean $\pm$SD) of linear growth variables of grandmothers

Variable	40-49 yrs (1)		50-59 yrs (2)		60-69 yrs (3)		70-79 yrs (4)		Diff [a, b]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
n	16		44		36		13		
Age (years)	46.68	2.06	55.32	2.81	65.06	2.79	73.05	2.43	$F = 323.44$ $p<0.001$ [a]
Height (cm)	144.28	5.18	143.50	4.57	142.48	4.65	141.85	5.32	$X^2 = 3.21$, $p = 0.359$ [b]
SH (cm)	77.36	2.98	76.35	2.64	74.96	3.10	74.73	2.52	$F = 3.83$, $p = 0.012$ [a]
SHR (%)	53.63	1.37	53.21	1.25	52.60	1.21	52.70	1.22	$F = 3.24$, $p = 0.025$ [a]
LL (cm)	66.92	3.49	67.14	3.10	67.52	2.66	67.62	3.62	$F = 0.18$, $p = 0.911$ [a]
RLLI (%)	46.37	1.37	46.78	1.25	47.40	1.21	47.30	1.22	$F = 3.23$, $p = 0.025$ [a]
KH (cm)	44.95	2.27	44.18	1.81	44.75	1.82	44.68	1.75	$F = 0.98$, $p = 0.404$ [a]

SH: Sitting height; SHR: Sitting height ratio (SH x 100/height); LL: Leg length (height – SH); RLLI: Relative leg length index (LL x 100/height); KH: Knee height; [a]One-way Anova; [b]Kruskal-Wallis rank sum test.

Table 7.14 Descriptive statistics (mean ±SD) of z-score values of height, SH and LL-for-age, and percentages of stunting and short trunk and legs in grandmothers

Indicator	Mean	SD	Stunting/Short trunk or legs*
			% (n)
Height-for-age	-2.64	0.77	89 (97)
SH-for-age	-2.49	0.90	83 (91)
LL-for-age	-2.04	0.76	69 (75)
SHR-for age	0.23	0.86	-

SH: Sitting height; LL: leg length; SHR: Sitting height ratio;
*Cut-off point = z-score of < -1.645 or below 5th centile (Frisancho AR. 2008. Anthropometric standards: an interactive nutritional reference of body size and body composition for children and adults. Ann Arbor, MI: The University of Michigan Press. 335 p).

7.3.2 Nutritional status of grandmothers according to body mass and body composition variables

Descriptive statistics of observed and derived values of grand-maternal body mass and body composition variables are given in Table 7.15. One-way Anova analysis showed significant differences in tricipital skinfold (TS) and %BF between age groups. Multiple-comparison tests revealed that the grandmothers of group 1 (40-49 years) had significantly higher values of TS than grandmothers of group 3 (60-69 years) as well as significantly lower values of %BF than grandmothers of groups 3 (60-69 years) and 4 (70-79 years). Kruskal Wallis analysis also revealed significant differences in subscapular skinfold (SS) between age groups. After multiple-comparison tests we found that grandmothers of group 4 (70-79 years) had significantly lower values than grandmothers of group 1 (40-49 years) and group 2 (50-59 years), and grandmothers of group 3 (60-69 years) had significantly lower values than grandmothers of group 1 (40-49 years). Lean body mass decreased significantly with age but significant differences were found only between group 1 (the youngest) and groups 3 and 4. Our results show in general two findings: 1) indicators of subcutaneous fat (TS and SS) and %LBM decrease as grandmothers' age increases and, 2) grand-maternal %BF increases with age.

Table 7.15 Descriptive statistics of observed and derived values (mean $\pm$SD) of body mass and body composition variables of grandmothers

Variable	40-49 yrs (1)		50-59 yrs (2)		60-69 yrs (3)		70-79 yrs (4)		Diff [a, b]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
n	16		44		36		13		
Age (years)	46.68	2.06	55.32	2.81	65.06	2.79	73.05	2.43	$F = 323.44$ $p<0.001$[a]
Weight (kg)	68.37	9.02	66.49	11.58	63.51	10.49	61.78	8.99	$X^2 = 4.30$, $p = 0.231$[b]
BMI (kg/m^2)	32.83	3.93	32.28	5.41	31.24	4.58	30.67	4.08	$X^2 = 2.99$, $p = 0.394$[b]
WC (cm)	96.83	6.63	97.25	9.09	96.12	11.26	97.36	7.76	$X^2 = 0.04$, $p = 0.998$[b]
HC (cm)	105.79	8.03	107.20	10.98	104.82	9.23	105.25	10.56	$X^2 = 0.72$, $p = 0.869$[b]
WHR	0.92	0.07	0.91	0.04	0.92	0.07	0.93	0.04	$X^2 = 1.40$, $p = 0.704$[b]
TS (mm)	27.64	6.26	26.04	6.35	21.75	6.41	21.64	4.85	$F = 4.45$, $p = 0.006$[a]
SS (mm)	26.02	4.36	23.94	6.47	21.01	6.19	18.98	4.30	$X^2 = 16.98$, $p<0.001$[b]
%BF	47.53	4.50	49.72	4.57	51.83	5.08	52.79	4.27	$F = 4.51$, $p = 0.005$[a]
%LBM	52.48	4.50	50.28	4.57	48.17	5.09	47.58	4.29	$F = 4.20$, $p<0.008$[a]

BMI: Body mass index (weight/height^2); WC: Waist circumference; HC: Hip circumference; WHR: Waist-to-hip ratio; TS: Tricipital skinfold; SS: Subscapular skinfold; %BF: Body fat percentage; %LBM: Body lean mass percentage; [a]One-way Anova; [b]Kruskal-Wallis rank sum test.

Eighty-three percent of the grandmothers showed risk for abdominal obesity (WC $\geq$ 88CM). As we found among the mothers, grandmothers with high WC have significant higher values of weight, BMI, TS, SS, sum of skinfolds and %BF (Table 7.16). We found that grand-maternal WC correlated with %BF at $r = 0.56$ ($p<0.001$).

Fifty-five percent of grandmothers reported to have been diagnosed with some sort of chronic disease. Type 2 diabetes *mellitus* and hypertension were the diseases with the highest percentages (21% and 28% respectively). Hypercholesterolemia (16%) and hypertriglyceridemia (12%) were also diseases with high percentages in grandmothers. Moreover, the coexistence of illnesses describes the adverse health condition of Maya grandmothers: 6% of them reported to have been diagnosed with diabetes and hypertension and in 11% there was hypercholesterolemia and hypertriglyceridemia.

Table 7.16 Differences in anthropometric variables between grandmothers with low and high waist circumference

Variables	Low WC (< 88cm)		High WC (≥ 88cm)		Diff [a, b]
	Mean	SD	Mean	SD	
n	18 (17%)		91 (83%)		
Age (years)	60.24	7.84	59.22	8.55	$t = 0.47$ $p = 0.640$[a]
Height (cm)	141.56	3.77	143.38	4.91	$z = -1.35$, $p = 0.177$[b]
Weight (kg)	53.14	7.73	67.61	9.65	$z = -5.39$, $p<0.001$[b]
BMI (kg/m^2)	26.47	2.64	32.88	4.40	$z = -5.53$, $p<0.001$[b]
TS (mm)	19.34	5.76	24.84	6.27	$t = -3.44$, $p<0.001$[a]
SS (mm)	17.90	4.70	23.64	6.06	$z = -3.64$, $p<0.001$[b]
SumSkf (mm)	37.24	9.41	48.55	11.51	$z = -3.88$, $p<0.001$[b]
%BF	47.24	4.84	51.10	4.71	$t = -3.16$, $p<0.001$[a]

BMI: Body mass index ($weight/height^2$); TS: Tricipital skinfold, SS: Subscapular skinfold; SumSkf: tricipital and subscapular; %BF: Body fat percentage; [a]Student t-test; [b] Wilcoxon rank sum test.

7.4 Nutritional conditions among participants of the three generations, descriptive comparisons and relevant combinations

Frequencies and prevalence of nutritional status categories by generation are given in Table 7.17. In all three categories of linear growth deficit the grandmothers had higher prevalence of stunting, short trunk and legs than mothers and children. Mothers showed a higher prevalence of these conditions than their children. The same pattern was found regarding the prevalence of risk for abdominal obesity. Underweight was only reported in 3 children and no mother or grandmother had a BMI value below 18.5 kg/m^2.

Table 7.17 Prevalence of nutritional conditions by generation

Criteria	F_3 (children)		F_2 (mothers)		F_1 (grandmothers)	
	n	%	n	%	n	%
Stunting	12	11	77	71	97	89
Short trunk	8	7	54	50	91	83
Short legs	32	29	59	54	75	69
Abdominal obesity (AO)	35	32	60	55	91	83

Stunting, short trunk and legs: z-score less than -1.645 or below 5^{th} percentile of height-for-age, SH-for-age and LL-for-age respectively; risk for AO in children: above 85^{th} percentile of WC-for-age; risk for AO in adult women: WC equal or above 88 cm.

Table 7.18 shows some relevant combinations of nutritional conditions among members of the three generations. We found that in only 6% of the triads none of the family members showed short stature. In other words, 94% of the triads have, at least, one stunted family member. Alarmingly, stunting coexisted in children, mothers and grandmothers in 10% of triads, which might be reflecting the effects of intergenerational influences and the persistence of adverse environmental conditions across generations. We also found that risk for abdominal obesity coexisted in all family members in 18% of the triads. In contrast, only 8% of the triads showed normal or healthy values of WC.

Table 7.18 Nutritional condition combinations among children-mother-grandmothers triads

Condition	Children	Mothers	Grandmothers	%
Stunting	×	×	×	6
	×	×	✓	1
	×	✓	✓	56
	✓	✓	✓	10
Abdominal obesity	×	×	×	8
	×	×	✓	24
	×	✓	✓	28
	✓	✓	✓	19

✓ Presence; × Absence
Stunting was defined when z-score or percentile of height-for-age was < -1.645 or below 5th; abdominal obesity (AO) was defined in children when z-score of waist-for-age was > 85th and > 88 cm in mothers and grandmothers.

7.5 Nutritional dual burden

7.5.1 Nutritional dual burden at individual level

The prevalence of NDB at the individual level was calculated in children, mothers and grandmothers. The coexistence of stunting (z-score of < -1.650 for height-for-age) and OW/OB (> 85th percentile of BMI-for-age) in children was only seen in 1% of the sample. We found the same prevalence when the combination of stunting and abdominal obesity (> 85th percentile of WC-for-age) was analysed.

As we noted in the Methods chapter, NDB in mothers and grandmothers was defined as the combination of short stature (<5th percentile of height-for-age) and abdominal obesity (WC > 88cm). Thirty-six percent of the mothers and 72% of the grandmothers presented NDB.

7.5.2 Nutritional dual burden at household level: mother-child dyads and grandmother-mother-child triads

The NDB at household level was analysed at mother-child dyads level and at grandmother-mother-child triads' level. In the first case we found that the combination of maternal abdominal obesity and stunted children was present in 6% of the dyads (Table 7.19). We did not find any pair with an underweight child and a mother with abdominal obesity. Additionally, we found that 19% of mother-child-dyads showed the combination of maternal stunting and OW/OB in children.

Six percent of the grandmother-mother-child triads showed the combination of stunted children and abdominal obesity in mothers and grandmothers. In contrast, the combination of abdominal obesity in children and stunting in grandmothers and mothers was more prevalent (18%).

Table 7.19 Prevalence of nutritional dual burden in mother-child pairs and child-mother-grandmother triads

Combinations	n	%
Dyads		
Stunted children & AO in mothers	7	6
Underweight children & AO in mothers	-	-
Stunted mother & AO in children	21	19
Triads		
Stunted children & AO in mothers and grandmothers	7	6
Stunted mother and grandmother & AO in children	20	18
Underweight children & AO in mothers and grandmothers	-	-

Stunting was determined when z-score or percentile of height-for-age was < -1.645 or below 5^{th}; abdominal obesity (AO) in mothers was determined when waist circumference (WC) was $\geq$ 88 cm, AO in children when percentile of WC-for-age was > 85^{th}; underweight in children was determined when BMI-for-age was below 5^{th} percentile of reference.

In summary, the nutritional status of children, mothers and grandmothers reflect the long term adverse socioeconomic environment experienced by the sample. Eleven percent of the children met the criteria for stunting, but 29% showed short legs, which means that deficit of growth is more evident in the lower body segments. Differences in the proportion of children with short legs, by sex, suggest that girls have a more positive growth status than boys. Thirty-six percent of the children were OW/OB and 32% have high WC. Short stature was seen in 71% of the mothers (short legs = 54% vs. short trunk = 50%) and in 90% of the grandmothers (short legs = 69% vs. short trunk = 83%). Using the 88 cm cut-off point for WC we found that 55% of mothers and 83% of grandmothers showed risk for abdominal obesity. Women of F_1 and F_2 with high WC showed significantly higher values of body fat indicators than women with low WC. Nutritional dual burden at individual level was present in 1% of children and in 36% and 72% of mothers and grandmothers respectively. Maternal abdominal obesity and stunting in children coexisted in 6% of mother-child dyads. Six percent of the grandmother-mother-child triads showed the combination of stunted children and abdominal obesity in mothers and grandmothers.

CHAPTER 8

Results

Socioeconomic and biological factors related to the physical growth of the children

8. Socioeconomic and biological factors related to the physical growth of the children

The general aim of this chapter is to show some socioeconomic and biological factors that have significant influence on the growth of the children (F_3). This chapter is organized in three sections: 1) description of the statistical methods used along the chapter, 2) description and analysis of the socioeconomic and biological factors that relate to the linear growth variables of children, and 3) description and analysis of the socioeconomic and biological factors that relate to the children's body mass and body composition variables. It is important to note that the results showed in this chapter do not included intergenerational effects. The results of the intergenerational influences on children's growth will be shown in Chapter 9.

8.1 Data analysis approach

8.1.1 Multiple regression models

Multiple regression models were performed to identify and measure the influence of socioeconomic and biological factors that best explain the growth of children. Outcome variables were: z-score values for height, LL, BMI, and WC, %BF and %LBM. We decided to perform models for these variables because they were used to describe the growth and nutritional status of children and the main results of the nutritional dual burden phenomenon. However, we ran additional models for raw measures of height and LL and also for FM and FFM (Appendixes 5-8).

8.1.2 Selection of predictor variables

Literature provides evidence of a set of socioeconomic and biological variables that potentially influence the physical growth during childhood (i.e. Bogin, 1999; Steckel, 2012). However, research reports over socioeconomic predictors on Maya children's growth from Yucatan are less available. Table 8.1 and 8.2 show the socioeconomic and biological variables that were examined during the identification of significant predictors.

These variables were chosen following two criteria: 1) socioeconomic variables whose biological effects have been analysed in the Maya from Merida city, 2) socioeconomic variables that distinguish Maya populations from non-Maya populations from Merida city.

Household assets, kitchen and toilet availability at home and construction materials of the house are variables that differentiate Maya families from non-Maya families in the city of Merida (Wolanski et al., 1993; Siniarska and Wolanski, 1999; Vázquez, 2013). In general, research reports show that Maya families experienced disadvantaged conditions in relation to these indicators. Family income has been documented as a significant predictor of growth in Maya children (Azcorra et al., 2009; Vazquez, 2013). However, according to our knowledge of the local context it is also important to take into account the income of fathers since they are who make the primary monetary contributions to the family. For this reason paternal income was also examined during the models' construction. According to our previous research experience in the city of Merida (Azcorra, 2007), many mothers are unaware of their partner's salary. For this reason we decided to use the paternal monetary contribution to the familial living expenses as a predictor variable. We define contribution as all money that the mother receives monthly from her partner for food, house, clothes, and health and education expenses. Given this situation, we decided to build additionally a dichotomous variable that expresses the current presence or absence of the father at home.

Antenatal care variables were also examined during the construction of the models. Specifically, we explored the effects of the number of ultrasounds that the mother received during the pregnancy (continuous) and ingestion of iron and vitamins supplementation during pregnancy (dichotomous, yes/no). Even when the literature shows that preeclampsia and gestational diabetes have a significant effect on prenatal growth, manifested mainly on the birth weight, we decided to examine the effect of these two variables (as a dichotomous variable) during modelling. Although the effects of these variables have not been examined in the context of the Maya population, we included them due to their specific relevance. Birth weight of the children was analysed in two ways: 1) as a continuous variable (in grams), and 2) as a dichotomous variable with normal weight and low weight at birth ($\leq$ 2500 gr) categories. We also asked the mothers if they smoked or if they were cohabiting with smokers during their pregnancy (dichotomous variable, yes/no). Since we lacked data about inter-genesic period, we calculate the interbirth period, defined as the time period between the birth of the previous offspring and the birth of the studied offspring (in months). A set of variables related to early feeding environment practices were included in the predictors group, among these the occurrence of breastfeeding during infancy (dichotomous, yes/no), the length of breastfeeding, the age of weaning, the age of introduction of formula milk (all three variables in months), and the use of formula milk (dichotomous, yes/no).

The effect of infectious diseases was analysed in two dimensions. We firstly use the presence of infectious diseases during the previous week of the survey (dichotomous). The second dimension was the use of categorical variables that assess the maternal perception about the health status of the child during different life stages, according to the presence or absence of infectious diseases.

Table 8.1 Socioeconomic predictors included in the analysis of children's growth

Variable	Continuous	Dichotomous	Categorical	Source
Crowding	Index	-	-	Vázquez, 2013
Household assets	Number of assets	0 = Absent 1 = Present	-	Wolanski et al., 1993; Siniarska & Wolanski, 1999
Toilet at home	-	0 = No 1 = Yes	-	Wolanski et al., 1993; Siniarska & Wolanski, 1999
Kitchen at home	-	0 = No 1 = Yes	-	Siniarska & Wolanski, 1999
Construction materials of the floor	-	0 = Cement 1 = Cement & tile	-	Vázquez, 2013
Construction materials of the walls	-	0 = Bricks 1 = Bricks & cement	-	Vázquez, 2013
Construction materials of the roof	-	0 = Bricks 1 = Bricks & cement	-	Vázquez, 2013
Maternal education	Number of years	0 = None 1 = Primary or >	0 = None 1 = Primary 2 = Secondary	Moguel, 2011; Vázquez, 2013
Famillal income (FI)	Monthly FI	-	-	Azcorra et al., 2009; Vázquez, 2013
Monetary familial contribution (MFC)	Monthly MFC	-	-	Azcorra, 2007
Paternal income (PI)	Monthly PI	-	-	Azcorra, 2007
Paternal monetary contribution (PMC)	Monthly PMC	-	-	Azcorra, 2007
Paternal laboral status	-	-	1=Employee 2=Employer 3=Self-employed	Malina et al., 2009, Vázquez, 2013
Grandmothers at home	-	0 = No; 1 = Yes	-	Vera, 2010
Ultrasounds during pregnancy	Number	-	-	Sparks, 2011

Table 8.2 Biological predictors included in the analysis of children's growth

Variable	Continuous	Dichotomous	Categorical	Source
Crowding	Index	-	-	Vazquez, 2013
Sex	-	0 = Females 1 = Males	-	Azcorra et al., 2009
Age	Years	-	-	Azcorra et al., 2009
Birth weight	Grams	0 = Normal birth weight 1 = Low birth weight	-	Azcorra et al., 2009; Vázquez, 2013
Birth order	-	-	Order	Azcorra et al., 2009
Preeclampsia during gestation	-	0 = No; 1 = Yes	-	Larsen et al., 1997
Diabetes during gestation	-	0 = No; 1 = Yes	-	Ornoy, 2005
Length of breastfeeding	Months	-	-	Thompson, 2012
Presence of breastfeeding	-	0 = No; 1 = Yes	-	Thompson, 2012
Age of weaning	Months	-	-	Thompson, 2012
Use of formula milk	-	0 = No; 1 = Yes	-	Thompson, 2012
Age of introduction of formula milk	Months	-	-	Thompson, 2012
Presence of infection disease during previous week	-	0 = No; 1 = Yes	-	Azcorra et al., 2009

8.1.3 Model building

Model building was done following an exploratory approach. In order to decide which variables should be included in the regression models, each predictor variable was regressed against each outcome variable. The variables that showed a significant prediction ($p<0.05$) of the outcome or were borderline significant ($p<0.10$) were retained in the model.

All models were adjusted for maternal anthropometric variables. Therefore, the model for the z-score of height was adjusted for maternal z-score of height; the model for the z-score of LL was adjusted for maternal z-score of LL and so on. These variables were used, in part, as proxy measures of genetic influences.

Diagnostic tests were applied to each model to assess its validity. Linear relationships between each predictor and the outcome variables were verified by producing and analysing scatter plots. Residuals were examined for assumptions of normality through statistical tests and dispersion diagrams. Non-colinearity between predictor variables was corroborated by the calculation of the variance inflation factor (VIF) values and in no cases violated assumptions. In each significant association between predictor and outcome variables, 95% CI were verified to ensure that the effect of predictor on the outcome variable was estimated with good precision. For each model all possible interaction variables between predictors were generated and regressed to the outcome to check its effect.

8.2 Socioeconomic and biological predictors of linear growth variables

8.2.1 Model of z-score for height

The model regarding children's height z-scores is shown in Table 8.3. Overall the variables included in the model explained 35% of the variance of the studied variable. Maternal height was the only significant variable that impacted positively the height of the children. This predictor contributed to explain 12% of variance. With a similar effect size, both the presence of preeclampsia and having lived with smokers during pregnancy influenced negatively the height of children, although the effect of cigarette smoke exposure was marginally significant ($p = 0.070$). Specifically, we found that those children whose mothers experienced preeclampsia had significantly lower z-score values for height (-1.04 ± 0.84 vs. -0.59 ± 0.79, $p<0.05$ Student t-test) than children whose mothers did not experienced preeclampsia. As expected, the increase in the crowding index impacted negatively the growth of children. Specifically, we found that the height of the children decreased 0.15 units of z-score per each additional member in the household. Even when the z-score values of growth measurements tend to standardize issues that are age-related, we found that age had a negative influence on the outcome variable. The mean of z-score for height decreased as age increased [6 = -0.46 ($\pm$0.81), 7 = -0.74 ($\pm$0.79), 8 = -0.82 ($\pm$0.74)], although one-way Anova analysis showed that these differences were not significant ($F = 2.11$, $p = 0.126$). Iron supplementation during pregnancy and birth weight had non-significant effects on children's height. Interaction between cigarette smoke exposure during pregnancy and birth weight was not significant. Children's sex was not included in the model because it did not significantly predict the outcome variable and their presence did not change the behaviour of the other predictors.

Table 8.3 Multiple regression model of socioeconomic and biological predictors for children's height z-score

Variable	Coefficient	S. E.	t	p	CI 95%	
Iron supplementation during pregnancy (Yes, n = 100)	0.53	0.33	1.64	0.104	-0.11	1.18
Mother's height (z-score)	0.40	0.10	4.11	<0.001	0.21	0.59
Birth weight (kg)	0.16	0.15	1.06	0.292	-0.14	0.46
Crowding index	-0.15	0.05	-2.96	0.004	-0.24	-0.05
Lived with smokers during pregnancy (Yes, n = 18)	-0.35	0.19	-1.83	0.070	-0.72	-0.03
Preeclampsia during gestation (Yes, n = 21)	-0.39	0.17	-2.27	0.026	-0.73	-0.05
Age (years)	-0.23	0.09	-2.65	0.009	-0.40	-0.06
Constant	1.42	0.88	1.61	0.110	-0.33	3.16

S.E.: standard error; n = 101, F (7, 93) = 7.23, p<0.001, R^2 = 0.35, adjusted R^2 = 0.30; Shapiro-Wilk residual normality test: w = 0.98, p = 0.355; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.21, p = 0.647.

8.2.2 Model of z-score for leg length

The model for children's LL z-score is shown in Table 8.4. All variables included in the model contributed to explain 39% of the variance for the outcome variable. Sex was a significant predictor of children's z-score of LL. The model showed that being a girl significantly predicts an increase in LL values of 0.59 units of z-score. This finding is consistent with results showed in Chapter 7, where the nutritional status of the participants is described. Girls, as a group, show significant higher z-score values for LL than boys (-0.80 $\pm$0.77 vs. -1.47 $\pm$0.89, p<0.001 Student t-test). The age of the children did not significantly predict the children's LL. We found that maternal z-score of LL impacted positively the outcome variable, although had a small effect (0.27 units of z-score of LL per each unit increased in the maternal z-score). After controlling for age, sex and maternal LL, we found that iron supplementation during gestation predicted positively the growth of the children and the presence of preeclampsia during gestation affected their growth negatively. Specifically, we found that those children whose mothers consumed iron supplementation during pregnancy showed significantly higher values of z-score of LL (-1.08 $\pm$0.88 vs. -1.88 $\pm$1.00, p<0.05 Student t-test) than children whose mothers were not supplemented. In contrast, we found that mothers who experienced preeclampsia had children with significantly lower values of the outcome variable (-1.53 +0.99 vs. -1.04 +0.85, p<0.05 Student t-test) than children of mothers who did not experienced preeclampsia. Paternal monetary contribution to familial living expenses predicted positively the growth of children's LL, although its effect was small and marginally significant [0.10 units of z-score per each additional 1,000 Mexican pesos (£ = 48.15)].

Table 8.4 Multiple regression model of socioeconomic and biological predictors for children's LL z-score

Variable	Coefficient	S. E.	t	p	CI 95%	
Iron supplementation during gestation (Yes, n = 100)	0.83	0.37	2.26	0.026	0.10	1.57
Sex (Girls, n = 56)	0.59	0.16	3.68	<0.001	0.27	0.92
Mother´s leg length (z-score)	0.27	0.10	2.69	0.009	0.07	0.48
Paternal monetary contribution to familial expenses (1000MXN/£48.15)	0.10	0.05	1.78	0.080	0.01	0.21
Birth weight (kg)	0.01	0.17	-0.08	0.938	-0.37	0.33
Age (years)	-0.14	0.09	-1.44	0.153	-0.34	-0.05
Preeclampsia during gestation (Yes, n = 21)	-0.50	0.20	-2.57	0.012	-0.90	-0.11
Constant	-0.83	0.94	-0.88	0.383	-2.71	1.04

S.E.: standard error; n = 91, F (7, 83) = 7.59, p<0.001; R^2 = 0.39, adjusted R^2 = 0.34; Shapiro-Wilk residual normality test: w = 0.98, p = 0.296; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 2.87, p = 0.103.

8.3 Socioeconomic and biological predictors of body mass and body composition variables

8.3.1 Model of z-score for BMI

The model of children's BMI z-score is shown in Table 8.5. All predictors of BMI into the model contributed to explain 40% of the variance of this variable. As expected, maternal BMI and child birthweight influenced positively the children's BMI, and each of these variables explained 5% of variance respectively. After controlling for birthweight and maternal BMI, we found that the number of ultrasounds mothers received during pregnancy, maternal education and the presence of grandmothers at home had a significant effect on the BMI of children. Specifically, we found that per each additional ultrasound received by mothers the children's z-score of BMI increased 0.16 units.

Table 8.5 Multiple regression model of socioeconomic and biological predictors for children's BMI z-score

Variable	Coefficient	S. E.	t	p	CI 95%	
Birth weight (kg)	0.39	0.15	2.55	0.012	0.09	0.70
Number of ultrasounds during pregnancy	0.16	0.04	4.22	<0.001	0.08	0.23
Mother´s BMI	0.04	0.01	2.73	0.008	0.02	0.08
Maternal education (reference = None)						
Primary (n = 25)	-0.67	0.26	-2.65	0.009	-1.18	-0.17
Secondary or > (n = 69)	-0.77	0.22	-3.44	0.001	-1.21	-0.32
Grandmother at home (Yes, n = 20)	-0.49	0.19	-2.55	0.013	-0.86	-0.11
Constant	-1.54	0.70	-2.20	0.030	-2.94	-0.15

S.E.: standard error; n = 103, F (6, 96) = 10.49, p<0.001, R^2 = 0.40, adjusted R^2 = 0.36; Shapiro-Wilk residual normality test: w = 0.98, p = 0.132; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.86, p = 0.354.

Maternal education explained 6% of the variance of the studied variable. After controlling for other predictors, we found that children whose mothers completed levels of primary or secondary education had significant smaller values of BMI in comparison with those children whose mothers did not complete some level of formal education. Specifically, primary and secondary education in mothers predicted reductions of 0.67 and 0.77 units of z-score of BMI, respectively. Additionally, we found that the presence of grandmothers at home predicted a significant reduction on the children's BMI. In particular those children who lived with their maternal grandmother at the moment of the research had about a half unit less of z-score of BMI.

8.3.2 Model of z-score for WC

The socioeconomic and biological predictors of children's WC z-score are shown in Table 8.6. Variables included in the final model explained 36% of the variance of the analysed variable. In general, models for WC and BMI showed similar results. After controlling for maternal WC and birth weight of the children, we found that maternal marital status during pregnancy was one of the strongest predictors in the model: those mothers who had a partner during pregnancy had children with more than one half units of z-score of WC more than children whose mothers did not have a partner during pregnancy. Maternal education influenced negatively the outcome variable. Again it was found that mothers with some level of formal education had a significant reduction in the outcome variable. The effect sizes of primary and secondary maternal education were of 0.59 and 0.54 units of z-score for WC respectively. As in the model for BMI, the number of ultrasounds the mother received during pregnancy was a predictor that positively impacted the WC of children, although the effect size was small (β = 0.10 per each additional ultrasound). No interaction between predictors was significant in the model.

Table 8.6 Multiple regression model of socioeconomic and biological predictors for children's WC z-score

Variable	Coefficient	S. E.	t	p	CI 95%	
Maternal marital status during pregnancy (Married, n = 94) (reference = Single)	0.61	0.19	3.16	0.002	0.23	0.99
Birth weight (kg)	0.26	0.13	2.04	0.045	0.02	0.50
Number of ultrasounds during pregnancy	0.10	0.03	3.20	0.002	0.04	0.16
Mother´s WC	0.02	0.00	3.33	0.001	0.01	0.03
Maternal education (reference = None)						
Primary (n = 25)	-0.59	0.22	-2.73	0.008	-1.02	-0.16
Secondary or > (n = 69)	-0.54	0.19	-2.91	0.004	-0.91	-0.17
Constant	-2.30	0.71	-3.25	0.002	-3.80	-0.89

S.E.: standard error; n = 103, F (6, 96) = 9.02, p<0.001; R^2 = 0.36, adjusted R^2 = 0.32; Shapiro-Wilk residual normality test: w = 0.98, p = 0.347; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.51, p = 0.476.

