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Individual, Familial, and Community Determinants
of Child and Adolescent Overweight and Obesity in Colombia

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Inés González-Casanova
B.S. Escuela de Dietética y Nutrición, México 2006

Advisor: Aryeh D. Stein, Ph.D.

An Abstract of
a dissertation submitted to the Faculty of the
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ABSTRACT

The general objective of this dissertation was to describe the epidemiology of child and adolescent overweight and obesity in Colombia. Two National Nutrition Surveys from Colombia 2005 and 2010 were analyzed to 1) Compare prevalence estimates of the most commonly used international classification systems to assess overweight and obesity in children 5 to 18; 2) Describe changes in the prevalence of overweight and obesity in Colombian children and adolescents between 2005 and 2010, by screen time, wealth, urbanization, and region; and 3) Identify the main predictors of overweight in Colombian children and adolescents at the individual, familial, and community level. The first study found that the prevalence estimates of overweight and obesity varied among the three main international classification systems. Further, results also show that the association (odds ratios and 95% confidence intervals) between combined overweight and obesity, and age and sex varied by system. Results from the second study show no significant change in the prevalence of overweight or obesity in Colombian children and adolescents 5-18 years overall (overweight= 12.2 to 12.7%; obesity=3.5 to 3.9%, p>0.05), or within sex, wealth, urban, rural, or region specific subgroups during this 5 year period. This unchanged and low prevalence of overweight and obesity in children and adolescents suggest a slow nutrition transition in Colombia compared to other low and middle income countries. Finally, for the third study results from this dissertation suggest the following associations: height and being a girl were positively associated and age was inversely associated with Body Mass Index Z-score (BMI-Z). At the family level overweight. BMI-Z and the odds of overweight were inversely associated with family size and living in an urban household, and positively associated with being part of an extended family and with wealth. The community level explained only between 2 and 3% of the variability in BMI. Through these three studies, a distinct epidemiologic pattern of child and adolescent overweight and obesity in Colombia was portrayed. Results from this dissertation have the potential to inform the design and implementation of programs and policies to prevent child and adolescent obesity in Colombia.

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A mi abuelo y abuela, a mi hermanito Adrián y a mi niña Amaranta

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CHAPTER 1: INTRODUCTION

Child and adolescent overweight and obesity have become a major public health problem worldwide (1). Obesity is defined as an excessive accumulation of adipose tissue and its presence during childhood or adolescence is associated with several health complications, such as psychosocial consequences, future obesity, diabetes, some types of cancer, hypertension and cardiovascular disease (2, 3). The increase in the prevalence of children and adolescent overweight and obesity is associated with changes in the social and built environment that alter dietary and physical activity patterns of the population, promoting a positive energy balance that leads to obesity (4). In Latin America the accelerated and polarized nature of these changes has caused overweight and obesity to coexist with the unresolved problem of under-nutrition and infectious diseases, generating a double burden to health systems (5). This particular nutritional panorama is associated with social and environmental processes specific to the Latin American context, such as recent economic growth, globalization and urbanization (in most countries) (6).

Despite the recognized importance of social and community determinants of child and adolescent obesity, research in this area is relatively new (7). In high income countries (HIC), new theoretical models, methods and interventions have been proposed in the last couple of decades (8). In Latin America, research in this area is even newer and little information has been generated in the region (8).Consequently, most interventions, programs and policies are designed and implemented targeting the determinants observed in HIC, disregarding the Latin American context. It is crucial to align the research in Latin America to current public health problems to create more effective interventions based on scientific evidence (9, 10).

Familial relationships and family structure have been identified as the most important factors in shaping children and adolescents' patterns of behavior, including diet, physical activity and sedentary behavior patterns which are the main determinants of obesity (11, 12). The conception of family in Latin America is an example of a fundamental difference of social contexts between this region and most high income countries (4, 13, 14). Families are embedded within the community, which is responsible for providing opportunities or creating barriers for children and adolescents to develop healthy behaviors, such as healthy eating and regular physical activity (15). Examples of particular determinants at the community and social level in Latin America are the multiple food aid programs, informal food vendors in the urban areas, and the perceived value of excessive weight, among others (5, 14, 16). Currently, there is a lack of information addressing these familial, community and social determinants of children and adolescents' overweight and obesity in Latin America.

For this dissertation, Colombia served as an example of a Latin American context to study overweight and obesity in children and adolescents. This country is a middle economy in Latin America that has made obesity prevention an important part of its political agenda. Two large national nutrition surveys have been conducted recently in Colombia: ENSIN 2005 (17) and 2010 (18). The general objective of this dissertation was to use the information from these two cross-sectional studies to describe the epidemiology of overweight and obesity in Colombian children and adolescents 5 to 18 years. This included the assessment of changes across time and of important factors associated with this disease. The factors identified are specific to Colombia, but findings from this study have the potential to be disseminated to other settings with similar contexts. The specific aims were:

Specific Aim 1: to estimate the prevalence of overweight and obesity using the three main international classification systems to assess overweight and obesity in children and adolescents; to assess their concordance, and if they suggest different associations with age, gender, location of residence (rural or urban) and socioeconomic status (SES) in a nationally representative survey from Colombia, 2005

Specific Aim 2: to describe changes in the prevalence of overweight and obesity in children and adolescents in Colombia between 2005 and 2010 by different factors including screen time, wealth, urbanization, and region.

Specific Aim 3: to assess the potential influence of family and community level predictors on weight status of Colombian children and adolescents, using multilevel modeling techniques to analyze two nationally representative samples of children and adolescents 5 to 18 years in Colombia.

In parallel, I hypothesized: 1) That the three international methods to assess child and adolescent overweight and obesity yield different prevalence estimates of overweight and obesity, but that the estimates of association between overweight and obesity and age, sex, rural or urban residence, and SES would be consistent across systems; 2) That there would be an overall increase in the prevalence of overweight and obesity in children and adolescents from Colombia between 2005 and 2010, and that this increase would particularly affect certain subgroups such as the urban population. 3) That predictors of overweight and obesity in children and adolescents from Colombia would not reflect the exact same associations that have been reported from HIC.

CHAPTER 2: LITERATURE REVIEW
OVERVIEW OF OVERWEIGHT AND OBESITY IN CHILDREN AND ADOLESCENTS

Physiology of childhood overweight and obesity: definition, consequences, and etiology

Childhood and adolescent overweight is defined as an excessive weight for height caused by an abnormal accumulation of adipose tissue (2, 19, 20). Different methods that are available to measure body fat and assess obesity in children and adolescents are described in table 2.1.

Table 2.1: Overview of commonly used techniques to assess body fat in children and adolescents

	Description	Limitations
Body Mass Index (BMI)	• BMI= weight/height^2 • Strong correlation with fat percent • In children, it is often expressed as standard deviations to account for age and sex • Index of nutritional status used to diagnose overweight and obesity and eating disorders (in combination with psychological tests) • Affordable and widely used for surveillance	• Does not distinguish between fat and lean mass • Not recommended to diagnose under-nutrition in children (does not reflect lean mass adequately) • Its predictive value for negative health outcomes is not as clear in children and adolescents • There is no agreement on which is the best age- and sex- specific classification system for BMI in children and adolescents
Skinfold thickness	• Used to rank individuals in terms of relative ‘‘fatness’’ or to assess the size of specific subcutaneous fat depots • In children can be used to estimate body density, fat-free mass, fat mass, and % body fat • Used in conjunction with validated prediction equations based on multi-component methods.	• Equations tend to be population specific. Accuracy is variable when applied in new populations • Most effective to assess fat deposits in specific body compartments • Precision and accuracy are poorer in obese children than in lean subjects • Lack of current international reference data • Slightly more invasive and time consuming than BMI

Circumfer-ences	• Useful in determining fat distribution • Waist, hip, and thigh circumferences are used to predict body fat distribution in children • Recent evidence suggests waist circumference is a good predictor of total body fat	• Difficult interpretation. Cut-offs not available for children • Lack of international reference • Needs excellent technique for data collection • Slightly more invasive and time consuming than BMI • Less accurate in obese or undernourished children
Bio-impedance analysis (BIA)	• Based on measurement of electrical resistance in the body. Tissues rich in water and electrolytes offer less resistance than adipose tissue • Total body water is used to estimate fat free mass. Total fat calculated by subtracting fat free mass from body weight.	• Affected by dehydration • Less accurate in children than in adults • More expensive than BMI
Densito-metry	• Hydrodensitometry was considered a "gold standard" to calculate fat mass and fat free mass. Subject submerges in a tank of water and density of fat mass and fat free mass are calculated based on displacement. Not practical in children. • An alternative is the Bod-Pod which uses air instead of water. Simpler, quicker, and more practical	• The Bod-Pod is extremely expensive and time consuming • Requires knowledge of the specific densities of fat and fat free mass, which vary in pediatric population
Dual energy X-ray absorption-metry (DXA)	• DXA is useful for assessment of the whole body as well as regional measurements of bone mass, lean mass, and body fat in children. The DXA scanner quantifies two main photon peaks as they pass through the body. • Gold standard to assess body composition in adults	• Expensive • Requires manufacturer specific software • Requires trained personnel • Invasive

Definitions of overweight and obesity should meet two criteria: reflect high body fat content and denote increased risk of negative health outcomes (20). Body Mass Index (BMI) has been suggested as a valid approach, meeting these two considerations and is widely used for surveillance (20). However, BMI of children and adolescents varies by age and sex (due to puberty and growth), thus, it is necessary to develop age- and sex- specific recommendations, which leads to the use of reference populations as comparison (21, 22). Some countries have developed and validated classification systems based on nationally representative samples of their population; however, international references are necessary to make comparisons across settings, and where country-specific classification systems are not available. Internationally, the most commonly used BMI classification systems for children 5 to 18 are:

- World Health Organization (WHO): was developed by WHO in 2007 following the release of the WHO child growth standards for preschool children which were based on a cohort of healthy children. This method uses data on children and adolescents 1 to 20 years from the National Center for Health Statistics (NCHS) reference of 1977 and from the growth standards for children under five. The result of this merging was a reference population of children and adolescents with a smooth transition at age 5, which helps link this recommendation with the one for younger children. This classification system defines overweight as >1 standard deviation (SD) from the mean of the reference population and obesity as >2 SD. Further, the cut-offs generated using this reference match closely the recommendations for adult population (which defines overweight at 25 kg/m^2 and obesity at at 30 kg/m^2) at age 19 (21).

-Center for Disease Control (CDC): were issued in 2000 as an update of the NCHS/WHO growth reference of 1977. They provide references for children 2 to 20 years based on information from the United States (US). This revised version of the growth curves for the US were developed with data collected by NCHS in five cross-sectional, nationally representative health examination surveys: the National Health Examination Surveys II (1963–65) and III (1966–70), and The National Health and Nutrition Examination Surveys I (1971–74), II (1976–80), and III (1988–94), which constitute samples of all civilian non-institutionalized population of this country. The final product includes age- and sex- specific 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 85th, 95th, and 97th smoothed percentile curves. The cut-offs for overweight and obesity, were established at the 85th and 95th percentile respectively. These growth charts were designed to serve as a reference for US population; however, they were the method of preference to assess BMI in international populations before the International Obesity Task Force classification system was issued in 2005 (23).

-International Obesity Task Force (IOTF): was issued in 2005 and was the first method developed with the specific objective of serving as an international BMI classification system. It used data from six nationally representative cross-sectional studies from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore and the US. The centile curve for each country was developed using the same smoothing techniques applied to develop the WHO and CDC classification systems, then age- and sex- specific cutoffs were calculated by extrapolating the adult cutoffs of overweight (25kg/m^2) and obesity (30 kg/m^2) (24).

The presence of overweight during childhood and adolescence is associated with a wide range of short and long term negative health outcomes, (19, 20). Short term, the excess in body fat increases the likelihood of children and adolescents presenting risk factors for non-communicable chronic diseases. Such risk factors affecting obese children, adolescents and young adults are hyperinsulinemia, glucose intolerance, hypertension, asthma, sleep apnea, social exclusion, and depression (25). Long term consequences include future obesity, as well as increased risk of type-2 diabetes, cardiovascular disease, some types of cancer, and premature mortality (20). Furthermore, studies from HIC have found negative associations of obesity in adolescence and early adulthood with later life social and economic conditions, such as social isolation, decreased educational attainment and lower income (26, 27).

The most important behavioral determinants of overweight and obesity are diet, physical activity and sedentary behavior. A chronic positive energy balance, where energy intake is greater than energy expenditure, leads to the excessive accumulation of adipose tissue defined as overweight or obesity (28). Energy intake is exclusively determined by diet, while energy expenditure is determined by basal metabolic rate, adaptive thermogenesis, food induced thermogenesis and physical activity (28). Most energy is expended in the basal metabolic rate to maintain the normal physiological functions of the human body. However, physical activity is a modifiable component of energy expenditure and has been identified as crucial to maintain energy balance. Recently, sedentary behavior (defined as time spent in activities that require less than 1.5 Metabolic Equivalents or METs, such as watching television or playing static video games) has been identified as an independent predictor of overweight and obesity, as well as an important risk factor of low self-esteem, antisocial behavior, and decreased academic achievement in children (29, 30). The biological and behavioral processes that determine energy balance are extremely complicated, and the specific contributions of diet, physical activity and sedentary behavior are not completely understood (28, 31). To understand the etiology and dynamics of childhood and adolescence obesity it is necessary to consider the different factors that determine dietary intake and physical activity, as well as the complicated interactions between these behaviors and body weight (31-33).

Eating behavior affects body weight through energy expenditure. The amount of energy consumed by children and adolescents is not only determined by biological requirements (28). The characteristics and composition of the diet as well as many other behavioral, psychosocial and environmental determinants influence the amount of energy consumed. Energy density (or the energy provided per weight) of foods and the macronutrient composition of the diet may influence energy intake in children and adolescents (32). The percentage of fat in the diet is associated with increased energy intake independently of energy density. The main determinants of energy density are the amount of fat, fiber and water in foods (34). Moreover, it has been demonstrated that foods with high fat content increase episodic energy intake independently of energy density. Conversely, fiber increases meal volume, decreases energy density and glyceamic index and is inversely associated with energy expenditure (33). Other factors that may be increasing energy intake in young people are the increase in portion sizes and specific eating patterns such as snacking behavior and skipping meals (35).

The nature of the influence of physical activity and sedentary behavior on body weight is also complicated. Although it is clear that both play an important role in the etiology of child and adolescent' overweight, it is still not completely understood how these different components of energy expenditure are associated with this disease (36). For example, it is not clear if the increase in the prevalence of overweight in children and adolescents is due to reductions in moderate to vigorous physical activity, to an increase in specific sedentary behaviors, or to a combination of both (37). Moreover, the interactions between eating habits and the control of food intake may complicate this association (33). Many studies report a positive association of time spent watching television and overweight and obesity in children and adolescents (38, 39). Television viewing influences energy balance not only by decreasing energy expenditure but also by altering eating behaviors (40). Due to methodological difficulties in assessing physical activity and sedentary behavior in children and adolescents and the low perceived value of monitoring these behaviors, surveillance data on physical activity and sedentary behavior is rarely available (41, 42).

The influence of the family as a social determinant of child and adolescent overweight and obesity

The family is the most important determinant of children and adolescents' beliefs, behaviors and lifestyles (12). "Families are the most central and enduring influence in children's lives regardless of their composition, income, education, or values. The health and well-being of children are inextricably linked to their parents' physical and emotional health, social circumstances, and child rearing practices" (12). This statement from the Family Task Force of the American Academy of Pediatrics is also applicable to the development of children and adolescents' overweight and obesity. Different elements of the family environment, structure, and interactions between its members have been suggested to influence children and adolescents' eating and physical activity behaviors (11, 34, 43).

Family structure is an important element associated with the development of obesity. In HIC countries, elements of family structure such as marital status,(44) number of parents in the home, and presence of siblings have been identified as predictors of children and adolescents' obesity (45); these factors influence eating and physical activity through mechanisms not completely understood. Most likely, the influence of family structure is through its effects on parent involvement, parenting style, quality of time with the child, social support and ability to cope with stressors (44, 45). Children of single parents have greater risk of unhealthy eating, low levels of physical activity, and overweight and obesity (46). Usually, single parents are the sole economic contributors to the household. They are also less likely to prepare meals at home and to eat as a family. Moreover, single parents have less time to be physically active and to encourage children to participate in physical activity, which is positively associated with active behaviors in children and adolescents (46). Another component of family structure that influences physical activity is the number of siblings in the household (47). To our knowledge, there are no studies examining the effect of family structure in children and adolescents' overweight and obesity specific to the Latin American context. Family in Latin America is considered of extreme importance for children and adolescents' development (14). Legally and historically, family in this region is represented as a patriarchal unit based on a monogamous marriage. However, historical research indicates that a large proportion of children born in Latin America since 1492 were not born into this type of two parent nuclear family structure (14). In traditional Latin American families, mothers of illegitimate children usually were not left alone (14, 48). Since birth, children become responsibility of every potential caretaker within the mother's family. Usually grandparents are the most important contributors, but all members of this extended family are linked to the children through "kinship" (14). Different studies have suggested globalization and migration potentially deteriorate this kinship that characterizes Latin American families. These two phenomena have also been linked to increases in the prevalence of obesity (14).

The characteristics, behaviors and beliefs of the parents are extremely important in determining eating and physical activity behaviors in children and adolescents. It has been suggested that health behaviors aggregate within families (49). Parental weight is strongly correlated with their children's BMI. This association has both a genetic and a behavioral component. Mother's are generally responsible for feeding the child. Infant feeding practices are extremely important in determining food preferences and dietary patterns (50). Older children have more freedom to make decisions regarding their dietary intake; nevertheless, parents determine food availability within the household; thus, their own dietary choices, beliefs, and feeding practices continue to influence children and adolescents' diets (43, 50). Maternal misperception of their own weight and of children's overweight has been associated with unhealthy eating, decreased PA, increased risk of overweight and resilience to change (51, 52). Physical activity in children and adolescents is strongly associated to parental physical activity and sedentary behaviors (53). The Framingham Children's Study found that children of active mothers were overall two times as likely to be active as children of inactive mothers. Moreover, children who had at least one active parent were 3.5 times more likely to be active, and children with two active parents were 5.8 times more likely to exercise (54). Similarly, the time parents spend watching television is correlated with children sedentary behaviors (43). Parental physical activity and sedentary behaviors have also been associated to children eating patterns. For example, children with active parents are more likely to consume fruits and vegetables (43).

Community Determinants of child and adolescent overweight and obesity

Community and the social environment seem to have a greater influence on children and adolescents' behaviors than adult's behaviors (55, 56). Different characteristics of built environments that promote or prevent healthy eating, physical activity, sedentary behavior and ultimately obesity have been identified in the United States and other HIC (56). "The community food environment is defined as the distribution of food sources, that is, the number, type, location, and accessibility of food outlets, with stores and restaurants being the most common" (55). Whereas "physical activity environments" are places where people can be active. (15) In the US, Australia, and other HIC, interest has been increasing in creating environments that promote active recreation and transportation (57). Availability of recreation facilities, parks and playgrounds have been associated with increased physical activity, decreased sedentary behavior and decreased odds of overweight in children (56). Meanwhile, population density, public transportation, availability of destinations, walking and cycling trails, and adequate sidewalks are some factors associated to active transportation (15). Important changes in the food and physical activity environments promoted by societal and political processes have affected diet and physical activity patterns of the population worldwide (58). For example, evidence suggests strong associations of countries' economic growth, urbanization and globalization with increased prevalence of overweight and obesity (58).

Economic growth and inequality

The level of countries' development, according to the United Nations, is defined based on standard of living, level of development of the industrial base, and the Human Development Index (HDI). Evidence suggests that as these indicators improve, overweight and obesity increase in both children and adults (59). This increase in overweight and obesity is considered to be due to changes in diet and physical activity environments. For example, there is evidence that consumption of sweet caloric beverages increases in parallel with gross national product, urbanization, and tourism. Also, physical activity in children decreases as TV ownership increases (60). Further, the association between economic growth and obesity seems to be moderated by household socioeconomic status (60).

In parallel, the level of inequality at the country and neighborhood levels seems to affect the country-level prevalence of overweight and obesity, as well as its social patterning (defined as a set of characteristics or behaviors associated with a social entity) (61). For example, a study in adults from 21 HIC found no association of obesity with overall country income, but a higher prevalence in countries with greater socioeconomic inequality (62). Similarly, a recent study of adolescents from 35 countries examined associations between macroeconomic indicators of income and inequality, and prevalence of overweight (61). This study reported a positive association of socioeconomic inequality with overweight among the HIC and a negative association among the middle income countries. Further, a recent study in

Los Angeles reported an inverse association between inequality at the neighborhood level and childhood and adolescence overweight and obesity; they hypothesized this association is due to the fact that economically disadvantaged households benefit from healthier environments promoted by the presence of wealthier households in the neighborhood (63). More information on social patterning and the effect of economic growth on specific countries in Latin America is provided in chapter 3.

Urbanization

Urban communities have both positive and negative impacts on the health and well-being of their inhabitants. On the positive side, people living in urban areas have better access to economic opportunities, education, health, and other public services (64-67). For example, evidence shows children in urban areas are generally at lower risk of stunting and underweight than those in rural areas. This is particularly true in Latin American countries (68). On the negative side, overcrowding, pollution, social deprivation, crime, lack of time, and stress-related illness are common risk factors in urban settings (69).

It has been suggested that the determinants of child nutritional status are different in urban and rural areas. Factors affecting child nutritional status in urban areas include a greater dependence on cash income and less dependence on agriculture and natural resources, a larger proportion of women-headed households, greater involvement of women in the labor force, smaller family size and weaker social networks (68). There is a large body of evidence linking urban environments to increased risk of overweight in both children and adults. In cities, there is less time spent in food preparation and greater access to processed foods high in fat and sugar. Also, work related physical activity is less in urban areas and high rates of crime, pollution, overcrowding, lack of green areas and recreation facilities among others limit physical activity and promote sedentary behavior, particularly among the urban poor (70). The high rates of urbanization in Latin America, where over 70% of the population resides in urban areas, has been identified as a major driving force of the obesity epidemic in the region (71).