8.3.3 Model of body fat percentage

Variables included in the model explained 39% of children's %BF variance (Table 8.7). As expected, the results showed that being a girl predicted an increase of almost 3.6% of children's body fat. Sex explained 12% of the variance in studied variable. The influence of maternal %BF was marginally significant and taller children had higher percentages of body fat. After controlling for children's sex, height and maternal %BF, we found that the number of ultrasounds mothers received during pregnancy positively impacted the outcome variable: per each additional ultrasound received by the mother, the children's %BF increased in 0.74 units. Overcrowding had a non-significant effect on children's %BF. Mothers with primary and secondary level of education predicted significant reductions on children's %BF. Specifically, the model showed that children whose mothers completed primary school had almost 5% less body fat in comparison to those children whose mothers did not complete some level of formal education. In addition, those children whose mothers completed the secondary level or more had 4.18% less body fat than those children whose mothers did not achieve any level of formal education. The model also showed that the presence of grandmothers at home predicted a significant reduction in the %BF of children. In particular, children with grandmothers at home had 3.17% less of body fat. Additionally we found that children with grandmothers at home had marginally significant lower values of %BF than children without grandmothers at home (28.00 $\pm$5.56 vs. 30.43 $\pm$5.67, p = 0.08 Student t-test), which also suggest that the presence of grandmothers at home is acting as a protector of children's health.

Table 8.7 Multiple regression model of socioeconomic and biological predictors of children's percentage of body fat

Variable	Coefficient	S. E.	t	p	CI 95%	
Sex (Girls, n = 56)	3.65	0.88	4.21	<0.001	1.93	5.38
Number of ultrasounds during pregnancy	0.74	0.22	3.37	0.001	0.30	1.17
Children's height	0.17	0.07	2.23	0.028	0.02	0.31
Maternal body fat (%)	0.17	0.09	1.74	0.085	-0.02	0.36
Crowding index	-0.36	0.32	-1.13	0.263	-0.99	0.27
Maternal education (reference = None)						
Primary (n = 25)	-4.95	1.43	-3.46	0.001	-7.79	-2.11
Secondary or > (n = 69)	-3.96	1.25	-3.15	0.002	-6.46	-1.46
Grandmother at home (Yes, n = 20)	-3.17	1.17	-2.71	0.008	-5.50	-0.84
Constant	3.70	10.20	0.36	0.718	-16.56	23.96

S.E.: standard error; n = 104, $F (8, 95) = 7.68$, $p<0.001$, $R^2 = 0.39$, adjusted $R^2 = 0.34$; Shapiro-Wilk residual normality test: w = 0.98, p = 0.228; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)} = 0.02$, p = 0.892.

8.3.4 Model of lean body mass percentage

Predictors included in the final model contributed to explain 40% of %LBM variance (Table 8.8). As expected, maternal lean body mass percentage predicted positively the outcome variable. The model showed that being a girl predicted a reduction in the %LBM of the children by 4 units. Children's height negatively predicted their lean mass; specifically children showed 0.17 units less of %LBM per each centimeter added to their height. After controlling for children's sex, height and maternal lean body mass (percentage), we found that maternal education and the presence of grandmothers at home impacted positively the lean body mass of the children. Mothers with primary and secondary level of education predicted 4.89% and 3.66% more of lean body mass respectively in comparison to children of mothers without any level of formal education. In addition, children with grandmothers living at home had almost 3% more lean body mass in comparison to children without grandmothers living at home. The number of ultrasounds was another variable with a significant impact of the children's %LBM. However, in contrast to %BF model, the number of ultrasounds negatively impacted the outcome variable. In particular, the lean body mass of children decreased significantly in 0.83% per each additional ultrasound received by mothers.

Table 8.8 Multiple regression model of socioeconomic and biological predictors for children's lean body mass percentage

Variable	Coefficient	S. E.	t	p	CI 95%	
Sex (Girls, n = 56)	-4.02	0.90	-4.45	<0.001	-5.81	-2.22
Number of ultrasounds during pregnancy	-0.83	0.23	-3.68	<0.001	-1.28	-0.38
Children's height	-0.17	0.07	-2.17	0.032	-0.33	-0.01
Maternal body lean mass (%)	0.20	0.09	2.00	0.049	0.01	0.39
Crowding index	0.41	0.33	1.23	0.220	-0.25	1.07
Maternal education (reference = none, n = 15) Primary (n = 25)	4.89	1.50	3.26	0.002	1.92	7.87
Secondary or > (n = 69)	3.66	1.32	2.78	0.007	1.05	6.27
Grandmother at home (Yes, n = 20)	2.82	1.20	2.35	0.021	0.44	5.20
Constant	78.60	11.48	6.85	<0.001	55.81	101.39

S.E.: standard error; n = 106, F (8, 97) = 8.03, $p<0.001$, $R^2 = 0.40$, adjusted $R^2 = 0.35$; Shapiro-Wilk residual normality test: w = 0.98, p = 0.186; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)} = 0.28$, p = 0.599.

Our results suggest that maternal education is acting as a protective factor for children's health. We performed additional analysis of the effect of this variable on anthropometric parameters of body mass and body composition. We consistently found that means of z-score values of BMI, WC and %BF were significantly lower in those children whose mothers reached some level of formal education and who were also closer to the 50th percentile of the references. Differences between children whose mothers reached primary and secondary levels of formal education were not significant in the three anthropometric parameters. In contrast, we found that children whose mothers had some level of education had higher %LBM in comparison with those children whose mothers did not reach some level of formal education (Table 8.9).

Additionally it was found that the proportions of children with "healthy BMI and WC" and "excessive BMI and WC" between the three categories of maternal education were significantly different. Children with healthy values of BMI and WC were more clustered in categories showing that the mothers had some level of formal education (Table 8.10).

Table 8.9 Differences in children's z-score values of body mass index and waist circumference and percentage of body fat by maternal education level

Variable	Maternal education level			F, p (One-way Anova)
	None (n = 15)	Primary (n = 25)	Secondary (n = 69)	
Z-score of BMI	1.35* (1.11)	0.69* (0.82)	0.58 (0.95)	F = 4.05, p<0.05
Z-score of WC	1.06* (0.77)	0.54 (0.70)	0.53* (0.78)	F = 3.09, p<0.05
%BF	33.58* (4.96)	28.05* (5.24)	29.90 (5.72)	F = 4.72, p<0.05
%LBM	66.42* (4.96)	71.95* (5.24)	70.10 (5.72)	F = 4.72, p<0.05

%BF: Body fat percentage; %LBM: Body lean mass percentage; *Significant differences (p<0.05) after Bonferroni post hoc multiple comparisons group.

Table 8.10 Children with healthy and excessive body mass index and waist circumference by maternal education level

	Body mass index			Waist circumference		
Maternal education	Healthy % (n=70)	Excessive % (n=39)	X^2, p	Healthy % (n=74)	High % (n=35)	X^2, p
None	7 (5)	26 (10)		8 (6)	26 (9)	
Primary	22 (15)	26 (10)	X^2 = 8.46, p = 0.015	27 (20)	14 (5)	X^2 = 7.12, p = 0.028
Secondary ≥	71 (50)	48 (19)		65 (48)	60 (21)	

Healthy BMI and WC: 5th to 85th percentile of the reference, Excessive BMI and high WC: above 85th percentile of the reference.

The presence of grandmothers at home was another variable with significant impact in the models for %BF and %LBM. Table 8.11 compares linear growth, body mass and body composition parameters between children according to the presence or absence of grandmothers at home. There are non-significant differences in height, LL and their z-score values. Except for percentage of lean mass, children with grandmothers at home show lower values for all parameters of body mass and composition, however marginally significant differences were only found in body fat and lean body mass percentage.

Table 8.11 Differences in linear growth and body mass and composition variables in children by presence of grandmother at home

Variables	Grandmothers at home				Diff
	Yes		No		
	Mean	SD	Mean	SD	
Height (cm)	119.30	6.83	119.41	5.69	t = 0.08, p = 0.939
Z-score of height	-0.79	0.96	-0.64	0.75	t = 0.79, p = 0.434
LL (cm)	55.40	3.70	55.43	3.72	t = 0.04, p = 0.966
Z-score of LL	-1.18	0.92	-1.11	0.89	t = 0.33, p = 0.746
BMI	16.80	2.45	17.71	2.71	*z* = 1.35, p = 0.176
Z-score of BMI	0.40	1.00	0.78	0.95	t = 1.62, p = 0.109
WC (cm)	57.37	6.60	59.69	6.95	z = 1.57, p = 0.117
Z-score of WC	0.38	0.79	0.65	0.77	t = 1.43, p = 0.156
%BF	28.00	5.57	30.43	5.67	t = 1.73, p = 0.085
%LBM	72.00	5.56	69.57	5.67	t = -1.73, p = 0.086
Sum of skinfolds (mm)	30.10	13.17	36.58	16.15	*z* = 1.63, p = 0.103

LL: Leg length; BMI: Body mass index; WC: Waist circumference; %BF: body fat percentage; %LBM: body lean mass percentage; Sum of skinfolds: tricipital, subscapular and iliac skinfolds; Wilcoxon rank sum was used in BMI, WC and sum of skinfolds.

In summary, antenatal and socioeconomic variables were detected as significant predictors of children's growth. Our analysis was divided into linear growth and body mass and body composition parameters. After controlling for children's age, children's sex and maternal height, we found that the crowding index at household, occurrence of preeclampsia during pregnancy and cigarette smoke exposure during pregnancy negatively influenced the children's height and LL. In contrast, iron supplementation during pregnancy and monetary paternal contribution impacted the same variables positively. Results for models regarding BMI and WC were similar. In both cases, after controlling for birth weight and maternal anthropometric parameters, we found that the number of ultrasounds predicted reductions in the outcome variables and maternal education impacted negatively. The presence of the mothers' partner during pregnancy predicted significant increases on the children's WC. Of relevance was the finding that maternal education predicted significant reductions in the percentage of body fat and significant increases in the percentage of lean mass of the children. Additional analysis suggested that children's nutritional status, based on BMI and WC, was healthier in those children whose mothers reached some level of formal education. The presence of grandmothers seems to protect against to children's OW/OB. Those children with grandmother at home had lower values of percentage of body fat and higher values for percentage of lean mass.

CHAPTER 9

Results

Intergenerational influences on the growth status of mothers and children

9. Intergenerational influences on the growth status of mothers and children

The aim of this chapter is to describe the intergenerational influences on the growth of the participants, particularly on children and mothers. For purposes of clarity, throughout this chapter grandmothers will be accompanied with the abbreviation F_1, mothers with F_2 and children with F_3. This chapter is organized in three sections. In the first section we describe the analytical approach to the data. The second presents the results of the analysis of the intergenerational influences of grandmothers (F_3) on mothers (F_2). The third provides the results that include the three generations of the sample, analysing the intergenerational influences of grandmothers (F_1) and mothers (F_2) on children (F_3).

9.1 Data analysis approach

Our approach to the intergenerational influences was based on three levels of analysis. Each of these levels had different purposes and different statistical procedures.

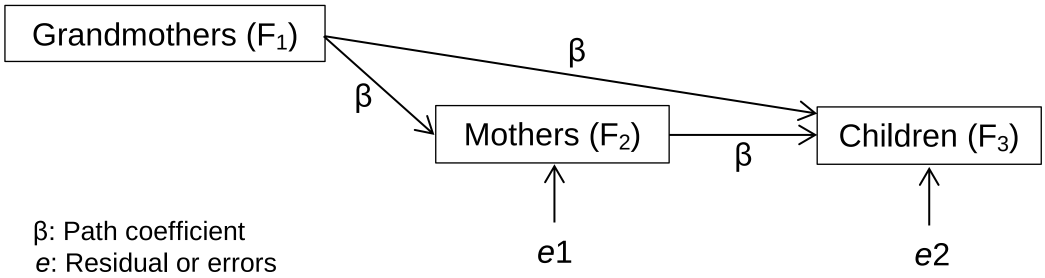
9.1.1 Bivariate and partial correlations

The first of these levels consisted of the calculation of bivariate and partial correlation coefficients for the growth parameters between generations. Bivariate correlations were useful to determine the strength of associations of the anthropometric parameters between grandmothers (F_1) and mothers (F_2). Partial correlations allow us to calculate the strength of relationships between two variables after accounting for the effect of other variables (Kleinbaum et al., 2008). Partial correlations were particularly useful in the analysis of the three generations of the sample. Specifically these allowed us to estimate the proportion of variance of children's (F_3) growth indicators attributed to maternal (F_2) predictors controlling the variance for grand-maternal (F_1) predictors and vice versa. The associations were classified according to the strength of correlations coefficients as weak ($r = 0.10$), moderate ($r = 0.30$) and strong ($r = 0.50$) (Cohen, 1988).

9.1.2 Path analysis

The second level of the analysis consisted of path analysis. In general, the path analytic method is an extension of the multiple regression analysis which aims to estimate the magnitude and significance of causal connections of a set of variables. The direction and magnitude of the connections between variables are given *a priori* under hypothesized systems. Path diagrams are the most convenient way to present a system of variables in a path analysis. Variables are classified, according to their role in the model, as exogenous and endogenous. Exogenous variables are those whose variation is explained by factors outside the model and their role is to explain other variables included in the model. Endogenous variables are those whose variation is explained by one or more variables within the model. Causal relationships between variables in a path analysis can be direct or indirect. Direct effects are those that go directly from one variable to another, and indirect effects between two variables are those that are mediated by one or more variables. Generally, path analyses compute standardized regression coefficients (β) which allow us to compare the magnitude of the effect of one or more explanatory variables. Importantly, when more than one causal variable is included in the model, the standardized coefficients express partial regression coefficients. These coefficients represent measures of the effect of one variable on another, controlling for other variables (Lleras, 2005). In this chapter, path analyses were used to measure the magnitude and significance of separated effects of grand-maternal (F_1) and maternal (F_2) anthropometric parameters on the growth indicators of the children (F_3). Figure 9.1 shows our input path diagram, which represents our hypothesized system of causal connections. Grandmothers (F_1) and children (F_3) represent exogenous and endogenous variables respectively. Mothers play both roles. We hypothesized that direct effects are given from grandmothers to mothers ($F_1 \rightarrow F_2$) and children ($F_1 \rightarrow F_3$) and from mothers to children ($F_2 \rightarrow F_3$). Furthermore, grandmothers may have an indirect effect on the children. Residuals or errors (*e*) represent the variation in the variable that is not explained by factors included in the model. We decided not to include socioeconomic explanatory variables in the path analyses because we aimed to identify and measure the effects of intergenerational influences contained only in the physical constitution of mothers and grandmothers. In our opinion the anthropometric characteristics of F_1 and F_2 provide us valuable information about living conditions experienced during growing years.

Figure 9.1 Input path diagram of the research



Children's growth indicators analysed were: 1) height, LL and KH and z-score values of height and LL, and 2) z-score values of BMI, WC, and sum of skinfolds and FM (kg). For each analysis we built a path diagram which included three direct path coefficients and their significance. Indirect effects of grandmothers (F_1) on children (F_3) were additionally calculated by multiplying the direct coefficients of grandmothers on mothers and of mothers on children. Total effects of grandmothers on children we calculated by adding direct and indirect coefficients. Residuals or errors were reported in each model. In all analyses the significance level was set at $\alpha = 0.05$.

9.1.3 Multiple regression models

The third level of analysis of intergenerational influences consisted of multiple regression models. The aim of these was to separate and measure the effect of anthropometric and socioeconomic intergenerational variables on the growth of participants. Two groups of models were performed: 1) models of the intergenerational influences of grandmothers (F_1) on mothers (F_2), and 2) models of the intergenerational influences of grandmothers (F_1) and mothers (F_2) on children (F_3). The first step for modelling was to identify those variables that should be included in the analysis. Table 9.1 shows all socioeconomic variables that were obtained through questionnaires (see questionnaire in Appendix 3) to assess the living conditions experienced by mothers (F_2) and grandmothers (F_1) during their childhood. These factors are grouped in characteristics of the family and household and particular events experienced during childhood.

Table 9.1 Socioeconomic intergenerational predictors of grandmothers (F_1) and mothers (F_2)

Family	Household	Events
Place of birth	Number of bedrooms	Serious parental illness
Place of growing-up	Presence of toilet	Parental death
Family size	Type of floor	Parental divorce
Number of offspring	Type of walls	Parental job loss
Birth order	Type of ceilings	Parental alcoholism
Type of health service	Household index	Paternal occupation
Type of drinking water	Household assets	Work during childhood
Crowding index		School attendance

In order to identify which variables should be included in the models each predictor variable was regressed against each outcome variable. Those variables with a significant prediction ($p<0.05$) of the outcome or those who were borderline significant ($p<0.10$) were introduced in the final model. Multiple linear regressions were performed using the enter method with the anthropometric indicators of children (F_3) and mothers (F_2) as the dependent variables and the anthropometric and socioeconomic parameters of the previous generation(s) as independent variables.

Models of the intergenerational influences of grandmothers (F_1) on mothers (F_2) were performed for outcome variables of z-scores values of height and LL, and KH (cm). These variables express the accumulated effects of living conditions experienced by the current generation and their mothers. For each analysis Model 1 included only the anthropometric parameter of the grandmothers (F_1). In Model 2 socioeconomic intergenerational variables were added.

Models of the intergenerational influences of grandmothers (F_1) and mothers (F_2) on children (F_3) were performed for outcome variables of z-score values of height, LL, BMI, WC and sum of tricipital and subscapular skinfolds. For each analysis Model 1 included only the anthropometric parameter of the mothers (F_2). In Model 2 the maternal socioeconomic intergenerational variables were added and in Model 3 the anthropometric and socioeconomic intergenerational variables of grandmothers (F_1) were added.

The validity of all models was assessed through several diagnostic tests. All models met the assumptions for multiple regression models building. Particular interest was given to multicollinearity between predictors included in the models; variance inflation factor (VIF) values informed us that no cases violated this assumption (in all models VIF for each predictor was less than 10 and mean VIF was less than 1.15). Additionally residuals of all models were normally distributed and all predictors had linear relationships with outcomes. For each model all possible interaction variables between predictors were generated and regressed to the outcome to check its effect.

9.2 Intergenerational influences of grandmothers on mothers

9.2.1 Association on growth indicators

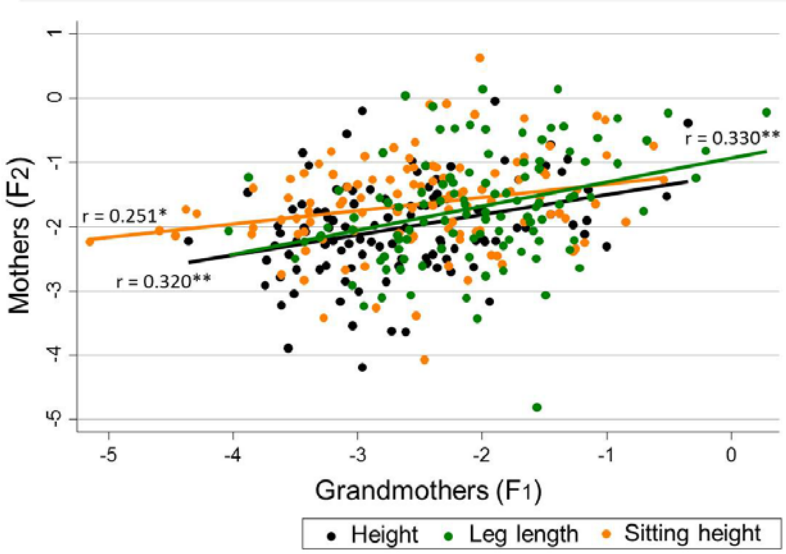
Correlation coefficients between grandmothers (F_1) and mothers (F_2) are given in Tables 9.2 and 9.3. Correlations of measurements and derived variables of linear growth were stronger than correlations for variables of body mass and body composition. Grandmothers (F_1) and mothers (F_2) correlated more in lower body segments (LL and KH) than in upper body segment (SH). This pattern was also evident on the z-score values of the anthropometric measurements (Figure 9.2). Correlation coefficients for LL, z-score of LL, and KH ranged from 0.3303 to 0.3459 and coefficients for SH and z-score of SH ranged from 0.2175 to 0.2514. Grandmothers (F_1) and mothers (F_2) association in SHR was also moderate and significant, and its correlation coefficient was smaller than coefficient of lower body segments but bigger than coefficients of upper body segments.

Table 9.2 Correlation coefficients in linear growth variables between grandmothers (F_1) and mothers (F_2)

Variables	r	p
Height (cm)	0.3203	$p<0.001$
SH (cm)	0.2175	$p<0.05$
LL (cm)	0.3459	$p<0.001$
KH (cm)	0.3306	$p<0.001$
SHR	0.2924	$p<0.05$
Z-score of height	0.3197	$p<0.001$
Z-score of SH	0.2514	$p<0.05$
Z-score of LL	0.3303	$p<0.001$

SH: Sitting height; LL: Leg length; KH: Knee height; SHR: Sitting height ratio.

Figure 9.2 Associations in z-score values for height, sitting height and leg length between grandmothers (F_1) and mothers (F_2)



*p<0.05; **p<0.001

The strongest associations in body composition were observed in the z-scores of sum of skinfolds and percentages of body fat and lean body mass. Grandmothers (F_1) and mothers (F_2) also correlated significantly in BMI and WC, but the coefficients were weaker than in skinfolds and measures of body composition.

Table 9.3 Correlation coefficients in body mass and body composition variables between grandmothers (F_1) and mothers (F_2)

Variables	r	p
Weight (kg)	0.1367	ns
BMI (kg/m^2)	0.2198	p<0.05
WC (cm)	0.2109	p<0.05
HC (cm)	0.1550	ns
WHR	0.1228	ns
TS (mm)	0.2024	ns
SS (mm)	0.2425	p<0.05
SumSkf (mm)	0.2588	p<0.05
Z-score of SumSkf	0.3566	p<0.001
FFM (kg)	0.0776	ns
%LBM	0.3027	p<0.05
FM (kg)	0.2002	p<0.05
%BF	0.3125	p<0.001

BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; WHR: Waist-to-hip ratio; TS: Tricipital skinfold; SS: Subscapular skinfold; SumSkf: Sum of skinfolds; FFM: Fat free mass; %LBM: Lean body mass percentage; FM: Fat mass; %BF: Body fat percentage; ns: not significant at level of α = 0.05.

9.2.2 Intergenerational influences modelling

Table 9.4 shows those socioeconomic factors experienced by the grandmothers (F_1) during their childhood that significantly ($p<0.05$) or borderline significantly ($p<0.10$) predicted anthropometric indicators of mothers (F_2). We consistently found that place of growing-up, type of floor of the house, household index and the availability of a radio at home predicted height, LL, KH and z-score values of height and LL of mothers (F_2). The availability of electricity at home only predicted the LL, z-scores of LL and KH of mothers (F_2).

Table 9.4 Socioeconomic variables experienced by grandmothers (F_1) during their childhood that predict growth factors in mothers (F_2)

Height	Z-score height	LL	Z-score LL	KH
Place of growing-up	Place of growing-up	Place of growing-up	Place of growing-up	Place of growing-up
Type of floor at home	Type of floor at home	Type of floor at home	Type of floor at home	Type of floor at home
Household index	Household index	Household index	Household index	Household index
Radio at home	Radio at home	Radio at home	Radio at home	Radio at home
		Electricity at home	Electricity at home	Electricity at home

Place of growing up: 0 – outside Merida city, 1 – in Merida city; Type of floor at home: 0 – ground, 1 – cement; Household index: 1 - Maya type (ground floor, palm leaf ceilings and wattle & daub walls), 2 – Perishable materials (ground or cement floor, cardboard or metal sheets in walls and ceilings), 3 – Construction materials (cement floor and cement blocks in walls and ceilings); Radio at home: 0 – no, 1 – yes; Electricity at home: 0 – no, 1 – yes.

Twenty-eight per cent of the grandmothers (F_1) grew up in communities outside Merida and still live there; 9% of the grandmothers were born in Merida city and have remained there; the 63% grandmothers migrated from towns and villages to Merida city. Their place of growing-up was established according to the age at which they migrated. Urban grandmothers were defined if they moved to the city before ~11 years of age. According to our criteria, 27% grandmothers who migrated to Merida grew up there. The type of floor of the house and the household index are variables that explored aspects of the same socioeconomic component. However, we chose type of floor variable because its regression coefficients and significance values were stronger than the household index variable. All household assets were included in the exploration analysis. However, only radio showed a significant effect on the outcome variables. The reason for this was because the presence of all other assets (television, washing machine, refrigerator, stove, car and bicycle) had a very low frequency (<5%) in the grandmothers' households during their childhood. In contrast, radio was present in 28% of households.

Models of the intergenerational influences of grandmothers (F_1) on maternal z-score values for height, LL, and KH are shown in Tables 9.5-9.7. We decided to model for z-score values since they were used to define the growth and nutritional status of grandmothers and mothers in the Chapter 7. For the model of KH we used raw data since the reference population used do not provide data to generate z-score values for this variable. As expected, the anthropometric parameters of the grandmothers (F_1) positively predicted the growth indicators of mothers (F_2) in all models. The coefficients and percentages of the explained variance were slightly higher in the model for LL than in the model for height [0.374 (10%) vs. 0.314(9%)]. For the KH model we found that per each centimetre of increase in grandmothers' KH (F_1) the KH of mothers (F_2) increased 0.355 cm. As in the models for LL, the anthropometric parameter of the grandmothers explained 10% of the variance of mothers' KH. We consistently found that, after the inclusion of socioeconomic intergenerational variables (in Model 2), the coefficients for the anthropometric predictors slightly increased and remained significant. Among the three models it was found that the place where grandmothers (F_1) grew up significantly predicted the growth status of the mothers (F_2). More specifically, we found that those women from F_1 who grew up in the city positively impacted on the height, LL and KH of their daughters (F_2). Place of growing-up coefficients were higher than coefficients of anthropometric parameters of grandmothers in all models. The bigger size effect of place of growing up was found in the KH model. Urban grandmothers (F_1) predicted an increase of 1 cm in daughters' (F_2) KH. The type of floor of the grandmothers' (F_1) household during their childhood had a non-significant effect in all models. The availability of radio at home was only significant for the KH model, predicting an increase of 0.856 cm in the mothers' (F_2) KH. The 'availability of radio at home' coefficient was higher than the anthropometric parameter of the grandmothers' coefficient but smaller than the place of growing-up coefficient. In addition, we found that after the inclusion of socioeconomic intergenerational variables, the percentage of explained variance increased between 7 and 8 units in the models for height and LL and about 10 units for the KH model.

Additionally we performed a model with mothers' (F_2) SHR as the outcome variable (see in Appendix 9). We found that the SHR of the grandmothers (F_1) positively predicted the SHR of the mothers (F_2). However, the coefficient was smaller than the coefficients for height, LL, and KH. The inclusion of socioeconomic intergenerational variables did not substantially change the effect of anthropometric parameter of the grandmothers (F_1) and no socioeconomic predictor had significant effect on the outcome variables. All variables included in the SHR model explained 12% of variance. For all models we excluded a grandmother who did not remember the age at which she migrated to the city during their childhood.

Table 9.5 Grand-maternal (F_1) intergenerational effects on maternal (F_2) z-score values for height

	Model 1		Model 2	
	B (S.E.)	p	B (S.E.)	p
Z-score of height	0.314 (0.090)	0.001	0.328 (0.088)	<0.001
Place of growing-up (omitted outside city: rural communities)				
-Grew up in Merida city			0.403 (0.154)	0.010
Type of floor of household (omitted ground floor)				
-Cement			0.082 (0.166)	0.623
Availability of radio at home			0.252 (0.155)	0.106
Constant	-1.186 (0.247)	<0.001	-1.347 (0.246)	<0.001
R^2 adjusted	0.094		0.173	

S.E.: standard error; n = 108, $F(4, 103) = 6.61$, $p<0.001$, $R^2 = 0.204$; Shapiro-Wilk residual normality test: w = 0.98, p = 0.228; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)} = 0.57$, p = 0.450.

Table 9.6 Grand-maternal (F_1) intergenerational effects on maternal (F_2) z-score values for leg length

	Model 1		Model 2	
	B (SE)	p	B (SE)	p
Z-score of leg length	0.374 (0.103)	<0.001	0.383 (0.103)	<0.001
Place of growing-up (omitted outside city: rural communities)				
-Grew up in Merida city			0.423 (0.180)	0.021
Type of floor of household (omitted ground floor)				
-Cement			0.043 (0.200)	0.832
Availability of radio at home			0.285 (0.180)	0.117
Availability of electricity at home			0.167 (0.245)	0.498
Constant	-0.934 (0.225)	<0.001	-1.145 (0.234)	<0.001
R^2 adjusted	0.101		0.174	

S.E.: standard error; n = 108, F (5, 102) = 5.51, p<0.001, R^2 = 0.213; Shapiro-Wilk residual normality test: w = 0.98, p = 0.100; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.02, p = 0.886.

Table 9.7 Grand-maternal (F_1) intergenerational effects on maternal (F_2) knee height

	Model 1		Model 2	
	B (SE)	p	B (SE)	p
Knee height	0.355 (0.098)	<0.001	0.376 (0.096)	<0.001
Place of growing-up (omitted outside city: rural communities)				
-Grew up in Merida city			1.007 (0.417)	0.018
Type of floor of household (omitted ground floor)				
-Cement			0.329 (0.459)	0.476
Availability of radio at home			0.856 (0.418)	0.043
Availability of electricity at home			0.120 (0.566)	0.832
Constant	29.665 (4.365)	<0.001	28.121 (4.286)	<0.001
R^2 adjusted	0.101		0.199	

S.E.: standard error; n = 108, F (5, 102) = 6.30, p<0.001, R^2 = 0.236; Shapiro-Wilk residual normality test: w = 0.99, p = 0.326; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.32, p = 0.571.

Since we found that the place where grandmothers (F_1) grew up was a significant intergenerational predictor of maternal height, LL and KH, we decided to perform additional analysis to understand the effect of this variable. Except for SHR, daughters (F_2) of urban grandmothers (F_1) showed significant ($p<0.05$) higher values in several growth variables than daughters (F_2) of non-urban grandmothers (F_1) (Table 9.8).

Table 9.8 Differences in linear growth indicators between women (F_2) whose mothers (F_1) grew up in the city and outside city

Indicators	Daughters (F_2) of urban mothers (F_1) (n = 29)		Daughters (F_2) of non-urban mothers (F_1) (n = 79)		p
	Mean	SD	Mean	SD	
Height (cm)	150.03	5.67	147.12	4.31	0.016
Z-score of height	-1.69	0.87	-2.14	0.68	0.006
LL (cm)	70.11	3.86	67.91	3.40	0.004
Z-score of LL	-1.32	0.88	-1.84	0.82	0.005
KH (cm)	46.35	2.50	45.15	1.73	0.021
SHR	53.28	1.14	53.78	1.19	0.057

LL: Leg length; KH: Knee height; SHR: Sitting height ratio.

In addition, we found that for some socioeconomic indicators of household quality those grandmothers (F_1) who grew up in the city experienced significantly better living conditions during their first years of life than grandmothers (F_1) who grew up outside the city (Table 9.9). Most of the grandmothers (F_1) who grew up outside the city migrated from rural communities within the State of Yucatan.