Globalization

Globalization is defined as the process towards a single worldwide culture and economy (72). It is funneled by improvements in global communications, technologies, travel, and trade. The process of globalization has had both positive and negative impacts on health (72). On one side, advances in health, science, and technology are rapidly spread across countries; food variety and availability increase, particularly in wealthy sectors of the population of high income countries and become less dependent on local production or seasonality; and international regulations and organisms have been created to try to secure the health and well-being of the global population (59). However, due to the increase in connectivity and mobility of the population disease spreads more rapidly, generating pandemics or large scale epidemics of both infectious and non-communicable chronic diseases. Generally, there is consensus that obesity has reached an epidemic level in most countries of the globe; some authors even suggest this disease has reached pandemic proportions (59). Obesity was originally considered to be only a public health problem in the US and other 'Western' economies. Through the process of globalization 'Western" lifestyles, such as diets high in fat and sugar, as well as decreases in active work, transportation, and leisure spread to Low and Middle Income Countries (LMIC), thus, increasing the prevalence of overweight and obesity in these settings. Examples of the 'clashes' between the introduction of these new technologies and human biology related to the epidemic of overweight and obesity around the globe are presented in table 2.2 (59).

Table 2.2: Technological clashes with human biology (59)

Biology	Technology
Sweet Preferences	Cheep caloric sweeteners, food processing benefits
Thirst and hunger/satiety mechanisms not linked	Caloric beverage revolution
Fatty food preferences	Edible oil revolution; high-yield oilseeds; cheap removal of oils
Desire to eliminate exertion	Technology in all phases of movement/exertion

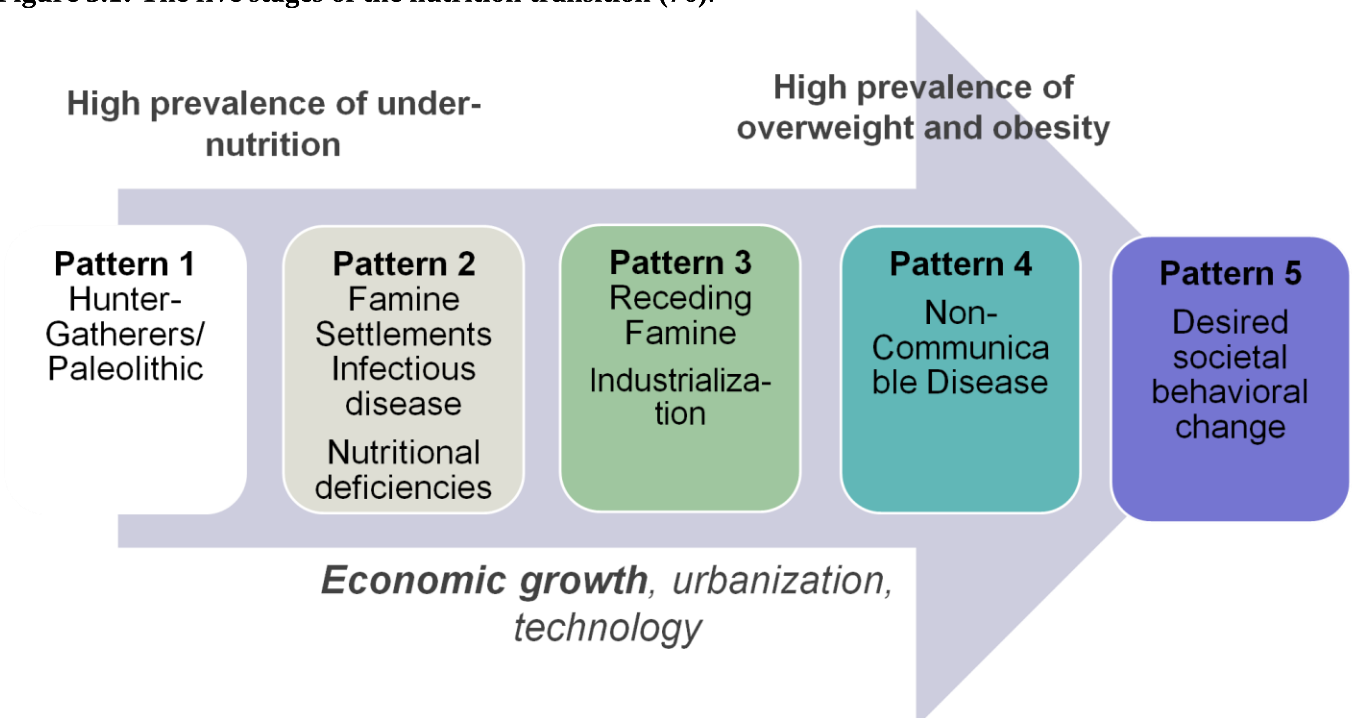
Source: Global Nutrition Transition and the Pandemic of Obesity in Developing Countries (Popkin, Adair & Ng 2012

CHAPTER 3: LITERATURE REVIEW
EPIDEMIOLOGY OF OVERWEIGHT AND OBESITY

The Nutrition Transition

The nutrition transition is defined as the change from a high prevalence of under-nutrition to high prevalence of overweight and obesity (73). The nutrition transition illustrates how dietary and physical activity pattern and change across time because they have been affected by different factors. It was initially described as a process with five different stages (Figure 3.1) (74, 75).

Figure 3.1: The five stages of the nutrition transition (76).



Source: The nutrition transition in low income countries: an emerging crisis (Popkin, 1994)

The first stage was defined as the hunter-gather societies (Paleolithic pattern) and it is characterized by a diet high in fiber and with low energy density, intense physical activity required to survive, and high mortality from infectious diseases (without reaching epidemic levels). This pattern translates into a young population with lean body composition and few nutritional deficiencies (74, 75).

The second stage is the “famine” stage characterized by agricultural societies; cereals become the base of the diet and variety decreases, food production required physical labor, mortality was high, especially due to infectious disease epidemics and food shortages that affect mainly women and children; during this stage nutritional deficiencies emerged and stature decreased (74, 75).

The third stage refers to the “receding famine”. In this stage animal protein and fruits and vegetables become more available but low variety continues. Some nutritional deficiencies start to disappear and public health interventions begin to improve the health of the population. However, maternal and children mortality remain high. New methods of food production appear through the industrial revolution, urbanization increases and women incorporate to the labor force (74, 75).

The fourth is the “chronic degenerative disease” stage. Diet becomes high in fat and animal products and low in micronutrients. Physical activity is not required anymore for work and transportation. This combination generates the energy imbalance that leads to obesity. Non-communicable chronic diseases associated with obesity and unhealthy lifestyles are prevalent in this stage (74, 75).

Finally, the fifth stage was defined as a behavioral change that societies undergo trying to achieve healthy lifestyles. In this stage there is a voluntary and organized change towards healthy diets and active living; which leads to a decrease in obesity and communicable diseases, and to healthy aging (74, 75).

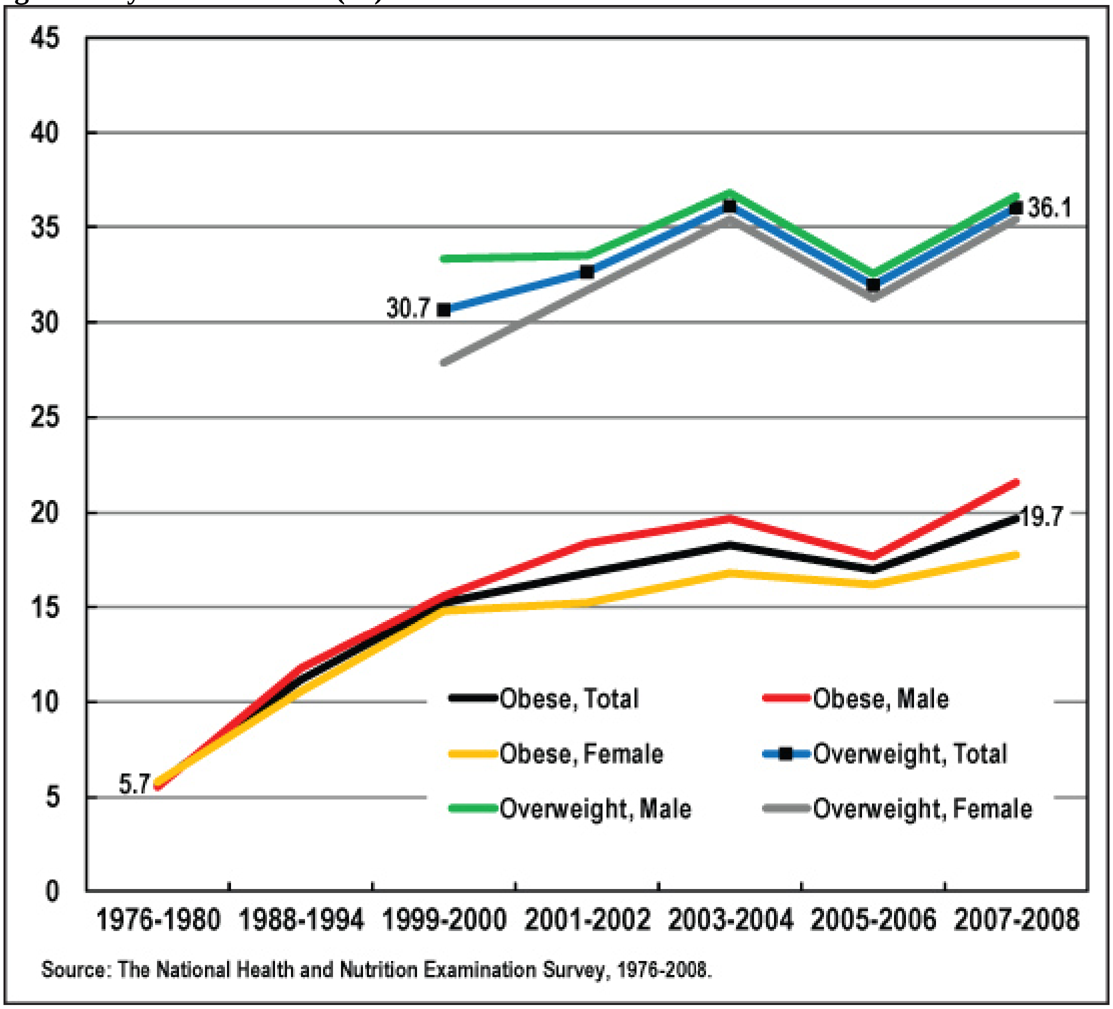
In practice, the nutrition transition does not necessarily occur in the order described above. Many countries, particularly LMIC are seeing a high prevalence of obesity and chronic disease which coexists with the unresolved problem of under-nutrition and re-emerging infectious diseases (77, 78). It is estimated that overweight and obesity affect over 1.5 billion adults worldwide, and that by 2030 2.16 billion adults will be overweight and 1.12 billion will be obese (59). The burden of these conditions is greater in populations of LMICs, more specifically in Asia, the Middle East, Africa, and Latin America, because the specific body composition of these population magnifies the effect of high BMIs on cardio-metabolic diseases (59) .

Overweight and obesity in children and adolescents from High Income Countries

Child and adolescent obesity was first identified as a public health problem in HIC. A review from 1989 described no social patterning in these countries. However, after 1990, studies of overweight and obesity in children and adolescents consistently show associations between economical disadvantage and overweight and obesity (61). A recent study conducted in adolescents age 12 to 15 from 35 European and North American countries found the highest prevalence of overweight in English-speaking countries (including the U.S.) and Mediterranean countries (such as Greece, Spain, Malta, Italy, etc) with over 25% of adolescents either overweight or obesity. In 21 out of the 24 HICs in this study overweight and obesity were inversely associated with socioeconomic status (with the exception of Sweden, Finland, and Greenland). Gross National Income was not associated with prevalence of overweight and obesity in HIC. However, economic inequality (measured by the Gini coefficient) at the country level was associated with higher prevalence of adolescent overweight in HICs but with lower prevalence in middle income countries (61).

The trends in childhood overweight and obesity in children and adolescents 6 to 17 in the U.S. from 1976 to 2008 are presented in figure 3.2. In 2008, the prevalence of combined overweight and obesity was of 36.1% and the prevalence of obesity of 19.7% (using the CDC classification system) (79). One of the few studies comparing trends of obesity in children older than five and adolescents across HIC (U.S. and Russia) and middle income countries (Brazil and China) was conducted by Wang et al in 2002 (Figure 3.2). Overweight and obesity increased in Brazil, China, and the U.S. and greatly decreased in Russia (due to a severe economic crisis in this country). The highest prevalence of overweight and obesity was in the United States, but the greatest increase was in Brazilian children (80).

Figure 3.1: Trends in overweight and obesity prevalence (%) among U.S. male and female children aged 6-17 years 1976-2008 (79)



Note: overweight and obesity were defined using the Center for Disease Control (CDC) classification system

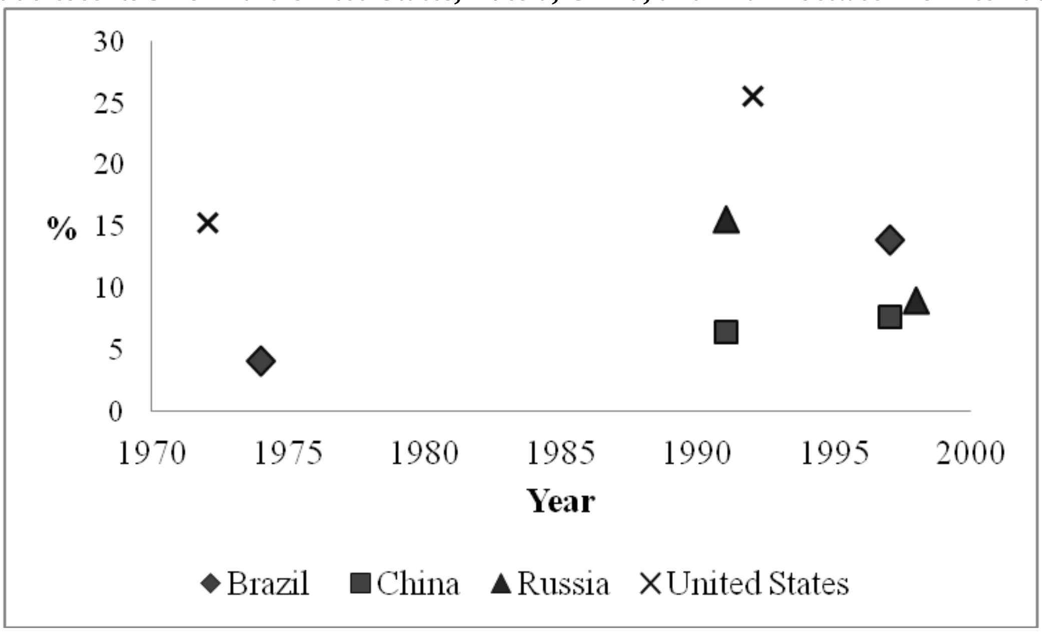
Overweight and obesity in Latin America and other Low and Middle Income Countries

The prevalence of child and adolescent overweight is increasing in most regions of the world. (81), however the greatest increases are being seen in LMIC (70, 76). Low and middle-income countries, including those in Latin America, usually follow similar patterns of nutrition transition (60, 70, 78, 82). In LMICs, overweight and obesity are initially concentrated in urban areas and in the wealthy, and as these countries reach a threshold of economic development, overweight and obesity become widespread in rural areas and among the economically disadvantaged (82-85). Conversely, in urban population, especially among the wealthy, access to opportunities for physical activity and healthy eating increase with countries' economic development and obesity control and prevention improves (86). While socioeconomic inequalities in chronic diseases and their risk factors have been studied extensively in high-income countries, few studies have investigated social inequalities in chronic disease risk factors in LMICs. The changes in diet towards an increase in consumption of salt, sugar, fat and processed foods happen more rapidly in LMICs (76, 87), same as the introduction of new technologies that promote an increase in sedentary leisure, transportation, and work related activities (88).

Information on trends of overweight in adults from LMICs is only available from Brazil, China, India, and Mexico, however recent studies in these countries do not address social patterning or the effect of urbanization (61, 62). A recent meta-analysis by Fleischer et al (87) including data from adults in 70 countries (both LMIC and HIC) concluded that social patterning is linked to the degree of urbanization: As country-level urbanization increases, overweight and obesity (measured by BMI) concentrate in less educated sectors (87). As noted before, urbanization affects human health through access to certain types of food, services, and exposure to particular working and living environments. However, there is a gap in access between the wealthy and the urban poor, where the poor may face greater barriers to achieve healthy lifestyles in urban settings (89, 90). In Latin America, a 2001 publication by the Pan American Health Organization (PAHO) called attention to the association between poverty and obesity that increases as countries develop economically (91). In Brazil, Monteiro et al. (1995) reported a higher increase in obesity among lower income families and an inverse association between BMI and income in the 30% wealthiest women (85). All recent reviews agree on the need to integrate societal and community determinants to the study of obesity in Latin America, and consider them essential to develop effective public health policies and interventions to prevent overweight and obesity in the region (87, 89, 90).

More information is needed to illustrate trends of child and adolescent overweight and obesity in Latin America, especially among school age children and adolescents, since most information currently comes from nationally representative samples of women in reproductive age and preschool children (16, 81, 92). In Brazil there was an increase in the prevalence of combined overweight and obesity in children and adolescents of approximate 9 percentile points between 1974 and 1997 (Figure 3.2). Similarly, in Mexico there was an increase in prevalence of overweight and obesity in children 5 to 11 years of 8 percentile points between 1999 and 2006 (93). In both cases, the increase in urban areas was greater than in rural areas.

Figure 3.2: Changes in the prevalence (%) of combined overweight and obesity in children and adolescents 5-18 in the United States, Russia, China, and Brazil between 1971 to 2000 (80)



Note: overweight was assessed using the International Obesity Task Force (IOTF) classification system.

CHAPTER 4: METHODS

Trends in children are of particular concern to governments in Latin America (and other LMIC), where increases of overweight and obesity in children coexist with the unresolved problem of under-nutrition and infectious diseases (94). Historically, policies and programs in Latin America were targeted to prevent and control the problem of under-nutrition. Some of these programs, particularly the ones that provide food or are poorly targeted and evaluated, may contribute to increase the prevalence of overweight and obesity in children and adolescents (16, 95). Hence, it is important to assess the impact of public policy and programs in Latin American countries and to design them based on knowledge of the specific epidemiology and social patterning of childhood and adolescent overweight and obesity in the region.

Setting

Colombia is located in the Andean region of South America and shares borders with Panama, Brazil, Venezuela, Ecuador, and Peru. It has access to the Caribbean and the Pacific Ocean. Colombia's population was of it has an estimated population of about 46 million habitants. This situates Colombia as the second most populated Spanish speaking country (after Mexico). Most its population (approximately 74%) resides in urban areas. Colombia had a Gross National Income per capita of approximately 6,000 USD in 2010, which situates it as the fourth largest economy in Latin America (96).

Data sources

We used information from two main sources: 1.the Demographic and Health Surveys (DHS), (97) 2.the National Survey of the Nutritional Situation in Colombia (ENSIN)(17) at two different time points: 2005 and 2010. These sources were linked using household and municipality identifiers to form a unique dataset with all the information relevant for the study. This was possible because of the coordinated design of the two surveillance systems which makes ENSIN a subsample of DHS. The National Census of 2005 was the sampling frame for DHS; hence some municipality level indicators could be linked to the households and the children. In summary, this study was a secondary data analysis of two cross sectional nationally representative samples of 2005 and 2010 from Colombia. A description of the datasets is presented in Table 4.1

Conceptual Framework

For this analysis we used a socio-ecological model of health behavior to study overweight and obesity in children and adolescents from Colombia. The ecological system theory, in the field of behavioral sciences and public health, focuses in the nature of people's transactions with their physical and socio-cultural surrounding (7). McLeroy, Bibeau, Steckler, and Glanz (1988), state that "the purpose of an ecological model is to focus attention on environmental causes of behavior and to identify environmental interventions" (98). The first ecologic model was proposed by Bronfenbrenner in 1979, he described three levels of influence: the *microsystem,* which refers to interpersonal interactions; the *mesosystem* that refers to interactions among the various settings, such as family, school, and work; and the *exosystem*, which refers to the larger social system. Also, he defined the nature of the relationship between individuals and these levels as reciprocal, where the individual affects and is affected by the environment (99). Other authors have proposed different ecological models of health behavior. The main characteristics of ecological models are their multilevel nature and the reciprocal influence of each level with the others (7, 98). These characteristics make ecological models especially attractive to study obesity because of the multi-factorial etiology of this disease and the complexity of the interactions between these factors to affect diet and physical activity, the two behavioral determinants of obesity, and ultimately body weight (100). Various ecologic models of obesity exist; for this proposal we use an adaptation of the model developed by Davison and Birch (2001) to study childhood obesity (See chapter 7) (101); which, in turn, was developed based on the United Nation Children's Fund (UNICEF) conceptual framework of the determinants of malnutrition (Figure 4.1) (102). The ecological model of childhood obesity situates childhood weight status at the center of the model and defines three levels of influence: 1. Child characteristics and child risk factors; 2. Parenting styles and family characteristics; and 3. Community, demographic and societal characteristics (Figure 4.2) (101).

Data Analysis

The specific data analysis procedures conducted for the three main studies of this dissertation are discussed in chapters 5 to 7. An overview of Hierarchical Linear Models (HLM) is presented in this chapter.

Hierarchical Linear Models

Hierarchical Linear Models (also known as multilevel models) originated from the social sciences and education fields. The use of HLM has theoretical and statistical justifications.

Theoretically, HLM is necessary to address the multilevel nature of most social and epidemiological relationships. An example is the ecological systems theory described above, which defines behaviors or health outcomes as a result of interactions of diverse factors at different levels. A common problem in epidemiology is the ecological fallacy where a group level relationship is assumed to hold at the individual level. For example, at the country level meat production is associated with overweight and obesity; however it is incorrect to assume that farmers are at greater risk of overweight and obesity. Conversely, another common mistake is to aggregate data from individuals to gain insight into the groups they belong, without using the appropriate statistical techniques (103).

Statistically, a common practice has been to use individual data analysis techniques, even with data or theories of hierarchical nature. This causes two main problems: Firstly, individuals from the same group will have correlated error terms; which violates an assumption of the linear regression techniques. Secondly, by ignoring context, they are assuming that the magnitude of the associations applies equally to all contexts, which might be another fallacy. An alternative solution to this problem has been to control for the grouping using statistical techniques such as the ANOVA or ANCOVA. However, grouping individual observations greatly decreases statistical power and ignores the variability within groups (103).

Hierarchical linear models are designed to predict values of a dependent variable based on a function of predictor variables at more than one level. An example of a basic two level hierarchical linear model with one predictor at each level would be:

Level-1 Model $BMI_{ij} = \beta_{0j} + \beta_{1j} * (Age) + r_{ij}$

Level-2 Model $\beta_{0j} = \gamma_{00} + \gamma_{01*} (Wealth\ Index_j) + u_{0j}$

$B_{1j} = \gamma_{10} + \gamma_{11*} (Wealth\ Index_j) + u_{1j}$

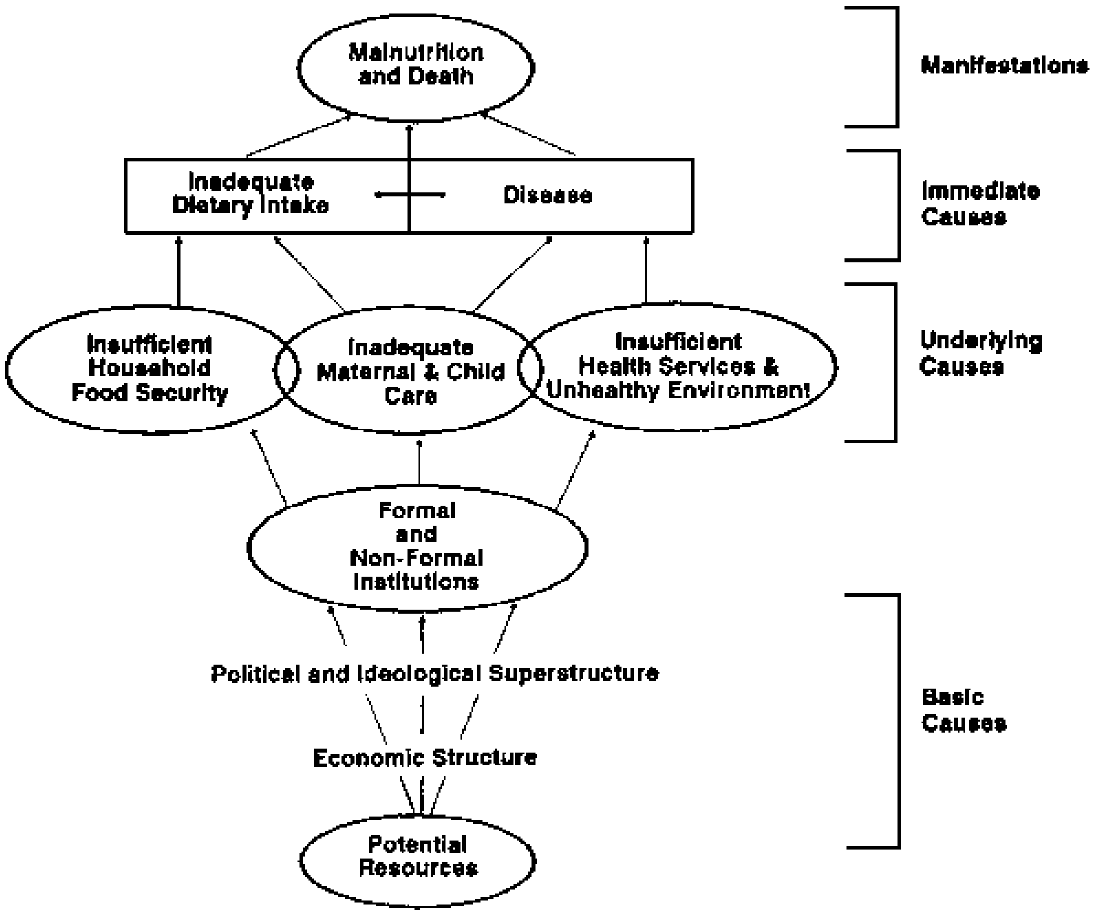
Where β_{0j} is the intercept at level-1 and, in this case, would be defined as the average BMI of children in family j when age and wealth equal 0. β_{1j} is the effect of age on BMI of family j. r_{ij} is the unexplained variance at level-1. γ_{00} is the mean value of BMI after controlling for wealth index. γ_{01} is the effect of wealth index on the average family BMI. u_{0j} is the unexplained variance in the intercept. γ_{10} is the mean value for the slope of age after controlling for wealth index. γ_{11} is the effect of wealth index on the effect of Age on BMI. u_{1j} is the unexplained variability in the effect of age on BMI after controlling dor Wealth Index.

The different types of HLM can be classified into three broad groups:

1. The unconditional models: the most basic form of HLM. Include just the intercepts. Are useful to assess the reliability (or the ability of each group to predict itself) and the intra-class correlation coefficient (ICC) which denotes the proportion of the variability explained at each level.
2. Random intercept models: intercepts are allowed to vary but either slopes are fixed (do not include error terms), or predictors at level-1 are not included
3. Random intercepts and slopes model: Both intercepts and slopes are allowed to vary at level two units. It is possible to include predictors at level-1 and level-2 (103)

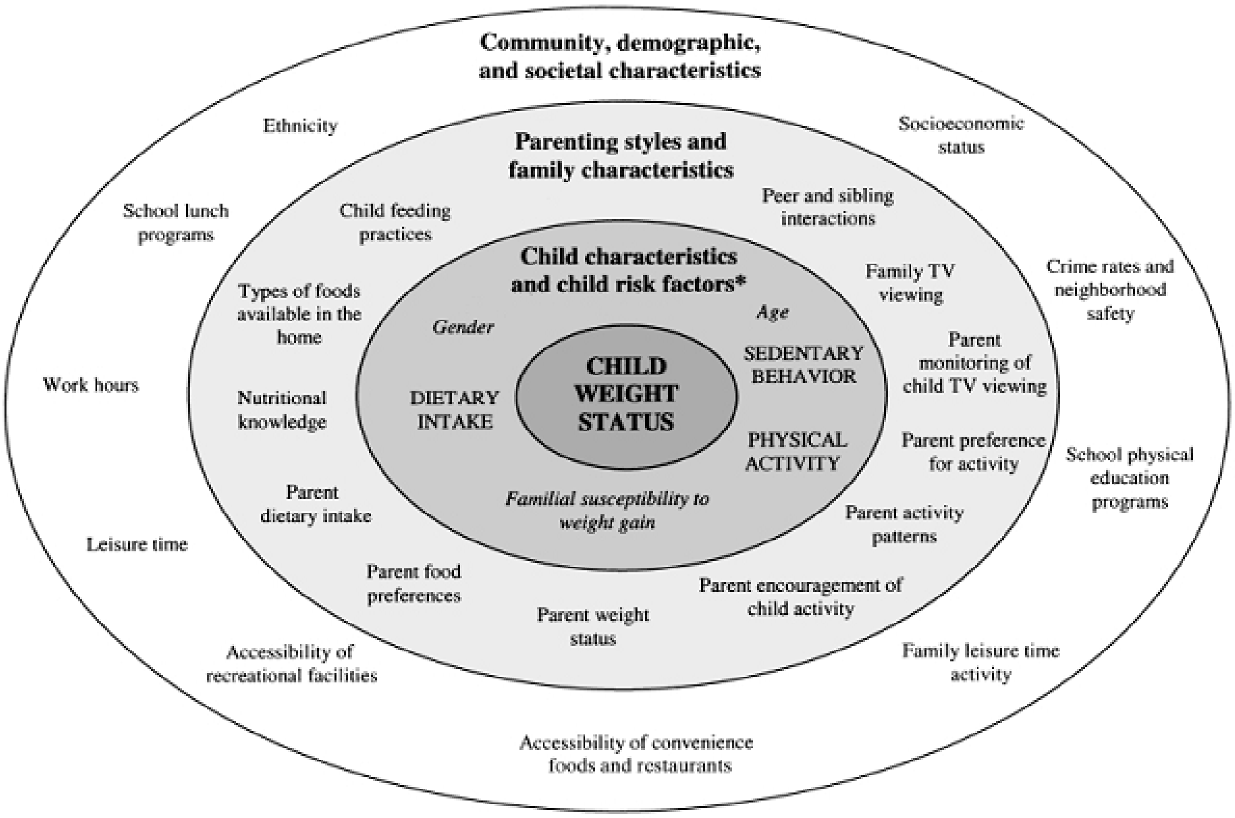
For this dissertation, the goal was to predict children weight status based on different predictors at the family and community levels**.** The final adjusted three-level model of BMI z-score is presented in table 4.2. This is a random intercept fixed slopes model with predictors at level 1, 2 and 3.

Figure 4.1. UNICEF conceptual framework. Determinants of child malnutrition (102).



Source: The State of the world children 1998. UNICEF (102)

Figure 4.2. Ecological Model of Childhood Obesity (Davidson and Birch, 2001) (101)



Source: A contextual model of child overweight, Davison and Birch 2001 (101)

Table 4.1: Description of the 2005 and 2010 Demographic and Health Surveys (DHS) and National Nutrition Surveys (Encuesta de la Situacion Nutricional de los Colombianos, ENSIN 2005)

	DHS (97)		ENSIN (17)	
	2005	**2010**	**2005**	**2010**
Description	Fourth in the series of surveys collected every five years with the objective of identifying problems associated with sexual and reproductive health	Fifth in the series of surveys collected every five years with the objective of identifying problems associated with sexual and reproductive health	First National Survey of the Nutritional Situation in Colombia	Second National Survey of the Nutritional Situation in Colombia
Institution	Profamilia (Private institution specialized in reproductive health)		Colombian Institute of Wellbeing (ICBF)	
Relevant Information	Household and individual questionnaires- includes questions on housing and living conditions, characteristics of all the persons living within the household such as family relationships, ages, etc. Anthropometric measurements of all individuals under 64 years		Questionnaire on health and Physical Activity: Adapted from the International Physical Activity Questionnaire (IPAQ). (Completed by everyone from 12 to 20 y only for ENSIN 2005). Weekly time spent watching television or playing video games (assessed in children ages 5 to 12 in ENSIN 2005 and 5 to 18 in ENSIN 2010). Health section: includes questions on self-perception of body image. (All adults 18 to 64 years). 24 hours recall of food consumption: Interview to the subject and the person that prepared the meals. In the case of children complemented by interviewing school caretakers (one in every ten persons 20 to 64 years of age).	
Sampling design and units	Probabilistic multistage stratified cluster sampling design 3,935 segments 37,000 households (approx.)		Subsample from DHS. 1920 segments 20,000 households (approx)	

Table 4.2: Hierarchical linear model of child BMI. Intercepts as outcome model with all predictors

Level 1 Model (Child)	$\text{BMIZ}_{ijk} = \pi_{0jk} + \pi_{1jk}*(HEIGHT_{ijk}) + \pi_{2jk}*(AGE_{ijk}) + \pi_{3jk}*(GIRL_{ijk}) + e_{ijk}$
Level 2 Model (Household)	$\pi_{0jk} = \beta_{00k} + \beta_{01k}*(WEALTH_{jk}) + \beta_{02k}*(FAMILY\_SIZE_{jk}) + \beta_{03k}*(EXTENDED\ FAMILY_{jk}) + \beta_{04k}*(URBAN_{jk}) + r_{0jk}$
Level 3 Model (Municipality)	$\beta_{00k} = \gamma_{000} + \gamma_{001}(GINI_k) + \gamma_{002}(PARK\ DENSITY_k) + \gamma_{003}(\text{PERCENT URBAN}) + u_{00k}$
Mixed Model	$BMIZ_{ijk} = \gamma_{000} + \gamma_{001}*\text{GINI}_k + \gamma_{002}*\ PARK\ DENSITY_{k\ k} + \gamma_{003}*\ \text{PERCENT URBAN}_k + \gamma_{010}*\text{WEALTH}_{jk} + \gamma_{020}*\ FAMILY\_SIZE_{jk} + \gamma_{030}*\ EXTENDED\ FAMILY_{jk} + \gamma_{040}*\text{URBAN}_{jk} + \gamma_{100}*HEIGHT_{ijk} + \gamma_{200}*AGE_{ijk} + \gamma_{300}*GIRL_{ijk} + r_{0jk} + u_{00k} + e_{ijk}$

Abbreviations: BMIZ= BMI z-score relative to the WHO reference; π_{0jk}=mean BMIZ children of family j in municipality k; $\pi_{1\text{-}3jk}$=slopesof height, age, and girl; β_{00k}= mean BMI of families in municipality k; $BMI_{01\text{-}04k}$=slopes of wealth, family size, extended family, and urban household; γ_{000}=average BMI of a children in the average family from the average municipality; γ_{nnn}=slopes of all level predictors.

CHAPTER 5: COMPARING THREE BODY MASS INDEX CLASSIFICATION SYSTEMS TO ASSESS OVERWEIGHT AND OBESITY IN CHILDREN AND ADOLESCENTS

Ines Gonzalez-Casanova, Olga Lucia Sarmiento, Michael Pratt, Solveig A. Cunningham, Julie A. Gazmararian, Reynaldo Martorell, Aryeh D. Stein

Abstract

Objective: To compare the International Obesity Task Force (IOTF) 2005, Center for Disease Control (CDC) 2000 and World Health Organization (WHO) 2007 body mass index (BMI) classification systems in terms of prevalence estimation and association with different demographic factors. **Methods:** The 18,265 children and adolescents ages 5 to 18 (mean=11.2, SD=3.9 years) in the nationally representative Colombian National Nutrition Survey of 2005 were classified as overweight or obese using IOTF, CDC and WHO criteria. We compared prevalence estimates according to each system and tested associations with age, sex, socioeconomic status and population density. **Results:** The prevalence estimates of combined overweight and obesity differed by system (In males: IOTF=8.5%, CDC=10.8%, WHO=14.1%. In females: IOTF=14.6%, CDC=13.8%, WHO=17.1%, $p<0.001$). Also, the association (odds ratios, OR and 95% confidence intervals, CI) between combined overweight and obesity, and age and sex varied by system. The odds of having overweight and obesity in children (5 to 10 years) compared to adolescents (11 to 18 years) were: IOTF=0.87, 0.77-0.98; CDC= 1.27, 1.14-1.42; WHO=1.21, 1.08- 1.35; those for females compared to males were: IOTF=1.84, 1.6- 2.10; CDC=1.33, 1.171.51; WHO= 1.25, 1.121.41). **Conclusion:** There is lack of consistency among the three main international systems in assessing overweight and obesity in children and adolescents. Appreciably different estimates of prevalence and associations with age and sex are obtained depending on which system is used. Future studies should assess how well each system reflects valid measures of body composition. **Keywords:** adolescents, BMI, Colombia, CDC, children, classification methods, IOTF, Latin-America, overweight, obesity, WHO

Introduction

Overweight and obesity in children and adolescents represents a burden to individuals and populations worldwide, due to associations between obesity and many adverse cardio-metabolic and psychosocial problems *(1)* . Concern with the increase in childhood obesity worldwide has led to the implementation of a wide range of programs and policies *(2)*. Interventions are often designed and targeted based on prevalence estimates and inferred associations with socio-demographic factors obtained from survey data *(1, 2)*. Typically, prevalence of overweight and obesity is estimated by categorizing individuals based on their Body Mass Index-BMI (kg/m^2); accuracy of this approach relies on the relation of this measure to the percentage of body fat (% BF) *(3)*.

The use of BMI is a widely-accepted and affordable method to infer body composition in children and adults *(3)*. However, in children (5 to 10 years) and adolescents (11 to 18 years), where gender and age play an important role in body composition *(4)*, there is not a clear consensus on which BMI classification system should be used to diagnose overweight and obesity *(5, 6)*. Three classification systems are frequently used internationally to assess obesity: 1) the International Obesity Task Force (IOTF) criteria, developed in 2005 by a group of IOTF experts, who extrapolated the adult BMI cut-off points for overweight (25 kg/m^2) and obesity (30 kg/m^2) to datasets from six different countries*(6)*; 2) the U.S. Centers for Disease Control (CDC) growth charts issued in 2000, a revision of the National Center for Health Statistics (NCHS) 1977 growth reference that incorporated data from five national surveys conducted between 1963 and 1994 in the United States (U.S.) and used statistical smoothing techniques *(7)*; and 3) the World Health Organization (WHO) criteria, which was developed by a WHO expert committee in 2007 using the 1977 NCHS growth reference from 5 to 19 years, supplemented with data from the WHO Child Growth Standards for children five and under (to facilitate the transition at age 5) *(5)*. The IOTF has been used increasingly outside of the U.S., but some evidence suggests this classification system has lower sensitivity than WHO, CDC and local classification systems for the diagnosis of overweight and obesity in children and adolescents, compared to percentage of body fat as the gold standard *(8-10)*. Some of the barriers to develop and validate BMI classification systems in older children and adolescents include the difficulty of finding a healthy reference population and the lack of long term follow up studies with information on health outcomes in diverse populations *(5, 6)*. Previous studies have reported that prevalence estimates of overweight and obesity in children and adolescents differ between the IOTF, CDC and WHO classification systems *(11-13)*. Generally, IOTF prevalence estimates are lower than other local and international references, and WHO estimates are higher. However, these studies examined limited age ranges of children, usually in samples that were not nationally representative, and did not describe differences in estimation by demographic characteristics. To address this gap, the objective of this study is to estimate the prevalence of overweight and obesity using the WHO, CDC and IOTF classification systems, to assess their concordance, and to determine whether they suggest different associations with age, gender, location of residence (rural or urban) and wealth in a nationally representative survey from Colombia.

Methods

Sample

We used data from the Encuesta Nacional de la Situacion Nutricional en Colombia (ENSIN) 2005 *(14)*, a nationally representative survey with a stratified cluster design, that is a subsample of the Colombian Demographic and Health Survey (DHS) 2005. The original DHS sample included 37,211 households stratified by clusters (household segments), out of which ENSIN sampled 17,740 households (Figure 1). The response rates for ENSIN ranged between 88% and 99% depending on measurement and region. We included all children and adolescents 5 to 18 years old with available information on age, sex, height and weight. We excluded participants with implausible values for weight, height and BMI (defined as over -/+5 SD away from the mean of the WHO reference population), with missing information on area of residence or the wealth index, and those who were pregnant.

BMI classification and outcome variables

We calculated BMI (weight(kg)/height^2(m^2)) of all participants and classified them as overweight, obese, or neither overweight nor obese using the IOTF, CDC, and WHO cutoffs. IOTF cutoffs are an extrapolation of the adult BMI cutoff points for overweight (25 kg/m^2) and obesity (30 kg/m^2). The CDC system defines overweight as a BMI over the 85th percentile of the reference population and obesity over the 95th percentile. The WHO system defines overweight as a BMI > 1 standard deviation (SD) and obesity as BMI > 2 SD from the mean of the WHO reference population (5).

Socio-demographic characteristics

Age: We computed age from the date of birth and date of interview, rounded it to the nearest integer year, and for the logistic regression models categorized it as children 5 to 10 years and adolescents 11 to 18 years. IOTF provides year-specific cutoffs; while, CDC and WHO provide month-specific cutoffs.

Sex: Male or female

Wealth : We used a wealth index (WI) developed for DHS that assesses presence in the household of a range of assets, such as television, type of flooring, water supply, refrigerator, electricity, radio, television, and domestic servant *(15)*. The wealth index was generated as the first component of a principal components analysis (PCA). Individuals are classified into five categories based on the distribution of the national household population (I=poorest to V=wealthiest) *(15)*.

Population density: Settlements with 10,000 inhabitants or less were classified as rural areas and those with a population of 10,001 or more as urban.

Statistical analysis

We estimated the prevalence of overweight and obesity using IOTF, CDC, and WHO classification systems. We classified as *Obese* all subjects with a BMI above the obesity cutoff points of each classification system and we considered as *combined overweight and obese* all subjects with a BMI above the cutoff point for overweight. . We compared the distributions of overweight and obesity according to WHO and CDC, against IOTF (the most widely used classification system in international settings) using Chi square tests. We did not compare the CDC system against the WHO system to avoid increasing the probability of a Type 2 error due to multiple comparisons.

Logistic regression analysis was conducted to estimate odds ratios (OR) and 95% confidence intervals (CI) of overweight, obesity, and combined overweight and obesity by each of the three classification systems (WHO, CDC, IOTF) according to age, sex, area of residence, and wealth index quintile (all the variables were modeled simultaneously). We tested for all possible two way multiplicative interactions (n=8) by age, sex, SES, and population density, using $p<0.05$ as a threshold. Analyses were conducted using SAS software, Version 9.2 of the SAS System for Windows. We used SAS callable SUDAAN (Research Triangle Institute, Research Triangle Park, NC, 2010) to account for the complex survey design and maintain the representativeness of the sample.

Results

We excluded 99 individuals with implausible values for weight, height or BMI, three individuals who lacked information on area of residence, and 446 girls who were pregnant. The final sample included 18,265 children and adolescents, 8,817 boys and 9,448 girls.

BMI by age and sex

BMI was normally distributed. The mean BMI increased with age (Figure 2); it was similar in boys and girls up to age 12, but after that age the patterns diverged, with a greater BMI increase among girls.