Table 9.9 Socioeconomic indicators experienced by grandmothers (F_1) during their childhood, by place of growing-up

Indicators	City	Outside city	p
Number of brothers	Mean = 6.55 ($\pm$2.84)	Mean = 7.01 ($\pm$3.09)	p = 0.468
Family size	Mean = 8.17 ($\pm$2.88)	Mean = 8.29 ($\pm$2.97)	p = 0.853
Crowding index	Mean = 6.64 ($\pm$3.08)	Mean = 7.39 ($\pm$3.23)	p = 0.225
Medical attention			
-Yes	55.17%	35.90%	X^2 = 3.24,
-No	44.83%	64.10%	p = 0.072
Piped water at home			
-Yes	13.79%	5.06%	X^2 = 2.36,
-No	86.21%	94.94%	p = 0.125
Floor material of house			
-Ground	62.07%	82.28%	X^2 = 4.87,
-Cement	37.93%	17.72%	p = 0.027
Roof material of house			
-Palm leaf	62.07%	89.87%	X^2 = 16.16,
-Metal/Cardboard	31.03%	3.80%	p<0.001
-Cement	6.90%	6.33%	
Walls material of house			
-Wattle & daub	55.17%	84.81%	X^2 = 10.47,
-Cement	44.83%	15.19%	p = 0.001
Electricity at home			
-Yes	31.03%	7.59%	X^2 = 9.74,
-No	68.97%	94.41%	p = 0.002
Radio at home			
-Yes	41.38%	22.78%	X^2 = 3.66,
-No	58.62%	77.62%	p = 0.056

The anthropometric parameters of the grandmothers (F_1) were significant intergenerational predictors. As we showed in Chapter 7, these women (F_1) showed very high prevalence of short stature. Short stature in adults reflects the presence of chronic malnutrition during childhood and adolescence. Table 9.10 shows that the daughters (F_2) of women of F_1 with short stature have significantly smaller growth indicators than daughters (F_2) of normal stature women (F_1). In addition, daughters (F_2) of women of F_1 with short stature showed significantly higher values of SHR, which means they have significantly lower leg length in proportion to their total stature. Short stature in adults was defined when the height-for-age indicator was below the 5^{th} percentile of the references.

Table 9.10 Differences in linear growth indicators between women (F_2) with short stature and normal height mothers (F_1)

Indicators	Women (F_2) with short height mothers (F_1) (n = 12)		Women (F_2) with normal height mothers (F_1) (n = 97)		p
	Mean	SD	Mean	SD	
Height (cm)	147.46	4.77	151.55	3.92	0.005
Z-score of height	-2.08	0.74	-1.45	0.60	0.005
LL (cm)	68.15	3.56	71.58	2.83	0.002
Z-score of LL	-1.78	0.85	-0.99	0.65	0.002
KH (cm)	45.31	2.04	45.75	1.25	0.019
SHR	53.74	1.17	52.77	1.13	0.008

LL: Leg length; KH: Knee height; SHR: Sitting height ratio.

9.3 Intergenerational influences of grandmothers and mothers on the children

9.3.1 Associations in growth indicators between grandmothers and children and between mothers and children.

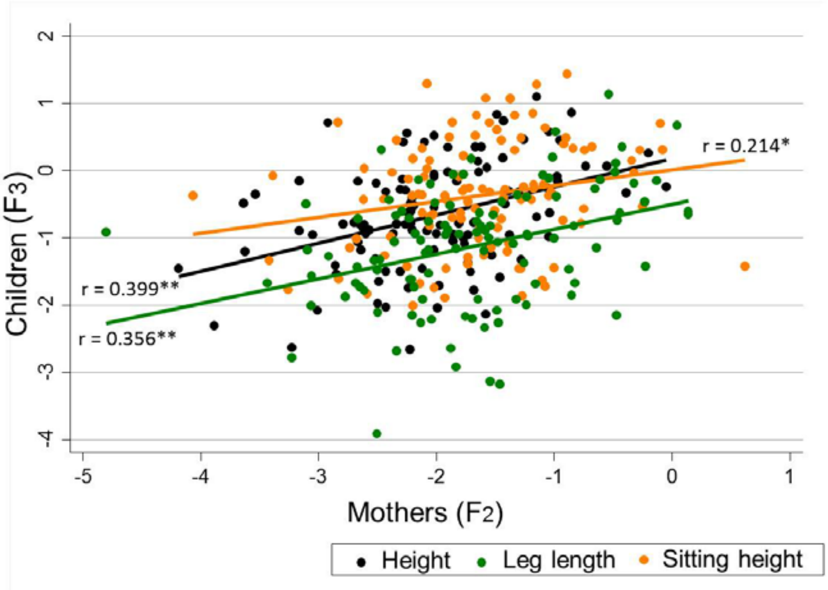
Bivariate and partial correlation coefficients for linear growth variables between mothers (F_2) and children (F_3) and between grandmothers (F_1) and children (F_3) pairs are shown in Table 9.11. As expected, the correlation coefficients were stronger in mother-children pairs than in grandmothers-children pairs. None of the correlations between grandmothers and children was significant. In general correlations between mothers (F_2) and children (F_3) decreased very slightly after the inclusion of grand-maternal effects. The strongest association in mothers-children pairs was found in the z-score for height. We also found that the associations in lower body segments (LL, z-score of LL and KH) were stronger than the associations in upper body segments (SH and z-score of SH) (Figure 9.3). Finally, mothers and children correlated significantly on the SHR values.

Table 9.11 Bivariate and partial correlations in linear growth variables between mothers, grandmothers and children

Variables	Mothers (F_2)		Grandmothers (F_1)	
	r	Partial r	r	Partial r
Height (cm)	0.2097*	0.2020*	0.0583	-0.0095
SH (cm)	0.1013	0.1066	-0.0125	-0.0356
LL (cm)	0.2376*	0.2136*	0.1109	0.0315
KH (cm)	0.2661*	0.2209*	0.1855	0.1071
Z-Height	0.3987**	0.3838**	0.1176	-0.0114
Z-Sitting height	0.2141*	0.1994*	0.0866	0.0346
Z-Leg length	0.3558**	0.3554**	0.0637	0.0611
SHR	0.2554*	0.2428*	0.0818	0.0078

SH: Sitting height; LL: Leg length; KH: Knee height; SHR: Sitting height ratio; *p<0.05; **p<0.001.

Figure 9.3 Associations in z-score values for height, sitting height and leg length between mothers (F_2) and children (F_3)



*p<0.05; **p<0.001; Plots were done using simple correlations

Bivariate and partial correlation coefficients regarding body mass and body composition variables between mothers (F_2) and children (F_3) and between grandmothers (F_1) and children (F_3) are shown in Table 9.12. Except for FFM and for %BF, both grandmothers and mothers correlate significantly with their children's measurements. In all significant correlations the coefficients decreased after including the effect of mothers and grandmothers respectively. The strongest partial correlations between mothers (F_2) and children (F_3) were found for BMI, WC, subscapular skinfold, and FM. The size of these associations was moderate. Of relevance was the finding that bivariate and partial correlations in weight, BMI, HC and FM between grandmothers (F_1) and children (F_3) were stronger than correlations between mothers (F_2) and children (F_3). This finding suggests that the grandmothers probably share with the children a common environment that is impacting children's biology. For this reason we explored the effect of proximity between grandmothers (F_1) and children (F_3) on some growth parameters.

Table 9.12 Bivariate and partial correlations in body mass and body composition variables between mothers, grandmothers and children

Variables	Mothers (F_2)		Grandmothers (F_1)	
	r	Partial r	r	Partial r
Weight (kg)	0.2551*	0.2265*	0.3008*	0.2777*
BMI (kg/m^2)	0.3115*	0.2591*	0.3332**	0.2856*
WC (cm)	0.3066*	0.2602*	0.3053*	0.2587*
HC (cm)	0.2171*	0.1744	0.3660*	0.3446**
TS (mm)	0.2667*	0.2255*	0.2698*	0.2281*
SS (mm)	0.2856*	0.2573*	0.1612	0.0984
SumSkf (mm)	0.2663*	0.2118*	0.2671*	0.2129*
FFM (kg)	0.1567	0.1478	0.1395	0.1293
%LBM	0.1757	0.1412	0.1403	0.0929
FM (kg)	0.2778*	0.2330	0.3000*	0.2596*
%BF	0.1758	0.1412	0.1375	0.0883

BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; TS: Tricipital skinfold; SS: Subscapular skinfold; SumSkf: Sum of skinfolds; FFM: Fat free mass; %LBM: Lean body mass percentage; FM: Fat mass; %BF: Body fat percentage; *p<0.05; **p<0.001.

The place of residence and participation in the care of children were used as proximity indicators. Table 9.13 shows bivariate correlation coefficients between children (F_3) and grandmothers (F_1) according to the current place of grandmothers' residence. Most of grandmothers (72%) lived in Merida city (urban grandmothers), chiefly in the same neighbourhood or even in the same household of the children. The remaining grandmothers (28%) lived in communities outside the city, but within the Yucatan state (non-urban grandmothers). Correlation coefficients showed that urban children-grandmother pairs correlated stronger than non urban children-grandmother pairs. None of the correlations between children and non-urban grandmothers was significant.

Table 9.13 Correlation between mass and body composition variables of children (F_3) and grandmothers (F_1), by place of residence of grandmothers

Variables	Grandmothers living in the city (n = 79)		Grandmothers living outside city (n = 30)	
	r	p	r	p
Weight (kg)	0.3263	0.003	0.2825	0.130
BMI (kg/m^2)	0.3691	<0.001	0.3015	0.105
SumSkf (mm)	0.2246	0.047	0.2942	0.115
FM (kg)	0.3351	0.003	0.2321	0.217

BMI: Body mass index; SumSkf: Sum of skinfolds; FM: Fat mass

Grandmothers (F_1) who reported to have been participating in the care of the children (F_3) showed a stronger, positive correlation with their grandchildren's weight, BMI, sum of skinfolds and fat mass (Table 9.14).

Table 9.14 Correlation between mass and body composition variables of children (F_3) and grandmothers (F_1), by grandmothers' participation in children's care

Variables	Participants (n = 23)		Non-participants (n = 86)	
	r	p	r	p
Weight (kg)	0.5039	0.007	0.2578	0.017
BMI (kg/m^2)	0.5606	0.005	0.2868	0.007
SumSkf (mm)	0.3922	0.064	0.2050	0.058
FM (kg)	0.3524	0.009	0.2781	0.010

BMI: Body mass index; SumSkf: Sum of skinfolds; FM: Fat mass

9.3.2 Path analysis on growth parameters among the three generations

The results of the path analysis are organized according to the biological meaning of the outcome variables. We first show the analysis for linear growth variables and then the results for the body mass and body composition variables.

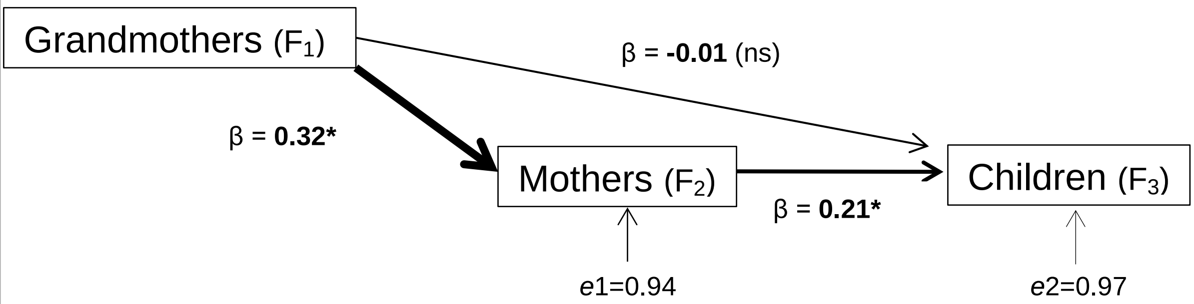
9.3.2.1 Path analysis for linear growth variables

Path diagrams for height, LL and KH are presented in Figures 9.4 to 9.6. In all models the strongest direct effects were consistently found from grandmothers (F_1) to mothers (F_2), followed by the direct effects of mothers (F_2) on children (F_3). Direct effects of grandmothers (F_1) on children (F_3) were weak and non-significant for these three variables. We also found for the models of height and LL that indirect effects of grandmothers (F_1) on children (F_3) were stronger than direct effects, which suggests that the causal effects of grandmothers on their grandchildren are present via the mothers' effect.

Path diagrams regarding z-score values for height and leg length are shown in Figures 9.7 and 9.8 respectively. The strongest direct causal effects were found from mothers (F_2) to children (F_3), followed in magnitude by the direct effects of grandmothers (F_1) on mothers (F_2). Again direct causal effects of grandmothers (F_1) on children (F_3) were weak and non-significant. Comparing the magnitude of direct and indirect path coefficients we found again that the effects of grandmothers on their grandchildren are present mainly through the maternal effect.

Additionally we performed a path analysis model with children's SHR as outcome variable (Appendix 10), and we found that the grandmothers (F_1) to mothers' (F_2) direct effect had the strongest path coefficient ($\beta = 0.29$, $p<0.05$), followed by the effect of mothers (F_2) on children (F_3) ($\beta = 0.25$, $p<0.05$). As in the previous analysis direct causal effect of grandmothers (F_1) on children (F_3) was weak and non-significant.

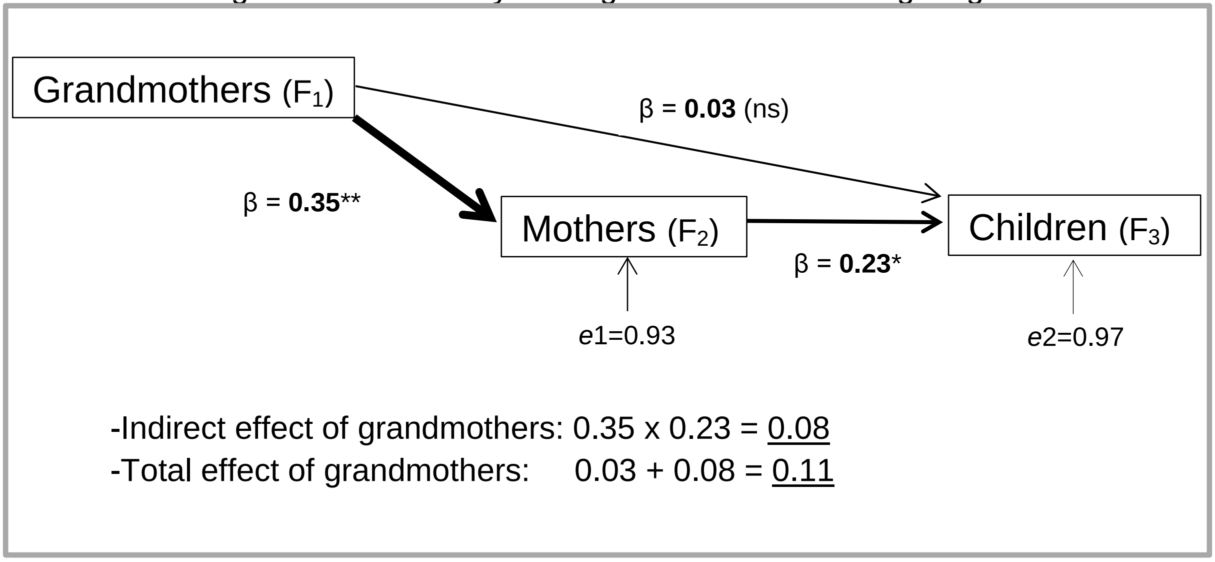
Figure 9.4 Path analysis diagram for children's height



-Indirect effect of grandmothers: 0.32 x 0.21 = <u>0.07</u>
-Total effect of grandmothers: -0.01 + 0.07 = <u>0.06</u>

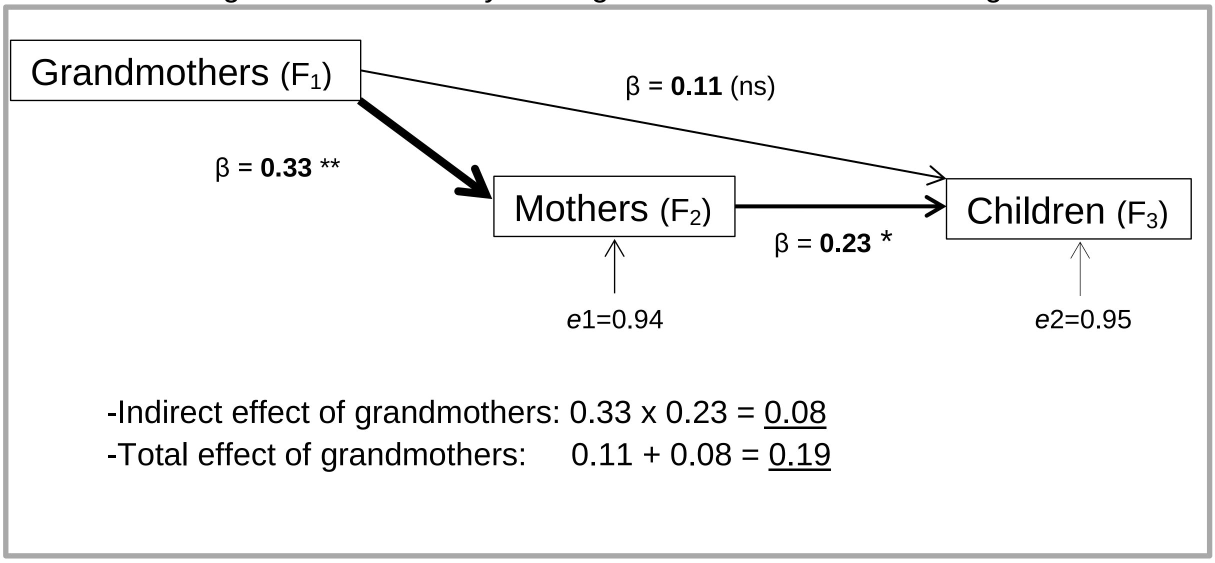
*p<0.05

Figure 9.5 Path analysis diagram for children's leg length



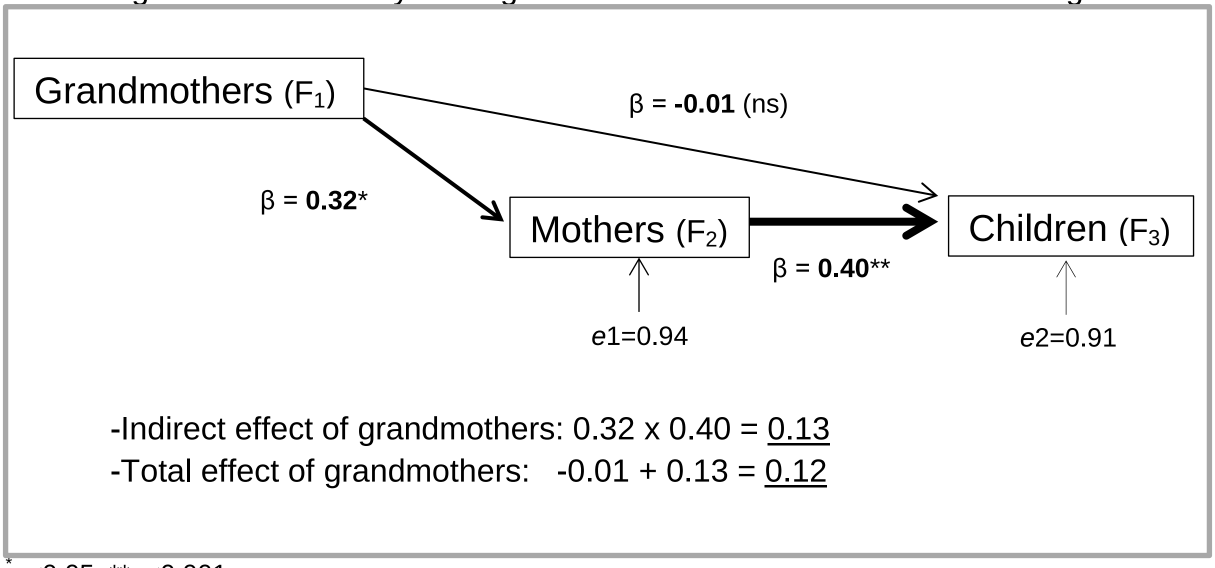
*p<0.05; **p<0.001

Figure 9.6 Path analysis diagram for children's knee height



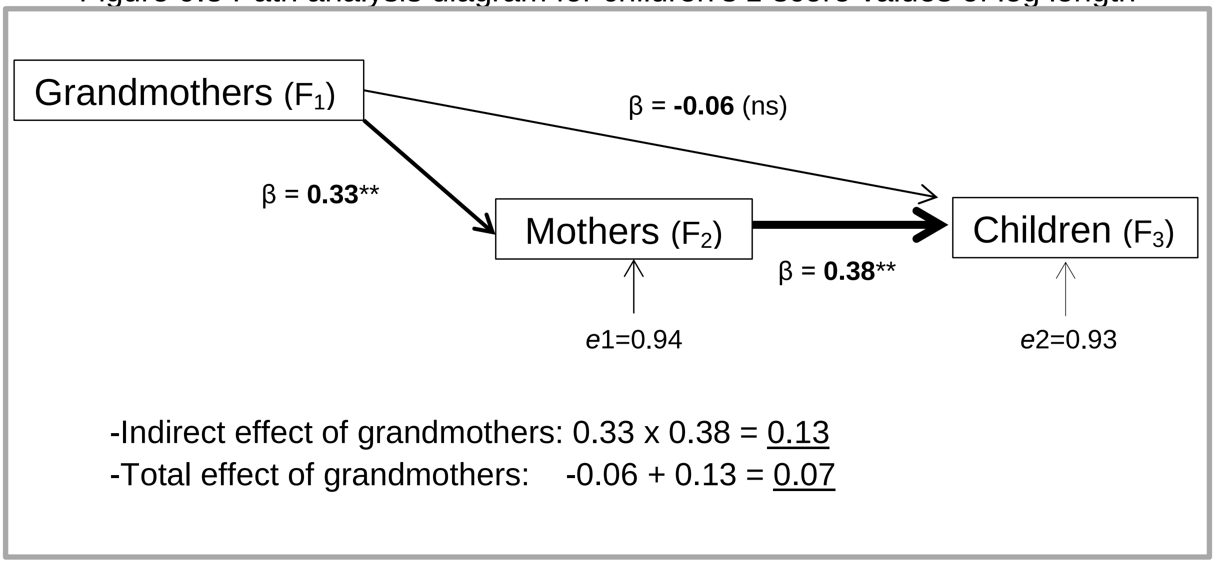
*p<0.05; **p<0.001

Figure 9.7 Path analysis diagram for children's z-score values of height



*p<0.05; **p<0.001

Figure 9.8 Path analysis diagram for children's z-score values of leg length



*p<0.05; **p<0.001

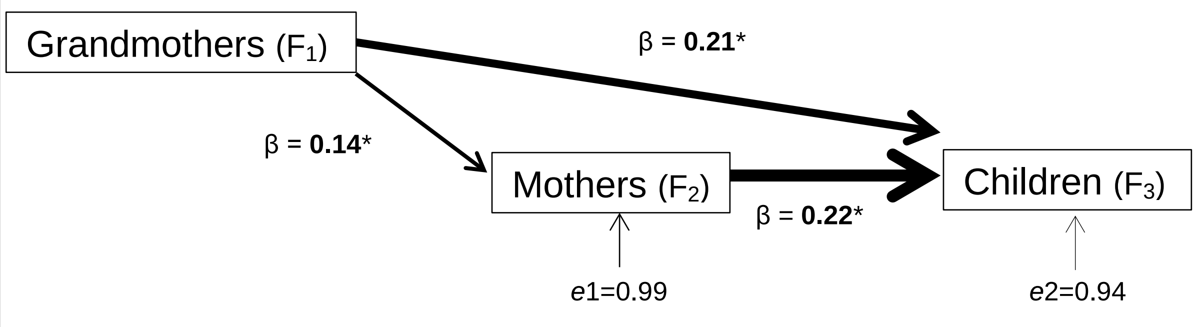
In all linear growth variables (raw and z-score values) directs effects of grandmothers (F_1) on mothers (F_2) and mothers (F_2) on children (F_3) were stronger than direct effects of grandmothers (F_1) on children (F_3). In addition total effects of grandmothers on children were in all variables weak and smaller than direct effects of grandmothers (F_1) on mothers (F_2) and mothers (F_2) on children (F_3).

9.3.2.2 Path analysis for body mass and body composition variables

Path analysis diagrams for z-score of weight and WC are presented in Figures 9.9 and 9.10 respectively. In both models all direct causal effects were significant, with the strongest effects present from mothers (F_2) to children (F_3). They were followed in magnitude by the effects from grandmothers (F_1) to children (F_3). Path coefficients of direct effects of grandmothers (F_1) on mothers (F_2) were the smallest but statistically significant. In both analyses total effects (direct + indirect) of grandmothers (F_1) on children (F_3) were even stronger than any other direct effect between generations.

Results of path analyses for z-score of BMI and FM (kg) (Figures 9.11 and 9.12) showed a different pattern. All direct causal effects were statistically significant. The grandmothers (F_3) to children (F_1) direct causal effects showed the strongest path coefficients. In both models they were followed by causal effects of mothers (F_2) on children (F_1). Even when causal effects from grandmothers to mothers were the smallest; their path coefficients were very similar in magnitude to the causal effects of mothers to children. Similarly, the total effect of grandmothers (F_1) on children (F_3) in z-score of BMI and FM were higher than any other direct effect between generations.

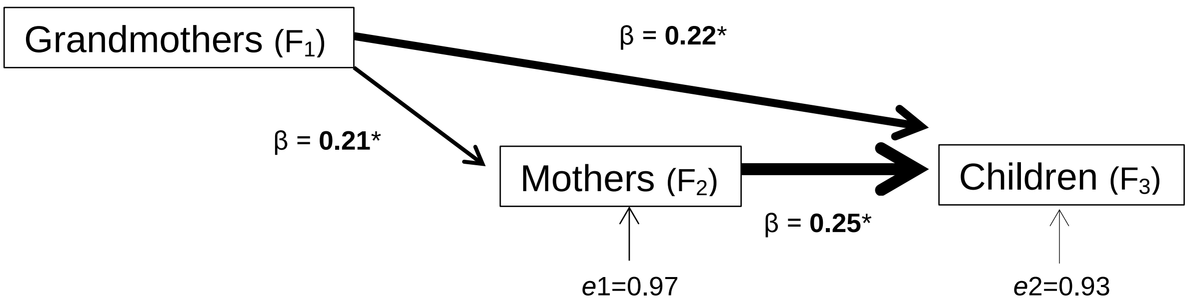
Figure 9.9 Path analysis diagram for children's z-score values of weight



-Indirect effect of grandmothers: 0.14 x 0.22 = 0.03
-Total effect of grandmothers: 0.21 + 0.03 = 0.24

*p<0.05

Figure 9.10 Path analysis diagram for children's z-score values of waist circumference

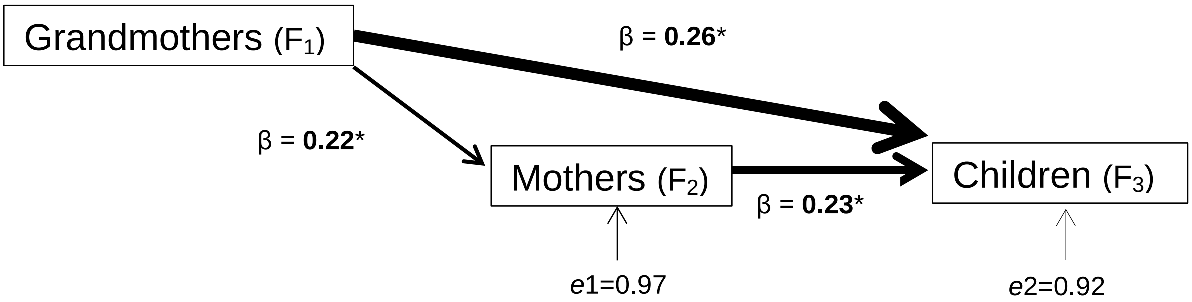


-Indirect effect of grandmothers: 0.21 x 0.25 = <u>0.05</u>

-Total effect of grandmothers: 0.22 + 0.05 = <u>0.27</u>

*p<0.05

Figure 9.11 Path analysis diagram for children's z-score values of body mass index

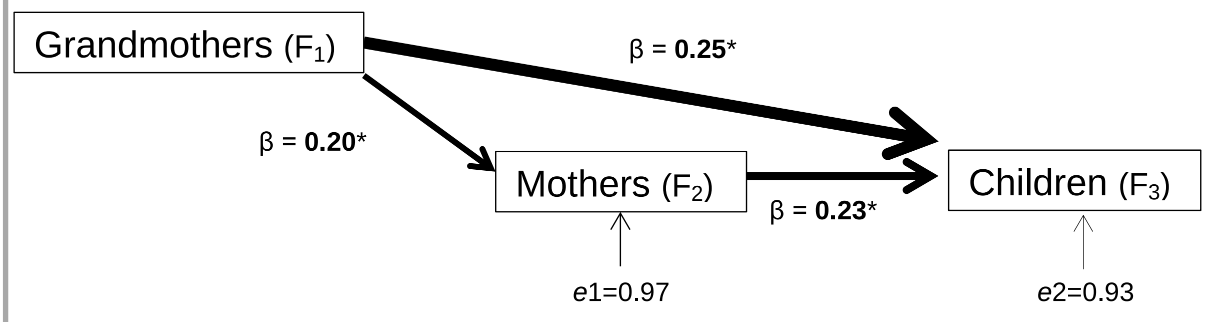


-Indirect effect of grandmothers: 0.22 x 0.23 = <u>0.05</u>

-Total effect of grandmothers: 0.26 + 0.05 = <u>0.31</u>

*p<0.05

Figure 9.12 Path analysis diagram for children's fat mass

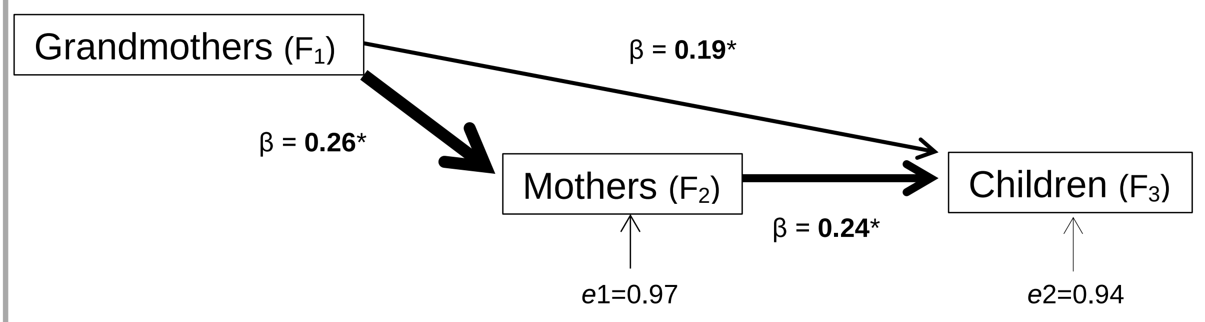


-Indirect effect of grandmothers: 0.20 x 0.23 = 0.05
-Total effect of grandmothers: 0.25 + 0.05 = 0.30

*p<0.05

Path analysis of z-scores for sum of tricipital and subscapular skinfolds is shown in Figure 9.13. Even when the strongest causal effects were found in grandmothers (F_1) to mothers (F_2) and mothers (F_2) to children (F_3), the direct causal effect of grandmothers (F_1) to children (F_3) was significant.

Figure 9.13 Path analysis diagram for children's z-score values of sum of skinfolds (tricipital and subscapular)



-Indirect effect of grandmothers: 0.26 x 0.24 = 0.06
-Total effect of grandmothers: 0.19 + 0.06 = 0.25

*p<0.05

Path diagrams for children's' percentage of body fat and lean body mass (kg and percentage) are shown in Appendixes 11, 12 and 13. In all models only direct effects from grandmothers (F_1) to mothers (F_2) were statistically significant. Effects from mothers and grandmothers to children were not significant.

On the other hand, for all cases, grandmothers (F_1) significantly affected all variables of body mass and body composition of their grandchildren (F_3). This finding is consistent with the results of the significant partial correlations between grandmothers and children. Particularly, for z-scores of BMI and fat mass variables the strongest direct causal effects were found from the grandmothers to the children.

9.3.3 Intergenerational influences modeling

The maternal (F_2) socioeconomic predictors (intergenerational predictors) of children's (F_3) anthropometric variables are shown in Table 9.15. We consistently found that 'paternal job loss during maternal childhood' predicted the children's z-score for height, LL, BMI, WC and sum of skinfolds. Sixteen per cent of the mothers (F_2) reported that during their childhood their fathers lost their job frequently. Maternal family size during childhood predicted the z-score for BMI, WC and sum of skinfolds. The median of maternal family size during childhood was 7 (interquartile range = 6 - 9).

Table 9.16 shows grand-maternal (F_1) socioeconomic predictors for children's (F_3) anthropometric variables. We consistently found that grand-maternal household index and grand-maternal family size during childhood significantly predicted children's z-score for height, LL, BMI, WC and sum of skinfolds. In addition, grand-maternal school attendance during childhood predicted z-score for BMI, WC and sum of skinfolds of the children. The median of grand-maternal family size during childhood was 8 (interquartile range = 6 - 10) and 63% of grandmothers reported having attended the school during his childhood.

Table 9.15 Socioeconomic variables experienced by mothers (F_2) during their childhood that predict growth factors in children (F_3)

z-score height	z-score LL	z-score BMI	z-score WC	z-score sum of skinfolds
Paternal job loss during maternal childhood	Paternal job loss during maternal childhood	Paternal job loss during maternal childhood	Paternal job loss during maternal childhood	Paternal job loss during maternal childhood
		Maternal family size during childhood	Maternal family size during childhood	Maternal family size during childhood

Paternal job loss during maternal childhood: 0 – no, 1 – yes; Maternal family size during childhood: continuous.

Table 9.16 Socioeconomic variables experienced by grandmothers (F_1) during their childhood that predict growth factors in children (F_3)

z-score height	z-score LL	z-score BMI	z-score WC	z-score sum of skinfolds
Household index	Household index	Household index	Household index	Household index
Grandmaternal family size during childhood	Grandmaternal family size during childhood	Grandmaternal family size during childhood	Grandmaternal family size during childhood	Grandmaternal family size during childhood
		Grandmaternal school attendance during childhood	Grandmaternal school attendance during childhood	Grandmaternal school attendance during childhood

Household index: 1 - Maya type (ground floor, palm leaf ceilings and wattle & daub walls), 2 – Perishable materials (ground or cement floor, cardboard or metal sheets in walls and ceilings), 3 – Construction materials (cement floor and cement blocks in walls and ceilings); Grand-maternal family size during childhood: continuous; Grand-maternal school attendance during childhood: 0 – no, 1 – yes.

9.3.3.1 Model of intergenerational influences on children's z-score values for height

The model of intergenerational influences on children's z-score for height is shown in Table 9.17. As we expected, maternal z-score for height positively predicted children's height in model 1. We found, in model 2, that after the inclusion of the socioeconomic intergenerational variables the effect of the maternal z-scores for height did not change substantially and remained significant. After the inclusion of anthropometric and socioeconomic parameters of the grandmothers in model 3 we found that all variables included in the analysis explained 25% of the outcome variance. The final model showed that the effect of maternal height remained significant. Specifically, we found that per each additional unit in the maternal anthropometric parameter, the children increased 0.416 units of z-score for height. The presence of short stature in grandmothers did not predict significantly the growth status of the children. Of relevance was the finding that grand-maternal home index significantly impacted the growth of children. Those grandmothers who lived during their childhood in a household built with perishable materials predicted a decrease of 0.439 units in their grandchildren's z-score for height. With a marginally significant effect ($p = 0.061$) it was found that grand-maternal family size during their childhood positively predicted the growth of children. The inclusion of grand-maternal anthropometric and socioeconomic predictors contributed to the increase of the explained variance of 8%.

9.3.3.2 Model of intergenerational influences on children's z-score values for leg length

The model of intergenerational influences on children's z-score for LL is shown in Table 9.18. Maternal z-score for LL positively predicted the growth parameter of children along the three models without substantial changes in the size of the regression coefficient. Model 2 showed that "paternal job loss during maternal childhood" negatively impacted on the growth of children but without statistical significance. Grand-maternal home index was one of the strongest predictors in model 3. Grandmothers who lived in a household built with perishable materials significantly predicted a decrease in the children's z-score for LL of 0.533 units. It was also found that grandmothers who lived during their childhood in a house built with durable materials positively impacted the growth of the children, but this effect was marginally significant (p = 0.059). Family size of grandmothers was another significant predictor in model 3. Specifically, we found that per each additional family member, the children's growth parameter increased in 0.073 units of z-score. The inclusion of the grand-maternal anthropometric and socioeconomic predictors in model 3 increased the percentage of explained variance by 16 units. In general, all predictors explained 30% of the variance in the outcome variable.

Table 9.17 Intergenerational effects on children z-score values for height

	Model 1		Model 2		Model 3	
	B (SE)	p	B (SE)	p	B (SE)	p
Maternal z-score of height	0.419 (0.093)	<0.001	0.401 (0.093)	<0.001	0.416 (0.094)	<0.001
Paternal job loss during maternal childhood			-0.317 (0.192)	0.103	-0.176 (0.187)	0.350
Grandmaternal short height					-0.271 (0.221)	0.221
Grandmaternal home index (reference = household Maya type[a])						
-Perishable materials (cardboard & metal)					-0.439 (0.154)	0.005
-Durable material (cement)					0.412 (0.321)	0.203
Grandmaternal family size during childhood					0.043 (0.023)	0.061
Constant	0.180 (0.200)	0.371	0.192 (0.199)	0.338	0.189 (0.323)	0.559
R^2 adjusted	0.151		0.164		0.248	

[a]Household Maya type: palm leaf roof, wattle & daub walls and ground floor; S.E.: standard error; n = 109, $F (6, 102) = 6.95$, $p<0.001$, $R^2 = 0.290$; Shapiro-Wilk residual normality test: w = 0.98, p = 0.126; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)} = 0.04$, p = 0.840.

Table 9.18 Intergenerational effects on children z-score values for leg length

	Model 1		Model 2		Model 3	
	B (SE)	p	B (SE)	p	B (SE)	p
Maternal z-score of LL	0.369 (0.094)	<0.001	0.352 (0.093)	<0.001	0.352 (0.083)	<0.001
Paternal job loss during maternal childhood			-0.381 (0.220)	0.086	-0.093 (0.192)	0.630
Grandmaternal short height					-0.040 (0.224)	0.859
Grandmaternal home index (reference = household Maya type[a])						
-Perishable materials (cardboard & metal)					-0.533 (0.155)	0.001
-Durable material (cement)					0.623 (0.326)	0.059
Grandmaternal family size					0.073 (0.023)	0.002
Constant	-0.498 (0.178)	0.006	-0.476 (0.177)	0.010	-0.767 (0.351)	0.031
R^2 adjusted	0.118		0.135		0.297	

[a]Household Maya type: palm leaf roof, wattle & daub walls and ground floor; S.E.: standard error; n = 106, F (6, 99) = 8.38, p<0.001, R^2 = 0.337; Shapiro-Wilk residual normality test: w = 0.99, p = 0.693; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.19, p = 0.660.

Grand-maternal (F_1) household index was a significant predictor in both models for children's linear growth variables. We found significant differences in the children's z-score for height and LL according to the categories of the grand-maternal household index: those children whose grandmothers lived in a house built with durable materials had the highest means for z-score values of height and LL, followed by children whose grandmothers lived in a Maya type household (Table 9.19). Children whose grandmothers lived in a house with the worst conditions (perishable materials) showed the lowest means for the growth parameters.

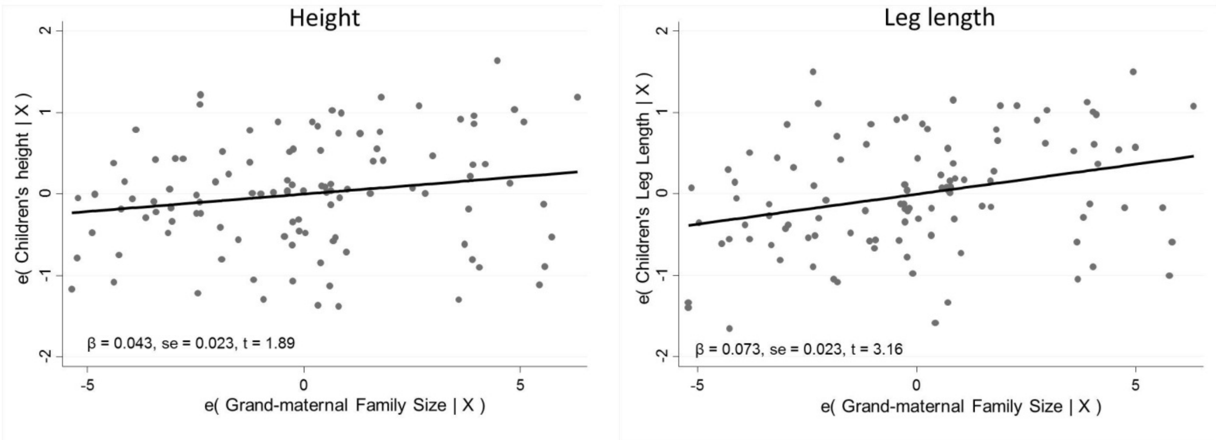
Table 9.19 Means (standard deviations) of z-score values of height and leg length by grand-maternal household index

Variable	Household index during childhood			*F, p
	Perishable materials	Maya type	Durable materials	
Z-score of height	-0.93 (0.85)	-0.60 (0.75)	-0.08 (0.52)	F = 3.57, p = 0.031
Z-score of LL	-1.44 (0.85)	-1.06 (0.86)	-0.18 (0.81)	F = 5.25, p = 0.007

LL: leg length; Perishable materials: ground or cement floor, cardboard or metal sheets in walls and ceilings; Maya type: ground floor, palm leaf ceilings and wattle & daub walls; Durable materials: cement floor and cement blocks in walls and ceilings; *One-way Anova.

Grand-maternal family size during childhood was another significant predictor of children's linear growth variables. However the effect of this variable was stronger in model for z-score of height than in the model for z-score LL (Figure 9.14).

Figure 9.14 Predictive relationships between grand-maternal (F_1) family size during childhood and children's (F_3) z-score values for height and leg length



Coefficients, standard errors and t values were produced controlling for all variables included in each final regression models

9.3.3.3 Model of intergenerational influences on children's z-score values for body mass index

The model of intergenerational influences on children's z-score for BMI is shown in Table 9.20. Maternal BMI significantly predicted the children's z-score values for BMI in models 1 and 2. We found in model 2 that, after the inclusion of the two socioeconomic intergenerational variables, the effect of maternal BMI slightly decreased but remained significant. Additionally we found in model 2 that "paternal job loss during maternal childhood" negatively impacted the BMI of children in 0.590 units of z-score. The inclusion of maternal socioeconomic predictors in model 2 increased the percentage of explained variance about 4 units. All variables included in model 3 explained 26% of the outcome variance. In model 3 we found that after the inclusion of anthropometric and socioeconomic intergenerational variables of grandmothers the effect of maternal BMI was not-significant. However, "maternal family size" and "paternal job loss during maternal childhood" impacted negatively on children's' BMI. Specifically, we found that per each additional family member in the maternal household children's z-score of BMI decreased 0.076 units. The effect of those mothers who reported that their fathers lost their job frequently shows a reduction of 0.468 units on the children's BMI. Of relevance was the finding that grand-maternal BMI positively predicted the BMI of children. Children's z-score for BMI increased in 0.052 units by each unit of grand-maternal BMI increased. We also found, in model 3, that grand-maternal school attendance during childhood negatively impacted children's z-score for BMI, this variable being one of the strongest predictors in the final model. Finally, after the inclusion of grand-maternal predictors by the percentage of explained variance of the outcome (children's BMI) increased by 14 units.

Table 9.20 Intergenerational effects on children z-score values for body mass index

	Model 1		Model 2		Model 3	
	B (SE)	p	B (SE)	p	B (SE)	p
Maternal BMI	0.060 (0.019)	0.002	0.047 (0.019)	0.014	0.019 (0.019)	0.303
Maternal family size during childhood			-0.046 (0.037)	0.213	-0.076 (0.035)	0.031
Paternal job loss during maternal childhood			-0.590 (0.243)	0.017	-0.468 (0.228)	0.042
Grandmaternal BMI					0.052 (0.018)	0.004
Grandmaternal family size during childhood					0.042 (0.029)	0.145
Grandmaternal home index (omitted household Maya type[a])						
-Perishable materials (cardboard & metal)					-0.260 (0.184)	0.161
-Durable material (cement)					0.137 (0.387)	0.726
Grandmaternal school attendance during childhood (reference = No)						
-Yes					-0.578 (0.169)	0.001
Constant	-1.046 (0.564)	0.066	-0.259 (0.680)	0.704	-0.797 (0.772)	0.305
R^2 adjusted	0.077		0.121		0.262	

[a]Household Maya type: palm leaf roof, wattle & daub walls and ground floor; S.E.: standard error; n = 109, F (8, 100) = 5.80, p<0.001, R^2 = 0.317; Shapiro-Wilk residual normality test: w = 0.98, p = 0.188; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 2.90, p = 0.090; Mean VIF = 1.09.

9.3.3.4 Model of intergenerational influences on children's z-score values for waist circumference

Model of intergenerational influences on children's z-score for WC is shown in Table 9.21. Models 1 and 2 showed similar results than models 1 and 2 for z-score for BMI. Maternal WC positively predicted the children's WC in model 1. We found in model 2 that, after the inclusion of socioeconomic intergenerational predictors, the effect of maternal WC did not change substantially and remained significant. "Paternal job loss during maternal childhood" negatively impacted the WC of children and the effect size of this variable was 0.519 units of z-score. The inclusion of maternal socioeconomic predictors in model 2 increased explained variance in 6%. We found, in model 3 that after controlling for all grand-maternal predictors the effect of maternal WC was weak and non-significant. Maternal family size and paternal job loss during maternal childhood impacted negatively the children's WC. Waist circumference of grandmothers predicted positively the children's z-score of WC. Specifically, we found that the outcome variable increased in 0.016 units of z-score per each unit of grand-maternal WC increased. Unlike the maternal effect, grand-maternal family size impacted positively in the WC of the children. Moreover we found that the perishable materials category of grand-maternal household index impacted negatively the WC of children, being the effect size of 0.307 units of z-score. Finally, we found that the z-score of children's WC decreased significantly in 0.450 units with grandmaternal school attendance during their childhood. Variables included in model 3 explained around 30% of the variance of the outcome variable. The inclusion of grand-maternal predictors increased the percentage of the explained variance in 16 units.

Table 9.21 Intergenerational effects on children z-score values for waist circumference

	Model 1		Model 2		Model 3	
	B (SE)	p	B (SE)	p	B (SE)	p
Maternal WC	0.021 (0.007)	0.002	0.017 (0.006)	0.011	0.007 (0.006)	0.256
Maternal family size during childhood			-0.040 (0.020)	0.166	-0.059 (0.027)	0.029
Paternal job loss during maternal childhood			-0.519 (0.193)	0.008	-0.408 (0.178)	0.024
Grandmaternal WC					0.016 (0.007)	0.028
Grandmaternal family size during childhood					0.049 (0.022)	0.029
Grandmaternal home index (reference = household Maya type[a])						
-Perishable materials (cardboard & metal)					-0.307 (0.143)	0.035
-Durable material (cement)					0.324 (0.304)	0.289
Grandmaternal school attendance during childhood (reference = No)						
-Yes					-0.450 (0.132)	0.001
Constant	-1.324 (0.605)	0.031	-0.559 (0.668)	0.405	-1.130 (0.828)	0.828
R^2 adjusted	0.079		0.137		0.298	

[a]Household Maya type: palm leaf roof, wattle & daub walls and ground floor; S.E.: standard error; n = 109, F (8, 100) = 6.73, p<0.001, R^2 = 0.350; Shapiro-Wilk residual normality test: w = 0.99, p = 0.881; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 1.78, p = 0.182; Mean VIF = 1.09.

9.3.3.5 Model of intergenerational influences on children's z-score values for sum of skinfolds

The results of the intergenerational analysis on children's z-score for the sum of skinfolds (tricipital and subscapular) are shown in Table 9.22. Model 1 showed that the maternal sum of skinfolds positively impacted on children's' sum of skinfolds. In model 2 none of the maternal socioeconomic variables significantly affected the outcome variable and the effect of maternal sum of skinfolds remained significant. In addition, the percentage of explained variance did not change substantially from model 1 to model 2. All variables included in model 3 contributed to explain 27% of the variance of the outcome variable. We found, in model 3, that after the inclusion of grand-maternal predictors the effect of maternal anthropometric parameter was non-significant. However, "maternal family size during childhood" negatively predicted the sum of skinfolds of the children with a marginally significant effect ($p = 0.068$). Grand-maternal sum of skinfolds and grand-maternal school attendance during childhood were the variables with the strongest effect on children's sum of skinfolds in model 3. Per each additional unit of grand-maternal z-score of sum of skinfolds the z-score of children's sum of skinfolds increased 0.255 units. Grand-maternal school attendance negatively impacted 0.530 units of z-score on the outcome variable. Finally, grand-maternal household index and grand-maternal family size had a marginally significant effect on children's sum of skinfolds. The addition of grand-maternal predictors to the model 3 increased the percentage of explained variance in 19 units.

Table 9.22 Intergenerational effects on children z-score values for sum of skinfolds (tricipital and subscapular)

	Model 1		Model 2		Model 3	
	B (SE)	p	B (SE)	p	B (SE)	p
Maternal sum of skinfolds	0.332 (0.109)	0.003	0.286 (0.112)	0.012	0.111 (0.112)	0.325
Maternal family size during childhood			-0.031 (0.031)	0.326	-0.051 (0.028)	0.068
Paternal job loss during maternal childhood			-0.264 (0.158)	0.097	-0.150 (0.147)	0.311
Grandmaternal sum of skinfolds					0.255 (0.090)	0.006
Grandmaternal family size during childhood					0.046 (0.023)	0.054
Grandmaternal home index (reference = household Maya type[a])						
-Perishable materials (cardboard & metal)					-0.298 (0.153)	0.054
-Durable material (cement)					0.250 (0.314)	0.427
Grandmaternal school attendance during childhood (reference = No)						
-Yes					-0.530 (0.138)	<0.001
Constant	0.360 (0.085)	<0.001	0.694 (0.264)	0.011	0.913 (0.324)	0.006
R^2 adjusted	0.071		0.083		0.270	

[a]Household Maya type: palm leaf roof, wattle & daub walls and ground floor; S.E.: standard error; n = 107, F (8, 98) = 5.90, p<0.001, R^2 = 0.325; Shapiro-Wilk residual normality test: w = 0.97, p = 0.060; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0-.69, p = 0.406; Mean VIF = 1.12.

In the three models of body mass and composition grand-maternal school attendance significantly impacted the outcome variables. This finding may suggest that grand-maternal education could be impacting positively the nutritional status of their grandchildren. Table 9.23 shows the percentages of normal and high values of BMI, WC and sum of skinfolds according to the grand-maternal school attendance. We consistently found that the proportion of children with normal (5^{th} to 85^{th} percentile of the reference) and high values (above 85^{th} percentile of the reference) were significantly different, being those children whose grandmothers attended the school more clustered in the "normal categories" and less present in conditions of risk for overweight/obesity, high WC and high skinfolds sum. This finding suggests that the positive effect of educational level of the caregivers could be impacting the following generations.

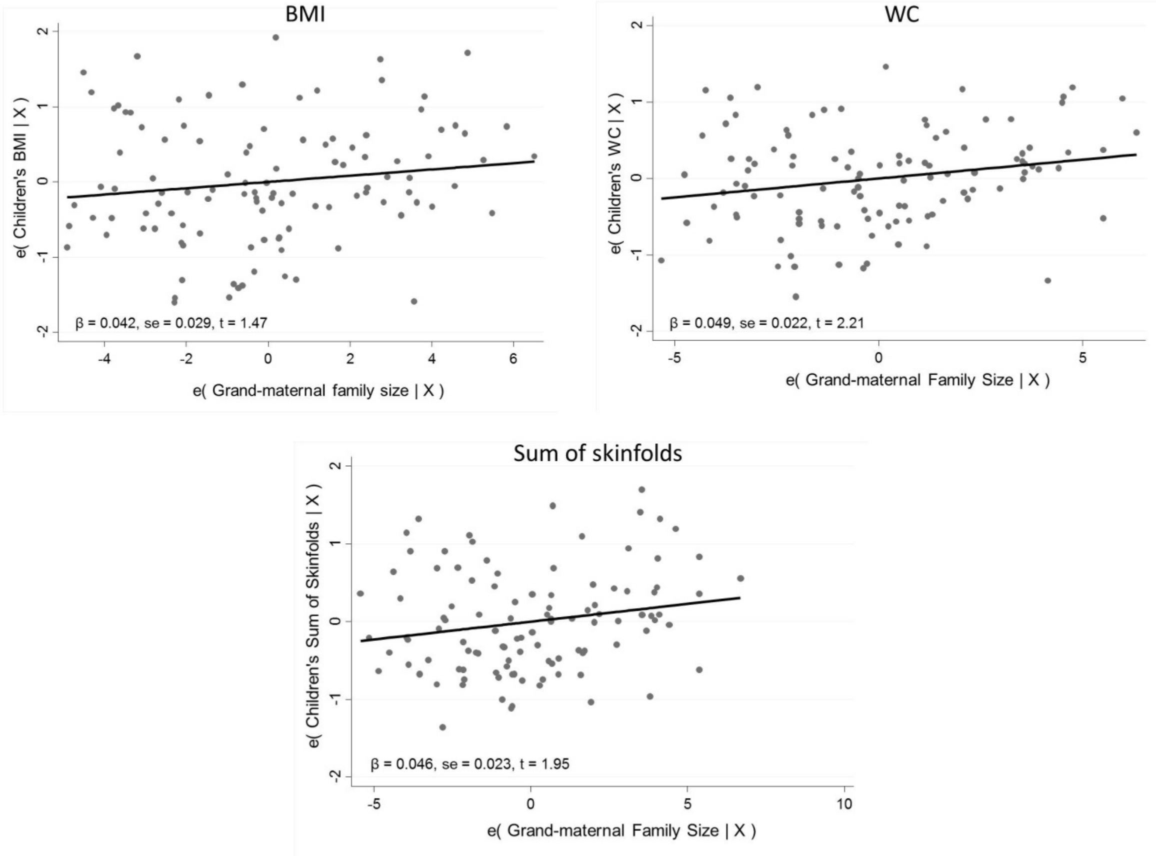
Table 9.23 Body mass index, waist circumference and sum of skinfolds of children according to grand-maternal school attendance

Condition	Grandmothers who attended the school n = 69	Grandmothers who did not attend the school n = 40	X, p
BMI			
Normal BMI	73% (51)	27% (19)	$X^2 = 7.69$,
Risk for OW/OB	46% (18)	54% (21)	p = 0.006
WC			
Normal WC	72% (53)	28% (21)	$X^2 = 6.87$,
High WC	46% (16)	54% (19)	p = 0.009
SumSkf			
Normal SumSkf	69% (57)	31% (26)	$X^2 = 4.32$,
High SumSkf	37% (14)	46% (12)	p = 0.038

Normal BMI, WC and SumSkf: >5^{th} – 85^{th} percentile of the reference, OW/OB, High WC, and High SumSkf: $\geq 85^{th}$ percentile of the reference.

Grand-maternal family size was another variable that consistently predicted, positively BMI, WC and sum of skinfolds of children. These positive effects were seen in the three models. Figure 9.15 shows the predictive effects of grand-maternal family on each outcome variable, after controlling for the effects of all predictors included in the final models. Predictive effects on WC and sum of skinfolds were very similar in magnitude followed by the effects on BMI.

Figure 9.15 Predictive relationships between grand-maternal (F_1) family size during childhood and children's (F_3) body mass index, waist circumference, and sum of tricipital and subscapular skinfolds



In summary, anthropometric and socioeconomic intergenerational influences were detected in this sample of three generations. Our analysis was based on two levels: 1) the intergenerational influences of grandmothers (F_1) on mothers (F_2), and 2) the intergenerational influences of grandmothers (F_1) and mothers (F_2) on the children (F_3). We found, in the first level of analysis, that the place where the grandmothers (F_1) grew up during their childhood positively predicted maternal z-score values for height, LL and KH. On the second level of analysis we found that mothers-children pairs correlated stronger in linear growth variables than grandmothers-children pairs. In contrast, grandmothers and children correlated stronger than mothers and children when variables of body mass and body composition were analysed. The path analysis showed that the strongest direct causal effects in linear growth variables were from grandmothers-to-mothers and from mothers-to-children, being the effect of grandmothers on children detected indirectly through the maternal effect. Significant direct causal effects were found among the three generations when body mass and body composition parameters were analysed. For some of models, the strongest causal effect was the one from grandmothers to children. Multiple regression models showed that household index and family size of grandmothers during their childhood significantly impacted the linear growth variables of the children. No maternal socioeconomic predictors had a significant effect on children’s linear growth. When z-score values for BMI, WC and sum skinfolds were analysed we found that maternal family size and paternal job loss during maternal childhood negatively impacted the growth of the children. Grand-maternal family size, household index and grand-maternal school attendance during childhood were detected as socioeconomic intergenerational predictors of children’s z-score of WC and sum of skinfolds.

9.3.3.6 Body fat

No socioeconomic intergenerational variables of mothers (F_2) and grandmothers (F_1) predicted fat mass (kg) and percentage of body fat in children (F_3). Therefore, additional intergenerational models were not performed. However, we explored expected associations between some body mass and body composition variables of mothers and grandmothers and children's values for fat mass and percentage of body fat. As expected, weight, WC, BMI, and sum of skinfolds of mothers and grandmothers significantly predicted children's fat mass and percentage (Table 9.24). In general prediction coefficients were similar.

Table 9.24 Bivariate linear regressions between maternal (F_2) and grand-maternal (F_1) body mass and composition and children's (F_3) body mass and composition

	Body fat mass (kg)		Body fat percentage	
	B (SE)	p	B (SE)	p
Mothers				
Weight (kg)	0.069 (0.023)	0.003	0.123 (0.046)	0.009
WC (cm)	0.078 (0.024)	0.002	0.147 (0.049)	0.004
BMI (kg/m^2)	0.144 (0.055)	0.010	0.241 (0.112)	0.034
SumSkf (mm)	0.068 (0.023)	0.003	0.105 (0.047)	0.027
FM (kg)	0.101 (0.034)	0.003	-	-
%BF	-	-	0.222 (0.120)	0.068
Grandmothers				
Weight (kg)	0.078 (0.024)	0.002	0.123 (0.050)	0.016
WC (cm)	0.087 (0.028)	0.002	0.145 (0.057)	0.013
BMI (kg/m^2)	0.177 (0.054)	0.002	0.285 (0.112)	0.012
SumSkf (mm)	0.055 (0.022)	0.014	0.081 (0.046)	0.077
FM (kg)	0.112 (0.034)	0.002	-	-
%BF	-	-	0.150 (0.111)	0.154

WC: Waist circumference; BMI: Body mass index; SumSkf: Sum of skinfolds; FM: Fat mass; %BF: Body fat percentage.

9.3.3.7 Lean body mass

No socioeconomic intergenerational variables of mothers (F_2) and grandmothers (F_1) predicted lean body mass and percentage of lean mass of the children. Therefore, additional intergenerational modeling was not performed. Through a personal communication, Dr. Christopher Kuzawa suggested that I analyse the effects of linear growth variables of the matrilineal ancestors on the lean body mass of the children. We found that no maternal and grand-maternal linear growth variable predicted children's lean body mass (Table 9.25).

Table 9.25 Bivariate linear regressions between maternal (F_2) and grand-maternal (F_1) linear growth variables and children's (F_3) lean body mass and percentage

	Body lean mass		Percentage of body lean mass	
	B (SE)	p	B (SE)	p
Mothers				
Height (cm)	0.030 (0.053)	0.578	-0.171 (0.112)	0.132
LL (cm)	0.021 (0.071)	0.769	-0.256 (0.150)	0.189
KH (cm)	0.057 (0.128)	0.659	-0.674 (0.266)	0.133
SHR	-0.133 (0.215)	0.535	0.843 (0.453)	0.165
Grandmothers				
Height (cm)	0.010 (0.054)	0.848	-0.041 (0.115)	0.721
LL (cm)	0.027 (0.084)	0.750	-0.121 (0.180)	0.503
KH (cm)	0.166 (0.136)	0.227	-0.499 (0.290)	0.191
SHR	-0.053 (0.199)	0.791	0.288 (0.426)	0.500

LL: Leg length; KH: Knee height; SHR: Sitting height ratio.

9.3.3.8 Intergenerational influences on children's birthweight

Through a personal communication, Dr. Christopher Kuzawa suggested that I analyse the effect of intergenerational factors on the birthweight of the children (F_3).

In Mexico, hospitals provide birth certificates to mothers at the moment of the child's birth. Birth certificates include children's birth weight and gestational age. Birth weight data was obtained in this research through two different ways. During home visits we asked the mothers for the children's birth certificates. However, only 50 (46%) of them provided this document. Birth weight (g) and gestational ages (weeks) were recorded from birth certificates (registered data). On the other hand, reported birth weights were obtained in 57 (52%) cases. None of these mothers remembered the gestational age of their children, but all of them could informed us if the doctor who attended the child's birth informed them if the child was a full term or a preterm baby (<37 weeks). We asked for reported data even in those cases where the mothers provided the birth certificates. In order to obtain unbiased data we asked first the information about the reported birth weight and then we asked to see the birth certificates. We compared registered and reported data in the first 50 cases. Since we did not find significant differences between them we decided to combine this two set of data in one variable. Reported data were used where registered date were not available. Table 9.26 shows descriptive statistics for the three sets of data: registered (birth certificates), reported and combined.