Prevalence of overweight and obesity by age and sex using three classification systems

The prevalence of combined overweight and obesity was highest according to the WHO classification in both males and females at all ages (Figure 3); the CDC classification yielded the lowest prevalence in males, and the IOTF classification yielded the lowest prevalence in females. Overall, the CDC and WHO distributions of overweight and obesity differed significantly from the IOTF distribution ($p<0.05$) (Table 1).

Overweight and obesity demographic patterns according to IOTF, CDC, and WHO classification systems

Overweight and obesity pattern according to IOTF: According to the IOTF classification, girls had higher odds than boys of combined overweight and obesity (OR= 1.84, CI 1.61, 2.10), but there was no association of sex with obesity alone. The likelihood of younger children (5 to 10 y) being obese was 1.52 that of adolescents. We found a significant interaction ($p<0.05$) between age and sex for combined overweight and obesity: 5 to 10 year-old females were less likely to be overweight or obese (OR=0.69, CI 0.59, 0.81) than 11 to 18 year-old females; while 5 to 10 year-old males were 1.28 (1.04, 1.58) times more likely to be overweight or obese than older boys. Both obesity and combined overweight/obesity were elevated in WI quintiles III, IV, and V as compared to the lower quintiles (Table 2). For combined overweight and obesity, there was a significant interaction between WI and sex ($p<0.05$): the positive association of overweight with WI was stronger in males than in females. Population density (urban vs. rural) was not significantly associated with overweight, obesity, or combined overweight and obesity after controlling for WI (Table 2).

Comparing overweight and obesity according to the CDC and IOTF systems: The magnitude of the CDC estimate of the association between being female and overweight and obesity (OR=1.33, CI 1.17, 1.51) was smaller than the IOTF estimate (OR=1.84, CI 1.61, 2.10). The association of combined overweight and obesity of with age was opposite to the one found with IOTF (OR of children versus adolescents: CDC=1.27, CI 1.14, 1.42 vs. IOFT= 0.87, CI, O.77, 0.97). Similar to IOTF, the interactions between age and sex for combined overweight and obesity were significant ($p<0.05$). The positive associations of obesity, and combined overweight and obesity with WI were broadly similar between the CDC system and the IOTF system (Table 2).

Comparing overweight and obesity according to the WHO and IOTF systems: Using the WHO classification system there was a positive association between combined overweight and obesity and being female (OR=1.25, CI 1.12, 1.41); the magnitude of this estimate was significantly different from the IOTF estimate ($p<0.05$) (Table 2). The association of combined overweight and obesity with age was also opposite to the one found with IOFT (and consistent with CDC). Similar to IOTF, there was no association between obesity and sex. The interaction between age and sex for combined overweight and obesity was significant ($p<0.05$). The positive association of obesity and of combined overweight and obesity with WI was consistent with the IOTF system (Table 2).

Discussion

We found prevalence estimates of overweight and obesity in Colombian 5 to 18 year old children and adolescents differed significantly across classification systems. These differences are consistent with other studies that have reported that the WHO system generally yields the highest prevalence estimates, while the IOTF system yields the lowest *(8, 11-13)*. It is critical to consider the effect of the choice of classification system on the prevalence estimate when comparing surveillance information from different settings or studies describing secular trends. The three classification systems for ages 5-18 years were developed with different objectives: IOTF included surveys conducted in six different countries (including those used to develop NCHS 1977) with the objective of obtaining an international reference *(6);* CDC used five different U.S. national nutrition and health surveys conducted between 1963 and 1994, with the objective of developing a reference for the U.S. population) *(7);* and finally, WHO was developed using only NCHS 1977 to have a "non- obese sample with expected heights" and to obtain an equivalent of the healthy population used to develop the growth charts for children under five *(5).* These different objectives and source of reference populations partially explain the differences in prevalence estimation. WHO yields the highest prevalence estimate of overweight and obesity because their reference population is intended to be a "non-obese sample" whereas CDC and IOTF are derived using more recent data in which the BMI distribution of the reference populations is already shifted towards the right because of the recent increase in child and adolescent BMI.

In this study, we used these three most widely used classification systems to estimate associations between basic socio-demographic characteristics and overweight and obesity. We found that the patterns of association differed depending on the classification system, especially in relation to age and sex. For example, according to IOTF but not according to WHO and CDC, there was an inverse association between age and overweight. The most relevant difference we found was for combined overweight and obesity, where according to the IOTF classification system there was an inverse association between child age and overweight or obesity, while according to the WHO and CDC systems this association was positive. It is possible that because IOTF is the only system which uses age in integer years and not in months (6), this system misses small age related variations in BMI, which may be more relevant children (5 to 10).

There was greater concordance between the estimates generated with the three systems when we examined obesity alone, rather than combined with overweight. This better agreement is encouraging because childhood obesity is more strongly associated with negative health outcomes than is overweight *(16)*. Apart from minor differences among the IOTF, and the CDC and WHO classification methods in the significance of association with Wealth Index (WI), we found no mayor disagreement among the three systems in the estimates of association with WI or population density after controlling for age and sex. In this sense, age and sex are different type of predictors because they were considered by all three classification systems when defining the cut-off points *(5, 6, 12)*, thus the variations in prevalence estimation are highly sex- and age-specific. This potentially explains the differences in association found for combined overweight and obesity.

The results of this paper outline the importance of considering the differences in BMI and population estimates depending on the classification system selected; this is especially relevant for researchers, organizations, and policy makers interested in using survey data to study associations of different socio-demographic factors with overweight and obesity in children and adolescents. It is particularly important to consider age and sex as covariates in all studies of childhood and adolescence overweight or obesity; not only because they are two of the most common confounders, but also, because they can account for part of the error introduced by the BMI classification systems. The use of waist circumference has recently been suggested as a reliable and feasible alternative to BMI for assessing total body fat in this age group *(17)*. However, there are similar problems with the interpretation of this measurement.

The main goals of assessing childhood obesity at the population level are to identify the prevalence, trends, and determinants of this condition, to design appropriate public health interventions to prevent it, and to identify populations at risk of suffering the health consequences of obesity. Hence, in order to advance the field of obesity research and prevention, we need to establish the potential of the available

BMI classification systems to reflect percentage of fat and to predict adverse health consequences, and develop valid and reliable systems to assess overweight and obesity in children and adolescents around the world. In the mean time, when studying associations of overweight and obesity with demographic characteristics in school children and adolescents, we recommend considering the objectives and limitations of the three systems in order to select the most appropriate for each study population. IOTF was the first recommendation designed specifically to be used in international populations, it used surveys from six different countries from 1963 to 1993, and the extrapolation of the adult BMI cut off points facilitates the transition from assessing children to adults BMI. However, it has low sensitivity diagnosing overweight and obesity compared to the other methods and does not provide month- specific cut points. The CDC system is frequently used internationally; however, it was designed using only information from the U.S., with the objective of documenting obesity trends in that country. The WHO classification is the only system designed using data from before the obesity epidemic; hence, it might be the most appropriate for countries where the prevalence of childhood obesity is still relatively low, such as Colombia. BMI is a convenient and feasible tool to screen for overweight and obesity in children and adolescents. However, further studies are needed to improve the interpretation of this measure, and to recommend a unique international BMI classification system that adequately reflects percentage of fat and risk of negative health outcomes.

This study has some limitations. First, we do not have information on body composition, including percent body fat, or reliable information on health outcomes (such as incidence of adult obesity, diabetes, and cardiovascular disease, other morbidities or early death) that we could use to determine which classification system performs best as a screening tool. Hence, we can only describe differences in prevalence. Also, in this cross sectional study, we cannot assess incidence of obesity, or follow the sample to assess BMI over time. These limitations add to the difficulties of assessing body composition in children and adolescents, where variations due to puberty and sexual maturation complicate the creation of universal cut-offs to classify overweight and obesity *(18-20)*. Still, the study included a large, nationally representative sample of Colombian children and adolescents and used three current and widely-recommended BMI classification systems. This approach allowed us to demonstrate the differences in estimates of prevalence and in the inference about associations with demographic factors among the three systems most frequently used to assess overweight and obesity internationally.

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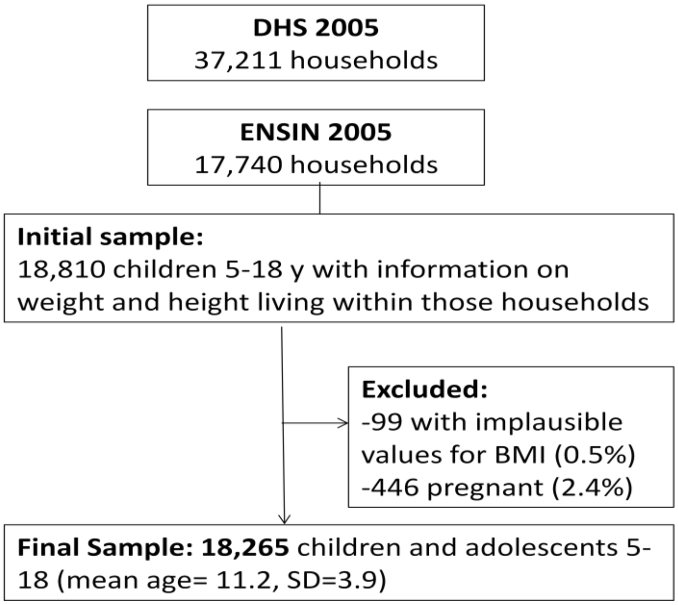
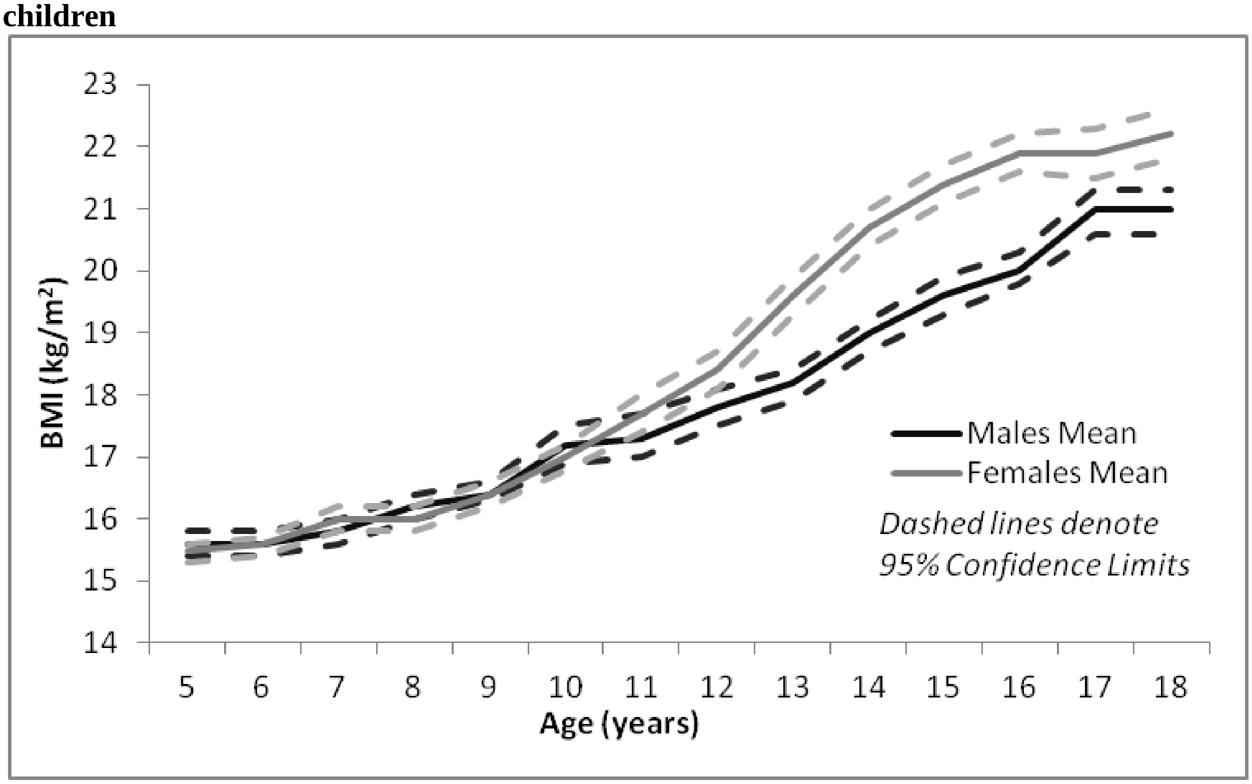
Figure 1: Description of the sample for this study. From DHS to the final sample of children and adolescents



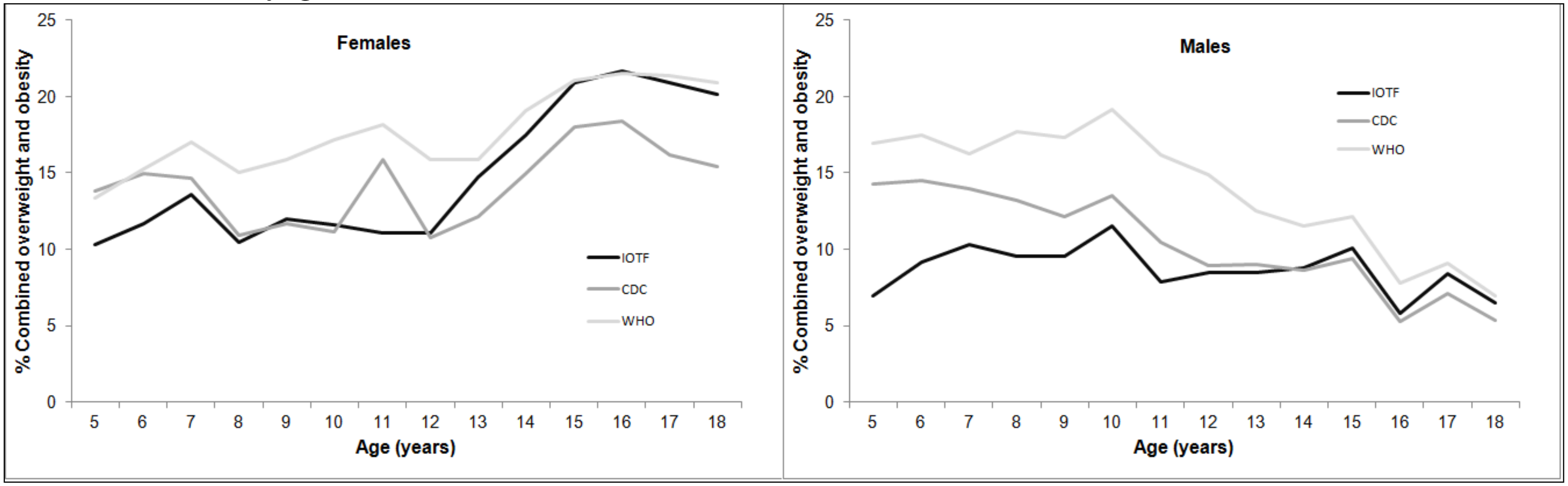
Abbreviations: DHS (Demographic and Health Surveys); ENSIN (Encuesta Nacional de la Situacion Nutricional en Colombia); BMI(Body Mass Index) SD(Standard Deviation)

Figure 2: Body Mass Index (BMI, kg/m^2) by age in years in Colombian 5 to 18 year old children



Data Source: Colombian National Nutrition Survey (DHS/ENSIN) 2005

Figure 3: Prevalence of combined overweight and obesity in children 5 to 18 years in Colombia estimated using WHO, CDC and IOTF classification methods by age and sex



Data Source: Colombian National Nutrition Survey (DHS/ENSIN) 2005.

Table 1: Prevalence of overweight and obesity by sex in 5 to 18 year old children in Colombia

% (SE)	Male (8817) *			Female (9448) *		
	IOTF[a]	CDC[b]	WHO[c]	IOTF	CDC	WHO
Neither overweight or obese	91.5(0.5)	89.2(0.5)	85.9(0.6)	85.4(0.6)	86.2(0.6)	82.9 (0.6)
Overweight (excluding obese)	6.7(0.4)	7.3(0.5)	10.3(0.5)	12.5(0.6)	10.6(0.5)	13.9(0.6)
Obese	1.8(0.2)	3.5(0.3)	3.8(0.3)	2.1(0.2)	3.2(0.3)	3.2(0.3)

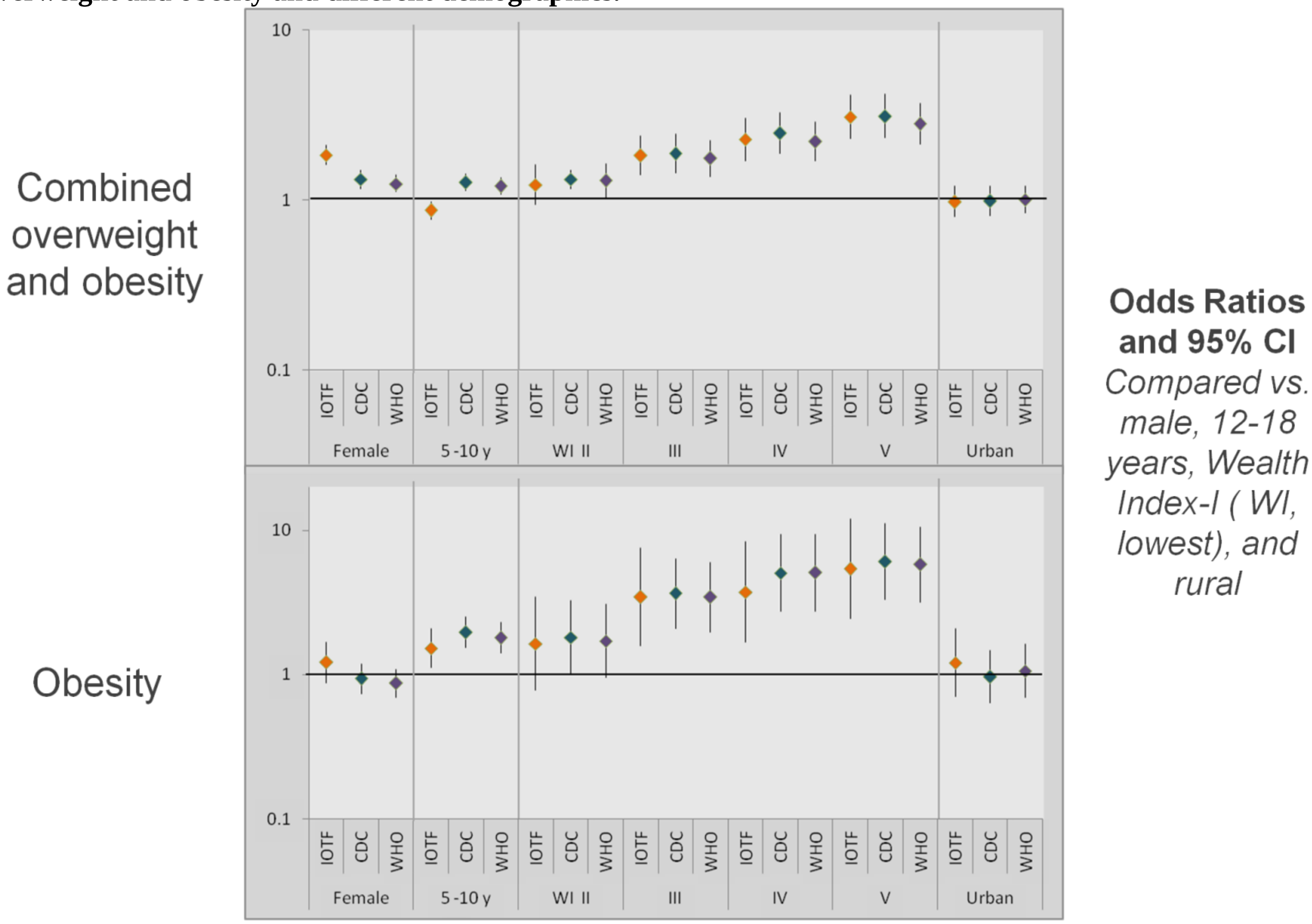
[a] Cole, T., et al., *Establishing a standard definition for child overweight and obesity worldwide: international survey.* BMJ, 2000. 320(7244): p. 1240-1243. [b] Kuczmarski, R., et al., *2000 CDC Growth Charts for the United States: methods and development.* Vital and health statistics. Series 11, Data from the national health survey, 2002(246): p. 1-190. [c] de Onis, M., et al., *Development of a WHO growth reference for school-aged children and adolescents.* Bulletin of the World Health Organization, 2007. 85(9): p. 660-667. **The distribution of overweight and obesity differs by WHO, CDC, IOTF classification systems within sex (p<0.05). Data Source: Colombian National Nutrition Survey (ENDS/ENSIN) 2005. SE= Standard Error.*

Table 2: Odds Ratios (OR) and 95% Confidence Intervals (95% CI) of the association between overweight and obesity and different demographics.

	IOTF			CDC			WHO		
	OR	95% CI LL	95% CI UL	**OR**	95% CI LL	95% CI UL	**OR**	95% CI LL	95% CI UL
Obesity									
Female	1.22	0.88	1.68	0.94	0.74	1.18	0.87	0.69	1.09
5 -10 y	1.52*	1.12	2.08	1.96*	1.54	2.51	1.80*	1.41	2.31
WI II	1.64	0.78	3.46	1.81*	1.01	3.27	1.71	0.95	3.08
III	3.45	1.59	7.52	3.66	2.09	6.40	3.46	1.98	6.02
IV	3.74	1.67	8.39	5.06	2.74	9.34	5.10	2.76	9.43
V	5.43	2.44	12.10	6.08	3.31	11.16	5.79	3.18	10.57
Urban	1.21	0.70	2.10	0.97	0.64	1.48	1.06	0.69	1.63
Combined overweight and obesity									
Female	1.84*	1.61	2.10	1.33*[a]	1.17	1.51	1.25*[a]	1.12	1.41
5 -10 y	0.87*	0.77	0.98	1.27*[a]	1.14	1.42	1.21*[a]	1.08	1.35
WI II	1.23	0.94	1.61	1.33*	1.17	1.51	1.30*	1.02	1.64
III	1.83*	1.41	2.39	1.88*	1.44	2.45	1.76*	1.38	2.26
IV	2.28*	1.71	3.04	2.48*	1.88	3.26	2.21*	1.70	2.88
V	3.09*	2.29	4.16	3.11*	2.32	4.19	2.81*	2.13	3.70
Urban	0.98	0.80	1.21	0.99	0.81	1.22	1.01	0.84	1.21

*In a model including sex, age categorical, wealth index and population density, with male, 11-18 years, Wealth Index I, and rural as the reference. [a]OR estimate significantly different from IOTF estimate (p<0.05).*Statistically significant p<0.05. Abreviation: WI I to V= Wealth Index categories one to five, from lowest SES to highest. UL=Upper Level, LL=Lower level*

Figure 4: Odds Ratios (OR) and 95% Confidence Intervals (95% CI) of the association between overweight and obesity and different demographics.