Table 9.26 Descriptive statistic of registered, reported and combined data of children's birth weight

	n	Mean (g)	SD	Diff
Registered	50	3104.04	502.43	z = 0.316, p = 0.752*
Reported	57	3071.60	458.15	
Combined	107	3088.88	480.27	

Registered: birth weight obtained from children's birth certificates; Reported: birth weight reported by mothers during home visits; Combined: reported data were used where registered data where not available.*Wilcoxon rank sum test

We performed multiple regression models for each set of data. Variables included in the models were those who significantly predicted ($p<0.05$) the outcome variable in a bivariate analysis. Anthropometric and socioeconomic intergenerational variables of grandmothers (F_1) and mothers (F_2) were analysed for their possible inclusion in the model. Because the regression models used natural logarithm-transformed dependent variable, β coefficients were reported as percentages.

The model for intergenerational influences on birth weight in registered data (n = 50) is presented in Table 9.27. In model 1 we only controlled for gestational age and in model 2 we included all the other predictors. No maternal and grand-maternal anthropometric variables predicted children's birth weight. After controlling for gestational age in model 1, we found that the absence of toilet at home and paternal job loss, both during maternal childhood impacted negatively the outcome variable; however their effects were marginally significant (p = 0.056 and p = 0.079 respectively). Specifically, the absence of toilet at home predicted a reduction in the birth weight of 11%. Paternal job loss during maternal childhood predicted a decrease of 7% in the children's birth weight. Gestational age explained 82% of the variance in the outcome variable. The effect of this variable did not change substantially after the inclusion of socioeconomic predictors in model 2. The inclusion of maternal intergenerational predictors increased 7% in the explained variance. No grand-maternal anthropometric and socioeconomic variable predicted children's birth weight.

Table 9.27 Intergenerational effects on children's birth weight (birth certificates)

	Model 1		Model 2	
	B (S.E.)	p	B (S.E.)	p
Gestational age (weeks)	0.060 (0.013)	<0.001	0.053 (0.013)	<0.001
Absence of toilet at home during maternal childhood			-0.111 (0.057)	0.056
Paternal job loss during maternal childhood			-0.072 (0.040)	0.079
Constant	5.660 (0.517)	<0.001	5.997 (0.514)	<0.001
R^2 adjusted	0.288		0.351	

S.E.: standard error; n = 50, F (3, 46) = 9.82, p<0.001, R^2 = 0.390; Shapiro-Wilk residual normality test: w = 0.96, p = 0.111; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 3.08, p = 0.079.

The model for intergenerational influences on birth weight in reported data (n = 57) is presented in Table 9.28. As expected, the model shows that those mothers who reported a preterm birth had children with significantly less birth weight. The effect of this variable did not change substantially after the inclusion of the intergenerational variables in model 2 and remained significant. We found in model 2 that maternal head circumference positively predicted the birthweight of their children. Specifically we found that per each centimeter of increase in maternal head circumference the birthweight of the children increased 3%. As in the previous model, the absence of a toilet at home during maternal childhood negatively predicted children's birth weight with an effect marginally significant (p = 0.076). Paternal job loss during maternal childhood did not significantly predict children's birth weight. No anthropometric and socioeconomic variable of the grandmothers predicted the birth weight of children. The inclusion of intergenerational variables in model 2 contributed to increase the explained variance in 14 units.

Table 9.28 Intergenerational effects on children's birth weight (reported data)

	Model 1		Model 2	
	B (S.E.)	p	B (S.E.)	p
Informed preterm (<37 weeks)	-0.351 (0.68)	<0.001	-0.334 (0.061)	<0.001
Maternal head circumference			0.034 (0.011)	0.003
Absence of toilet at home during maternal childhood			-0.079 (0.044)	0.076
Paternal job loss during maternal childhood			-0.023 (0.037)	0.534
Constant	8.057 (0.020)	<0.001	6.228 (0.593)	<0.001
R^2 adjusted	0.316		0.454	

S.E.: standard error; n = 57, F (4, 52) = 12.63, p<0.001, R^2 = 0.493; Shapiro-Wilk residual normality test: w = 0.98, p = 0.413; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.02, p = 0.876.

The model for intergenerational influences on birth weight in the combined data set (n = 107) is shown in Table 9.29. After controlling for informed preterm births in model 1, we found again in model 2 that maternal head circumference positively predicted the birth weight of the children. Children's birth weight increased 2% per each centimeter increase in mothers' head circumference. The absence of toilet at home during maternal childhood negatively affected the outcome variable and the size effect was about 10% in the children's birth weight. Paternal job loss during maternal childhood also impacted negatively the birth weight, but with a marginally significant effect (p = 0.075). In general, all variables included in the final model explained about 40% of outcome variance and the intergenerational variables included in model 2 contributed to increase the percentage of explained variance in 11 units. No grand-maternal anthropometric and socioeconomic variables predicted the outcome variable.

Table 9.29 Intergenerational effects on children's birth weight (birth weight registered and reported)

	Model 1		Model 2	
	B (S.E.)	p	B (S.E.)	p
Informed preterm (<37 weeks)	-0.348 (0.053)	<0.001	-0.338 (0.049)	<0.001
Maternal head circumference			0.021 (0.008)	0.011
Absence of toilet at home during maternal childhood			-0.099 (0.035)	0.005
Paternal job loss during maternal childhood			-0.050 (0.028)	0.075
Constant	8.048 (0.014)	<0.001	6.938 (0.446)	<0.001
R^2 adjusted	0.286		0.398	

S.E.: standard error; n = 107, F (4, 102) = 14.69, p<0.001, R^2 = 0.420; Shapiro-Wilk residual normality test: w = 0.99, p = 0.287; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 2.70, p = 0.100.

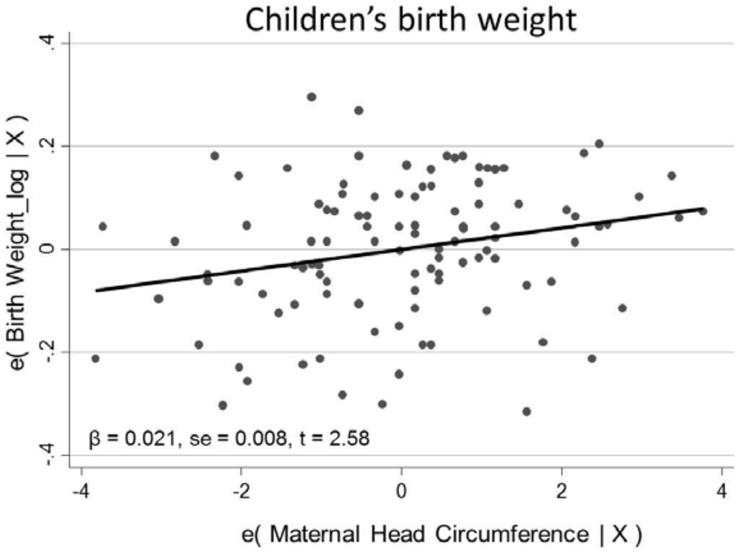
We found that no linear growth variables of mothers and grandmothers significantly predicted the birth weight of the children (Table 9.30). We were particularly interested in the effect of maternal and grand-maternal height, leg length and knee height, but none of them were significantly associated with children's birth weight. Only maternal head circumference significantly predicted the birthweight of the children in reported and combined data. The effect of this variable remained significant after controlling for preterm birth, absence of toilet at home and paternal job loss during maternal childhood (Figure 9.16).

Table 9.30 Effect of maternal (F_2) and grand-maternal (F_1) anthropometric variables on children's (F_3) birth weight in bivariate regressions models

	B	S.E	p
Mothers			
Height (cm)	11.02	9.61	0.254
LL (cm)	12.53	12.95	0.335
KH (cm)	22.67	23.26	0.332
BMI (kg/m^2)	12.90	9.72	0.187
Head circumference (cm)	68.74	28.10	0.016
Grandmothers			
Height (cm)	-9.81	9.73	0.316
LL (cm)	-4.52	15.30	0.768
KH (cm)	-23.10	24.76	0.353
BMI (kg/m2)	3.82	9.87	0.699
Head circumference (cm)	42.70	29.78	0.155

LL: Leg length; KH: Knee height; BMI: Body mass index.

Figure 9.16 Predictive relationship between maternal (F_2) head circumference and children's (F_3) birth weight



Adjusted for preterm births and maternal socioeconomic factors

CHAPTER 10

Discussion

10. Discussion

10.1 Nutritional status of participants

10.1.1 Nutritional status of children

The growth and nutritional status of children reflect, in general, the quality of the environment in which they live. It is also a very sensitive indicator of levels of poverty experienced by families. In terms of linear growth, we found two relevant results: lower body segments are more affected by the social environment and, the boys of this sample seem to be more negatively affected by the harsh environmental conditions than girls.

Even when 11% of children were classified as stunted, 29% of the sample was leg stunted and only 7% showed short trunk for their age. Our results support the hypothesis proposed by Isabella Leitch (1951) that leg length is often more sensitive to the quality of the environment than is total height. Leitch's hypothesis has been supported by many studies, which were reviewed by Bogin (2012). Two studies, most relevant to our Mexican-Maya research, include one by Frisancho et al. (2001), who found for a sample of 2,985 Mexican-Americans aged 2-17 years of age, that individuals with a low Poverty Income Ratio (PIR) had significantly shorter legs than individuals with higher PIR values. There were no significant differences in sitting height by PIR values. Another study by Bogin et al. (2002) found that children (5 to 12 years old) of Guatemala-Maya parents who migrated to the United States were 11.54 cm taller than Maya children living in Guatemala and 60% of height increment (6.83 cm) was explained by the differences in leg length. The authors noted that improvements in the living conditions in the U.S., such as the use of safe drinking water, the availability and access to health care, school breakfast and lunch programs were some of the main factors that could explain the differences between the groups.

Another relevant finding of this research was the differences between boys and girls in some of the growth parameters. Specifically, we found that girls, as a group, exhibited significant higher z-score values for LL (-0.80 $\pm$0.77 vs. -1.47 $\pm$0.89, p<0.05) and SH (-0.09 $\pm$0.82 vs. -0.68 $\pm$0.79, p<0.05). These differences were explained in the context of the growth status; the proportion of boys and girls with short legs was significantly different, boys being more leg stunted than girls. One possible explanation for this would be that girls receive a preferential care that enhances their growth status. However, according to our experience in the place of research, the cultural practices among the Maya from Yucatan do not favour girls or boys in terms of nutrition. Our findings could be interpreted in the context of the sexual differences in sensitivity to environmental conditions (Stini, 1975; Wolanski and Kasprzak, 1976; Stinson, 1985). In 1985, Sara Stinson published a review paper in which, analysing data about mortality, morbidity and pre-and-postnatal growth, found "…*at least weak support for the hypothesis that males are less buffered than females against the environment during growth and development*" (1985, p 141). It has been also proposed that under favourable conditions the sexual size dimorphism will be large than under unfavourable conditions (Nikitovic and Bogin, in press). We did not find significant differences in the raw variables for height, SH and LL between boys and girls. However, we found that girls revealed higher values of knee height ratio (30.67 vs. 30.40 p = 0.06, Student t-test), which means that the proportion of knee height in relation to the total height is higher in girls than in boys. These results suggest that boys of our sample are reacting differently to the environmental conditions, and that these are being reflected, at least, in the growth pattern of low body segments. In the evolutionary context, the fact that females are more resistant to environmental stresses makes sense in terms of ensuring their reproductive success.

The prevalence of child stunting in this sample was 11%. Our results are similar to results of stunting for Mexico (9.9%) as a whole, but the prevalence in our sample is lower than the results published for the Yucatan State (23.6%) in the last National Health and Nutrition Survey of 2006. Unfortunately, this national study does not include data for leg length or trunk. In another research project we studied a sample of 841 children (9-to-17 years) from different socioeconomic levels in Merida City. We found that 16% of non-Maya children were stunted and 24% and 30% of children with one and two Maya surnames respectively were classified as stunted (Unpublished results from the Laboratory of Somatology at the Department of Human Ecology, *CINVESTAV*, Merida, Mexico). Our prevalence of stunting is more similar to that of non-Maya children. It is possible that the differences in the age range and sample sizes play an important role in the presence and magnitude of chronic undernutrition. Two previous studies have been conducted in the south of Merida. In the first of them, the prevalence of stunting among rural-to-urban Maya migrants (4-to-6 years old) was 22% (Varela-Silva et al., 2009), which doubles the prevalence found in our research. In the second study we found that in a sample of 58 children (7-to-9 year old) with two Maya surnames, 31% were stunted (Varela-Silva et al., 2012). Both studies used the same reference and cut-off points that we used in this research (NHANES III, below 5th percentile of reference for height-for-age). These comparisons clearly show that children studied in this research are in better biological condition than Maya immigrants and non-migrants from the south of Merida. Our sample included children belonging to families not only from the south, but also from the east and west parts of Merida, where socioeconomic conditions are slightly better (Dickinson et al., 1999). This situation could explain the differences found between these two previous studies and our current research.

Available evidence suggests that stunted children usually grow to be stunted adults (Bogin et al., 1992; Martorell et al., 1994). A recent review of longitudinal studies shows that stunting during childhood is strongly linked to short stature and reduced lean body mass, reduced cognitive ability, less schooling, and lower income in adulthood (Walker et al., 2007; Black et al., 2008; Victoria et al., 2008). A recovery in growth deficit requires some improvement in the environmental conditions. Unfortunately, it is very common that familial conditions surrounding an undernourished child do not change during the following years of growth. This is particularly true for social groups who experience chronic socioeconomic adverse conditions, such as the Maya. Indeed, growth deficits usually increase as Maya children grow during the juvenile and adolescent stages of life (Bogin et al., 1992).

In contrast, 36% of children in our sample were classified as OW/OB. This prevalence is very similar to that found for the Yucatan State by the National Health and Nutrition Survey of 2006 (36.3%) (INSP-SSP, 2007). However, our prevalence is ten percent higher than the prevalence for Mexico as a whole in the same age group (26.3%) (Shamah-Levy et al., 2007). Our sample’s prevalence for OW/OB is similar to that found in the sample of 841 children (9-17 years of age) of different socioeconomic conditions in the city of Merida (30%) (Unpublished results from the Laboratory of Somatology at the Department of Human Ecology, *CINVESTAV*, Merida, Mexico), and also similar to that found in previous studies in the south of Merida by Varela-Silva et al. in 2009 (33%) and in 2012 (27.5%). In general our results and the previously quoted describe the severity of the malnutrition among the growing subjects from Yucatan and particularly among the disadvantaged socioeconomic groups as the Maya.

In addition, 32% of children showed high WC or risk for abdominal obesity. This prevalence is higher than the prevalence (20%) found in the sample of 841 children from Merida City (Unpublished results from the Laboratory of Somatology at the Department of Human Ecology, *CINVESTAV*, Merida, Mexico). Although the evidence for health risk associated with an excessive WC in children is less solid than in adults, some reports (Flodmark et al., 1994; Freedman et al., 1999; McCarthy et al., 2001; Colín-Ramírez et al., 2009) suggest a strong association between this anthropometric measure and relevant health risk factors. For example, Freedman and colleagues (1999) found that WC was significantly associated to adverse levels of triacylglycerol, low density lipoprotein cholesterol, high density lipoprotein cholesterol and insulin in a sample of 2996 African-Americans and European-Americans children of 5 to 17 years old from the U.S. The authors state that *"…these findings likely reflect the ability of waist circumference to function as an index of both fat distribution and generalized obesity"*. Similar results have been found in adolescents (Flodmark et al., 1994). In another study, Collín-Ramírez et al. (2009) found, in sample of 8-to-10 year old Mexican children, that systolic hypertension was more common among those individuals with high WC. Some authors suggest, in fact, adopting WC as valid alternative indicator to BMI in early ages (McCarthy et al., 2001).

We estimated %BF in children through bioelectrical impedance analysis using a recently developed equation for Mexican children (Ramirez et al., 2012). However, unfortunately references for Mexican children are not available. The Comprehensive (NHANES III) reference organized by Frisancho (2008) allows calculation of percentiles and z-score values for this variable but only in children older than 12 years old. Therefore nutritional status according to the %BF for our sample of children was not defined.

10.1.2 Nutritional status of mothers and grandmothers

In general, the mothers and grandmothers of our sample showed both extremes of malnutrition: chronic undernutrition, expressed by short stature and high rates of OW/OB.

The deficit in growth in adult women was evident in total height, trunk and legs. To better understand the nature of this height deficit we reviewed findings of the Longitudinal Study of Adolescent Growth of Leeds, which measured healthy children from schools in Leeds, England (Buckler, 1990). The findings of the Leeds Study show that the growth pattern of the lower limbs and the trunk during the childhood and adolescent stages of development are different. Before puberty and up to the onset of the adolescent growth spurt, height increments are relatively greater for the legs than for the trunk. According to the analysis of the Leeds Study the age for the peak of leg length velocity in girls was estimated to be 11.67 $\pm$0.99 years compared to 12.34 $\pm$1.07 years for trunk. However after puberty, the acceleration of growth is much more evident in trunk (sitting height) than in legs. Once the velocity peaks for both legs and trunk have passed, the growth of legs declines more rapidly than trunk. On average, in girls, the growth of the trunk ends at ~17 years of age, compared to ~15 years of age for the termination of growth of the legs. Our results indicate that the Maya mothers and grandmothers had growth deficits during both their childhood and adolescence. These adult women were characterized by short stature, with short trunk and short legs. We interpret this as a result of adverse living conditions experienced by these Maya women during all stages of growth and across both generations.

Most of mothers (71%) and grandmothers (90%) were classified as stunted. Among the mothers the deficit of growth was slightly more severe in the length of the legs (59%) than in the length of the trunk (54%). Our sample’s prevalence of maternal short stature is higher than the one found in the sample of 201 women from different socioeconomic groups of Merida (52%) but similar to that found in women with one (65%) and two (72%) Maya surnames (Unpublished results from the

Laboratory of Somatology at the Department of Human Ecology, *CINVESTAV*, Merida, Mexico). Our results regarding maternal short stature are also similar to the two previous studies conducted in the south of Merida that report that 70% (Varela-Silva et al., 2009) and 81% (Varela-Silva et al., 2012) of mothers were stunted.

A limiting factor in the study of intergenerational patterns of growth is the decrease in stature of adults due to ageing. In general, after the age of 40 years total height is reduced by about 1 cm per decade and this decline may accelerate after the age of 70 years (Minaker, 2011). The reduction in stature affects the upper body relatively more than the legs (Chumlea et al., 1985). These age changes may influence the correlations in measurements between generations. We believe that this limitation is reduced through the use of z-scores as they are standardized for both sex and age.

We found that the growth deficit of grandmothers was more evident in the trunk (83%) than in the leg length (69%). We used z-scores based on the United States NHANES III growth references, which helps to account for the loss of height with age. However, as most of the height loss with age is due to changes in the upper body, and because it is possible that references include women in better health conditions than the Maya, then it is also possible that the Maya grandmothers experienced greater reduction in trunk length as they aged. If so, this could be inflating the percentage of Maya grandmothers with short trunk length.

The Maya are one of the populations with lowest stature in the world (Bogin, 1999). Even when the genetic load is taken into account, differences in height between populations are largely attributed to differences in the environmental quality experienced (Ulijaszek et al., 1998). The extremely short statures of mothers (147.91 cm $\pm$4.84) and grandmothers (143.08 cm $\pm$4.77) can be attributed to the chronic adverse socioeconomic conditions during their growing years. Short stature in adults is strongly correlated with high morbidity and mortality rates. Particularly, cross-sectional and longitudinal studies show that height is inversely related to respiratory diseases, such as bronchitis, coronary heart disease, and stroke (Barker et al., 1990; Leon et al., 1995; Forsen et al., 2000). In addition, women with short legs have greater risk for higher percentages of body fat, greater insulin resistance and higher prevalence of type 2 diabetes (Lopez-Alvarenga et al., 2003; Asao et al., 2006).

Overweight and obesity are another serious health problem among the Maya people. In our sample, 55% of the mothers showed risk for abdominal obesity (WC > 88 cm). Using BMI as indicator, the 2006 National Health and Nutrition Survey of Mexico classified 76.7% of urban women (older than 20 years) from Yucatan as OW/OB (> 25 kg/m^2). However, recently, Wilson et al. (2011) found that both a high SHR (i.e., relatively short legs) and stunting significantly reduce the association between BMI and body fat percentages in adult Maya women from Merida, Mexico. In this research we found that mothers and grandmothers with a WC lower than 88 cm had significantly lower values of tricipital and subscapular skinfolds and %BF than women with a WC higher than 88 cm. This result also suggests that WC is more appropriate to evaluate health risk in Maya women. If we use BMI to assess the mothers of this research we would find out that 85.3% of them would be classified as OW/OB (OW = 39% and OB = 46%).

All mothers in the sample had values for percentage of body fat (estimated by bioelectric impedance analysis) higher than 30%. However, it is possible that the equations used in this research overestimated BF% values of Maya women. Unfortunately there is no available specific equation for adult Mexican population and that is the reason why we used an equation that has been validated in a group of North American Indians (Stolarczyk et al., 1994). This equation requires the values of weight and height of individuals to be applied and the women of our sample show in general low values of stature (mean = 147.91 cm $\pm$4.84) and high values of weight (mean = 65.47, $\pm$11.51).

The assessment of nutritional status of old people is even more challenging. Our results are consistent with the geriatric literature about the biological changes that occur with age. Specifically, we found that values for tricipital and subscapular skinfolds and %BF were significantly lower in the youngest grandmothers. Most of grandmothers (83%) showed risk for abdominal obesity, condition strongly associated with several health-risk factors, i.e. diabetes, hypertension and heart diseases, particularly in old people (Bermudez and Tucker 2001; Hirani 2011, Rodrigues-Barbosa et al., 2011), including Mexicans (Rosas-Carrasco et al., 2012).

Our results support previous reports that the Maya population from Yucatan experienced undernutrition in the childhood and adolescence and then overweight and obesity in adulthood (Dickinson, 1997).

10.1.3 Nutritional dual burden

Under and overnutrition coexist in the three generations of our sample. Eleven percent of the children were classified as stunted, 29% showed short legs for their age and, at the same time, 36% and 32%, respectively, were identified with excessive BMI and WC for their age. Current maternal and grand-maternal phenotypes clearly describe the presence of an adverse environment during the growing years and a chronic accumulation of fat tissue.

The prevalence of individual nutritional dual burden in the sample of children (stunting + high BMI or stunting + high WC) was very low (1%). Available studies suggest that NDB in children is more prevalent during the first five years of life. For instance, studying a sample of Mexican infants, Fernald and Neufeld (2007) found that the prevalence of individual NDB was 10.3% in 2-to-3 year old children, 12.1% in 3-to-4 year old, 10.4% in 4-to-5 year old and 5.9% in 5-to-6 year old children. In previous research conducted in same area of Merida we found that 2.4% of the studied preschoolers (4-to-6 year old) showed the coexistence of stunting and high BMI (Varela-Silva et al., 2009). Another recent study conducted in the south of Merida found that 3.4% of studied children (7-to-9 years of age) met the criteria for NDB (Varela-Silva et al., 2012). The differences in the prevalence of NDB between our research and the two previous studies conducted in the south of Merida are because our prevalence of stunting is lower (11% vs. 22% and 31% respectively).

In contrast, 36% of the mothers in our sample showed the combination of short stature (below <5th percentile of height-for-age) and risk for abdominal obesity (WC > 88 cm). Using BMI as indicator for OW/OB, Varela-Silva et al. (2012) found that short stature (below <5th percentile of height-for-age) and OW/OB (BMI >25) was present in 74.1% of Maya mothers from the south of Merida they studied. Only for comparison purposes we calculated the prevalence of NDB in mothers using BMI to identify OW/OB in mothers and grandmothers. We found that 61.5% of mothers and 83.5% of grandmothers were classified as NDB. This prevalence of maternal NDB is lower than the one found in the sample of Maya (1 Maya surnames: 92% and 2 Maya surnames: 83%) and non-Maya (73%) mothers from different socioeconomic groups of Merida (Unpublished results from the Laboratory of Somatology at the Department of Human Ecology, *CINVESTAV*, Merida, Mexico).

The combination of maternal abdominal obesity and child stunting was seen in 6.4% of mother-child dyads. However, most of available studies report the combination of child stunting and maternal obesity using BMI as indicator. Our prevalence of child stunting and maternal OW/OB (BMI > 25) is 9.2%. Table 10.1 shows prevalence of NDB in mother-child pairs in different populations, including the sample of this research. Guatemala is the country with the highest prevalence of the coexistence of child stunting and maternal OW/OB, not only in Latin America but also globally. The prevalence of NDB using BMI in mothers in our sample is similar to the prevalence found in countries such as Nicaragua, Bolivia and Ghana, but higher than African countries such as Malawi and Nigeria and Mexico as a whole. Varela-Silva and collaborators (2012) reported a prevalence of 27.6% in a previous study conducted in the south of Merida. However the number of mother-child pairs studied was small (n = 58). Very few studies have reported the combination of child stunting and maternal abdominal obesity. Our results suggest that this combination is higher in our sample than in Mexico as a whole.

Table 10.1 Prevalence of nutritional dual burden in mother-child pairs in different populations

Combination	Prevalence	Population and criteria	Source
Child stunting/Maternal OW/OB			
Kyrgyz Republic	4.6%	Children: 6-60 months; Mothers: >18 yrs old; Stunting: height-for-age below -2 SD of the WHO/NCHS/CDC 1979; Maternal OW/OB: BMI > 25.	(Garret and Ruel, 2003)
Nicaragua	9.8%		
Bolivia	11.0%		
Guatemala	13.4%		
Egypt	14.0%		
Guatemala	16.0%	Children: 6-60 months; Mothers: > 18 yrs old; Stunting: height-for-age below -2 SD of the WHO/NCHS/CDC 1979; Maternal OW/OB: BMI > 25.	(Garret and Ruel, 2005)
Mexico	6.1%	Children: < 5 yrs old; Mothers: 12-49 yrs old; Stunting: < -2 SD of WHO/NCHS/CDC 1979; Maternal OW/OB: BMI > 25.	(Barquera et al., 2007)
Bangladesh	1.0%	Children: 3-5 yrs old; Mothers: 13-49 yrs old; Stunting: height-for-age below -2 SD of WHO 2006; maternal OW/OB: BMI > 25.	(Jehn & Brewis, 2009)
Malawi	6.0%		
Nigeria	6.0%		
Colombia	7.0%		
Nicaragua	12.0%		
Ghana	12.0%		
Bolivia	15.0%		
Peru	16.0%		
Guatemala	23.0%		
Guatemala	18.2%	Children: 12-60 months; Mothers: 18-49 yrs old; Stunting: height-for-age below -2 SD of WHO 2006; maternal OW/OB: BMI > 25.	(Lee et al., 2010)
Mexico, Maya population	27.6%	Children: 7-9 yrs old; Mothers: 22-49 yrs of age; Stunting: below 5th percentile of NHANES III; maternal OW/OB: BMI > 25.	(Varela-Silva et al., 2012)
Mexico, Maya population	9.2%	This research Children: 6-8 yrs old; Mothers: 22-49 yrs old; Stunting: height-for-age < 5th percentile of NHANES III; maternal OW/OB: BMI > 25	
Child stunting/Maternal abdominal obesity			
Mexico	2.0%	Children: < 5 yrs old; Mothers: 12-49 yrs old Stunting: < -2 SD of WHO/NCHS/CDC 1979; Maternal AO: WC > 88 cm.	(Barquera et al., 2007)
Mexico, Maya population	6.4%	This research Children: 6-8 yrs old; Mothers: 22-49 yrs old Stunting: height-for-age < 5th percentile of NHANES III; maternal AO: WC > 88cm	

10.1.4 Implications for health and interventions

Our findings indicate that the future health and human capital[5] of the studied children is compromised. The epidemiological mosaic of Yucatan shows an alarming increase in chronic degenerative diseases. The three leading causes of death in Yucatan are heart diseases (most of them related to ischemic process) malignant tumours and type 2 diabetes mellitus. The 'developmental origins of health and disease' paradigm suggests that early environments (prenatal and postnatal) experienced by individuals predispose them to develop chronic degenerative diseases during adulthood (Gluckman et al., 2010). It is possible that poor environmental conditions experienced by Maya mothers (F_2) and grandmothers (F_3) during their childhood and adolescence are being reflected in the biological status of them of their descendants (F_3). According to the National Survey of Health and Nutrition of 2006 the prevalence of type 2 diabetes and hypertension among women from the Yucatan State was 5.4% and 12.6% respectively. Eighteen percent of the mothers and fifty-five percent of the grandmothers of our sample reported to have been diagnosed with at least one chronic disease. Six percent of the grandmothers reported the coexistence of diabetes and hypertension.

The current lifestyle and health behaviors of the population cannot be ignored. As in many other countries, during the last 30 years Mexico has experienced an evident shift to a high fat and refined carbohydrates diet. This change has been accompanied by a dramatic increase in energy intake from beverages in all different age groups (Barquera et al., 2008; Barquera et al., 2010). Estimations suggest that 28%, 21%, 20% and 22% of the total energy intake in preschoolers, scholars, adolescents and adults, respectively, comes mainly from high energy content beverages (sodas and sweetened beverages). Archeological evidence suggests that the pre-Columbian Maya diet consisted basically of a mix of crops including several kinds of beans, pumpkin, chili, fruits and corn as their central element. This diet changed during the Colonial and Independent period, incorporating foods from

[5] According to Lanzi (2007) human capital is defined as a set of formal and informal skills possessed by an individual that gives him/her the possibility to enrich his/her life. Human capital has three categories: 1) basic skills, such as read and write, 2) professional skills, such as the use of techniques to develop or operate tools, and 3) the use of complex functions involving self-learning processes and problem solving skills.

Europe, Africa and Asia. However, the dietary pattern of Mayas changed in a more marked way during the last five decades. Rural-to-urban migration, the expansion of road networks connecting small and traditional communities to major urban centres and the development of a touristic economy led to significant changes in the Maya diet (Gurri and Balam, 1992). One of the most relevant changes has been the transition from a system of food production for self-consumption to one characterized by the commoditization and delocalization of foods (Leatherman and Goodman, 2005).

During our fieldwork we identified that the families from our sample depend largely on small local stores (in Mexico called *tiendas*) for their food supply. Local *tiendas* offer basic staples, mainly beans, rice, pasta, sugar, tinned products, sodas and snacks such as chips, cookies and candies. We have evidence showing that the families in our sample are experiencing nutritional transition. However, in our opinion the consumption pattern is also masked by poverty. Many of the products and foods frequently consumed are the lowest priced in the small stores, and these also tend to satisfy immediate energy requirements of the family.