In a model including sex, age categorical, wealth index and population density, with male, 11-18 years, Wealth Index I, and rural as the reference. [a]*OR estimate significantly different from IOTF estimate (p<0.05).*Statistically significant p<0.05. Abreviation: WI I to V= Wealth Index categories one to five, from lowest SES to highest. UL=Upper Level, LL=Lower level*

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CHAPTER 6: CHANGES IN OVERWEIGHT AND OBESITY AMONG CHILDREN AND ADOLESCENTS IN COLOMBIA BETWEEN 2005 AND 2010

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Reynaldo Martorell, Michael Pratt, Aryeh D. Stein

ABSTRACT

Objectives. We describe five-year changes in overweight and obesity among children and adolescents in Colombia, using information from two large national nutrition, demographic, and health surveys from 2005 and 2010.

Methods. We used chi-square tests to assess significant changes in the prevalence of overweight and obesity in Colombian children 5 to 18 years by age, sex, wealth, urban residence, and region and explored associations between screen time and overweight.

Results. There were no significant changes in the prevalence of overweight or obesity in Colombian children and adolescents 5-18 years overall (overweight= 12.2 to 12.7%; obesity=3.5 to 3.9%, $p>0.05$), or within sex, wealth, urban, rural, or region specific subgroups in these 5 years. The relationship between screen time and overweight in these children disappeared after controlling for wealth.

Conclusions. Colombia, a middle income country in Latin America, has made obesity prevention a priority through a wide variety of public policies to prevent obesity and promote physical activity. These policies seem to have been effective preventing child and adolescent overweight and obesity, further studies should look at the specific impact of each policy and assess the feasibility of replicating them in other settings.

Introduction

Low and middle income countries (LMIC) are experiencing a decrease in the prevalence of under-nutrition and an increase in overweight, resulting from population-level changes in diet and physical activity patterns[1, 2]. In Latin America, this nutrition transition has been particularly rapid in urban areas[3, 4] and parallels the region's economic development[5, 6]. In LMIC, including those in Latin America, the nutrition transition generally follows a consistent pattern[2, 5, 7, 8]: Overweight and obesity are initially concentrated in urban areas and in the wealthy, and spread to rural areas and the economically disadvantaged as these countries reach a threshold of economic development [4, 8-10]. Most studies documenting the nutrition transition in Latin America have focused on adult women and preschool children[11-15]. Nationally representative studies of the prevalence of overweight and obesity in children and adolescents in LMIC are rare [11]. Children (ages 5-11) and adolescents (ages 12-18) are developing physically and cognitively, hence this stage is key for determining adult body composition and shaping behaviors such as diet, physical activity, and sedentary behaviors[16]. To develop and target programs, policies and interventions to prevent child and adolescent obesity, it is important to conduct analyses on nationally representative samples. Recently, Colombia conducted two large national nutrition surveys (Encuesta Nacional de la Situacion Nutricional en Colombia-ENSIN 2005 and 2010), which included representative samples of children and adolescents. Data from ENSIN 2005 suggests a higher prevalence of overweight in children and adolescents from the wealthier strata[17], a pattern consistent with an early stage of the nutrition transition . The objective of this study was to use the information from these surveys to describe the nutrition transition as reflected in Colombian children and adolescents between 2005 and 2010. We therefore describe changes in prevalence of overweight and obesity in Colombian children and adolescents 5 to 18 by age, sex, wealth, urbanization, region, and screen time. 2010[18]).

Methods

Sample Description

This analysis included data from ENSIN (a subsample of the Colombian Demographic and Health Surveys-DHS) from 2005 and 2010. The sample for these surveys was obtained using a multi-stage, stratified, clustered design, and included 37,211 households in 2005 and 50,670 households in 2010[19, 20]. It is representative of the Colombian population at a national level[19, 20]. Extensive information on data collection procedures and data quality can be found at the Demographic and Health Surveys (DHS)[21] or Instituto Colombiano de Bienestar Familiar[22] websites. Briefly, data on height and weight was measured by trained dietitians; screen time was reported by the main caregiver. The response rate was 89% for ENSIN 2005 and 84% for ENSIN 2010. Data collection and data management protocols were adapted from the ones developed for the National Health and Nutrition Examination Surveys of the United States[23].

For this analysis, we included all children and adolescents between 5 and 18 years old, who had available information on height and weight. We excluded children with values on weight, height or BMI that were ≥ 6 SD above the mean of the World Health Organization-WHO reference population)[24], with missing values on any of the socio-demographic indicators (age, sex, wealth index, area of residence, region), or who were pregnant (figure 1). Information on time spent watching television or playing video games (screen time) was collected only for children 5-11years.

Outcome

Overweight and obesity: Calculated Body Mass Index-BMI (weight(kg)/height^2(m^2)). We defined overweight as a BMI > 1 standard deviation (SD) and obesity as BMI > 2 SD from the mean of the reference population[25].

Exposure

Screen time: Studies from high income countries have identified screen time (the most common measure of sedentary behavior in children) as an important determinant of overweight and obesity, as well as an independent determinant of decreased fitness, lower self-esteem and socialization skills, and decreased academic achievement. [26] Time spent watching TV or playing videogames was assessed in 2005 and 2010 for children 5-11 years, by asking the primary caregivers how many hours and minutes per day or per week the child usually spent in front of a screen, either watching television or playing video games. Using the international recommendation for screen time in children of <2 hr per day[26], we classified children as meeting (<2 hours) or exceeding the recommendation (2 or more hours).

Socio-demographic characteristics

Age: Age was categorized as 5 to 11 years (elementary school age) and 12 to 18 years (secondary school age).

Socioeconomic Status (SES): Assessed using a wealth index (WI) developed for DHS based on the presence in the household of a range of assets, such as television, type of flooring, water supply, refrigerator, electricity, radio, television, domestic servant[27]. The wealth index was generated as the first component of a principal components analysis (PCA). Individuals are classified into five categories based on the distribution of the national household population (I=poorest to V=wealthiest) [27].

Urbanization: The main city of the municipality as well as areas of the municipality with basic services such as water, electricity, pavement, health services, etc, are considered urban. Areas without such services are considered rural.[28]

Region: Colombia is divided into six main regions: Atlantica, Oriental, Central, Pacifica, Bogota, and Amazonia. Atlantica is a tourist destination and important investments have been made to promote its beaches, however, an important part of the local population does not benefit from these investments, generating substantial inequality in the region; Oriental is rich in woods and plains, and has an important cattle and farm industry; Central is the most industrialized region in the country and includes important metropolitan areas; Pacifica, the poorest region in the country, has been especially impacted by internal armed conflict; Bogota is the capital city and is the largest metropolitan area in Colombia; Amazonia is the largest and least populated region, including some of the most inaccessible communities, and has been also affected by armed conflict. [29]

Statistical Analysis

Changes in the prevalence of overweight and obesity by demographic characteristics

We calculated the prevalence of overweight and obesity in children and adolescents by sex, age, wealth index quintiles, population density, and region. We assessed statistical significance of the differences in prevalence of overweight and obesity between 2005 and 2010 for these different subgroups using chi-square tests.

Estimating incidence from prevalence

Prevalence (proportion of the population that is overweight or obese at one specific point in time) is one way to monitor the epidemiology of childhood obesity. However, incidence (number of new cases of obesity over those at risk in a certain period of time) is a better measure of potential risk of becoming obese and of temporal changes in the epidemiology of childhood and adolescence obesity. Programs and policies to prevent obesity should target population subgroups where obesity is increasing rapidly (those who have greater incidence of obesity). Further, evidence suggests that countries with low prevalence of overweight and obesity and improving economies usually have a high incidence of childhood and adolescence obesity, which later plateaus after reaching a certain prevalence threshold.[30] Hence, information on incidence, together with prevalence, is important to better understand the nutrition transition in different countries. Incidence is typically calculated from prospective studies; however nationally representative cohort studies are expensive and infeasible in most LMICs. Under certain circumstances incidence has been estimated from repeated cross-sectional studies, particularly in the field of HIV (human immunodeficiency virus) [31, 32]. We estimated the incidence of obesity (not including overweight) in children 5 to 11 years and adolescents 12 to 18 years in Colombia from the information on weighted prevalence from 2005 and 2010 of different age groups. We made the following assumptions to account for the cross sectional nature of this data: 1) that the epidemic is stable, which means that the point prevalence observed for people at certain age is assumed to be the same prevalence that would be observed for younger people when they reach the same age; 2) that incidence was constant during the 5 years between the two surveys (e.g. if there was an increase in prevalence from 5% to 10% then we assumed prevalence increased 1% each of the five years); 3) that mortality in these children and adolescents is negligible, and that mortality is the same in both obese and non-obese individuals; 4)that obesity prevalence was 0 at birth and 3.1% in children 0-4 years (data from ENSIN 2005); and 5) that children and adolescents who become obese remain obese (and thus are not at risk anymore).We adapted the spreadsheet published by Hallet et al [18] by considering mortality in both obese and non-obese equal to 0.01 and we modified the age categories to 5-11 and 12-18. All calculations were based on weighted estimates and sample sizes. This estimation was conducted using Microsoft Excel 2010.

Screen time distribution and association with overweight and obesity

We calculated the proportion of children 5 to 11 years who reported watching two or more hours of screen time per day stratified by wealth index quintiles, population density, and region. Chi-square tests were used to assess changes in the distribution of screen time between 2005 and 2010 within these subgroups.

We assessed the prevalence of overweight and obesity by screen time and used chi-square tests to compare the prevalence of overweight and obesity in children who reported less than two hours of screen time, to the prevalence in children who reported two or more hours. We used multiple logistic regressions to control for age, sex, place of residence, wealth, and region.

Sample weights were used to account for the sampling design. All analyses were conducted using SAS 9.3 and SAS callable SUDAAN.

Results

The final sample for analyses of overweight and obesity included 18,265 children 5 to 18 years in 2005 and 54,131 in 2010. The final sample for analyses that included screen time was 6,395 children 5 to 11 years in 2005 and 12,098 in 2010. (Figure 1) Children 5 to 11 and girls each represent about 50% of the samples (Table 1), and the majority was from urban areas (76% and 68%, respectively). There was a decrease in the proportion of children and adolescents from Amazonia from 28% in 2005 to 19 % in 2010. All differences were addressed through sample weights.

Changes in overweight and obesity from 2005 to 2010

The overall prevalence of overweight and obesity did not change significantly between 2005 (12.2% and 3.5%, respectively) and 2010 (12.7% and 3.9%, respectively) (Table 2). The only significant differences observed were increases in the prevalence of obesity in adolescents (12 to 18) from 2.6% in 2005 to 3.4% in 2010 ($p<0.01$), and in overweight and obesity in the second lowest wealth quintile ($p<0.01$); however, the test for heterogeneity is not significant($p>0.05$). There was a decrease in the prevalence of overweight and obesity in Amazonia ($p<0.01$).

The incidence of obesity in children 5 to 11 years was 1.5 new cases per 1000 person years (PY) and in adolescents 12 to 18 years the incidence was 2.6 new cases per 1000 PY.

Changes in screen time from 2005 to 2010 and overweight and obesity in children

The percentage of children 5 to 11 years who watched two or more hours of television per day was similar in 2005 and 2010 (57.6% and 57.5% respectively). We observed no significant differences between 2005 and 2010 within strata of sex, wealth index, place of residence, and region (data not shown).

Overweight and obesity by screen time

The prevalence of overweight and obesity was significantly higher among children who reported two or more hours of screen time compared to those who watch less than two hours per day in both 2005 (20.5% vs. 15.5% overweight or obese) and 2010 (21.8% vs. 16.6% overweight or obese) (Figure 2). However, after adjusting for age, sex, wealth, place of residence, and region, this relationship was attenuated ($p>0.05$ in 2005 and 2010).

Discussion

In this study, we used information from two national nutrition and health surveys from Colombia to describe changes in the prevalence of overweight and obesity in children and adolescents, to estimate incidence rates in these two age groups, and to explore associations between screen time and combined overweight and obesity in this country.

Colombia is the fourth largest economy in Latin America. If the nutrition transition in this country was following a pattern similar to that observed in other LMICs with similar economies, we would expect either a higher prevalence of childhood or adolescence overweight and obesity or a steep increase in prevalence over time. However, the results of this analysis show a relatively low prevalence of overweight and obesity in Colombian children 5 to 18 years and no significant changes in prevalence between 2005 and 2010. This is in marked contrast to Mexico, where the prevalence of combined overweight and obesity in children 5-12 years increased from 27% in 1999 to 35% in 2006[33] and then stabilized at 35% in 2012. The prevalence of obesity in children and adolescents (6 to 18 years) from Brazil rose from 4.1% to 13.9% between 1975 and 1997, [34] Evidence suggests that there has been a plateau in the prevalence of overweight and obesity in the last decade in some HIC and LMIC[35]. Results from our study show no increase in the prevalence of obesity in children 5 to 11 and a slight increase of 0.8% in the prevalence in adolescents 12 to 18. Further, we estimated an incidence of 1.5 new cases of obesity per 1000PY in children 5 to 11 and 2.6 new cases per 1000PY in adolescents; which is extremely low compared to the incidence in the United States (the only country with available data on national incidence of obesity in adolescents) where the five-year incidence (1996 to 2001) was of 12.7%[30].

A possible explanation for our results is the low degree of economic globalization in Colombia. Globalization is accepted as one of the factors promoting the nutrition transition in Latin America, particularly the influence of 'Western' lifestyles, such as a diet high in saturated fats and sugars and an increase in screen time promoted by the import of new technologies, mainly coming from the United States [36-38]. Colombia did not have a free trade agreement with the United States until 2011 [39], hence exposure to goods and technologies coming from this and other high income countries started late, compared with other countries with similar economies, such as Mexico and Brazil. This new commercial relationship between the US and Colombia is not reflected in the 2010 ENSIN. Moving forward, it will be important to study the impact of this policy.

Colombia has been in the forefront of public health initiatives designed to prevent overweight and obesity at the national and local levels in Colombia. These include the "Ciclovia" project in Bogota, which began in 1976 and was the first initiative in the world to close the streets to traffic at least once a day, which allows people to use them for different physical activities; there are currently close to 200 "ciclovias" throughout the country[40]. Another example is the "Muevete" (Move) program, which started in Bogota in 1998 and has expanded to other Colombian cities. This program couples a mass media campaign with programs to promote physical activity in schools, work sites, health care centers, and community settings[41]. Colombia has enacted laws that aim at strengthening the prevention and control of chronic diseases through the promotion of healthy lifestyles. These policies include the National Public Health Plan , (Plan Nacional de Salud Publica, Law 1122 of 2007); the law 1355 of 2009 (also known as "the obesity law" which identifies obesity as a major public health problem and outlines suggestions to promote healthy eating and physical activity in the Colombian population[42]); the creation of a multidisciplinary commission to coordinate and guide the promotion, development, and measurement of physical activity (Decreto 2771of 2008), and the administrative agreement between the Ministry of social protection and the former Colombian Sports Institute (COLDEPORTES) of 2011 to develop a strategy to promote physical activity and healthy lifestyles through the national sports network, as well as to prevent non-communicable diseases. These policies are in line with others from the sports and recreation sector which promote physical activity, such as the 1997 law for culture promotion that promotes physical activity through culture [43], the decennial national sports, recreation, physical education, and physical activity plan 2009-2019, and the act of 2011 which transformed the National Sports Institute (COLDEPORTES) into "the sports, recreation, physical activity, and use of free time administrative department". These policies are not common in other Latin American countries, especially before the obesity epidemic. If these policies have been effective in Colombia in preventing an increase in childhood and adolescence overweight and obesity, the feasibility of adapting and implementing them in other countries with similar economic and social characteristics should be assessed.

On the other hand, the few significant differences we found in this analysis should not be overlooked. We found a 0.8% increase in the prevalence of obesity in adolescents (12 to 18 years). Obesity is associated with worse health outcomes than overweight; hence, this increase in adolescents might suggest a need to target interventions to overweight children to prevent them from becoming obese. Adolescents have often been overlooked by public health programs and research. Future interventions to prevent obesity in Colombia should consider targeting this age group. Other significant change was the decrease in overweight and obesity in Amazonia. This region has the most disperse population and includes some of the most inaccessible communities, and has been greatly affected by the armed conflict. [29] Further qualitative and quantitative studies are needed to adequately assess the nutritional status of the population in Amazonia and design interventions that target their specific needs and characteristics.

Another finding of this study was the association between overweight and obesity and screen time in children 5 to 11 years. This association was attenuated after adjustment for age, sex, wealth, place of residence, and region. The main confounder was wealth: children of wealthy households have both a higher prevalence of overweight and obesity and of watching two or more hours of television or videogames per day. These findings outline the importance of socioeconomic status, and suggest the need to consider it in the design of programs to prevent childhood obesity or decrease screen time in Colombia.

Despite the contributions of this study, at least three limitations should be noted. First, it is a comparison of two cross-sectional studies, thus limiting the ability to establish causality. Second, screen time was assessed only in children 5 to 11 years in 2005; hence the association of screen time and overweight and obesity could not be assessed in adolescents. Third, incidence was calculated from two cross-sectional surveys, adapting a method that has only been tested for HIV. Nonetheless, this study also has important strengths to consider. First, it included two large nationally representative surveys of Colombia with high quality data collection methods. Secondly, we were able to study changes by different demographic characteristics, which allowed us to compare the prevalence and incidence of overweight and obesity in Colombian children and adolescents to that of other countries. Finally, to our knowledge, this is the first study that uses a method validated in other discipline to estimate childhood and adolescence incidence rates.

Results from this study raise important questions about the specific factors associated with the prevalence of overweight, obesity and screen time in Colombia, and how they have interacted to slow the nutrition transition. If Colombia's emphasis on obesity prevention proves to have resulted in a slower nutrition transition in children and adolescents, these results should be further disseminated.

Figure 1: ENSIN 2005 and 2010 final overweight and obesity and screen time final samples included in this study

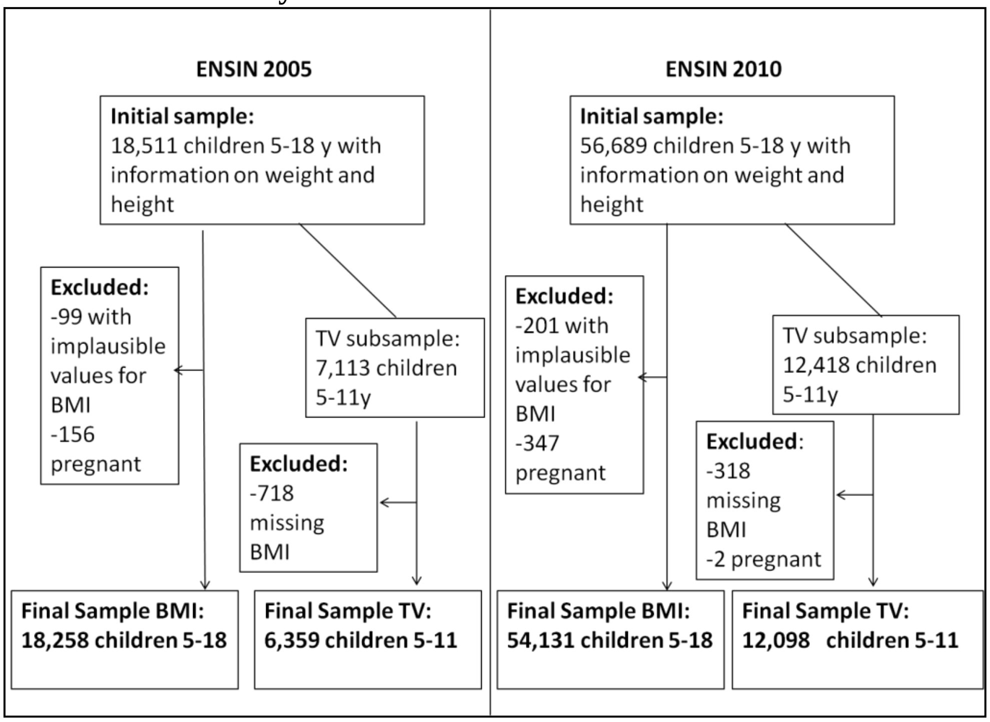


Table 1: Characteristic of Colombian children and adolescents in 2005 and 2010.

	Children included in analysis of overweight and obesity		**Children included in analysis of screen time**	
	2005	**2010**	**2005**	**2010**
Total sample	18,265	54,131	6,395	12,098
5-11 years (%)	53	47	100	100
Girls (%)	52	50	50	48
Urban (%)	76	68	79	68
Wealth Index (%)				
I (Lowest)	24	34	20	32
II	28	26	28	26
III	22	18	23	20
IV	16	13	17	13
V (Highest)	10	9	12	9
Region (%)				
Atlantica	24	23	21	24
Oriental	11	15	16	14
Central	18	24	16	23
Pacifica	15	14	11	13
Bogota	4	6	8	6
Amazonia	28	19	27	20

Note: Differences in sample proportions were addressed through sampling weights to assure the national representativeness of the sample.