The coexistence of under and overnutrition in the same household brings several implications for possible interventions, particularly related to education for health and nutrition. The combination of maternal overweight and child undernutrition raises several questions for those who plan the interventions. The most relevant of these (for their implications) is related to the information that families should receive. Should health promoters provide recommendations on nutrition that seek reducing the overweight problem among the adult family members? Or should they provide recommendations that seek to reduce the chronic undernutrition in children? It is clear that interventions should address both problems. However, to do that it is necessary that mothers or caregivers make decisions that can be very difficult to make in the context of their poverty status. Low education levels of the mothers and caregivers and low purchasing power complicate the effectiveness of interventions even when they have clear objectives and appropriated methodologies.

Our findings suggest that the political-economic system of the Merida region has several negative effects on the biology of the Maya. Using the perspective proposed by Wells (2012b), the economics and politics of a society are capable of shaping both extremes of malnutrition, stunting and obesity, in the same economically disadvantaged group. In our opinion, the biological conditions of the Maya people will not improve if their living conditions do not improve. Education, income, and health services are just some factors that should be taken into account in local, regional and national politics.

10.2 Socioeconomic and biological factors related to the physical growth of children

We analysed variables of linear growth: z-score of height and LL, and variables of body mass and composition: z-score of BMI and WC, %BF and %LBM.
After controlling for maternal height, LL and children's sex and age effect, we found that reported preeclampsia impacted negatively the height and LL of children. During gestation preeclampsia reduces the blood flow to the placenta restricting the supply of nutrients to the fetus, which in turn, can produce intrauterine growth restriction. In addition, the normal blood circulation from the placenta to the fetus, through the umbilical vein and then through the ascending aorta, provides the majority of the blood (high in oxygen and nutrients) to the head and arms of the fetus. After upper body segments have been oxygenated, the descending blood flow, through iliac arteries, provides blood (with less oxygen) to the legs of the fetus (Moore et al., 2011). Reduced birth weight could be expected when preeclampsia is present. However, we did not found any association between preeclampsia and children's birth weight, neither any interaction between these variables in the models of children's height and LL. We found that the effect of reported preeclampsia on children's growth was slightly stronger on LL than in height (-0.50 vs. -0.39 units of z-score).

Having lived with smokers during pregnancy was another factor that negatively impacted the current height of the children. Most of the mothers reported that was the husband (or partner) the person who smoked during their pregnancy. No mother reported having smoked during pregnancy. The effect of prenatal smoke exposure on the reduced fetal growth has been widely documented (e.g. Luciano et al., 1998; Kallen, 2000). In general, the impact on birth weight has been estimated in between 150 and 200 g (Kramer, 1987; Cliver et al., 1995; Kramer, 1998; Wright et al., 1998). It has also found that neonates born to women who reported smoking during pregnancy showed a reduction of 0.6-1.9% in several neonatal anthropometric measurements such as head, abdominal circumference, arm and leg length and triceps, thigh and subscapular skinfolds (Cliver et al., 1995). Maternal exposition to environmental tobacco smoke has also showed a decrement in offspring birth weight, although of smaller magnitude (Rubin et al., 1986; Ahlborg, 1994; Mainous and Heuston, 1994; Rebagliato et al., 1995, Windham et al., 1999; Windham et al., 2000). Specifically, Martinez et al. (1994) reported that the birth weight of newborns from non-smoking mothers whose fathers smoked more than 20 cigarettes per day had, on average, 88 g less. We specifically found that children whose mothers cohabited with smokers during pregnancy had 0.35 z-score units of height-for-age less than children whose mothers did not live with a smoker during pregnancy.

We also found that overcrowding was negatively linked to the height of the children. Sixty-two percent of the families were classified as overcrowded (> 2.5 persons per room) at the moment of the research. Vázquez-Vázquez et al. (in press) found the same results studying a bigger sample with more socioeconomic variation from the city of Merida, showing that children who belong to an overcrowded family exhibit 0.63 cm less height per extra person per room. Our model for height (as a raw variable) showed that, after controlling for other socioeconomic and biological predictors, children belonging to overcrowded families exhibited 0.90 cm less of height than children who did not belong to an overcrowded family.

Mothers who reported to have ingested iron supplementation during pregnancy had children with a better linear growth status. However, the effect of iron supplementation was only significant for LL. Developmental plasticity theory suggests that, in a situation of scarce resources, the trade-offs between body segments in prenatal growth will favour the head and trunk (Bogin, 2012). If the availability of resources improves it might be expected that resources would be allocated for the growth of lower body segments. After controlling for all other predictors, we found that children of mothers who consumed iron supplementation during gestation exhibited 0.83 units more of z-score values for LL than children of mothers who were not supplemented. However we did not found significant differences in the proportion of children with short legs between supplemented and non-supplemented mothers.

We also found that the sex of the children was a significant predictor of their LL. In particular, girls as a group showed longer LL than boys after controlling for other socioeconomic and biological factors. This result is consistent with findings explained in Chapter 7 regarding the nutritional status of the participants.

As expected, birth weight positively predicted BMI and WC of children. However, the impact was slightly stronger on children's BMI (0.39 vs. 0.26 units of z-score per each kilogram of birth weight increased). Previous studies conducted among the Maya from Merida have shown positive associations between birth weight and height and KH (Vázquez-Vázquez et al., in press) and weight and arm muscle and fat area (Azcorra et al., 2009). In addition, Varela-Silva et al. (2009) found that urban Maya children with birth weights less than 3,000 g were a third as likely (OR 0.28 CI 95% 0.12 - 0.65) to be classified as overweight (> 85th percentile of BMI-for-age) in comparison with children within the normal birth weight range (3,000 - 3,500 g). In general, these findings suggest that the birth weight of Maya children from Yucatan is a determinant factor for postnatal growth. Even when overweight children in our sample showed higher birth weights than non-overweight children (mean = 3,148 $\pm$525.95 vs. 3,054 $\pm$452.50), the differences were not significant (z = -0.91, p = 0.363, Wilcoxon rank sum).

Studying a sample of urban Maya migrants from the south of Merida, Azcorra et al. (2009) found that, after controlling for sex, age, birth weight and socioeconomic status, birth order predicted a reduction of 1.87 kg in the weight and 3.87% in the arm fat area at the age of 4-to-6 years. Birth order of the children studied in this research was a non-significant predictor of any growth variable (linear growth and body mass and body composition). We suggest that the meaning of birth order effect in the context of Maya population from Yucatan is more related with the distribution of economic resources in the household than with its biological meaning.

We found that those mothers who had a partner present during pregnancy had children with higher WC. Some other findings suggest that it is possible that mothers with present partners during pregnancy offered to their children a better environment during gestation. For instance, we found that birth weight of children with 'married' mothers during gestation were higher than children of 'single' mothers during gestation (3,110 g $\pm$478.73 vs. 2,949 g $\pm$484.23, p>0.05). Furthermore, we found that 60% of 'single' mothers had no intentions of becoming pregnant, in comparison to 38% of mothers with partners. We suggest that the presence of a partner during gestation could increase the availability of resources in the family. It is also possible that the emotional support given to mother by their partners played an important role on the birth outcomes.

Our results suggest that maternal education acts as a protector factor for children's health. Even when children's linear growth (height and LL) has not been influenced by maternal education, we found that those children whose mothers reached some level of formal education (primary or secondary level) had lower percentages of body fat and higher percentages of lean body mass. These effects were significant after controlling for children's height, sex, and maternal %BF and %LBM. The effect of maternal education on children's nutritional status (Handa, 1999; Fedorov and Sahn, 2005; Frost et al., 2005; Boyle et al., 2006) and mortality (Caldwell, 1979; Cleland and van Ginneken, 1988; Basu and Stephenson, 2005) has been widely documented, particularly in developing countries. Even low levels of maternal education have shown significant effects on the reduction of risk for child mortality (Basu and Stephenson, 2005). The specific mechanisms through which maternal education acts on child outcomes have not been well determined. However, evidence suggests that maternal practices and knowledge are key pathways (Behrman and Wolfe, 1987: Armar-Klemesu et al., 2000). For instance, Armar-Klemesu et al. (2000) found in a sample of 556 households of Accra, in Ghana, that maternal education was strongly associated with better child feeding, health seeking practices and hygiene practices. Maternal education was used in our research as a variable with three categories: 1) None, 2) Primary (6 years) and 3) Secondary or more (equal or more than 9 years). We found that mothers with primary or secondary education predicted less %BF and higher percentages of lean body mass on children. However, we did not find differences in the effect of primary and secondary education, which suggest that, in the context of our sample, mothers with either primary education or secondary education act as protector factor for their children's health. We also explored the possible mediators of maternal education in this research. Mothers with no level of education described their children 'as sickly' (according to the presence of infectious diseases) with higher frequency (73% vs. 56%) in comparison to those mothers with some level of education. According to this finding it is possible that mothers with some level of education have more or better hygiene practices to protect their children against the presence of infectious diseases. In addition, mothers with no level of education reported to be more exposed to cigarette smoking during pregnancy (27% vs. 15%) and reported to have saved money for the child birth with lower frequency (46% vs. 57%). In the context of the Maya from Merida City, Vázquez-Vázquez et al. (in press) found that maternal education positively influenced height and KH of children in a sample of 841 boys and girls (9 to 17 years of age). Our results shows that maternal education is not associated with children's linear growth and the proportion of stunted children does not differ by maternal education categories. One possible explanation for this finding is that linear growth is the result of more cumulative environmental experiences. However, it is also possible that the size of our sample and the low educational level of the mothers do not allow the effect of this variable to be manifested.

According to our results the presence of grandmothers in the children's home seems to be a factor that also acts as protector of children's health. Specifically, the presence of the grandmother at home predicted lower percentages of body fat and higher percentages of lean body mass in children. Many studies provide evidence of the benefits of grandmother's presence on children's growth, development and mortality (Pope et al., 1993; Hawkes et al., 1997; Sear et al., 2000; Gibson and Mace, 2005; Sear and Mace, 2008), with maternal grandmothers being the more solicitous among grandparents (Euler and Weitzel, 1996). Some of these studies quantified the kin effect considering if the grandmother was alive or dead at the moment of the research. For instance, studying a longitudinal dataset from rural Gambia, Sear et al. (2000) found that the presence of maternal grandmothers improved the height and weight and reduce the risk for mortality among the children (from 1 to 5 years of age) in comparison to children whose grandmothers were dead at the moment of the research. In the description of the concept 'grandmaternal niche', Scelza (2009) highlights two very common traits of grandmothers that make them uniquely perform care practices that influence positively the children's welfare. Firstly, grandmothers are part of the closest social group of mothers and children, which facilitate their involvement in care activities. Secondly, grandmothers are well skilled and knowledgeable caretakers; they have the cumulative experience after having raised their own offspring from birth to reproduction. Based on our field observations and previous experiences in the area of study, we suggest that grandmothers have a positive effect on children's health through several specific mechanisms: 1) grandmothers are often responsible for the selection and preparation of food for children, 2) they often take the children to medical services when the mother is absent, 3) they often alleviate their daughters from some of heavy domestic tasks, allowing the mothers to allocate time for the children, 4) working grandmothers contribute significantly to the living expenses in the household.

The biological effect of the grandmothers' presence in this research is only manifested on children's body mass and composition. We did not find significant differences in the children's linear growth (height, SH and LL) according to the presence of grandmothers at home. This suggests that environmental conditions chronically experienced by children have a stronger effect on their growth. In contrast, we found that children with the grandmother at home are 1.40 kg lighter, and 2.41 cm and 6.47 mm lower in WC and sum of skinfolds respectively than children without the grandmother at home.

The number of ultrasounds that mothers received during pregnancy predicted lower values of percentage of body fat and higher values of percentage of lean mass on children. The number of ultrasounds has been suggested to be a good indicator for monitoring and evaluating perinatal health (Zeitlin et al., 2003), but its use in epidemiological study is rare. The Mexican regulations on health states that women in low-risk pregnancies should be provided with at least five prenatal assessments and two ultrasounds (NOM, 1993). In other countries such as England the National Health Service provides at least two ultrasounds during pregnancy, additional ultrasounds will be practiced in circumstances where risks for abnormalities are detected (NHS, 2013). Eighty-four percent of the mothers in our sample reported to have received between 1 and 4 ultrasounds and 12% of the mothers between 5 and

10 ultrasounds during gestation. It is possible that mothers who received more or additional ultrasounds were diagnosed with some perinatal risk factors and it might be possible that the prenatal growth of those children was not as expected. We found that children whose mothers received between 1 and 2 ultrasounds exhibited more lean body mass than children whose mothers received more than 4 ultrasounds (71.66% $\pm$5.16 vs. 67.92% $\pm$5.84). It is possible that, in the context of this research, the number of ultrasounds is acting as an indicator of conditions experienced by children in utero and postnatal growth.

10.2.1 Implications for possible interventions

Maternal cigarette smoke exposure, maternal education and iron supplementation during gestation are significant factors that, negatively and positively, shape the nutritional status of the children. These factors operate through behavioural mechanisms that may be beneficial or detrimental for the health of the children and for other family members. Improvements in the levels of formal education require, in the particular case of Mexico, structural changes in the social policies and their beneficial effects must be expected at long term. However, nutrition and health education interventions can be used as a good alternative. Education for health and nutrition is a particular preventive action that potentially modifies the behaviour related to the health at household level.

In general, interventions on health education in the context of the urban Maya groups from Merida are scarce and many of them have been implemented by the government of the Yucatan State or by the municipal government of the Merida City. All educational programs are focused on mothers who regularly use the health and community centres located in neighbourhoods of middle and low socioeconomic status.

According to our experience of the area where we conducted our research and in particular of the health and community centres, most of the intervention programs implemented in the south of Merida have weaknesses that can be grouped in the following categories: 1) have unclear objectives and goals, 2) seek to provide knowledge on health instead of giving effective strategies to modify the behavioural patterns, and 3) the information that people receive during the health programs is not adapted to the context of urban poverty and nutritional dual burden. In addition, some of these interventions include the sale (at very low cost) of food packages to the mothers enrolled in the programs. The right to purchase the food packages is often conditional on the attendance to the sessions of health education, which reduces the effectiveness of interventions.

Some evidence suggests that maternal autonomy in decision-making have positive impacts on the health and growth of the offspring (Shroff et al., 2011). Most of the mothers in our sample, who reported being exposed to cigarette smoke during pregnancy, also stated that it was their partners who smoked during their pregnancy. Does this finding suggest that mothers were not able or allowed to make the right decisions on their own, for themselves and their offspring during gestation? During our fieldwork we identified that most of the mothers live in a context of gender inequality and domestic violence. Even when during the informative meetings we suggested the mothers talk with their partners before taking the decision to participate in the study, we found that during some home visits the husbands were uncomfortable with our presence at home. In some cases we had to stop the application of questionnaires and anthropometry because we noticed that the mothers were afraid of the repercussions of their husbands' discomfort with our presence. We also found cases of mothers who reported that they would be interested in taking part in the study but that their husbands would not agree and this could cause many problems at home. We suggest that interventions in education for nutrition and health should be accompanied by interventions that aim to increase the maternal autonomy in decision-making. Mothers make decisions not only in the context of children feeding practices, but also in the context of using the appropriated health services for the children and for themselves.

As in many other places, interventions conducted in neighbourhoods of the south of Merida are implemented when women have started their reproductive stage some years ago and often when their offspring are in childhood. Women need to receive education for health and nutrition before any child is born. Some research experiences show promising results when nutrition education and behaviour change programs are targeted to school girls (Smitasiri and Dhanamitta, 1999). However, positive results must be expected in the long-term. We suggest that if women received appropriate education for health and nutrition before reproduction they could take better decisions during pregnancy and after child birth. For instance, during pregnancy women could avoid to be exposed to cigarette smoke and other toxic substances and to ensure the consumption of micronutrients. After child birth mothers could, for instance, develop better practices of breastfeeding and weaning.

A relevant question in this context is who should be the target population of interventions on education for health and nutrition? We think that women play an important role on children and family welfare, therefore their participation in interventions should be a priority for policy makers and government institutions. It should also be a priority that interventions focus on girls and boys; this could ensure short and long term positive effects of their health and long term beneficial effects on the growth and development of their offspring. Our results suggest that grandmothers play an important role on children's health. At present, interventions on education for health and nutrition do not take into account the participation of grandmothers in the children's care and sometimes ignore the biological effect of the presence of grandmothers at home. We suggest that interventions should be planned with ingenious strategies that allow the participation of grandmothers in programs to improve the nutritional status of children. It is also necessary that fathers be involved in the programs of education for health in order to maximize the benefits for children's and family health.

It is also a priority that structural changes in the Mexican economic and political system take part as soon as possible in order to reduce the levels of poverty among the Maya and other ethnic groups. We recognize that interventions of education for health will not be effective enough if the living conditions of the Maya do not improve.

10.3 Intergenerational influences on the growth status of mothers and children

10.3.1 Intergenerational influences of grandmothers on mothers

In general, correlations in anthropometric measurements between grandmothers and mothers were stronger in linear growth variables than in measures of body mass and body composition. This finding could be explained by the fact that body mass and composition is much more sensible to age changes in adults than measures of linear growth. The grandmothers of our sample were, on average, 27 years older than their daughters.

We also found that correlations in measures of lower body segments (LL and KH) were stronger than correlations of upper body segments. Associations between grandmothers and mothers regarding the lower segments of the body provide us with a more precise measure between these two generations. This opinion is based upon the idea that lower body segments (femur + tibia) are less affected by height reduction with age (Bogin, 2012).

We found that grandmother-mother correlation coefficients in height, LL and KH were of 0.320, 0.345 and 0.330 respectively. All these coefficients are smaller compared with those found in the 1958 British National Cohort and published by Alberman et al. (1991) and by Hypponen et al. (2004). Studying the same cohorts, Alberman and collaborators found that the correlation between mothers and daughters in height was 0.469 with daughters being measured at 23 years of age and Hypponen and collaborators found that the correlation slightly decreased to 0.450 when daughters were measured at 33 years of age. In both cases mothers' height were reported. The differences in the coefficients between this research and findings provided by Alberman and Hypponen could be explained by the intergenerational differences in height. Alberman et al. (1991) reported that the intergenerational increase in height was 1.2 cm on average. In this research, we found that mothers were on average 4.8 cm taller than grandmothers. However, we think that correlations between grandmothers and mothers of this research are being reduced by the loss of height experienced by grandmothers with age. Literature suggests that after 40 years of age total height is reduced by about 1 cm per decade (Minaker, 2011).

Our models of intergenerational influences of grandmothers (F_1) on mothers (F_2) showed that both biological and socioeconomic factors influence the linear measurements of mothers. As expected, the total height and lower body segments (LL and KH) of mothers (F_2) were positively predicted by the grand-maternal (F_1) anthropometric parameters. In addition, the models showed that grandmothers (F_1) who grew up in Merida city had daughters (F_2) with higher values for height, LL and KH. Our analysis clearly showed that the effect of grand-maternal size and place of growing up operates independently. In fact, we found that after adjusting for the effect of place of growing up, the effect of grand-maternal size became stronger. In general, the effect of grand-maternal size was similar on height, LL and KH; however the magnitude of the effects was slightly stronger in LL and KH than in height, which is consistent with the idea that lower body segments are more sensitive to environmental conditions.

Our results suggest that KH is possibly the most sensitive segment analysed in mothers (F_2). For them, KH was significantly influenced by grand-maternal (F_1) variables such as body size, place of growing up and the availability of radio at home during childhood. Some evidence suggest that this body segment exhibits more variation than the femur and is sometimes more sensitive than overall height (Anderson et al., 1963; Meadows and Jantz, 1995; Jantz and Jantz, 1999; Floyd, 2008).

We consistently found that grandmothers (F_1) who grew up in the city of Merida predicted higher heights and longer LL and KH in their daughters (F_2). In Chapter 9 we showed the results with plausible explanations for this finding. Specifically we found that “urban” grandmothers differed from “non-urban” grandmothers in several socioeconomic aspects during childhood. Urban grandmothers had more access to medical services, lived in households with better construction quality (floor, roof and walls) and had more access to electricity at home. Some of these factors may have had direct effects on the biology of the grandmothers during their growth stage, such as the presence and duration of infectious diseases. Non-urban grandmothers may have been more exposed to climate conditions (high temperatures during day and high levels of humidity during nights) in the context of a household with low access to electricity. The presence of infectious diseases could have been treated only with home remedies. We hypothesize that “urban” grandmothers experienced living conditions that promoted a better growth status during their childhood. Perhaps those living conditions were not enough to avoid negative growth trajectories, even 86% of “urban” grandmothers show short stature. However, grandmothers who grew up in communities outside Merida showed significantly lower values of height, LL and KH (and z-score values of height and LL) than “urban” grandmothers. It is possible that “urban” grandmothers reached their reproductive stage with a better nutritional status and then had children in better biological conditions (growth and development). If urban grandmothers reached their reproduction stage in relatively good biological conditions it is also possible that they had better fed practices with offspring, including breastfeeding and weaning. The analysis of the intergenerational effects of grandmothers on mothers suggests that living conditions experienced by one generation influence the growth of next generation.

10.3.2 Intergenerational influences of grandmothers and mothers on children

Except for SH, we found that mothers (F_2) and children (F_3) correlated significantly for all linear growth measures. Correlations for raw variables (height, LL and KH) were smaller in comparison to other studies. For instance, mothers-children correlation in height was r = 0.202. In their analysis of the 1958 British National Cohort, Hypponen et al. (2004) found that mothers correlate with girls in r = 0.370 and with boys in r = 0.390 (children measured at the age of 7 years). When we split our results by sex, we found that mothers and girls correlate in r = 0.180 and mothers-boys pairs in r = 0.253. It is possible that differences in correlations between this research and results provided by Hypponen et al. (2004) are due to the differences in height between mothers and children in both studies. We suggest that children of this research are experiencing better living conditions than those experienced by their mothers during their childhood. It has been suggested that mother-offspring correlations in height will be high when the environmental conditions are equally beneficial for both generations (Bogin, personal communication). Therefore, we also suggest that, given our results, mother-offspring correlations will be low when the living conditions experienced by the younger generation are better or less stressful than those experienced by the oldest generation. On average, most of the six–year-old children of this research have reached 78% of their mothers' height and 7-8 years old children have reached 80% - 85% of their mothers' height, respectively. This finding suggests that children will be possibly taller than their mothers.

Mother-child correlations in z-score values for height and LL were stronger than correlations of raw variables, which mean that mothers and children show more similarity in their growth status in relation to the references than in their raw measures. We also found that mothers and children correlate more in their lower body segments (LL and KH) than in their upper body segments (SH), which supports the hypothesis that leg length relative to total stature is a more sensitive indicator of the quality of the environment for nutritional and health status than is siting height. This seems to be true across the three generations.

Grandmother-child correlations in linear growth measures were weak and non-significant. Does this mean that grandmothers do not influence children's growth? The results of the path analysis showed that effects of grandmothers on children were stronger in indirect pathways than in direct pathways. This finding suggests that grand-maternal (F_1) effects on children's (F_3) growth status is embodied and manifested through the mothers (F_2). This idea makes sense if we consider that members of our species express phenotypic traits that resemble to the nearest matrilineal ancestor (Towne et al., 2012).

Path analysis results showed consistently two patterns of effects for the linear growth measures among the three generations. For the raw measures of height, LL and KH the strongest direct causal effects were found from grandmothers (F_1) to mothers (F_2) followed by the effect of mothers (F_2) on children (F_3). Analysis of z-score values showed that the strongest directs effects were found from mothers (F_2) to children (F_3) followed, in magnitude, by the effect of grandmothers (F_1) to mothers (F_2), which is consistent with the idea that mothers and children show higher similarity in their growth status in relation to the reference data.

Genetic factors cannot be ignored in the context of our results. However two relevant considerations should be pointed out: 1) recent evidence suggests that many genes influence the linear growth of our species, although each gene explain only a small proportion of the heritability of a given trait (Mortier and Vandem Berghe, 2012), and 2) heritability (measured through parent-offspring correlations) tends to be lower in populations under disadvantaged living conditions. Evidence for this comes from several studies. For instance, reviewing 24 studies of parent-child correlations, Mueller (1976) found that heritability tends to be low in developing countries, in which the presence of several environmental factors tend to induce variation in the trait of growth and reduce the phenotypical expression of heritability. This 'heritability reduction' can be exacerbated when populations experience economic changes that result in marked differences in height between parents and offspring (Towne et al., 2012). Even when associations between grandmothers (F_1) - mothers (F_2) and mothers (F_2) – children (F_3) pairs of this research can be expressing the effect of the genes, we suggest they are also reflecting the intergenerational load of living conditions experienced by matrilineal ancestors.

Unlike linear growth measures, mothers (F_2) and grandmothers (F_1) were associated with children (F_3) in most of the body mass and body composition variables. This finding was consistent with results seen in the path analysis, which clearly showed that both mothers and grandmothers influence significantly the children's growth measures. The correlation between mothers (F_2) and children (F_3) in weight was $r = 0.255$, lower than those reported in several studies conducted in developing and developed nations (Towne et al., 2012). This finding could be explained by the fact that mothers of this research exhibited excessive weights in comparison to other populations. The differences in weight between mothers and children are clearly exacerbated by the maternal levels of overweight and obesity.

Of more relevance was the fact that associations in weight, BMI, skinfolds and fat mass were stronger in grandmother-child pairs than in mother-child pairs. This finding may be explained by the physical proximity between grandmothers and children. Our results showed that grandmothers who live in the city of Merida and those grandmothers who reported to have participated in the care of children during their first years of life had stronger correlation coefficients than those grandmothers who live outside Merida and grandmothers who did not care for their grandchildren during previous life stages. It is possible that grandmothers and children have a more common food environment than mother-child pairs. According to our experience in the place of research, even when grandmothers and children do not share the same household, grandmothers show an active participation in the selection and preparation of food that is given to children.

Our results suggest that the nutritional and health status of children of this research is shaped into a complex system of inter-related social and biological factors. Most of the studies analyse the factors present in the mother-child dyads ignoring the biological influences of other caregivers. However, in the context of public health policies the presence and role of grandmothers is possibly a window of opportunity that could be taken into account to improve the nutritional status and health of children and adolescents. For instance, Maya grandmothers have a vast knowledge on traditional foods that could be used. The promotion of traditional diets can be a useful strategy to reduce risks for health in adults, children and adolescents. However we think that interventions in health promotion will have more chance to be effective if they focus on the family as a unit of analysis and not only on the mothers as caregivers.

Intergenerational effects were detected on children’s prenatal and postnatal growth. Even when the aim of this research was to analyse if the biosocial background of mothers and grandmothers influence the current growth status of children, we detected factors of the biosocial background of matrilineal ancestors that related to the prenatal growth of children. Specifically we found that maternal head circumference influenced positively the birth weight of children. Head circumference is *per se* a good indicator of both prenatal and postnatal growth and is also a good expression of brain growth. At birth, head circumference have attained the ~62% of head circumference at adult stage. During infancy (0-3 years old) brain grows more rapidly than almost any other body tissue and at the age of 7 the brain has completed their growth (Bogin, 1999). Evidence suggests that body segments and tissues that show high growth velocities are more susceptible to be affected by environmental factors. Perhaps one of the few studies that have reported a significant association between maternal head circumference and offspring birth weight comes from Lechtig et al. (1975). This study was conducted in Guatemala with a population with high rates of chronic malnutrition. Specifically, the authors found that babies' birth weight was related to maternal head circumference even after controlling for maternal height and weight. Other studies show that maternal size during childhood (e.g. Hypponen et al., 2004; Martin et al., 2004) and adulthood (e.g. Emanuel et al., 1992; Hypponen et al., 2004) predicts birth weight in offspring. We found that maternal linear size (height, LL or KH) was not related to children's birthweight. A raising question in the context of our results is why maternal head circumference and not maternal size (height or leg length) was associated to children's birth weight? One possible explanation is that mothers' height was very low and reduced in variation (147.91 $\pm$4.84). It is possible that maternal size effect on children's birth weight is constrained by the presence of high rates of maternal chronic undernutrition. Another possible explanation comes from Emmanuel's (1986) contribution. Emmanuel (1986, p 30) suggest that "*maternal growth disturbance – prenatal or postnatal- may predispose to later adverse reproductive outcome is largely indirect, and such measurements as maternal birth weight and maternal adult stature are crude and need to be translated into more direct mechanisms*". Emmanuel suggests that deficiencies in crude measures as height and body proportions may be related to growth disturbance of organ systems which in turn may induce in the next generation negative trajectories of prenatal and postnatal growth.

The absence of toilet at home during maternal childhood was another factor that impacted negatively the children's birth weight: 78% of mothers (F_2) reported the absence of toilet at home during their childhood. It is possible that these mothers were more exposed to infectious agents and diseases during childhood. Even in the absence of signs and symptoms of clinical infectious, the presence of infectious microorganisms in the body or in the surrounding environment generate the activation of immunological mechanisms of defence. These mechanisms demand the use of energy and nutrients, if the exposure to infectious agents occurs constantly the demand of nutrients and energy will be equally continuous. Appetite reduction is another sign of the presence of infectious diseases. These processes explain partially the growth deficit in populations that experience poor levels of sanitation (Ulijaszek et al., 1998). This situation could be exacerbated by the low accessibility to medical services: 31% of the mothers (F_2) reported not being taken to the doctor when they were ill, during their childhood. We hypothesise that mothers' growth was affected by the continuous presence of infectious diseases during childhood, which in turn possibly influenced the prenatal growth and development of their children (F_3).

Our models of intergenerational influences showed that children's height and LL were positively predicted by maternal height and LL respectively. Maternal size effect did not change substantially after the inclusion of grand-maternal anthropometric and socioeconomic factors, which suggests independent effects of biological and socioeconomic factors on children's growth.

We found that children's height and LL were influenced by conditions experienced by grandmothers during their childhood: 1) characteristics of the household and 2) family size. In relation to the first variable, we classified grandmothers' households in three categories: 1) those built with durable materials (blocks and cement), 2) those built with perishable materials (cardboard and metal) and, 3) the common Maya household type (palm leaf roof, wattle and daub walls and ground floor). We hypothesized that mothers who lived in a household of the first category belonged to families who experienced in general better living conditions, followed by grandmothers who live in a Maya household type and, final we think that grandmothers who grew up in a house built with perishable materials belonged to families who experienced the most disadvantaged conditions. Our analysis showed that those grandmothers who were exposed to perishable materials impacted negatively the height and LL of children in half a unit of z-score value. In contrast, those grandmothers who lived in a house made of durable materials predicted positive changes in the growth of the children, although this result was only marginally significant for children's LL. We suggest that the grandmothers' home index is a good indicator of environmental quality during the growing years. The effect of grand-maternal home index was more evident on children's LL than in total height, which suggests that this segment is more sensitive to intergenerational influences.

Children's WC and sum of skinfolds (z-score values) were also influenced by the grand-maternal home index. According to our models children whose grandmothers lived in a house built with perishable materials were predicted with lower values of WC and skinfolds. However, the effect of grandmothers' home index over these traits was smaller in comparison to the effect on children's linear growth, which can be explained by the fact that WC and skinfolds are measures that are more sensitive to recent environmental factors.

Grand-maternal family size was another intergenerational predictor of children's linear growth. Our results showed that grandmothers who lived in bigger families during their childhood predicted better growth status for their grandchildren. In fact, grandmothers' family size impacted positively the growth of the children not only for linear growth measures but also for BMI, WC and skinfolds. This finding makes sense in the context of the demographic characteristics of self-subsistent social groups. In general, rural societies, including the Maya, dependent on agricultural activities for self-consumption take advantage of the family size to increase their production of staples. Evidence for this comes from the ethnographic study of Kramer (2005) developed in *Xculoc*, a Maya farming village in the Yucatan. In her book "Maya children: Helpers at farm" Kramer describes how family size and the presence of offspring at home until 25 years of age contribute significantly to increase the production of maize and benefits for the family. Maya families of *Xculoc* have, on average, 7 children and the presence of grandparents at home is very common. Kramer also found that children are assigned childcare activities and domestic chores from around three years of age and then are involved in laborious task of harvesting and transporting the maize. Domestic work and childcare are gender-based, with females allocating more time to these activities. In our study 74% of the grandmothers reported that their fathers worked for most part of their lives in the *milpa*. On average, grandmothers' family size was 8 and the number of offspring was 7. Therefore we hypothesized that those grandmothers belonging to bigger families experienced better conditions during growth, which in turn have positive intergenerational impacts on the growth of their grandchildren. The impact of grandmothers' family size on children's height, LL, WC and skinfolds was very similar, around a half unit of z-score value.

Our models of intergenerational influences also showed that after adjusting for maternal height; grand-maternal short stature did not influence the linear growth of children. However grand-maternal socioeconomic intergenerational factors explained 8% and 16% of variance of children's height and LL, respectively.

Grandmothers' family size (during childhood) positively influenced the growth of their grandchildren. In contrast, maternal (F_2) family size during childhood impacted negatively the growth of their offspring. Specifically, we found that those mothers who grew up in bigger families predicted lower values on children's BMI, WC and skinfolds. Unlike grandmothers, most of the mothers grew up in the city of Merida and, as expected, their families were not dependent on the *milpa*. However their families were still big; on average mothers' family size was 7 and the mean of number of offspring was 5. This finding suggests that mothers who lived in bigger families experienced disadvantaged living conditions during the first years of life, which in turn impacted their own growth and development. This result is related to the finding that mothers who reported that their fathers lose their job very often during their childhood predicted negative values on children's BMI and WC. A relevant question in this context is who are these mothers who reported that their fathers lost their job very often? Most of them were born and grew up in Merida; belonged to big families (on average 7 members) and their fathers had low skilled and low-paid jobs; 41% of mothers' fathers were masons, 24% worked in the construction of wells and fences and the rest were low skilled employees in different areas of the economy. All of them had low-wage temporary jobs. These findings are consistent with the labour dynamic shown by Maya groups after experiencing rural-to-urban migration (Lizama et al., 2008).

As expected, maternal BMI, WC and skinfolds predicted positively the BMI, WC and skinfolds of children. However, these effects were substantially attenuated and kept non-significant after the inclusion of grand-maternal anthropometric factors (BMI, WC and skinfolds). The strongest grand-maternal effect over children was found in the sum of skinfolds (tricipital and subscapular); specifically it was found that per each unit of skinfolds increased in grandmothers the children increased 0.25 units of z-score value. This finding confirms that, at least in the context of this sample, grandmothers have a stronger effect than mothers on children's body mass and subcutaneous fat.

The mechanisms through which grandmothers influence the biology of children could be many. Our results showed that those grandmothers who attended school (during childhood) predicted in their grandchildren significantly lower values of BMI, WC and sum of skinfolds. Even when 86% of grandmothers who attended school reached only the third year of primary education our results showed that the grandchildren of these women had healthier values of BMI, WC and skinfolds than children of grandmothers who did not attended school during childhood. Can grand-maternal education be considered an intergenerational influence? Intergenerational influences have been defined by Emanuel (1986 p 27) "*as those factors, conditions, exposures, and environments experienced by one generation that related to the health, growth, and development of the next generation*". We suggest that in the context of this definition grandmothers' education is an intergenerational influence. However, given the proximity between grandmothers and children the mechanism seems to be more direct. Even with a poor level of education, our results suggest that grandmothers (who attended school) are able to make better decisions on children feeding practices and care than grandmothers without any level of formal education. Since we did not find differences in growth between grandmothers who attended the school and those who did not attended we believe that both groups experienced, in general, the same living conditions during childhood, which also suggests that effect of grandmothers' education is through behavioural mechanisms.

In general, our results of intergenerational influences are consistent with the theoretical models proposed by Kuzawa (2008) and Wells (2010) in the sense that the phenotype of studied children seems to be more adjusted to the maternal ancestors' phenotype and to their nutritional history. This does not necessarily imply that predictive adaptive responses proposed by Gluckman and collaborators do not play a role in the context of the Maya population. Historical and sociological studies suggest that living conditions of the Maya from Mexico have remained in adversity across several generations. However, the scope of this research is limited to study the growth status of children during a specific period of postnatal life and how it relates to maternal and grandmaternal phenotype and past living conditions.

10.3.3 Implications of intergenerational influences

The biological condition showed by the Maya people in this research reveals the effect of chronic deprivation along several generations. Our results suggest that environments experienced by mothers and grandmothers during their first years of life impacted negatively their own growth and have at the present time significant influences on children's (F_3) growth trajectories. Mechanisms through which intergenerational influences operate have been not completely elucidated. However, gestation seems to be a key period which triggers complex biological processes that help to explain some phenotypic traits and conditions in individuals. The exposure to hormones can induce durable epigenetic modifications that potentially modify the offspring physiology, metabolism and functions during postnatal stages (Kuzawa and Thayer, 2011).

Accumulated evidence suggests that offspring biology is possibly less sensitive to rapid changes in the current environment when adverse intergenerational influences or signals are present. For instance, some studies of nutritional interventions during pregnancy have shown little or moderate impacts on the offspring development (Villar et al., 2007; Kramer and Kakuma, 2010). In contrast, larger effects have been found when nutritional interventions have been done prior to pregnancy. Understanding the timescale at which intergenerational influences operate is particularly important if we are interested in implementing effective interventions to improve the nutritional and health status of the current and future generations. Even if well planned interventions are implemented in populations with long histories of deprivation and poverty only long term results should be expected (Kuzawa and Tahyer, 2011).

We believe that Maya people will not overcome the intergenerational traces if poverty levels are not substantially reduced. According to official reports, by 2010, 46.2% (52 million) of the Mexican population was classified as multidimensionally poor (CONEVAL, 2013). That is, almost five out of ten Mexicans were not able to satisfy their minimum needs of feeding, health and education services, housing and social security. As in many other regions of the world, poverty in Mexico tends to be more severe in indigenous groups, including the Maya. Historically, the south-east of Mexico has shown greater economic backlashes and higher poverty levels in comparison to the centre and the north of the country. Social assistance programs have increased in number in the last ten years. The most important of them, by its impact, is *Oportunidades* (Opportunities). As we noted previously, this program was designed to promote investment in education and health in poor families. *Oportunidades* provides cash grants to poor families to promote food consumption, the grants are conditional on children staying in school and having regular health checks. Its main impact comes through the accumulation of human capital to help younger generations to get higher lifetime incomes and break the intergenerational transmission of poverty (Levy, 2006). Being evaluated by national and foreign institutions, the effect of *Oportunidades* has been considered positive. However, given the magnitude of the problem the net effect of social assistance programs remain still insufficient. According to the Organization for Economic Co-Operation and Development (OECD) the public spending on social protection has risen in Mexico threefold since the mid-eighties; however 6.3% of GDP in 2003 was still at low end among OECD countries (OECD, 2007). We believe that reducing the poverty levels in Mexico necessarily implies to reduce the levels of social inequality through the distribution of wealth more equitably.

11. Conclusions

11.1 Nutritional status of participants

Aim 1: **To assess the nutritional status and nutritional dual burden prevalence in participants**. This aim was achieved.

- Eleven percent of the children met the criteria for stunting and the linear growth deficit was more evident in lower body segments than in trunk (29% of leg stunting vs. 7% of short trunk for age).
- Girls showed significant higher values of z-scores values for trunk and leg length than boys and boys were significantly more leg-stunted than girls.
- Thirty-six percent of the children showed excessive BMI for their age (18% overweight and 18% obesity). Concomitantly, 32% of them showed excessive values for WC for their age, showing risk for abdominal obesity.
- Mothers (F_2) exhibited short statures; 71% of them were classified as stunted. The deficit of growth was severe in both trunk (54%) and leg lengths (59%).
- Fifty-five percent of the mothers (F_2) showed risk for abdominal obesity (WC > 88 cm); these mothers exhibited significant high values of skinfolds and high percentage of body fat.
- Most (89%) of grandmothers (F_1) were classified with short stature. The prevalence of short trunk (83%) and short legs (69%) was also very high.
- Eighty-three percent of the grandmothers (F_1) showed risk for abdominal obesity (WC > 88 cm); they also exhibited significant higher values of weight, BMI, skinfolds and percentage of body fat.
- Combinations of nutritional conditions among members of the three generations showed that: 1) in only 6% of the triads none of the family members showed short stature, 2) stunting coexisted in F_1-F_2-F_3 in 10% of the triads, 3) risk for abdominal obesity coexisted in F_1-F_2-F_3 in 18% of the triads, and 4) only 8% of the triads showed normal or healthy values for WC.

11.1.1 Nutritional dual burden

- Our results confirm that under-and-overnutrition coexists among children, mothers and grandmothers. Therefore, the studied sample can be defined as nutritional dual burden sample.
- Among the children, the coexistence of stunting & OW/OB and stunting & risk for abdominal obesity was found in 1% of the sample.
- The coexistence of short stature and risk for abdominal obesity was detected in 36% of mothers and in 72% of grandmothers.
- The combination of maternal risk for abdominal obesity and stunting in children was found in 6% of mother-child dyads. The combination of maternal risk for abdominal obesity and underweight child was not found.
- The combination of maternal short stature and OW/OB in children was present in 19% of mother-child dyads.
- Six percent of the triads showed the combination of stunted children and risk for abdominal obesity in mothers and grandmothers. In contrast, the combination of risk for abdominal obesity in children and stunting in adult women was identified in 18% of the triads.

11.2 Socioeconomic and biological factors related to the physical growth of children

Aim 2: **To identify the antenatal and socioeconomic factors that shape nutritional status of children (F_3).** This aim was achieved.

- Antenatal and socioeconomic factors were detected as significant predictors of children´s growth.
- Maternal cigarette smoke exposure during gestation, preeclampsia and household overcrowding impacted negatively the height (z-score values) of the children.
- Children´s leg length (z-score values) was affected negatively by the presence of preeclampsia and influenced positively by the iron intake during gestation. Models showed that being a girl predicts longer leg length, which is

consistent with the possibility that boys are less buffered against environmental conditions.

- Body mass index of children (z-score values) was significantly reduced by maternal education and by the presence of the grandmother at home. It significantly increased with birth weight and with the number of ultrasounds that the mother received during gestation.
- Mothers with a partner during pregnancy predicted an increase in children's WC (z-score values). In contrast, children´s WC was significantly reduced with the increase of maternal education.
- The percentage of body fat of the children was significantly increased by the number of ultrasounds that the mother received during pregnancy and significantly reduced by the maternal education, household overcrowding and the presence of grandmothers at home.
- According to our model, children whose mothers finished the primary or secondary level of education had significantly lower percentages of body fat compared to children whose mothers did not reached any level of education.
- Additionally children with "healthy or normal values of BMI and WC" were more clustered in categories of some level of maternal education.
- Percentage of lean body mass of the children was significantly reduced by the number of ultrasounds that the mother received during pregnancy and positively influenced by the maternal education and the presence of the grandmother at home.
- Children whose mothers reached some level of education (primary or secondary) exhibited significantly higher values of lean body mass than children whose mothers did not reach any level of formal education.
- Our results suggest that maternal education is a factor that acts as a health protector for the children. Our results also suggest that even low levels of maternal education are relevant in the context of the biological implications on offspring health.
- Since the body fat increased and lean body mass of children decreased with the increment in the number of ultrasounds that the mothers received during pregnancy, our results suggest that this factor is possibly a good indicator of conditions experienced by offspring *in utero*.

- Children´s percentage of body fat decreased and the percentage of lean mass increased with the presence of the grandmother at home. This result suggests that the presence of grandmothers at home is a factor that has a protector effect on children´s health.

11.3 Intergenerational influences on the growth status of mothers and children

Aim 3: **To assess the intergenerational influences on the growth of participants [Grandmothers (F_1) → Mothers (F_2), Grandmothers (F_1) and Mothers (F_2) → Children (F_3)].** This aim was achieved.

11.3.1 Intergenerational influences of grandmothers on mothers

- Correlations between grandmothers (F_1) and mothers (F_2) were stronger in linear growth measures than in body mass and body composition measures.
- Mothers and daughters were more associated in measures of lower body segments than in upper body segments.
- The correlation in height between grandmothers (F_1) and mothers (F_2) was relatively smaller to that found in previous studies. Intergenerational increments in our sample seem to be the best explanation for this finding.
- Grandmothers (F_1) who grew up in Merida city during childhood predicted higher values in the height, LL and KH of their daughters (F_2). This result suggest that grandmothers who grew up in Merida experienced better living conditions during their growing years.
- Mothers' (F_2) KH seems to be the most sensitive body segment that reflects socioeconomic and biological intergenerational influences.
- Our results suggest that grand-maternal (F_1) size (height, LL and KH) and socioeconomic intergenerational factors show independent effects on their daughters' (F_2) growth status.

11.3.2 Intergenerational influences of grandmothers and mothers on children

- Intergenerational factors influenced the prenatal and postnatal growth of the children of this study.

- Maternal (F_2) head circumference positively predicted the birth weight of children. No maternal body segment (height, LL and KH) was significantly associated to children's birth weight.
- The absence of toilet at home during maternal (F_2) childhood negatively predicted birth weight of the children.
- No anthropometric and socioeconomic intergenerational factors of the grandmothers (F_1) were significantly associated with children's birth weight.
- In postnatal growth, mothers (F_2) and children (F_3) correlated in the most of linear growth measures, with stronger correlations being seen in the lower body segments. Grandmothers (F_1) and children (F_3) did not correlate in linear growth measures.
- Mother-child correlation in height was small in comparison to other studies, which can be explained by the higher increments in height between children and mothers in comparison to other studies.
- Grandmothers (F_1) and mothers (F_2) correlated significantly with children (F_3) in almost all body mass and body composition variables. Of relevance was the fact that correlations between grandmothers (F_1) and children (F_3) for some parameters were stronger than in mother-child pairs.
- Our results suggest that grandmothers (F_1) and children (F_3) share a more common food environment and possibly a common obesogenic environment.
- Mother-child correlation in weight was small in comparison to other studies. We suggest that excessive weights and high levels of overweight/obesity in mothers are reducing the mother-child correlation.
- Path analysis among the three generations for their height, LL and KH showed that strongest direct causal effects were found from grandmothers (F_1) to mothers (F_2) followed, in magnitude, by the effect of mothers (F_2) on children (F_1). When z-score values were analysed the strongest causal effects were found from mothers (F_2) to children (F_1) followed by the effect of grandmothers (F_1) to mothers (F_2).
- Effects from grandmothers to children regarding their height, LL and KH were weak and only found through maternal effects (indirect effects).
- Path analysis for body mass and body composition variables showed significant direct causal effect from grandmothers (F_1) and mothers (F_2) to

children (F_3) and from grandmothers (F_1) to mothers (F_2). Indirect effects of grandmothers (F_1) on children (F_3) (through maternal effects) were weak.

- Maternal (F_2) height, LL and KH predicted positively the linear growth of children (height, LL and KH respectively) and these effects did not change substantially after the inclusion of grand-maternal linear growth variables.
- Children's height and LL were negatively influenced by grandmothers' home index, being more affected those children whose grandmothers lived during childhood in a household built with perishable materials.
- Height and LL of children were positively impacted by grand-maternal (F_1) family size during childhood, which suggest that grandmothers who lived in big families (dependent on activities for self-subsistence) during childhood experienced better living conditions.
- In contrast, maternal (F_2) family size affected negatively the BMI, WC and skinfolds of children. We suggest that mothers who grew up in bigger families experienced adverse living conditions that affected their own growth.
- Paternal job loss during maternal childhood predicted significant reductions on children's BMI and WC. Most of the fathers of the mothers (F_2) had low skilled and paid jobs which possibly impacted negatively on the mothers' growth during childhood.
- Anthropometric maternal (F_2) effects on children's BMI, WC and skinfolds were substantially reduced and kept non-significant after the inclusion of grand-maternal (F_1) BMI and WC values.
- Grandmothers (F_1) who attended school during childhood predicted significant reductions on children's BMI, WC and skinfolds. Grandmothers with some level of education had grandchildren with healthier values of BMI, WC and skinfolds.
- Even having very low levels of education, our results suggest that grandmothers' education is acting as a health protector factor on the children.

11.4 Overall thesis conclusion

This thesis provides results of the first biosocial study that includes three generations of Yucatec Maya. Our results regarding the living conditions of the Maya families confirm the findings provided by previous studies: the living conditions of the Maya from the city of Merida are characterized by socioeconomic deprivation. Current and past living conditions are being reflected in the current growth and nutritional status of members of the three generations. Our results clearly show that children, their mothers and their maternal grandmothers exhibit both extremes of malnutrition: undernutrition (low height-for-age in children and short stature in adults) and overnutrition. This is the first study to report results about nutritional dual burden in a sample of three generations. The main aim of this research was to investigate if the biosocial background of maternal ancestors is related to the current growth and nutritional status of the children of the third generation. Our results suggest that living conditions experienced not only by mothers but also by maternal grandmothers during their childhood is contributing to shape the growth of children: in terms of linear growth and body mass and composition. Grandmothers and mothers who lived in better conditions during first years of life have children with better growth and nutritional status. In addition our findings suggest that grandmothers play an important role in the children’s biology. This study highlights the need for: 1) research about the long term health implications of intergenerational influences and, 2) interventions on education for health and nutrition in the youngest generations. We recognize that intergenerational traces will not be overcome by the Maya if their living conditions do not improve and their poverty levels are not reduced substantially.

11.5 Future research

During the process of this research a number of further research questions raised. Some of these questions could help us to understand the current biological status of the Maya population from Yucatan and their determinants. Therefore, the following comments relate to potential future research projects.

- The current study was mainly designed to investigate the intergenerational influences on the postnatal growth of children of the third generation. The factors associated to prenatal growth among the Maya may be different and therefore this should be investigated.

- The analytical approach of this study was basically quantitative. The factors associated to the intergenerational influences may be also explained using qualitative approaches. Mixed methods (quantitative and qualitative) could help to understand the determinants of intergenerational effects among the Maya.

- There is a need for longitudinal studies about the physical growth of Maya children from Yucatan. Longitudinal approaches could help us to understand the process of nutritional conditions (i.e. undernutrition and overnutrition) and their determinants. Longitudinal studies would also allow us to design interventions to improve the nutritional and health conditions among the Maya.

- Given the high prevalence and health implications of nutritional dual burden at household level (mother-child pairs) among the Maya, there is a need to investigate the biosocial factors that contribute to determine the presence of this phenomenon. It is necessary to design and perform studies that allow making inferences to populations.

- Extensive historical literature has documented the chronic deprivation and poverty among the Maya from Yucatan, there is a need for establish a link of analysis between the historical events and the biological status of the population.

- There is a clear need for intervention studies in the context of Maya population. We believe that interventions on nutrition and health education could be an important strategy to improve the nutrition and health status of future generations. We also believed that interventions should be focused on children (particularly girls) prior the reproduction.

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APPENDIX 1 Informative letter to mothers

Translated into English from the original version written in Spanish

RESEARCH AND ADVANCED STUDIES CENTER OF THE NATIONAL POLYTECHNIC INSTITUTE OF MEXICO
HUMAN ECOLOGY DEPARTMENT

Dear Mother

The Research and Advanced Studies Center of the National Polytechnic Institute of Mexico (*CINVESTAV*), located in Merida is performing a study to find out how children grow physically between the ages of six and eight.

Your son or daughter has been selected from a large group of children to participate in the study, for which we invite you to attend a meeting for mothers that will take place at the school on January 9th at 8:00 AM to inform you more about the study.

There will be no cost to you for participate in this research. With your act of participation we will make donations of cleaning materials to the school.

Child's name: ____

Group: ____

APPENDIX 2 Questionnaire used in informative meetings

Translated into English from the original version written in Spanish

RESEARCH AND ADVANCED STUDIES CENTER OF THE NATIONAL POLYTECHNIC INSTITUTE OF MEXICO
HUMAN ECOLOGY DEPARTMENT

Cinvestav

Child's name: ____
School: ____

Mother's name: ____
Mother's address: ____
Phone number: ______________________ Mobile: ________________________
Maternal grandmother's name: _______________________________________
Grandmother's address: ____

APPENDIX 3 Questionnaire

Child ID __________

Translated into English from the original version written in Spanish

FAMILIAL AND INTERGENERATIONAL FACTORS THAT SHAPE NUTRITIONAL STATUS OF URBAN MAYA HOUSEHOLDS IN MERIDA, MEXICO

Centre for Global Health and Human Development, Loughborough University, UK
Human Ecology Department, CINVESTAV, Merida, Mexico

PARTICIPANTS' REFERENCES

Circle around (O) **the number** of the corresponding option. **Don't use** X or checkmark.

School: ____________________________________ **Grade & group:** _________

Time: 1. Morning 2. Afternoon

Child's name: __________________________________ **Sex: 1. Male 2. Female**
Name(s) / Paternal surname / Maternal surname

Mother's name: ____
Name(s) Paternal surname Maternal surname

Child & mother's address:

Street: ___________ #__________ By: ____________________________________
Suburb: ____
Home number: ____________ Mobile: ___________ Office number: ____________
References: ____
____

Appointments: ____
____

GRANDMOTHER' REFERENCES

Grandmother's name: ____
Name(s) Paternal surname Maternal surname

Does grandma live in the same household? 0. No 1. Yes
(If negative write down grandmother's address)

Grandmother's address:

Street: ___________ #__________ By: ____________________________________
Suburb: ____
Home number: __________ Mobile: __________ Office number: _______________
References: ____
Locality: _______________ Town/ City: _______________ State: ______________

The grandmother: 1. Understand and speak Spanish 2. Understand Spanish but doesn't speak 3. Only speak Maya

Appointments: ____

FAMILIAL AND INTERGENERATIONAL FACTORS THAT SHAPE NUTRITIONAL STATUS OF URBAN MAYA HOUSEHOLDS IN MERIDA, MEXICO

Centre for Global Health and Human Development, Loughborough University, UK
Human Ecology Department, CINVESTAV, Merida, Mexico

ANTHROPOMETRIC SHEET for CHILDREN

Child's name: ____ **Sex**: **1.** Male **2.** Female

Name (s) Paternal surname Maternal surname

Birth date: ________ _________ ________ **Age:** ___________________________

Day Month Year (Years)

Measurement date:	Day______ Month________ Year______
Measurer (initials):	
Recorder (initials):	
Weight (kg):	

Lengths

Height (cm):	
Sitting height (cm):	
Knee height (cm):	
Arm length (cm):	

Circumferences

Arm (cm):	
Head (cm):	
Waist (cm):	
Hip (cm):	

Skinfolds

Triceps (mm):			
Subscapular (mm):			
Suprailiac (mm):			

BIA

Measurer:	
BioScan ID:	
Impedance:	
Reactance:	

Notes:

____

ANTHROPOMETRIC SHEET for MOTHERS AND GRANDMOTHERS

	MOTHER	***GRANDMOTHER***
Name:		
Birth date:	Day____ Month _____ Year ____	Day____ Month _____ Year ____
Age (years):		
Pregnant:	**0.** No **1.** Yes	**0.** No **1.** Yes
Begining of the last menstrual period:	Day____ Month ______ **1. NA**	Day_____ Month _____ **1. NA**
Measurement date:	Day____ Month______ Year_____	Day_____ Month _____ Year ____
Measurer (initials):		
Recorder (initials):		
Weight (kg):		

Lengths

Height (cm):		
Sitting height (cm):		
Knee height (cm):		
Arm length (cm):		

Circumferences

Arm (cm):		
Head (cm):		
Waist (cm):		
Hip (cm):		

Skinfolds

Triceps (mm):						
Subscapular (mm):						

BIA

Measurer:		
BioScan ID:		
Impedance:		
Reactance:		

Notes: ______________________________

____

FAMILIAL AND INTERGENERATIONAL FACTORS THAT SHAPE NUTRITIONAL STATUS OF URBAN MAYA HOUSEHOLDS IN MERIDA, MEXICO

Centre for Global Health and Human Development, Loughborough University, UK
Human Ecology Department, CINVESTAV, Mérida

FAMILIAL SOCIOECONOMIC QUESTIONNAIRE

Application date: ______ ______ ______ Applied by: _________
Day Month Year Initials

Instructions Thank you for your collaboration. The next questions are related to your family and household.

0. BM: 0. No **1.** Yes

1. Your house is:
__ Own, Did you buy the land/house Yes___ No ___ __ Borrowed
__ Rented, $ ____________________ /month __ Other: __________________

2. How many persons live in the house? ____
3. How many rooms are used for sleeping? ___1 ___2 ___3 ___4 ___5 ___6 ___7
4. Which type of water is commonly used to drink in the house? (Circle around only one option)
__ Purified __ Piped water __ Boiled tap water __ Filtered tap water Other_________

5. You used to cook in: (Circle around only one option)
__ Kitchen only used to cook __ Room used also for other activities __ In the backyard __does not cook

6. You used to cook with: (Circle around only one option)
__ Gas stove __ Wood fire __ Carbon __ Other: _________________________________

7. Currently in your house there is: (Circle around only one option)
__ Toilet __ *Letrina* __ In the backyard __ Other: _________________________________

In relation to the construction materials of your house: (Circle around only one option on each case)

8. Floors	__ Ground	__ Cement	__ Tile	Other: ______
9. Ceilings	__ Metal/Cardboard	__ Roof blocks	__ Roof blocks & cement	Other: ______
10. Walls	__ Metal/Cardboard	__ Blocks	__ Blocks & cement	Other: ______

Are there any of the next items in your home?

11. TV	Yes ___	No ___	**17. Refrigerator**	Yes ___	No ___
12. Pay TV system	Yes ___	No ___	**18. Stove**	Yes ___	No ___
13. Land line	Yes ___	No ___	**19. Car**	Yes ___	No ___
14. Mobile phone	Yes ___	No ___	**20. Motorcycle**	Yes ___	No ___
15. Computer	Yes ___	No ___	**21. Bicycle/Tricycle**	Yes ___	No ___
16. Washing machine	Yes ___	No ___	**22. Air conditioner**	Yes___	No____

23. Which language is commonly used in home?
__ Spanish __ Maya __ Spanish & Maya __ Mostly Spanish but expressions in Maya

24. Do you grow any food in the backyard? Yes ___ No ___ **(If answer no, skip to 26)**
25. Which ones? (Write down all mentioned by the respondent and circle around the appropriate number for your consumption)

Fruits/ Vegetables	Consume it?	Fruits/ Vegetables	Consume it?	Fruits/ Vegetables	Consume it?
	0. No 1. Yes		**0. No 1. Yes**		**0. No 1. Yes**

Now, please tell me the next information about all people who live in your house, including family and non-family members.

First name	Kinship (<u>in relationship to the child</u>)	Birth date ____/_____/____ Day Month Year	Age (yrs)	Education <u>Maximum level attained</u> & <u>Total of years</u> (including repeated years)	Occupation (<u>to specify occupation</u>)	Income (<u>day/week/month</u>) in pesos	Familial contribution (day/week/mo) in pesos	Maya use 1 speak 2 Underst 3 Read 4 Write 5 None
Manuel	Father	27/Oct/1976	34	2° Secondary / 9 years	bricklayer	$ 65 /day	$50 /day	2

First name: for confidentiality purposes should be only recorded the first name of each family member.
Kinship options: Mother, Father, Brother/Sister, Grandmother, Grandfather, Uncle, Aunt, Cousin, Nephew, Niece, None.

Now let's suppose that during the last month your family earned 100 pesos, please tell me, how many pesos you expended during the last month of the next items?