Table 2: Prevalence (%) of overweight and obesity by demographic factors in Colombian children 5 to 18 years in 2005 and 2010

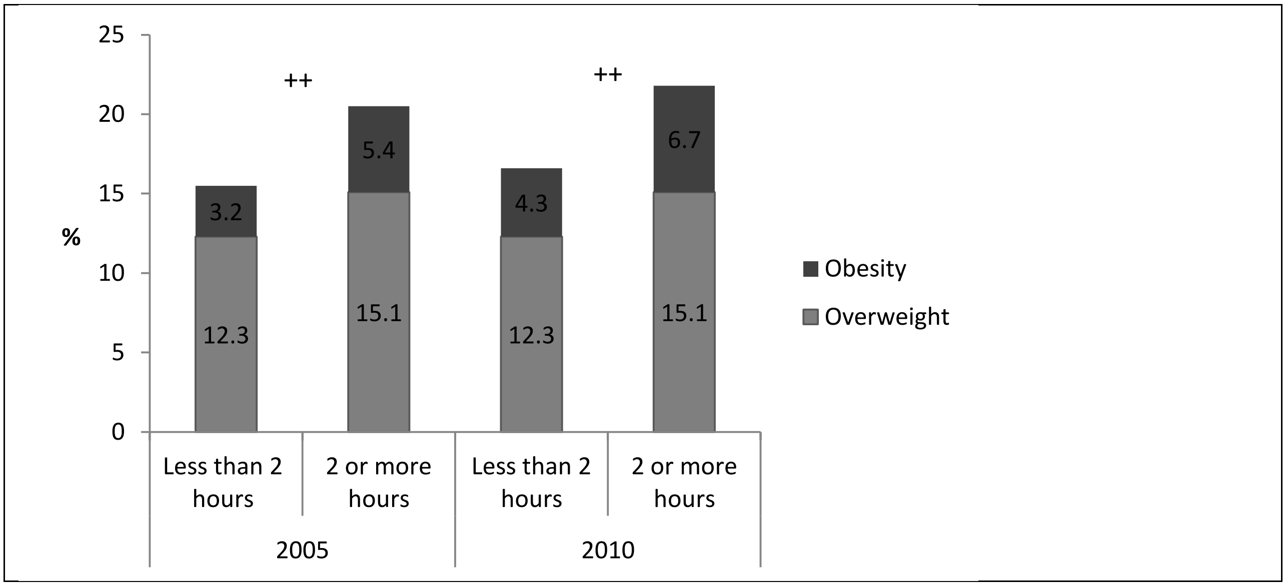
	Overweight[a] (%)		Obesity[a] (%)	
	2005	**2010**	**2005**	**2010**
Overall	12.2	12.7	3.5	3.9
Age group				
5-11 y	12.3	12.1	4.3	4.6
12-18 y	12.1	12.3	2.6	3.4**
Sex				
Boys	10.3	11.4	3.8	4.4
Girls	13.9	14.1	3.2	3.4
Place of Residence				
Rural	9.6	10.8	1.7	2.4
Urban	13.3	13.5	4.2	4.5
Wealth Index				
I (Lowest)	8.7	8.9 [b]	1.2	1.8[b]
II	10.4	12.0**	2.0	3.0**
III	12.2	13.1	3.9	4.1
IV	14.0	14.3	5.5	5.0
V (Highest)	17.7	17.1	5.9	7.1
Region				
Atlantica	8.8	9.7	2.5	3.0
Oriental	12.3	12.2	4.4	4.1
Central	12.6	12.8	3.7	4.4
Pacifica	12.9	14.9	3.6	4.3
Bogota	16.8	15.4	3.2	4.1
Amazonia	15.3	11.8**	4.7	3.5**

** Xi-squared tests, $p<0.05$

[a]The prevalence of overweight and obesity was determined using the WHO BMI international reference for children over 5 years of age(21).

[b]Test for heterogeneity of trend not significant $p>0.05$

Figure 2: Prevalence of overweight and obesity by screen time in Colombian children 5 to 11, 2005 and 2010



++p<0.01, X-square test of the difference between prevalence of combined overweight and obesity in children watching less than 2 hours of screen time per day, compared to children watching 2 or more hours per day. These differences lose significance after adjusting for sex, wealth, urbanization, and region.

There were no significant differences between 2005 and 2010 within screen time subgroups

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CHAPTER 7: INDIVIDUAL, FAMILIAL, AND COMMUNITY PREDICTORS OVERWEIGHT AND OBESITY IN CHILDREN AND ADOLESCENTS

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Introduction

Overweight and obesity in children and adolescents are becoming major concerns in both low and middle income countries (LMIC) and high income countries (HIC) (Khang & Park, 2010; Martorell et al., 2000; Martorell et al., 1998; Monteiro et al., 2004; Morales-Ruan Mdel et al., 2009; B. M. Popkin & Gordon-Larsen, 2004; Wang & Lobstein, 2006) Excess adiposity during these ages increases risk of adult obesity, cardio-metabolic disease, and psychosocial problems (Best et al., 2010; Dietz, 1998; Lobstein et al., 2004). Because children and adolescents are developing physically and cognitively, their behaviors are more likely to be affected by social and community environments (Best et al., 2010; Dietz, 1998; Lobstein et al., 2004; B. Popkin, 2010; B. M. Popkin & Gordon-Larsen, 2004; Powell et al., 2010; Samuelson, 2004; Timperio et al., 2010). Research examining the determinants of overweight and obesity has evolved from conceptual models based on simple causal relationships between individual factors and excessive weight, to models identifying complex relationships among individual, social, and environmental factors at different levels of influence (Aytur et al., 2008; Davison & Birch, 2001; Fraser, 2005; Gordon-Larsen, 2003; McLeroy et al., 1988; Powell et al., 2010; Samuelson, 2004; Timperio et al., 2010).

At the individual level two different types of determinants of overweight and obesity have been identified, the specific characteristics of the child: the behavioral factors, such as diet, physical activity and sedentary behavior, and the child or adolescent specific risk factors such as age, sex, height, and other biological and metabolic factors (Davison & Birch, 2001). For example, evidence suggests that girls are generally more likely to be overweight than boys (Daratha & Bindler, 2009; Nogueira et al., 2012); that older children and adolescents are usually at higher risk of overweight and obesity compared to younger children (Ernst et al., 2012); and that chronic under nutrition or low height for age (e.g. stunting) is positively associated with overweight(Duran et al., 2006; Fernald & Neufeld, 2007; Mukuddem-Petersen & Kruger, 2004).

Studies from HIC have identified specific factors at the family (or household) and community level as important determinants of overweight and obesity in children and adolescents (Chen & Escarce, 2010; Davison & Birch, 2001; Grant et al., 2010; Kral & Rauh, 2010; Timperio et al., 2010; L. Tremblay & Rinaldi, 2010).

Familial relationships and family structure have been identified as the most important factors in shaping children and adolescents' patterns of behavior, including diet, physical activity and sedentary behavior patterns, which are the main determinants of obesity (Birch & Davison, 2001; Schor, 2003). For instance, family structure, such as being an only child, parental beliefs and behaviors, such as parents' inadequate diet and physical activity, and socioeconomic factors, such as lack of economic resources or education have been associated to child and adolescent overweight and obesity (Chen & Escarce, 2010; Davison & Birch, 2001; Kral & Rauh, 2010; Moraeus et al., 2012; Rosaneli et al., 2012; L. Tremblay & Rinaldi, 2010).

Finally, at the community level, urban environments particularly underserved and poorly designed urban neighborhoods are also associated with increased risk of overweight and obesity (Fraser, 2005; Kruger et al., 2006). Conversely, availability of parks and recreation facilities has been shown to promote physical activity in children thereby, contributing to the prevention of overweight and obesity (Bedimo-Rung et al., 2005; Blanck et al., 2012; Cohen et al., 2006; Cohen et al., 2010; Cohen et al., 2007). A study in Los Angeles suggested that within neighborhood inequality is protective against increases in the prevalence of overweight and obesity (Bjornstrom, 2011). All this information on the correlates of childhood and adolescence overweight and obesity is useful to design and target policies and interventions (Finkelstein & Bilger, 2012; Karp & Kral, 2012).

Most countries in the Latin American region have experienced large increases in the prevalence of overweight and obesity over the last 20 years (Albala et al., 2001; Monteiro et al., 1995; B. M. Popkin, 1994; Rivera et al., 2004; Rueda-Clausen et al., 2008). Information on the determinants of overweight and obesity specific to Latin American and other LMIC is scarce, particularly in children and adolescents (Wang & Lobstein, 2006). Consequently, information from HIC is used to design policies and interventions to prevent obesity in LMIC.(Llanos et al., 2008; Sreevatsava et al., 2012) The objective of this study was to assess the potential influence of family and community level predictors on weight status of Colombian children and adolescents, using multilevel modeling techniques to analyze two nationally representative samples of children and adolescents 5 to 18 years in Colombia.

Methods

Sample description

We analyzed data from *Encuesta Nacional de la Situacion Nutricional de los Colombianos* (ENSIN) 2005("Encuesta Nacional de la Situacion Nutricional en Colombia ", 2005) and 2010("Encuesta Nacional de la Situacion Nutricional en Colombia," 2010) and from the Colombian Demographic and Health Surveys (DHS)("Demographic and Health Surveys Website," 2012) 2005 and 2010. The sample for these surveys was obtained using a multi-stage, stratified, clustered design. It is representative of the Colombian population at a national and departmental level.("Demographic and Health Surveys Website," 2012; Encuesta Nacional de la Situacion Nutricional en Colombia ", 2005; Encuesta Nacional de la Situacion Nutricional en Colombia," 2010) For this analysis, all children and adolescents between 5 and 18 years old, with available information on height and weight were included. Observations with implausible values on weight, height or BMI (defined as over 6 SD above the mean of the World Health Organization-WHO reference population), with missing values on any of the individual, familial, or community predictors (age, sex, wealth index, population density, caregiver's education, park density, and Gini coefficient), and those who were pregnant were excluded from the final analysis.

Contextual model and Variable Selection

Hierarchical linear models (HLM) are more appropriate to describe associations of ecological frameworks than ordinary logistic regression.(Luke, 2004) Ecological frameworks describe associations of different factors at different levels, which ultimately influence an individual level outcome (in this case BMI-Z and overweight). Hierarchical linear models allow to, not only control for the clustering of the observations into different structures or organizations (such as families or municipalities), but also to use that clustering to assess the variability at each level of interaction and identify potential predictors of the outcome.(Luke, 2004) We developed our analysis based on an adaptation of the contextual model of childhood obesity proposed by Davidson and Birch in 2001. The original model has three levels of interaction that ultimately affect child's weight: the individual level, the family level, and the community level. Further, this model identifies important factors at each of those three levels that interact among them and ultimately affect children's weight status. The model adapted for this study includes the same three levels: the child (individual), the household (family) and the municipality (community), as well as important predictors of weight status included in our analysis (Figure 1). A description of all the variables included in the model follows.

Weight Status (outcome)

Body Mass Index: We computed Body Mass Index-BMI (weight(kg)/height^2(m^2)) of all subjects and their BMI Z-score (BMI-Z) relative to the World Health Organization (WHO) reference population for children 5 to 18 years. (M. de Onis et al., 2006). The WHO system defines overweight as a BMI > 1 standard deviation (SD) and obesity as BMI > 2 SD from the mean of the reference population. Body mass index Z-score was used as a continuous dependent variable in linear models and was classified into "low" (<-1 SD), "normal" (-1 SD to 1 SD) and overweight (>1SD) for multinomial models. The cutoff of >1 SD was used instead of the traditional definition of underweight as <-2 SD from the mean of the WHO reference population, because only around 2% of the Colombian children and adolescents fall into that classification, which is too low for the multinomial models to adequately run.

Level 1: Child (Individual)

Age: We computed age from the date of birth and date of interview and converted it into years

Height: height in centimeters was included in order to control for the presence of stunting (low height for age), which is historically associated with low socioeconomic status and has also been identified as a predictor of overweight. (Duran et al., 2006; Fernald & Neufeld, 2007; Mukuddem-Petersen & Kruger, 2004)

Level 2: Family (Household)

Socioeconomic Status (SES): We used a wealth index (WI) developed for DHS that assesses presence in the household of a range of assets. The wealth index was generated using principal components analysis (PCA). Individuals are classified into five categories based on the distribution of the national household population (I=poorest to V=wealthiest) (Rustein, 2004).

Urban households: In Colombia, households within the main city of the municipality (or municipality head), as well as areas of the municipality with basic services such as water, electricity, pavement, health services, etc, are considered urban . Areas without such services are considered rural .("Departamento Administrativo Nacional de Estadística,")

Education: Years of schooling of the "most likely" caregiver based on traditional gender roles in Colombia were used. (Devault, 1991) This corresponds usually to the mother's years of schooling, except if the mother was not alive or was not living with the child. In those cases years of schooling of the father, grandmother, or grandfather were used in that order of preference.

Extended family: Families with members besides the parents and their offspring (i.e. grandparents, aunts, uncles, etc) living within the same household were classified as extended. Families with only the parents and their offspring living within the same household were classified as nuclear. This information was self reported by the respondent of the DHS household questionnaire.

Family Size: number of members living within the same household.

Level 3: Community (Municipality)

***Park density*:** We obtained the number of blocks with parks per municipality and divided it by the number of total blocks per municipality. This information was obtained from the Colombian National

Census of 2005("Departamento Administrativo Nacional de Estadística,"). We converted municipalities' park density into Z-scores.

Gini Coefficient: We used the Gini inequality coefficients of Colombian municipalities, which were calculated using information from the Colombian National Census of 2005(von Schirnding & Yach, 1991). We converted Gini coefficients to Z-scores to standardize these values.

Park density and Gini coefficients at the municipality level were obtained from the 2005 Colombian National Census, which is implemented every 10 years; the same values were used for the 2005 and 2010 models.

Percent of urban households: we calculated the percentage of urban households per municipality dividing number of urban households by total households within each municipality and multiplying it times 100.

Statistical Analysis

We built five three-level hierarchical linear models using data from 2005, where we included all predictors from each of the three levels in different blocks. The models included: 1. unconditional model with random intercepts and no predictors; 2. Random intercepts fixed slopes with level-1 predictors only; 3. Random intercepts fixed slopes with level 2 predictors only; 4.Random intercepts fixed slopes with level 3 predictors; 5. Random intercepts fixed slopes with all predictors at three levels. These models had BMI-Z as the outcome, the child at level-1, family or household at level-2, and municipality at level-3. The predictors included in the models were age and sex at level-1; wealth index, urban households, extended family, and family size at level-2; and park density, Gini coefficient, Z-scores and percent of urban households at level-3. We also tested for cross-level interactions of wealth index quintiles with park density and Gini coefficient (model 6). Significance was declared at $p<0.05$. We assessed multicolinearity of the predictors using variance inflation factors. The final model was selected based on the theoretical framework and the best fit (tested using deviance statistics, Akaike Information Criterion-AIC, and Bayesian Information Criterion-BIC). We ran the same six models using data from 2010 to assess consistency of the associations across surveys. The model including all predictors of interest was also computed using multinomial hierarchical linear modeling techniques in order to detect the potential existence of non-linear associations of the predictors with BMI-Z and to increase the interpretability of the associations with overweight. For the multinomial models, the outcome was the probability of “Low BMI” (BMI-Z<-1 SD), “Normal BMI” (BMI-Z between -1 and 1 SD), or “Overweight” (BMI-Z>-1 SD). All Statistical analyses were conducted using SAS 9.2, SAS callable Sudaan, and HLM 7.0.Weights at the individual level were used to account for the sample designs.

Results

The final sample for this study included 9119 children, 4420 households, and 177 municipalities in 2005 and 21,520 children, 12,452 households, and 104 municipalities in 2010. Body Mass Index z-score was normally distributed in both the 2005 and 2010 samples. The mean of all individual level variables (BMI-Z, age, sex, and height) was consistent across surveys. At the family and municipality level most variables were consistent across surveys, except for an increase in the percentage of urban households. (Table 1)

Results from the three-level hierarchical linear model of BMI Z-Score

Results from the six models from 2005 and the six models from 2010 are presented in table 2. The unconditional models showed reliability estimates of 0.56 and 0.46 at the household level and 0.42 and 0.53 at the municipality level for 2005 and 2010, respectively. These results indicate a significant correlation of BMI-Z among children living in the same household and among households within the same municipality, supporting the use of hierarchical linear models. The household level explained 40% of the variability in BMI-Z in 2005 and 31% in 2010. The municipality level explained 3% of the variability in 2005 and 2% in 2010 (Table 2).

The model that best fits the data (based on the deviance) in both 2005 and 2010 includes height, age, and sex at the individual level; wealth index, place of residence, family size, and extended family at the household level; and percent of urban households, park density and Gini coefficient z-scores at the municipality level (model 5, table 2). The model including the interaction terms (model 6, table 2) had the smallest Deviance, AIC, and BIC; however, reduction in the deviance was not statistically significant in either year. Education was dropped from all the models because of multicollinearity with wealth. According to these models, at the child level, height and being a girl were positively associated with BMI-Z in both 2005 and 2010. Age was inversely associated with children BMI-Z in both surveys At the household level, wealth index was positively associated with BMI-Z in 2005 and children living in extended families had on average higher BMI-Z than those living in nuclear families in 2010. Family size and living in the urban area of the municipality were inversely associated with children BMI-Z in both

2005 and 2010. At the municipality level, Gini Coefficient was positively associated with BMI-Z only in 2010 but park density did not predict BMI-Z on either year. Percentage of urban households per municipality was also inversely associated with BMI-Z score in 2005 and 2010 (Table 2).The effect of percentage of urban households per municipality is a contextual effect, and is independent of the urban or rural status of individual households within the municipality.

Results from the three-level multinomial hierarchical linear model of weight status (low BMI vs. normal and overweight vs. normal)

For the low BMI category, the unconditional model had a reliability of 0.15 in 2005 and 0.10 in 2010 at the household level, and of 0.46 and 0.48 at the municipality level. At the child level, girls had lower odds of low BMI than boys; the odds of low BMI were inversely associated with height, and positively with age in both 2005 and 2010. At the family level, odds of low BMI were inversely associated with wealth , were less in children from extended families compared to those from nuclear families, and higher in urban areas compared to rural (OR1.21, $p<0.02$), in 2010 but not in 2005. Family size was a positive predictor of the odds of low BMI in both 2005 and 2010. At the municipality level, Gini coefficient z-score was inversely associated with the odds of low BMI in 2010, and percentage of urbanization was slightly associated with the odds of low BMI both years. (Table 3)

For the overweight category, the unconditional model yields a reliability of 0.16 at the household level and 0.46 at the municipality level in 2005, and of 0.09 at the household level and 0.57 at the municipality level. At the child level, height and being a girl were positive predictors of the odds of overweight and obesity. The odds of overweight were inversely associated with age according to both surveys. At the family level, wealth index was positively associated with overweight both years and being part of an extended family positively predicted the odds of overweight only in 2010. The odds of overweight were inversely associated with family size both, in 2005 and 2010. Gini coefficient, park density and percentage of urban households did not predict overweight (all $p>0.05$ in 2005 and 2010).

Discussion

This analysis identified important individual, familial, and community predictors of BMI and overweight in Colombian children and adolescents 5 to 18 years. The individual level explained most of the variability in BMI-Z (57 to 67%). Both, BMI-Z and the odds of overweight and obesity were inversely associated with age and positively associated with height, whereas girls had higher BMI-Z and were more likely to be overweight than boys. The household or family level also explained an important proportion of the variability in BMI-Z (31 to 40%). Wealth and being part of an extended family were positively associated with BMI-Z and overweight; whereas, family size and living in an urban household (or in a highly urbanized municipality) were inversely associated with BMI-Z and overweight. The municipality level explained only between 2-3% of the variability in BMI-Z. At this level, Gini coefficient was positively associated with BMI-Z.

The positive association of BMI with height and being a girl is consistent with current literature. There is evidence linking height in children and adolescents with increased risk of obesity; since it appears that the increased risk of overweight linked to stunting, or low height for weight, affects mainly adult population (McDonald et al., 2009). Also, studies from both LMIC (Gupta et al., 2012; Kruger et al., 2006) and HIC (Daratha & Bindler, 2009; Nogueira et al., 2012), have reported a higher likelihood of overweight in girls compared to boys, mainly due to the process of female sexual maturation, in conjunction with social norms that favor physical activity in boys. However, the inverse association between age and overweight is contrary to current knowledge. Studies from other settings have consistently reported an increase in the prevalence of overweight with age, which is believed to be partially due to a lengthier exposure to obesity promoting environments (Ernst et al., 2012).

Wealth was a strong positive predictor of overweight in Colombian children and adolescents. This is consistent with an early pattern of the nutrition transition. Also, we found significant interactions of both height and sex with wealth. The association between height and BMI-Z is stronger in higher wealth quintiles. Few authors have hypothesized that the global increase in children's weight is due to secular trends in height associated with better health and living conditions (as opposed to a "global epidemic of obesity")(Ernst et al., 2012; M. S. Tremblay & Willms, 2000). It is possible that the predecessors of children and adolescents of higher socioeconomic strata in Colombia have been exposed to better conditions (compared to those from lower strata) and therefore their offspring have a higher BMI-Z attributable to secular trends in height. Conversely, the interaction between sex and wealth results in a smaller difference between girls and boys BMI-Z in the wealthier strata. Girls and adolescents from higher socioeconomic strata are usually more concerned with weight control(Palma-Coca et al., 2011) and have more resources to achieve a healthy weight (Kołoło & Woynarowska, 2004).

The negative association between living in urban areas and overweight and obesity is contrary to evidence linking urban environments to increased risk of overweight. It is possible that Colombian children and adolescents from urban households or more urbanized communities have better access to information, health services, and public policies promoting physical activity and preventing obesity. Potentially, programs implemented in Colombian cities to promote physical activity, such as the "Ciclovia" ("Biking path") and "Muevete" ("Move") are contributing to prevent overweight in Colombia's cities. Also, these results signal the need to design interventions targeting rural households to promote healthy weight in rural children and adolescents.