Food (inside and outside the home):	
Housing (house rent payment, housing payment, electricity, water, garbage collection):	
Cleaning products (for clothes, house, and tableware):	
Health (medical services and drugs):	
Leisure (cinema, visits to a park, travel to a community):	

Offspring ID _________

BIOLOGICAL & SOCIOECONOMIC QUESTIONNAIRE FOR CHILDREN

39. Ego is the: 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th of your children? (Circle around)

40. How many siblings does Ego have? _________siblings (write down a zero if necessary) (If Ego is only child or the first one skip to 45th question)

41. What is the date of birth of your son prior to Ego? _____ _____ ______
Day Month Year

42. At what age did you had your first pregnancy? _____________ Years

43. Could you save money for the birth of your first child? 0. No **1.** Yes (If the answer was negative skip to question 45)

44. For how long did you save money? _______ months or _________ years (Write down 999 if she doesn't remember it)

45. At what age did you get pregnant of Ego? _______ years old (Write down 999 if she doesn't remember it)

46. What was your marital status when you got pregnant of Ego? (Circle around only an option)
1.Single **2.**Married **3.**Law marriage **4.**Divorced **5.**Separated **6.**Widow

47. When you found out you got pregnant (of Ego):
1. You wanted to get pregnant **2**. You didn't want to get pregnant

48. Could you save money for the birth of Ego? 0. No **1.** Yes (If the answer was no, skip to the question 50)

49. For how long did you save money? _______ months or _________ years (Write down 999 if she doesn't remember it)

50. Please tell me if you have had any abortion? 0. No **1.** Yes **2**. Didn't want to answer (If the answer was no or didn't want to answer, skip to 52 question)

51. **How many abortions have you had?** ___________ abortions

52. Did you receive medical care during the pregnancy of Ego during the first three months?
0. No **1.** Yes **2.** Didn't remember it

53. Did you receive medical care during the pregnancy of Ego between the 4th to 6th months?
0. No **1.** Yes **2.** Didn't remember it

54. Did you receive medical care during the pregnancy of Ego after 6th month? 0. No **1.** Yes
2. Didn't remember it

55. Did you receive any ultrasounds during your pregnancy? 0. No **1.** Yes (If the answer was No, skip to question 57)

56. How many ultrasounds did you receive? ______ ultrasounds (Write down 999 if she doesn't remember it)

57. Did you take folic acid or vitamins during the pregnancy of Ego? 0. No **1.** Yes **2.** Didn't remember

58. Did you take iron during the pregnancy of Ego? 0. No **1.** Yes **2.** Didn't remember

59. Did you suffer diabetes during the pregnancy of your child Ego? 0. No **1.** Yes **2.** Didn't remember

60. Did you suffer high pressure (diagnosed preeclampsia) **during the pregnancy of Ego?**
0. No **1.** Yes **2.** Didn't remember

61. Did you suffer high pressure (diagnosed eclampsia) **during labor of Ego? 0.** No **1.** Yes
2. Didn't remember

62. Did you suffer any infectious disease (urinary, vaginal, chickenpox) **diagnosed during the pregnancy of Ego? 0.** No **1.** Yes **2.** Didn't remember

63. Which ones? ____

64. Did you smoke or lived with smokers during the pregnancy of Ego?
0. No **1.** Yes **2.** Didn't remember

65. Your child Ego was born at: ____
Village City/Community State

If Ego was born in Mérida, skip to question 67

66. At what age did Ego come to live in Mérida? _______ months or ________ years old

67. Ego was born at:

1. ___ Health Centre(SSA)	**3.** ___ *ISSSTE*	**5.** ___ At home with a midwife
2. ___ *IMSS*	**4.** ___ Particular	**6.** ___Other (Specify):_________________

68. The birth weight of Ego was: _________ kg (Write down 999 if she doesn't remember it)

69. Did the doctor say you that Ego had low weight at birth? 0. No **1.** Yes **2.** Didn't remember

70. How long was your pregnancy of Ego? _____Weeks ______Months (Write down 999 if she doesn't remember it)

71. Did the doctor say you that Ego was premature? 0. No **1.** Yes **2.** Didn't remember

72. Do you have the birth certificate (BC) of Ego? 0. No **1.** Yes (If the answer was No, skip to question 74)

If the answer was affirmative, please ask for the BC and copy:
73. **Birth weight:** _________ gr. **74. Gestational age**: ____________ weeks

74. Ego was born by:
1. Natural childbirth **2.** Caesarean

75. Did you breastfeed Ego? 0. No **1.** Yes (If the answer was No, skip to question 79)

76. For how long you fed Ego only with maternal milk (exclusive breastfeeding)**?**
___________ Days or ___________ Months

77. How old was Ego when you stopped breastfeeding? ________ Days or _______ Months

78. Did you give Ego formula milk (powdered)**? 0.** No **1.** Yes (If the answer was No, skip to question 81)

79. How old was Ego when started to give him/her formula milk? _____ Days ______ Months

80. How old was Ego when you started to give him/her foods (fruit, vegetables, cereals)**?**
___________ Months

Tell me if given the presence of diseases like cold, cough, diarrhea, respiratory, intestinal, skin, or mouth infections Ego was:

81. 1st year of life	82. From 1 to 3 years old	83. From 3 to 5 years old	84. 5 years and older	Ranges
1. Very healthy	**1.** Very healthy	**1.** Very healthy	**1.** Very healthy	once every 3 months
2. Healthy	**2.** Healthy	**2.** Healthy	**2.** Healthy	once every 2 months
3. Sickly	**3.** Sickly	**3.** Sickly	**3.** Sickly	once or twice per month
4. Very sickly	**4.** Very sickly	**4.** Very sickly	**4.** Very sickly	More than twice a month, different diseases or of the same disease

85. Has Ego been sick (infections) **during the last month? 0.** No **1.** Yes (If the answer was No, skip to question 89)

86. How many times? _________ Times

87. Which illnesses? ____

88. Is Ego currently sick of an infection: 0. No **1.** Yes (If the answer was No, skip to question 93)

89. Which infection? ____

90. Is Ego receiving medical care? 0. No **1.** Yes (If the answer was No, skip to question 93)

91. What kind of treatment is Ego receiving? (Write down the name of the medication or other treatment)

____

____

92. Is Ego currently sick of a chronic disease: 0. No **1.** Yes (If the answer was No, skip to question 97)

93. What chronic disease does Ego suffer? ____________________________________

94. Is Ego receiving any medical treatment? 0. No **1.** Yes (If the answer was No, skip to question 97)

95. What kind of treatment is Ego receiving? Write down the name of the medication)

____

96. Which is the medical service that regularly uses for Ego? (Circle around only one option)

1. None	**4.** *SSY*	**7.** Military hospital	**10.** Private health
2. *IMSS*	**5.** *Seguro Popular*	**8.** *PEMEX*	**11.** *Similares*
3. *ISSSTE*	**6.** Opportunities	**9.** *UADY*	**12.** UNI's & community centers

97. Did the grandparents cared Ego before he/she went to elementary school?
0. No **1.** Yes (If the answer was No, skip to question 107)

98. Did the grandparents cared Ego during his/her first year of life?
0. No **1.** Yes (If the answer was No, skip to question 101)

99. Who? (Circle around more than one option if needed)
1.Maternal grandmother **2.**Maternal grandfather **3.**Paternal grandmother **4.**Paternal grandfather

100. What kind of care? (Circle around more than one option if needed)
1. Only cared **2.** Fed him **3.**Took him to the doctor

101. Did the grandparents take care of Ego from 1 to 3 years old?
0. No **1.** Yes (If the answer was No, skip to question 105)

102. Who? (Circle around more than one option if needed)
1.Maternal grandmother **2.**Maternal grandfather **3.**Paternal grandmother **4.**Paternal grandfather

103. What kind of care? (Circle around more than one option if needed)
1.Only cared **2.**Fed him **3.**Took him to the doctor

104. Did the grandparents take care of Ego from 3 to 5 years old?
0. No **1.** Yes (If the answer was No, skip to question 108)

105. Who? (Circle around more than one option if needed)
1. Maternal grandmother **2.**Maternal grandfather **3.** Paternal grandmother **4.** Paternal grandfather

106. What kind of care? (Circle around more than one option if needed)
1. Only cared **2.** Fed him **3.**Took him to the doctor

107. Does Ego is currently cared by his/her grandparents regularly?
0. No **1.** Yes (If the answer was No, skip to question 111)

108. If you answered yes, who? (Circle around more than one option if needed)
1. Maternal grandmother **2.**Maternal grandfather **3.**Paternal grandmother **4.**Paternal grandfather

109. What kind of care? (Circle around more than one option if needed)
1. Only cared **2.** Fed him **3.**Took him to the doctor

110. Does your child (ego) speak Maya?
0. No **1.** Yes

111. Does your child (ego) understand Maya?
0. No **1.** Yes

ID ____________________

MATERNAL LIFE CONDITIONS DURING CHILDHOOD QUESTIONNAIRE

Application date: ______ ______ ______ Applied by: _______________
Day Month Year (Initials)

112. Please tell me where were you born and the places where you have lived.

	Village/town/city	Municipality	State	How long lived or have lived there (years)	Arrival age
Was born					
Place 1					
Place 2					
Place 3					
Place 4					
Place 5					
Place 6					
Place 7					
Place 8					
Place 9					
Place 10					
Current residence					

(If she was born in Merida, skip to question 115)

113. If you were not born in Merida, why you moved to this city?
1. Labor/Economic **3**. Personal **5.** Other(specify)________________
2. Educational (she or other) **4**. Health (she or other)

114. You were born in: (the grandmother can answer this question of necessary)
1. At home with midwife **2.** Rural clinic **3**. Hospital or health centre **4.** Other (specify) ____________

115. How many siblings you had, including those who died? (Including little brothers and sisters)
_______________ Siblings (Write down zero if necessary)

116. You were the 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th born (Circle around the right number)

117. How many people lived at home during your childhood including relatives and non-family members? __________________ persons

118. How many rooms you had in your house for sleep? __________ rooms

Who took care (watch for your diet and health) **of you as a child in the next periods?** (Circle around more than one option if is necessary)

119. Since you were born to 5 years
1. Mother
2. Grandparents
3. Others

120. From 6 to 12 years
1. Mother
2. Grandparents
3. Others

121. From 13 to 15 years
1. Mother
2. Grandparents
3. Others
4. None

122. When you got sick during your childhood, what kind of care you received mostly?
1. None **2**. They took you to the doctor **3.** Home remedies **4.** *Curandero* **5.** Other___________
(If they didn't take her to the doctor, skip to question 125)

123. What kind of Care Service did they take you? (Circle around only one option)
1. Health Centre (SSA) **2.** *IMSS* **3.** *ISSSTE* **4.** Particular Physician

124. What kind of drinking water consumed your family when you were a child? (Circle one option)
1. Well water **2**. Piped water **3.** Boiled tap water **4.** Filtered tap water **5.** Purified **6.** Other_______

125. When you were a child, at home you had: (Circle around only one option)
1. In the backyard **2**. *Letrina* or *Fosa* **3.** Toilet **4.** Other (specify) ______________

What materials your home was built?

126. Floors	__ Ground	__ Cement	__ Tiles	Other: __________
127. Ceilings	__ *Huano*	__ Metal/Cardboard	__ Roof blocks	__ Roof blocks & cement
128. Walls	__ Woods	__ Metal/Cardboard	__ Blocks	__ Blocks & cement

129. What was the main source of light in your house when you were a child? (Circle around only one option)
1. Candles **2**. Oil **3.** Kerosene **4.** Electricity **5.** Other (specify)________________

Which of the next assets were at home when you were a child?

130. TV	**0.** No	**1.** Yes		**134. Stove**	**0.** No	**1.** Yes
131. Radio	**0.** No	**1.** Yes		**135. Car**	**0.** No	**1.** Yes
132. Washing machine	**0.** No	**1.** Yes		**136. Bicicle/Tricicle**	**0.** No	**1.** Yes
133. Refrigerator	**0.** No	**1.** Yes		**137. Motorcycle**	**0.** No	**1.** Yes

138. Which was the main language spoken at home when you were child?
1.Spanish **2**. Maya **3.** Spanish and Maya **4.** Other (specify) ________________

I need to know if during your childhood and youth, in your family had cases like:

139. Serious illness of any parent	**0.** No	**1.** Yes	**140.** Who? ______________________
141. Did it affect you? 0. No **1.**Yes **142. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
143. Death of any parent	**0.** No	**1.** Yes	
144. Did it affect you? 0. No **1.**Yes **145. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
146. Parental divorce or separation	**0.** No	**1.** Yes	**147.** How old were you? ____________
148. Did it affect you? 0. No **1.**Yes **149. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
150. Parental job loss	**0.** No	**1.** Yes	**151.** How often?
152. Did it affect you? 0. No **1.**Yes **153. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
154. Alcoholism of any family member	**0.** No	**1.** Yes	**155.** Who? _____________________
156. Did it affect you? 0. No **1.**Yes **157. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
158. Sale or paw of goods for money	**0.** No	**1.** Yes	**159.** How often? __________________
160. Did it affect you? 0. No **1.**Yes **161. How affected you? 1.**Economically **2.**Emotionally **3.**Health			

162. Which was the occupation of your father when you were child? _____________________
____

163. Which was the occupation of your mother when you were child? ____________________
____

164. Did you work during your childhood or youth? 0. No **1.** Yes (If the answer was no, skip to question 168)

165. At what age did you start working? ___________________ years old

166. What was your work?
____

CURRENT SITUATION OF THE MOTHER

167. What is your marital status?
1. Single **2**. Married **3.** Free union **4.** Divorced **5.** Separated **6.** Widow

168. Do you live with your husband or partner? 0. No **1.** Yes

At home, who takes the decisions for:

169. The items you would spent money for (Circle around more than one option, if necessary)
1. She **2**. Her husband or partner **3.** Other(s) (specify) ________________________

170. What will be eaten at home?
1. She **2**. Her husband or partner **3.** Other(s) (specify) ________________________

171. How much will be spent on the health care of the family?
1. She **2**. Her husband or partner **3.** Other(s) (specify) ________________________

172. Are you suffering a chronic illness currently diagnosed? (Like diabetes, hypertension, cholesterol, triglycerides) **0.** No **1.** Yes (If she answer no, thanks and end the interview)

173. Which ones?

(Thanks her and end the interview).

Grandmother ID ____________________

GRANDMOTHER LIFE CONDITIONS DURING CHILDHOOD QUESTIONNAIRE

Application date: ______ ______ ______ Applied by: _______________
Day Month Year (Initials)

174. Please tell me where were you born and the places where you have lived.

	Village/town/city	Municipality	State	How long lived or have lived there (years)	Arrival age
Was born					
Place 1					
Place 2					
Place 3					
Place 4					
Place 5					
Place 6					
Place 7					
Place 8					
Place 9					
Place 10					
Current residence					

(If she was born in Merida, skip to question 177)

175. If you were not born in Merida, why you moved to this city?

1. Labor/Economic **3**. Personal **5.** Other(specify)___________
2. Educational (she or other) **4**. Health (she or other)

176. You were born in:
1. At home with midwife **2.** Rural clinic **3**. Hospital or health centre **4.** Other (specify)_____________

177. How many siblings you had, including those who died? (Including little brothers and sisters)
_______________ Siblings (Write down zero if she is only child)

178. You were the 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th born (Circle around the right number)

179. How many people lived at home during your childhood including relatives and non-family members? ___________________ persons

180. How many rooms you had at home for sleep? __________ rooms

Who took care (watch for your diet and health) **for you as a child in the next periods?** (Circle around more than one option if is necessary)

181. Since you were born to 5 years
1. Mother
2. Grandparents
3. Others

182. From 6 to 12 years
1. Mother
2. Grandparents
3. Others

183. From 13 to 15 years
1. Mother
2. Grandparents
3. Others
4. None

184. When you got sick during your childhood, what kind of care you received mostly?
1. None **2**. They took you to the doctor **3.** Home remedies **4.** *Curandero* **5.** Other _____________
(If they didn't take her to the doctor, skip to question 187)

185. What kind of Care Service did they take you? (Circle around only one option)
1. Health Centre (SSA) **2.** *IMSS* **3.** *ISSSTE* **4.** Particular Physician

186. What kind of (drinking) **water consumed your family when you were a child?** (Circle one)
1. Well water **2**. Piped water **3.** Boiled tap water **4.** Filtered tap water **5.** Purified **6.** Other__________

187. When you were a child, at home you had: (Circle around only one option)
1. In the backyard **2**. *Letrina* or *Fosa* **3.** Toilet **4.** Other (specify) ______________

What materials your home was built?

188. Floors	__ Ground	__ Cement	__ Tiles	Other: ______________
189. Ceilings	__ *Huano*	__ Metal/Cardboard	__ Roof blocks	__ Roof blocks & cement
190. Walls	__ Woods	__ Metal/Cardboard	__ Blocks	__ Blocks & cement

191. What was the main source of light in your house when you were a child? (Circle one option)
1. Candles **2**. Oil **3.** Kerosene **4.** Electricity **5.** Other (specify) ________________

Which of the next assets were at home when you were a child?

192. TV	**0.** No	**1.** Yes		**196. Stove**	**0.** No	**1.** Yes
193. Radio	**0.** No	**1.** Yes		**197. Car**	**0.** No	**1.** Yes
194. Washing machine	**0.** No	**1.** Yes		**198. Bicicle/Tricicle**	**0.** No	**1.** Yes
195. Refrigerator	**0.** No	**1.** Yes		**199. Motorcycle**	**0.** No	**1.** Yes

200. Which was the primary language spoken at home when you were child?
1. Spanish **2**. Maya **3.** Spanish and Maya **4.** Other (specify) ________________

I need to know if during your childhood and youth, in your family had cases like:

201. Serious illness of any parent	**0.** No	**1.** Yes	**202.** Who? _____________________
203. Did it affect you? 0. No **1.**Yes **204. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
205. Death of any parent	**0.** No	**1.** Yes	206. Who? _____________________
207. Did it affect you? 0. No **1.**Yes **208. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
209. Parental divorce or separation	**0.** No	**1.** Yes	**210.** How old were you? __________
211. Did it affect you? 0. No **1.**Yes **212.How affected you? 1.**Economically **2.**Emotionally **3.**Health			
213. Parental job loss	**0.** No	**1.** Yes	**214** How often? _________________
215. Did it affect you? 0. No **1.**Yes **216. How affected you? 1.**Economically **2.**Emotionally **3.**Health			
217. Alcoholism of a family member	**0.** No	**1.** Yes	**218.** Who? _____________________
219. Did it affect you? 0. No **1.**Yes **220.How affected you? 1.**Economically **2.**Emotionally **3.**Health			
221. Sale or paw of goods for money	**0.** No	**1.** Yes	**222.** How often? ________________
223. Did it affect you? 0. No **1.**Yes **224.How affected you? 1.**Economically **2.**Emotionally **3.**Health			

225. Which was the occupation of your father when you were child? ______________________
____

226. Which was the occupation of your mother when you were child? _____________________
____

227. Did you work during your childhood or youth? 0. No **1.** Yes (If the answer was no, skip to question 168)

228. If the answer was affirmative, **What kind of work?** ______________________________

229. At what age did you start working? ___________________ years old
230. Did you go to school? 0. No **1.** Yes (If the answer was no, skip to question 233)
231. What year did you achieve? Grade________ scholar level _______________
232. How many children did you had? (including living and deceased) _________ children
233. How old were you when you got pregnant of your first child? _______ years old
234. How old were you when you got pregnant of Egos's mother? _______ years old
235. Are you currently suffering any chronic illness? (diabetes, hypertension, cholesterol)
0. No **1.** Yes (If she answer no, thanks and end the interview)
236. If the answer was affirmative, Which kind of illness?

APPENDIX 4 Feedback form for mothers

Translated into English from the original version written in Spanish

RESEARCH AND ADVANCED STUDIES CENTER OF THE NATIONAL POLYTECHNIC INSTITUTE OF MEXICO
HUMAN ECOLOGY DEPARTMENT

Cinvestav

G I R L O R B O Y

Name: ____ Sex: _________ Age: _______ (years)
Measurement date: ________ / ________ / ________

H E I G H T

Height: __________ m *For exclusive use of health personel* Percentile: ______ Z-score: ______

Anthropometric diagnosis
______ Short stature ______ Stature slightly low _____ Healthy range
Minimum height-for-age: ________ m

WEIGHT

Weight: _____ kg BMI: _____

Anthropometric diagnosis according to BMI for children with slightly low height or healthy range height: ____ Underweight ____ Healthy weight ____ Overweight ____ Obesity

Healthy weight range for normal BMI calculated according to height, age and sex of the child: _____ kg to _____ kg

Healthy weight range for age and sex when low stature is present: _____ kg to _____ kg

MOTHER

Name: ____ Age: _____ Weight: _____ BMI: _____

Anthropometric diagnosis according to BMI:
_____ Underweight _____ Healthy weight _____ Overweight _____ Obesity

Healthy range of weight: _____ kg to _____ kg We suggest to reduce: _____ kg

GRANDMOTHER

Name: ____ Age: _____ Weight: _____ BMI: _____

Anthropometric diagnosis according to BMI:
_____ Underweight _____ Healthy weight _____ Overweight _____ Obesity

Healthy range of weight: _____ kg to _____ kg We suggest to reduce: _____ kg

References used

- For the diagnosis of body mass index (BMI) in children with low height and slightly low healthy range: Internacional Obesity Task Force, Cole *et al.*, 2000. Establishing a standard definition for child overweight and obesity worldwide: International survey, British Medical Journal, 320:1240-1243. Se utilizó la misma referencia para el cálculo de rango de peso saludable por IMC.
- Para evaluar estatura y cálculo del rango de peso saludable por edad y sexo: Frisancho, 2008. Anthropometric Standards. An Interactive Nutritional Reference of Body Size and Body Composition for Children and Adults, Ann Arbor: University of Michigan Press. Based on the third National Health and Nutrition Examination Survey.
- For suggested reduction of kilograms: National Institute of Health, NHLBI Obesity Education Initiative. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight in Adults.

APPENDIX 5 Multiple regression model of socioeconomic and biological predictors for children´s height

Variable	Coefficient	S. E.	t	p	CI 95%	
Age (years)	4.58	0.47	9.74	<0.001	3.64	5.51
Mother's height (cm)	0.33	0.08	3.95	<0.001	0.16	0.49
Crowding index	-0.90	0.28	-3.26	0.002	-1.45	-0.35
Lived with smokers during pregnancy (Yes, n = 18)	-2.09	1.03	-2.02	0.046	-4.14	-0.04
Preeclampsia during gestation (Yes, n = 21)	-2.36	0.96	-2.46	0.016	-4.26	-0.46
Constant	41.11	12.95	3.17	0.002	15.42	66.80

S.E.: standard error; n = 106, $F (5, 100) = 29.78$, $p<0.001$, $R^2 = 0.60$, adjusted $R^2 = 0.58$; Shapiro-Wilk residual normality test: w = 0.98, p = 0.123; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)} = 1.49$, p = 0.223.

APPENDIX 6 Multiple regression model of socioeconomic and biological predictors for children´s leg length

Variable	Coefficient	S. E.	t	p	CI 95%	
Age (years)	2.66	0.33	8.18	<0.001	2.01	3.31
Mother's LL (cm)	0.26	0.08	3.50	0.001	0.11	0.41
Crowding index	-0.37	0.19	-1.95	0.054	-0.75	-0.01
Lived with smokers during pregnancy (Yes, n = 18)	-1.32	0.71	-1.86	0.066	-2.73	0.09
Preeclampsia during gestation (Yes, n = 21)	-1.51	0.67	-2.25	0.026	-2.84	-0.18
Constant	19.29	5.88	3.28	0.001	7.63	30.94

S.E.: standard error; n = 106, F (5, 100) = 21.15, p<0.001, R^2 = 0.51, adjusted R^2 = 0.49; Shapiro-Wilk residual normality test: w = 0.99, p = 0.390; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.01, p = 0.940.

APPENDIX 7 Multiple regression model of socioeconomic and biological predictors for children´s fat mass (kg)

Variable	Coefficient	S. E.	t	p	CI 95%	
Sex (Girls)	0.80	0.37	-0.54	0.589	-0.76	0.43
Number of ultrasounds during pregnancy	0.33	0.09	3.63	<0.000	0.15	0.52
Children's height	0.21	0.04	5.07	<0.000	0.13	0.29
Maternal body fat (kg)	0.07	0.02	2.84	0.005	0.02	0.12
Crowding index	-0.07	0.13	-0.52	0.604	-0.33	0.19
Children´s age (years)	-0.16	0.30	-0.54	0.589	-0.75	0.43
Maternal education (reference = None) Primary (n = 25)	-1.84	0.61	-3.01	0.003	-3.05	-0.63
Secondary ≥ (n = 69)	-1.57	0.55	-2.87	0.005	-2.65	-0.48
Grandmother at home (Yes, n = 20)	-1.33	0.50	-2.67	0.009	-2.31	-0.34
Constant	-17.92	4.12	-4.35	0.000	-26.09	-9.74

S.E.: standard error; n = 103, F (9, 93) = 10.90, p<0.001, R^2 = 0.51, adjusted R^2 = 0.47; Shapiro-Wilk residual normality test: w = 0.99, p = 0.495; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.12, p = 0.692.

APPENDIX 8 Multiple regression model of socioeconomic and biological predictors for children´s lean body mass (kg)

Variable	Coefficient	S. E.	t	p	CI 95%	
Birth weight (kg)	0.81	0.33	2.42	0.017	0.15	1.48
Children height (cm)	0.34	0.04	9.23	<0.001	0.27	0.41
Age (years)	-0.10	0.26	-0.38	0.701	-0.61	0.41
Sex (Girls)	-1.08	0.32	-3.44	0.001	-1.71	-0.46
Constant	-24.29	3.40	-7.15	<0.001	-31.03	-17.55

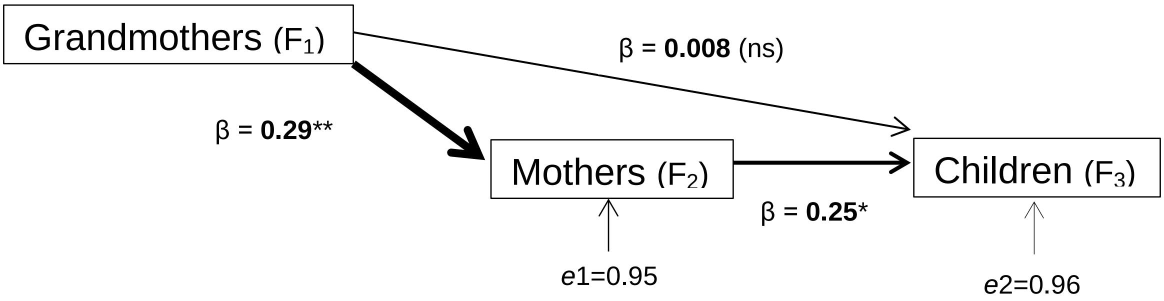
S.E.: standard error; n = 106, $F(4, 101) = 44.06$, $p<0.001$, $R^2 = 0.64$, adjusted $R^2 = 0.62$; Shapiro-Wilk residual normality test: w = 0.99, p = 0.358; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)} = 2.79$, p = 0.094.

APPENDIX 9 Grand-maternal (F_1) intergenerational effects on maternal (F_2) sitting height ratio

	Model 1		Model 2	
	B (SE)	p	B (SE)	p
Sitting height ratio	0.272 (0.086)	0.002	0.293 (0.087)	0.001
Place of growth (reference = Outside city: rural communities)				
-Grew up in Merida city			-0.367 (0.259)	0.159
Type of floor of household (reference = Ground floor)				
-Cement			-0.006 (0.286)	0.984
Presence of radio at home			-0.208 (0.259)	0.424
Presence of electricity at home			-0.598 (0.353)	0.094
Constant	39.234 (4.554)	<0.001	38.351 (4.638)	<0.001
R^2 adjusted	0.077		0.117	

S.E.: standard error; n = 108, F (5, 102) = 3.83, p<0.05, R^2 = 0.158; Shapiro-Wilk residual normality test: w = 0.99, p = 0.465; Breusch-Pagan/Cook-Weisberg homoscedasticity test: $X^2_{(1)}$ = 0.31, p = 0.577.

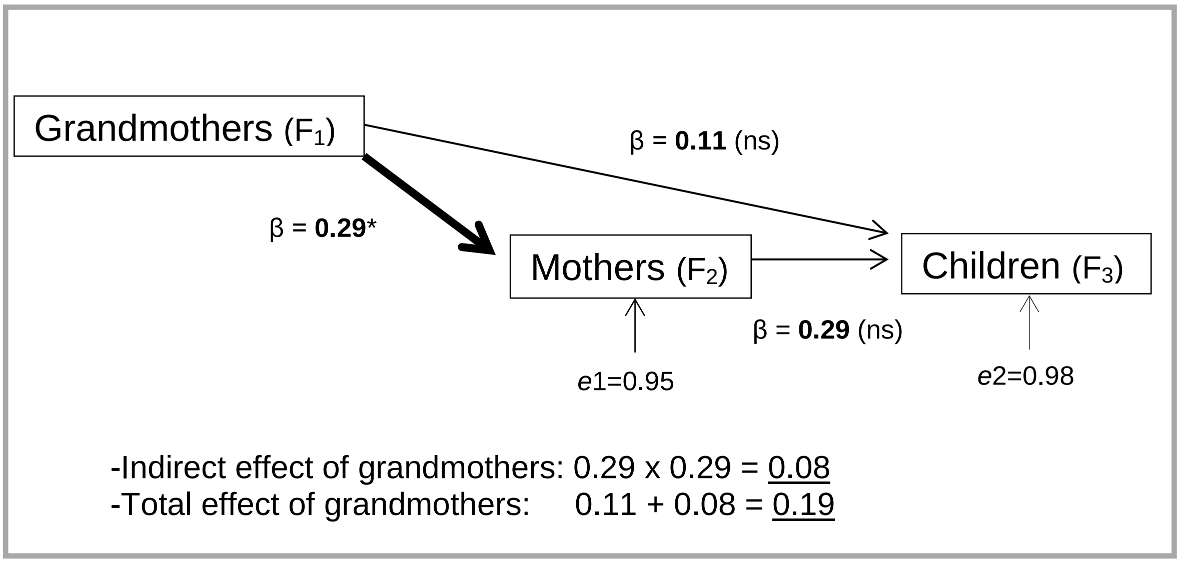
APPENDIX 10 Path analysis diagram for children's sitting height ratio



-Indirect effect of grandmothers: 0.29 x 0.25 = 0.07
-Total effect of grandmothers: 0.07 + 0.008 = 0.078

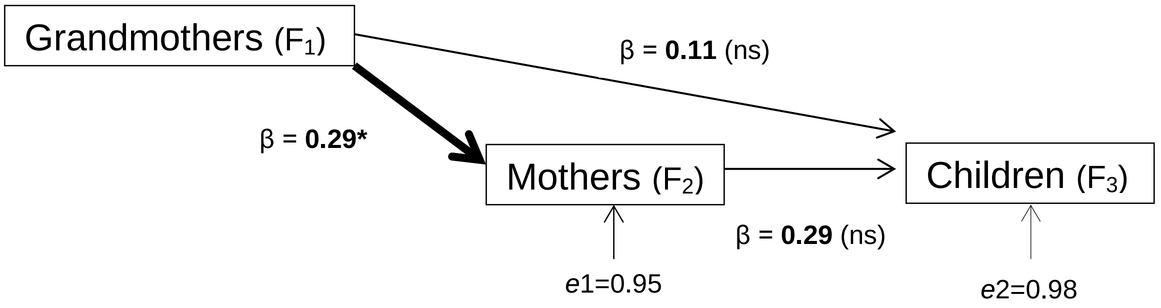
*p<0.05; **p<0.001

APPENDIX 11 Path analysis diagram for children's percentage of body fat



*$p<0.05$

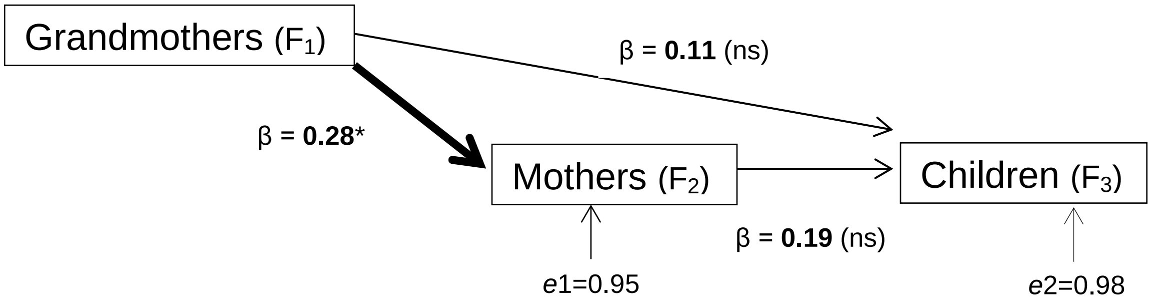
APPENDIX 12 Path analysis diagram for children's lean body mass



-Indirect effect of grandmothers: 0.29 x 0.29 = 0.08
-Total effect of grandmothers: 0.11 + 0.08 = 0.19

*p<0.05

APPENDIX 13 Path analysis diagram for children's percentage of lean body mass



-Indirect effect of grandmothers: 0.28 x 0.19 = 0.05
-Total effect of grandmothers: 0.11 + 0.05 = 0.16

[*]p<0.05