The influence of family structure was explored in this analysis through family size and extended families. The odds of overweight were inversely associated with family size. This is consistent with evidence from HIC showing that having siblings and having at least two adults in the household decrease the risk of overweight in children (Chen & Escarce, 2010; Jacoby et al., 2003; Kral & Rauh, 2010). Conversely, being part of an extended family predicted higher BMI-Z and a greater likelihood of being overweight. It is possible that certain family members influence children and adolescent behaviors. For example, having a grandmother as the main caregiver has been reported to increase the likelihood of overweight in children(Moschonis et al., 2010).Older generations are still concerned with the problem of under-nutrition and thus might not perceive children and adolescence overweight as unhealthy(Moschonis et al., 2010). More information on the specific composition of these families would be useful to better understand this opposite associations of family size and extended families with overweight in Colombian children and adolescents. Further, information on the influence family structure on childhood and adolescence overweight could potentially be useful to design public health interventions targeting key household members or specific family structures.

Gini coefficient was positively associated with BMI-Z (but not with overweight) and inversely associated with low BMI. These associations could mean that unequal environments are protective against underweight in Colombia. It is possible that the presence of wealthy community members improves overall municipal infrastructure and increases access of economically disadvantaged households to health and social services (Bjornstrom, 2011). In this sense, there are two factors important to consider. First, not all the children and adolescents classified as low BMI are underweight (defined as a BMI <-2 SD from the mean of the WHO reference population). Studies looking specifically at the influence of inequality on under-nutrition would be helpful to better understand these results. Secondly, the associations were only significant in 2010 while the information on Gini coefficients is from 2005. Community level predictors are relatively constant across time. A possibility is that the influence of these predictors on weight status happens progressively; hence, future studies should consider the value of including information from the past when studying the influence of community factors on individual outcomes.

A significant proportion of the variance at the individual level remains unexplained after adjusting for sex, age and height. This unexplained variability could potentially be explained by the behavioral determinants of overweight and obesity (diet and physical activity), which could not be included in this analysis due to lack of information on these predictors.

This study has some limitations worth noting. It was a secondary data analysis; hence, relevant predictors such as diet, physical activity, parental beliefs and behaviors, and specific family structure could not be included in the analysis. Also, limited information is available at the municipality level. The Colombian National Census is conducted every ten years; thus, we used the same information at the municipality level for both the 2005 and 2010 models. Also, the cross sectional nature of the data limits our ability to establish direct causality.

On the positive side, we analyzed two nationally representative samples of Colombian children and adolescents and identified important individual, familial, and community predictors of overweight in this population. To our knowledge, this is the first study that uses hierarchical linear models to study the influence of individual, familial, and community factors on BMI and overweight in a repeated nationally representative sample of children and adolescents. Through this analysis we were able to identify important similarities and differences between Colombian and HIC. These context specific associations will be useful to guide the design and implementation of interventions to prevent childhood and adolescence obesity in Colombia, and potentially in other Latin American settings. An important difference identified in this study was the large proportion of the variability in BMI-Z that was explained at the family level, which outlines the importance of family and household clustering in Colombia. Future studies of childhood and adolescence obesity should consider the relevance of predictors at this level and the feasibility and effectiveness of family level obesity prevention programs. Results from this study could also be useful to design and target interventions in other Latin American and LMIC of similar characteristics.

Table 1: Descriptive Statistics for the 2005 and 2010 samples

	2005			2010		
Variable	**N**	**Mean/%**	**SD**	**n**	**Mean/%**	**SD**
Child (Individual)	9119			21520		
BMI Z-Score[a]		-0.08	0.99		-0.04	1.01
Height (cm)		139.8	19.5		141.1	19.3
HAZ-Score		-0.70	1.02		-0.69	1.01
Age (years)		11.2	3.9		11.6	3.8
Girl (%)		52	50		50	50
Family (Household)	4420			12452		
Wealth Index (quintiles)		2.8	1.3		3.0	1.3
Urban[c] (% of households)		70	46		82	39
Extended (%)		49	50		44	50
Family Size(members)		5.2	2.1		4.7	1.9
Community (Municipality)	177			104		
Gini Index Z-score		-0.13	0.97		-0.13	1.07
Park Density Z-score		0.02	1.21		-0.01	1.15
Percent Urban[d] (mean)		60.8	29.8		66.5	25.8

[a]Body Mass Index Z-Score relative to the WHO reference population for children 5-18 years, 2007(Mercedes de Onis et al., 2007)

[b]Height for Age Z-score relative to the WHO reference population for children 5-18 years, 2007(Mercedes de Onis et al., 2007)

[c]Urban= household level variable. A household is classified as urban if it is located in an area of the municipality with basic services, such as electricity, water, town hall, etc. Otherwise, the house is classified as rural.

[d] Percent Urban= variable created by dividing the number of urban household within a municipality by the total number of households within that same municipality

Table 2: Hierarchichal linear model of the individual, household, and municipality predictors of Body Mass Index Z-Score relative to the WHO reference population in children and adolescents from Colombia, 2005 and 2010

Parameters	ENSIN 2005 Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	ENSIN 2010 Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Fixed Effects[+]												
Intercept, γ_{000}	-0.04	-0.14	0.35**	-0.04	0.22**	0.17*	-0.02	-1.48**	0.35**	-0.02	0.18**	0.18
Level 1 (Child)												
Height (cm), , γ_{100}		0.01**			0.01**	0.01**		0.02**			0.02**	0.02**
Age(years), γ_{200}		-0.08**			-0.07**	-0.07**		-0.10**			-0.09**	-0.09**
Girl(vs. boy), γ_{300}		0.18**			0.17**	0.17**		0.20**			0.18**	0.18**
Level 2 (Household)												
ICC	***40% (0.40)***						***31% (0.31)***					
Reliability	***0.56***						***0.42***					
Wealth Index[c] γ_{010}			0.11**		0.09**	0.09**			0.11**		0.11**	0.13**
Urban(vs. rural)[a] γ_{020}			-0.18**		-0.14**	-0.09**			-0.18**		-0.09**	-0.09**
Family Size(members)γ_{030}			-0.05**		-0.05**	-0.05**			-0.05**		-0.04**	0.04**
Extended(vs. nuclear) γ_{040}			0.05		0.05	0.05			0.05**		0.05*	0.05*
Height/ *Wealth Index, γ_{110}						0.01**						0.00
Age/ * Wealth Index, γ_{210}						-0.07**						-0.01**
Girl/ * Wealth Index, γ_{310}						-0.002						-0.02*
Level 3 (Municipality)												
ICC	***3% (0.03)***						***2% (0.02)***					
Reliability	***0.46***						***0.53***					
Gini (z-score) γ_{001}				-0.01	-0.003	0.007				0.00	0.05**	0.05
Parks (z-score) γ_{002}				0.03	0.01	-0.02				0.04*	0.03	0.02
% Urban[b] γ_{003}				-0.001	-0.002*	-0.002*				0.001	-0.002*	-0.002*
Wealth Index /												
*Gini, γ_{011}						-0.02						0.05
*Parks, γ_{012}						0.02						-0.001

Urban/												
*Gini, γ_{021}						-0.03						0.002
*Parks, γ_{022}						0.02						0.01
Random Parameters												
Variance intercept												
Level 1, u_{00}	0.58**	0.58**	0.58**	0.57**	0.57**	0.57**	0.68**	0.66**	0.68**	0.68**	0.67**	0.67**
Level 2, r_0	0.41**	0.39**	0.39**	0.41**	0.37**	0.37**	0.32**	0.30**	0.29**	0.32**	0.28**	0.28**
Level 3, σ^2	0.03**	0.03**	0.02**	0.03**	0.02**	0.02**	0.02**	0.01**	0.01**	0.01**	0.01**	0.01**
Deviance	24839	24642	24684	24835	24511	24431	60034	59444	59637	60027	59100	59052
AIC	24847	24656	24700	24849	24539	24473	60042	59458	59653	60041	59128	59094
BIC	24875	24706	24757	24899	24638	24623	60074	59528	59716	60097	59240	59261

**Significantly different from zero, p<0.01
*Significantly different to from zero, p<0.05
+Regression coefficients should be interpreted as the average change in BMI-Z per unit change in the predictor, after controlling for all other covariates
[a]Urban= household level variable. A household is classified as urban if it is located in an area of the municipality with basic services, such as electricity, water, town hall, etc. Otherwise, the house is classified as rural.
[b]% Urban= contextual variable created by dividing the number of urban household within a municipality by the total number of households within that same municipality
AIC= Akaike Information Criterion-AIC; BIC= Bayesian Information Criterion
[c]Wealth Index Quintiles

Table 3: Multinomial hierarchical linear model of the individual, household, and municipality predictors of Low Body Mass Index and overweight in children and adolescents from Colombia, 2005 and 2010

	2005				**2010**			
	Unconditional		**Adjusted**		**Unconditional**		**Adjusted**	
Parameters	**Coefficient**	**Odds Ratio (95% CI)**	**Coefficient**	**Odds Ratio (95% CI)**	**Coefficient**	**Odds Ratio (95% CI)**	**Coefficient**	**Odds Ratio (95% CI)**
For Category 1 (Low BMI vs. Normal)								
Fixed Effects								
Intercept, γ_{000}	-1.57**	0.21 (0.18,0.24)	-1.82**	0.16 (0.12,0.22)	-1.50**	0.22 (0.21,0.24)	-1.58**	0.21 (0.18,0.24)
Level 1 (Child)								
Height (cm) γ_{100}			-0.02**	0.98 (0.97,0.99)			-0.02**	0.98 (0.97,0.99)
Age (years), γ_{200}			0.11**	1.12 (1.07,1.18)			0.12**	1.13 (1.09,1.17)
Girl (vs. boys) γ_{300}			-0.36**	0.70 (0.61,0.80)			-0.39**	0.68 (0.62,0.74)
Level 2 (Household)								
Reliability	***0.15***				***0.10***			
Wealth Index(quintile)γ_{010}			-0.08	0.92 (0.84,1.01)			-0.11**	0.90 (0.88,0.91)
Urban (vs, rural) γ_{020}			0.25	1.28 (1.00,1.65)			0.19**	1.21 (1.15,1.28)
Family Size (members) γ_{030}			0.06	1.06 (1.02,1.10)			0.04**	1.04(1.04.1.06)
Extended (vs.nuclear) γ_{040}			-0.15	0.86 (0.70,1.07)			-0.04*	0.96 (0.93,1.00)
Level 3 (Municipality)								
Reliability	***0.46***				***0.48***			
Gini coefficient Z-score γ_{001}			0.02	1.02 (0.89,1.18)			-0.08*	0.92 (0.88,0.97)

Park Density Z-score γ_{002}			-0.00	1.00 (0.90,1.11)			-0.04	0.96 (0.92,1.00)
% Urban γ_{003}			0.005**	1.01 (1.00,1.01)			0.004**	1.00 (1.00,1.01)
Random Parameters								
Variance intercept								
Level 1 and 2, r_0	0.70		0.69**		0.49		0.48	
Level 3, σ^2	0.22**		0.19**		0.05**		0.04**	
For Category 2 (Overweight vs. Normal)								
Fixed Effects								
Intercept, γ_{000}	-1.76**	0.17 (0.16,0.19)	-1..33**	0.27 (0.19,0.37)	-1.65**	0.19(0.18,0.21)	-1.31**	0.27 (0.23,0.31)
Level 1 (Child)								
Height (cm) γ_{100}			0.02**	1.02 (1.01,1.04)			0.03**	1.03 (1.03,1.04)
Age (years), γ_{200}			-0.15**	0.86 (0.81,0.93)			-0.19**	0.83 (0.80,0.86)
Girl (vs. boys) γ_{300}			0.20*	1.22 (1.04,1.42)			0.11**	1.11 (1.02,1.21)
Level 2 (Household)								
Reliability	***0.16***				***0.09***			
Wealth Index(quintile) γ_{010}			0.19**	1.21 (1.08,1.36)			0.25**	1.28 (1.23,1.33)
Urban (vs, rural) γ_{020}			0.04**	1.04 (0.77,1.41)			-0.08**	0.9 (0.78,1.10)
Family Size (members) γ_{030}			-0.11**	0.90 (0.86,0.93)			-0.09**	0.92 (0.89,0.94)
Extended (vs.nuclear) γ_{040}			-0.01	0.99 (0.84,1.17)			0.12**	1.13 (1.03,1.24)
Level 3 (Municipality)								

Reliability	***0.46***					
Gini coefficient Z-score γ_{001}		0.06	1.07 (0.97,1.17)		0.05	1.05 (0.98,1.12)
Park Density Z-score γ_{002}		0.03	1.03 (0.92,1.15)		0.03	1.03 (0.98,1.09)
% Urban γ_{003}		0.004	1.00 (0.99,1.00)		0.003	1.00 (1.00,1.00)
Random Parameters						
Variance intercept						
Level 1 and 2, σ^2	0.58**	0.86**		0.51	0.44	
Level 3, r_0	0.07**	0.05**		0.09**	0.04**	

**Significantly different from zero, p<0.01

*Significantly different to from zero, p<0.05

[a]Urban= household level variable. A household is classified as urban if it is located in an area of the municipality with basic services, such as electricity, water, town hall, etc. Otherwise, the house is classified as rural.

[b]% Urban= contextual variable created by dividing the number of urban household within a municipality by the total number of households within that same municipality

Low BMI= BMI below -1 SD from the mean of the WHO reference population for children and adolescents 5-18.(Mercedes de Onis et al., 2007)

Overweight=BMI over 1 SD from the mean of the WHO reference population for children and adolescents 5-18.(Mercedes de Onis et al., 2007)

[c]Wealth Index Quintiles

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CHAPTER 8: SUMMARY AND CONCLUSIONS

The present study is a secondary analysis of two large national nutrition surveys from Colombia. We used information on 5 to 18 year children and adolescents' anthropometric measurements, as well as on their individual, familial and community characteristics to: 1) Compare the prevalence and association estimates of the three main BMI classification systems for children and adolescents 5 to 18 in a nationally representative sample from Colombia. 2) Describe changes in child and adolescent overweight and obesity in Colombia between 2005 and 2010 by screen time, age sex, wealth, urbanization, and region. 3) Identify specific predictors of BMI in Colombian children and adolescents at the individual, familial, and community level. Results from this study will be useful to guide future efforts to prevent and control childhood and adolescence overweight in Colombia. Further, to our knowledge, this is the first study that uses hierarchical linear models to assess overweight and obesity in children and adolescents from an ecological perspective in a nationally representative sample from a LMIC.

Key Findings

Comparing three international BMI classification systems

We hypothesized that the three international methods most commonly used to assess child and adolescent overweight and obesity (International Obesity Task Force –IOTF 2005, Center for Disease Control- CDC 2000 and World Health Organization-WHO 2007 would yield different prevalence estimates of overweight and obesity in our sample of Colombian children and adolescents, but that the estimates of association between overweight and obesity and age, sex, rural or urban residence, and wealth would be consistent across systems. We found that indeed the prevalence estimates of overweight and obesity varied among the WHO, CDC, and IOTF systems (In males: IOTF=8.5%, CDC=10.8%, WHO=14.1%. In females: IOTF=14.6%, CDC=13.8%, WHO=17.1%, $p<0.001$). These findings are consistent with the literature showing that WHO and CDC yield higher prevalence estimates of overweight and obesity compared to IOTF. However, our results also show that the association (odds ratios and 95% confidence intervals) between combined overweight and obesity, and age and sex varied by system. The odds of having overweight and obesity in children (5 to 10 years) compared to adolescents (11 to 18 years) were: IOTF=0.87, 0.77-0.98; CDC= 1.27, 1.14-1.42; WHO=1.21, 1.08-1.35; those for females compared to males were: IOTF=1.84, 1.6- 2.10; CDC=1.33, 1.17-1.51; WHO= 1.25, 1.12-1.41).

There was greater concordance between the estimates generated with the three systems when we examined obesity alone, rather than combined with overweight. This better agreement is encouraging because childhood obesity is more strongly associated with negative health outcomes than is overweight *(3)*. Apart from minor differences among the IOTF, and the CDC and WHO classification methods in the significance of association with Wealth Index (WI), we found no mayor disagreement among the three systems in the estimates of association with WI or population density (urban or rural) after controlling for age and sex. In this sense, age and sex are different type of predictors because they were considered by all three classification systems when defining the cut-off points *(21, 24, 104)*, thus the variations in prevalence estimation are highly sex- and age-specific. This potentially explains the differences in association found for combined overweight and obesity.

The WHO classification is the only system designed using data from before the obesity epidemic; hence, it might be the most appropriate for countries where the prevalence of childhood obesity is still relatively low, such as Colombia. BMI is a convenient and feasible tool to screen for overweight and obesity in children and adolescents. Further studies are needed to improve the interpretation of this measure, and to recommend a unique international BMI classification system that adequately reflects percentage of fat and risk of negative health outcomes.

Changes in overweight and obesity in Colombia

For this study, our hypothesis was that there would be an overall increase in the prevalence of overweight and obesity in children and adolescents from Colombia between 2005 and 2010, and that this increase would particularly affect certain subgroups such as the urban population. However, we found no significant changes in the prevalence of overweight or obesity in Colombian children and adolescents 5-18 years overall (overweight= 12.2 to 12.7%; obesity=3.5 to 3.9%, p>0.05), or within sex, wealth, urban, rural, or region specific subgroups in these 5 years. Further, we estimated a low incidence of child and adolescent obesity in Colombia (4.6 new cases per 1000 PY in children 5-11 and of 2.6 new cases per 1000 PY in adolescents 12-18). This unchanged prevalence of overweight and obesity in children and adolescents, combined with the low levels of incidence and prevalence suggest a slow nutrition transition in Colombia compared to other LMICs.

Additionally, before adjusting for demographic confounders, we found an association between watching two or more hours of screen time per day and overweight and obesity, nevertheless this association disappeared after adjusting for age, sex, wealth and population density. Wealth was strongly correlated with both screen time and overweight and obesity, and was a strong confounder of this association.

Colombia, a middle income country in Latin America, has made obesity prevention a priority through a wide variety of public policies to prevent obesity and promote physical activity. If public policies in Colombia have been effective preventing child and adolescent overweight and obesity, their potential applicability in other settings should be assessed.

Individual, familial and community predictors of overweight and obesity in Colombian children and adolescents

Studies from HIC have identified associations of child and adolescent overweight and obesity with specific factors at the individual, familial, and community level. We hypothesized that these predictors, which are commonly used to design and target interventions in LMICs, would have different associations with Colombian children and adolescents' BMI and nutritional status to the ones described in HIC. We found that most of the variability in BMI is at the individual level (57 to 67%). Height and being a girl were positively associated and age was inversely associated with BMI-Z and overweight. The family level explained (31 to 40%) of the variability in BMI-Z. Wealth was the strongest predictor of BMI-Z and overweight (0.09 to 0.11 increases in BMI-Z per wealth quintile increase). Body Mass Index Z-score and the odds of overweight were inversely associated with family size and positively associated with being part of an extended family. The community level explained only between 2 and 3% of the variability.

Strengths and Limitations

This dissertation has strengths and limitations worth mentioning. First, the nature of this study is a repeated cross-sectional. This design does not allow assessing causality; hence all the results are only inferences of association based on the available data. Also, this was a secondary analysis and was constrained to the available information. In other words, these surveys were not designed for this particular study and information on some important predictors is limited or not available. Examples of this limitation are the lack of information on adolescents' television viewing in 2005, as well as the insufficient information to determine parental beliefs and behaviors, which are an important part of the original contextual model. The etiology of youth overweight is extremely complicated and variables interact at many different levels. The analytic techniques available only permit to look at three different levels of influence. Finally, information on children and adolescents is only available in this two time points, which limited our ability to describe trends in the prevalence of overweight and obesity/

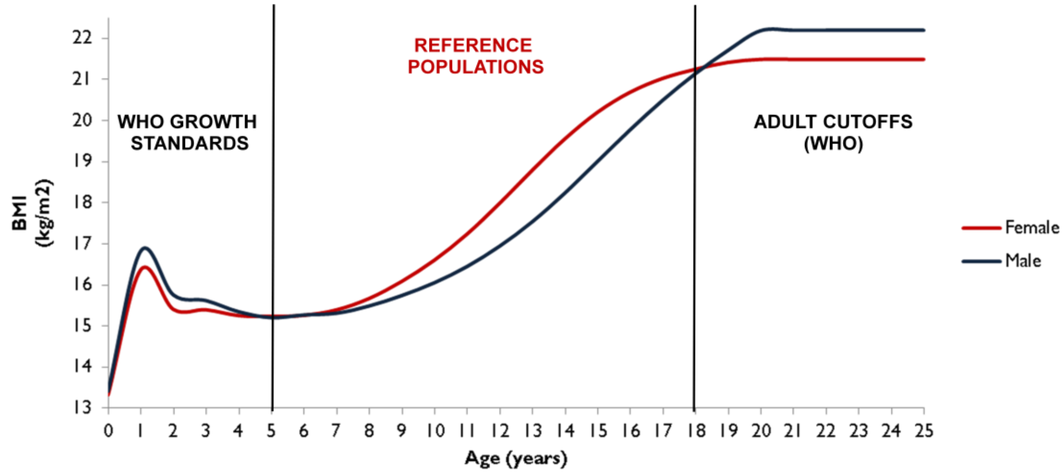
Conversely, some of the strengths of this dissertation are that all methodology was based on accepted contextual models, which have been suggested as appropriate to study the etiology of overweight and obesity. We had information from two different time points which allowed us to assess changes over time and to assess stability of the associations. The clustering of the data allowed us to study associations across three different levels of interaction. Additionally, we were able to pool information from three different surveillance systems (DHS, ENSIN, Census) and hence we have information available on many different individual, familial and environmental predictors of youth overweight and obesity in Colombia.

Discussion and Recommendations

Measurement of overweight and obesity

Validity of results of epidemiologic and public health studies depends on the use of adequate measurement techniques. Selection of methods and classification systems to assess overweight and obesity in children and adolescents between 5 and 18 years of age is particularly challenging (105). Body mass index is recognized as a reliable and valid method to assess these conditions in adults where measures are no longer affected by growth and sexual maturation (105). In children and adolescents, growth and maturation are addressed by the use of age- and sex- specific growth standards or reference populations (21, 24, 105). More specifically, for children younger than five years, the WHO growth standards (a cohort of healthy children monitored from birth to age five) is the recommended classification system to assess body composition (21). Nonetheless, for older children and adolescents there is no clear consensus on which BMI classification system best reflects an excess in body fat mass and future negative health outcomes (Figure 8.1).

Figure 8.1: Body Mass Index 50th percentile by age of Colombian children, adolescents and adults: Methods to assess overweight and obesity in each age group.



Source: ENSIN, 2005

Both international and country-specific reference populations have been used to assess overweight and obesity in children and adolescents older than five years (106-108). Country-specific BMI classification systems have the advantage of including information only from the country of interest and, in general, they have been recommended as screening tools in clinical settings (106-110). Evidence suggests country-specific classifications have better sensitivity compared to international classification systems, particularly compared to IOTF classification systems, using percentage of fat mass as the gold standard (111). On the other side, international classification systems are needed to compare across countries and for countries where national reference populations are not available, such as Colombia.

It has long been acknowledged that prevalence estimates vary depending on the classification system used to generate them; which has led to the recommendations of always stating the classification system selected, as well as being consistent when comparing data from different countries or assessing time trends (87, 107, 112). However, to our knowledge, this dissertation is the first study to report a disagreement in associations with age and sex based on the classification system used. This finding reveals that the impact of BMI classifications systems on overweight and obesity epidemiologic and public health studies is greater than previously consider. For example, the final model in study 3 (chapter

7) suggests an inverse association between age and BMI-Z score relative to the WHO population, which is consistent with the results from study 1. However, results using WHO are in disagreement with those obtained using IOTF, which estimated a positive association between age and overweight and obesity in Colombian children and adolescents. Because only one direction of the association of overweight and obesity with age is correct, one of the two classification systems is necessarily introducing bias into the results. A big limitation of this study, which is frequent in surveillance data, is the lack of biological indicators or better measurements to assess percentage of fat and negative health outcomes. This limitation, not only precludes the comparison of the three international classification systems to a gold standard, but also raises concerns about the validity of the associations with age and sex in studies 2 and 3 (although after controlling for these two factors, associations with socio-demographic factors are consistent across systems).

It was important to select a classification system for the rest of the analyses despite the lack of a gold standard. In the face of this limitation, the WHO was provisionally selected as the most appropriate for Colombian children due to the following considerations:

- The CDC classification system is the United States' country-specific classification system. It includes data from both before and after the rise in the prevalence of overweight and obesity. Hence, it most likely underestimates the prevalence of overweight and obesity in Colombian children and adolescents (23).
- Evidence suggests the IOTF classification system has low sensitivity compared to other country-specific and international classification systems(111). The methods used by this system to extrapolate the adult cut-off points to the different ages and sex have been questioned by different authors (106, 111). The curves were forced in order to set the age 18 cut points at 25kg/m^2 for overweight and 30 kg/m^2 for obesity (the adult cut-off points), which seems to create an unnatural decrease in the curves during adolescence (106).

- The WHO classification system was developed using data from before the obesity epidemic; which most likely increases its sensitivity to assess overweight and obesity. It provides month-specific cut points and statistical methods were used to smooth the transitions at age 5, and from adolescence into adulthood (21). Also, the BMI distribution of the WHO population is very similar to that of Colombian children and adolescents both in 2005 and 2010.
- Other countries in the region have decided to start using the WHO classification system; using this same system for the present analysis will facilitate international comparisons.

An important recommendation for surveillance systems in Colombia and other countries would be to (if possible) include other anthropometric and biological indicators of percentage of body fat (for example height circumference, skin folds) and risk factors for negative health outcomes (C-reactive protein, insulin resistance) in at least a subsample of children and adolescents. Moving forward, it will be important to identify the most valid international BMI classification system to assess overweight and obesity in diverse populations.

Nutrition transition

The nutrition transition has traditionally been defined as the process described in the introduction; which is characterized by an increase in the prevalence of overweight and obesity and a decrease in the prevalence of under-nutrition driven by changes in diet and physical activity, and the social and build environment. Popkin described two different patterns of change: 1.a slower and more ordered process in HIC, where the four initial stages of the nutrition transition happen progressively one after the other and health systems have more room to respond; and 2. a rapid and polarized process characteristic of LMIC, where overweight and chronic diseases coexist with the unresolved problems of under-nutrition and infectious diseases (58, 59, 113, 114). The increase in overweight and obesity in HIC started first and was primarily driven by industrialization and technological advances that altered the lifestyles of the population, causing an increasing dietary energy intake and sedentary behavior, and decreasing physical activity (58, 59). The nutrition transition in LMIC started later than in HIC; however societal dynamics such as globalization, urbanization, and economic growth seem to have accelerated the increase in overweight and obesity in low and middle economies (58, 59). These nutrition transition patterns were initially suggested based mainly on information from representative samples of adults and children from HIC, and from representative samples of women and young children from few LMIC, such as Mexico, Brazil, China, and India.

There is less information specific to children and adolescents 5 to 18 years; however, available evidence from many HIC, as well as from Brazil and Mexico suggests increases in the prevalence of overweight and obesity in this age group follow similar patterns to the ones observed in adults and younger children (115, 116). That is, an initial increase of overweight and obesity in urban areas and in the rich and later shifts to the economically disadvantaged and rural areas (115, 116). These changes are driven by globalization, urbanization, and economic development and strongly affected by country- and local- level wealth inequality.

Results from this dissertation suggest a different pattern of nutrition transition in Colombian children and adolescents (see chapters 6 and 7). According to this study, overall, there were no significant increases in the prevalence of overweight and obesity in Colombian children and adolescents between 2005 and 2010 despite the steady growth of Colombian economy in these 5 years; these results contrast with the nutrition transition patterns of other middle economies (where prevalence of overweight and obesity is strongly correlated with economic growth). Urbanization was not associated with overweight and obesity in Colombia after adjusting for age and sex; to the contrary, after controlling for wealth, BMI and odds of overweight were significantly higher in rural household and municipalities compared to urban. Wealth was positively associated with overweight and obesity, which is consistent with an early stage of the nutrition transition. Inequality at the municipality level was positively associated with BMI (but not with overweight) and negatively associated with low BMI, suggesting a potential role of local-level inequality in preventing underweight; potentially wealthy members of unequal municipalities contribute to improve access to sanitation and infrastructure in those communities.

An interesting exercise is to compare our results in Colombia to data from Mexico. Both countries are located in the Latin American region and over 70% of their population resides in cities. Mexico has the second largest GDP in the region and Colombia the fourth; however economic growth between 2008 and 2010 was greater in Colombia (4% annual average) compared to Mexico (0.2% annual average). Mexico is located in North America and borders with the US in the north. Mexico has conducted four national nutrition surveys (1988, 1999, 2006, and 2012). Information from this country has contributed greatly to describe the nutrition transition in LMIC. The increase in overweight and obesity in Mexican children exhibits a different pattern to the one described in this study; most noticeably, the hypothesis that economic growth and urbanization are the main factors driving the nutrition transition does not seem to hold in Colombian children (table 8.2).

Table 8.2: A comparison of the patterns of nutrition transition in middle income countries, Mexico, and Colombia (PAHO 2010, (93, 94)

	Middle income countries (theoretically)	Mexico	Colombia
Economic growth	Fast increase in the prevalence of overweight and obesity promoted by economic growth	GDP annual growth: 2005:3.2% 2006:5.2% 2007:3.3% 2008:1.2% 2009: -6% 2010: 5,5% Childhood overweight: 1999: 26.9% 2006:34.8% 2012:34.4%	GDP annual growth: 2005: 4.7% 2006: 6.7% 2007: 6.9% 2008: 3.5% 2009: 1.7% 2010: 4% Childhood overweight: 1999: unknown 2005:16.6% 2010:16.7%
Urbanization	Urban environment and lifestyle associated with overweight and obesity	70% Urban Childhood Overweight 2006: Urban: *29.6%* Rural:*17.2%* ***(IOTF estimates)***	74% Urban Childhood Overweight 2005: Urban: 17.5% Rural: 11.3%

		Greater odds of overweight in **urban** after adjusting for age, sex and wealth.	Greater odds of overweight in **rural** areas after adjusting for age, sex, and wealth
Inequality	Country-level inequality inversely associated with overweight Effect of community level inequality has not been assessed	Gini coefficient of inequality: 48.3 Overweight: 34.8% Unknown	Gini coefficient of inequality:55.9 Overweight:16.7% Inequality (Gini) not associated with overweight in children and adolescents, inversely associated with low BMI
Wealth (household level)	Initially, overweight and obesity affect primarily the wealthy. As countries develop economically overweight and obesity shift to the economically disadvantaged	Wealth positively associated with overweight in 1999 and 2006 (data from 2012 still not available)	Wealth positively associated with overweight in 2005 and 2010
Globalization	Availability of food products and technology from ‘western’ economies associated with higher prevalence of overweight and obesity	North American Free Trade Agreement (United States, Mexico and Canada), 1994	Free trade agreement with the United States, 2011

A potential explanation for the different patterns of nutrition transition in Mexico and Colombia is the lower degree of globalization in Colombia; more specifically, the differences could be due to a weaker commercial and cultural influence of the US in Colombia compared to Mexico. There is evidence that the North American Free Trade Agreement (NAFTA) signed by Canada, Mexico, and the US in 1994 has influenced the Mexican consumer food environment (117, 118). The US has exported important amounts of foods with high fat and sugar content into Mexico over the last two decades. Agricultural investments from the US have altered the production, processing, distribution, and retail of Mexican products, thus transforming the Mexican food system into an industrialized food chain similar to the one of the US that has been associated with overweight and obesity (117, 118). Conversely, persistence of traditional diets and local foods seem to be protective against overweight and obesity. Traditional afro-Colombian and indigenous diets, to this date, include a wide variety of fruits, leaves, seeds, and roots. Further, availability and variety of fruits in Colombia are among the greatest in the world (119, 120). It is possible that the low degree of globalization in Colombia combined with the resilience of traditional diets and the high fruit availability, are responsible for the relatively low prevalence of overweight and obesity in children compared to Mexico. Colombia signed a free trade agreement with the US in 2011. Information from the nutrition survey of 2015 will be useful to assess the effect of this agreement on the nutrition transition in Colombia.

The epidemiology of overweight and obesity in Colombian children does not seem to fit the traditional model of nutrition transition for a middle income country. There are two possible explanations for this result: either Colombia presents a very particular case of nutrition transition or the information used to describe the pattern of nutrition transition is based only on limited data from the few LMIC with strong surveillance systems (Mexico, Brazil, China, and India). Also, it might be possible that the nutrition transition in children and adolescents does not follow the same patterns described using data from adult women and preschool children.

In the future, it will be important to conduct multi-country studies of comparable data (in terms of time frame, methodology, age group, etc) to further understand the different patterns of nutrition transition in LMIC. If, in fact, Colombia is a unique case of nutrition transition the particular characteristics which have contributed to prevent overweight and obesity in children and adolescents from this country should be identified. Besides the low degree of globalization and the high country-level inequality, which have been shown to be associated with lower prevalence of overweight and obesity, Colombia has been particularly interested in the prevention of overweight and obesity and the promotion of physical activity through public policy. A more in depth discussion of the implications of this dissertation for Colombian public policy is presented next.

Public Policy in Colombia

An important justification for this dissertation was to provide evidence to improve design and implementation of public policy to prevent overweight and obesity in Colombian children and adolescents. Results from this study raise important issues in this area and could contribute to a better understanding of the effect of Colombian public policy on preventing child and adolescent obesity. This section presents a brief discussion of the findings relevant to Colombia´s obesity prevention policies and issues some recommendations based on those findings.

Information from surveys can be useful to design and target programs and policies. Through this study we identified different factors associated with overweight and obesity at the individual, familial, and community level (8, 121, 122). Usually, policy interventions have the greatest impact on factors at the community level. Unfortunately, it was only possible to assess inequality, park density, and urbanization as predictors of BMI at the community level. Further, the community level explained only a very small proportion of the variability in BMI. This does not necessarily mean implementing policies at the community level has little or no impact at the individual level or household level. Two considerations are important: First, the way variability is distributed across levels might be an artifact of this specific model where the sample size of the family level is much smaller than the size of the municipality clusters. Secondly, some of the variables at the family level are traditionally studied at the municipality level, for example urbanization.

Two recommendations drawn from this considerations are: First, future studies should consider using HLM in combination with other techniques that allow a more direct assessment of the effects of the built environment and policy interventions on individual outcomes; for example, an analysis using Geographic Information Systems could be a better way to assess the effect of parks on childhood overweight and obesity in Colombian cities. The second recommendation would be for researchers and policy makers to try to identify the ways community factors interact with family units and design policies that take advantage of the links between family and community. For example, a potential policy addressing the increased likelihood of overweight in children from extended families could be to create community centers (or implement programs in the ones available) offering nutrition and active living workshops for adults at the same time that sports and recreation activities are offered for children.

Targeting interventions and programs is a major determinant of policy effectiveness. An adequate targeting helps improve the impact of interventions by assigning the available resources to those who need it most (110, 123). Results from the three analyses of this dissertation provide information that could potentially contribute to improve targeting of Colombian policies and interventions to prevent child and adolescent overweight and obesity. For example, some targeting and design recommendations based on results from this dissertation are:

- <u>Different strategies to prevent and control overweight and obesity based on socioeconomic strata:</u> Wealth was an important predictor of overweight and obesity in Colombian children and adolescents; hence interventions to prevent overweight and obesity should address the specific needs of each socioeconomic stratum. For example, wealthy children and adolescents currently have the highest odds of overweight and obesity. This may be because they have better access to industrialized foods, sedentary transportation and leisure activities and because these behaviors are desirable among them. Because wealthy families also have better control over their environment, a potential intervention for these families could be a media campaign promoting specific active behaviors to make them desirable for wealthy children and adolescents. Another strategy could be to give concessions to sport clubs and healthy food venues and then use their taxes to improve the nutrition or physical activity environment for the general population.

  On the other side, children and adolescents of low socioeconomic strata currently have lower odds of being overweight or obese, this is partially explained by the persistent problem of under-nutrition, but also by a lower access to industrialized high-density foods and sedentary lifestyles (it is also possible that these sectors are more attached to traditional diets). This does not mean low socioeconomic strata are not vulnerable to overweight and obesity; to the contrary, because underserved populations are more vulnerable to their environment, small changes in healthy food availability or access to opportunities to be physically active can rapidly shift the burden of overweight and obesity to the economically disadvantaged (1, 61, 124). Consequently, it is important for the Colombian national and local governments to keep implementing inclusive policies and programs to promote physical activity and prevent overweight, and to assess the impact of those policies particularly in low socioeconomic strata.

- Implement programs and policies at the family level: There is evidence that family level interventions are effective improving children and adolescents' diet, physical activity, and weight status. In this study, an important proportion of the variability in BMI was at the family level. Programs that incorporate components for all family members, such as activities, dance classes, sport competitions, sport training, etc., could be useful to improve health and prevent obesity in the entire family. Further, family structure, included in the models as family size and extended or nuclear family, was associated with overweight and obesity in Colombian children and adolescents. The fact that being part of an extended family increases the likelihood of overweight, whereas family size is inversely associated with overweight and obesity suggests different family members play different roles in the development of overweight and obesity. For example, it is possible that presence of siblings promotes physical activity in children, but presence of adults besides the parents does not. Future studies should assess the role of specific family members in the development or prevention of child and adolescent overweight in Colombia. Grandparents are important figures in Latin American families (125); it would be interesting to further explore their specific role on Colombian children and adolescents' diet, physical activity, and weight status.

Moving forward, it will be important to target policies and interventions in Colombia to those family structures where children and adolescents are at higher risk of overweight and obesity, for example extended or small families.

- Design interventions targeted to adolescents: Health in this age group has historically been overlooked worldwide (126). Results from this dissertation suggest that the only demographic where there was a significant increase in the prevalence of obesity was in adolescents. Even though according to WHO classification system (but not to IOTF) the lowest prevalence of overweight and obesity is in adolescents, the increased in prevalence of obesity should be considered and addressed by policy makers in Colombia. Adolescents are more independent than children; their behaviors are less influenced by family members and more susceptible to peers. Further, sexual maturation, teenage pregnancy, sexual concerns, smoking, alcohol consumption, eating disorders, among others are particularly important subjects to address during adolescence (126-129). In our study almost 1% of adolescents were excluded due to pregnancy, suggesting teenage pregnancy is a public health concern in Colombian adolescents. Another public health concern in adolescents that can affect weight and nutritional status is alcohol consumption. There was not enough information to assess the potential impact of alcohol consumption on adolescents' energy intake but this should be addressed in future studies. Another health concern related to adolescents' diet and weight status are eating disorders. Results from this dissertation (study 3) suggest an interaction between wealth and sex where the odds of being overweight of wealthy females compared to that of males is less in higher wealth strata. This might be because wealthy adolescents have greater concerns about their weight. Policies trying to prevent overweight and obesity, especially those targeted to adolescents, should be careful to avoid increasing obesity related stigma and unhealthy eating behaviors in adolescents. Future studies could take advantage of the information available from ENSIN, which includes a section on perception of body weight and dietary behaviors, to assess to what extent unhealthy behaviors and perceptions are associated with overweight and obesity in adolescents.

Based on all these issues related to adolescence in Colombia, a recommendation would be to design a comprehensive policy to prevent unhealthy behaviors in adolescents. This policy could incorporate preventive measurements for risky sexual behaviors, alcohol consumption, unhealthy diet and sedentary behavior. Also, evaluations of this policy could assess the interactions among all these specific behaviors.

- <u>Acknowledge the limitations of surveillance systems:</u> as mentioned before there are some important issues with surveillance data that most be considered when utilizing this information for policy design, targeting, or evaluation. First, the nature of this study design, a repeated cross-sectional, makes impossible to determine causality. In other words, it is impossible to know the direction of the associations. An example is the association between height and overweight: it is possible that taller children are at higher risk of obesity, but it is equally possible that the reason behind obese children being taller is that obesity increases growth. A more complex example is the association between being part of an extended family and being overweight; in this case, it is highly unlikely that children cause their families to become extended, however that does not mean that extended families are directly causing the children to become obese, but it is only a piece of the complex relationships at different levels of the ecological model that affect weight status (in other words, prohibiting extended families is not an adequate policy to prevent overweight in children). These issues of surveillance data should be carefully considered when designing policies and interventions to prevent overweight in Colombian children and adolescents.

  As mentioned before, another potential problem with child and adolescent overweight and obesity surveillance data is that different BMI classification systems suggest different associations with age and sex. In this sense, it is important to acknowledge this limitation and refrain from designing and targeting public policy to specific age or sex groups based solely on these estimations. For example, it could be problematic to target resources to prevent overweight in younger children based on the WHO estimation, since according to IOTF adolescents have greater odds of being overweight and none of these systems has been validated. A recommendation to Colombian researchers and policy makers is to consider developing specific growth charts for children and adolescents. Including ENSIN 2015 (which is on the planning stage), Colombia will have three different time points that could be used to develop country specific growth charts for children and adolescents. These charts could be useful to track changes overtime and to compare with international references. Further, ENSIN includes a biomarker subsample that could be useful to validate the different international classification systems as well as the Colombian specific classification systems. Moving forward, it will be important to identify specific biomarkers that could reflect an abnormal accumulation of fat tissue and to assess the feasibility of collecting this information from a representative sample of Colombian children and adolescents.

It is important to note that, over the last six decades, Colombia has implemented several policies and programs to promote physical activity and prevent overweight and chronic diseases. A more in depth description of such policies, which include national laws and plans as well as local programs and interventions, is presented in chapter 6. Briefly, some of the most relevant at the national level are the “obesity law” and the decennial Physical Activity plan issued in 2008 and 2009 respectively. At the local level, Colombia has almost 200 “ciclovias” of different lengths, which close the streets for cyclists and pedestrians at least once a week. The largest and first ciclovia to be implemented closes the streets of Bogota at least once per week. As mentioned before, these policies could be behind the insignificant increases in the prevalence of overweight and obesity in Colombian children and adolescents. However, the reach, implementation, utilization and ultimately the impact of these policies on behaviors and health status has not been evaluated.

In order better understand the impact of past, present, and future policies and programs to prevent obesity in Colombia, it is necessary to develop adequate evaluations for each type of intervention. A possible mean to evaluate program participation and associations with health outcomes and behaviors could be through ENSIN. Currently, a section of ENSIN includes question on program participation, however it does not include participation on physical activity or obesity prevention interventions. Including questions addressing these issues could be an improvement for ENSIN 2015. Another way to assess programs and policies that are currently being implemented is by taking advantage of the geographic information available in ENSIN 2010, which could provide input about the effects of policies improving access and availability of opportunities to be physically active or for healthy eating.

A recommendation for future policies is to always include a component on program and policy evaluation. The field of under-nutrition has developed different ways to overcome the ethical and logistic challenges of evaluating public policies and programs. For example, because it is unethical, impractical, and often impossible to have a control group in public health interventions, researchers have taken advantage of gradual scaling-up. In other words, often programs and interventions are initially implemented only in a portion of the eligible population and then, as resources become available, they are scaled up to cover the entire population. In these instances, the eligible population that is included later in the intervention serves as a control group for impact evaluations of nutrition policies and interventions. This and other examples demonstrate how the field of obesity prevention could benefit from the experience of other fields. Evaluation is an important component of developing, implementing, and sustaining successful policies. It is important to identify effective ways to evaluate obesity prevention efforts in Colombia in order to be able to discern if policies are responsible from preventing an increase in child and adolescent overweight and obesity in this country.

Finally, as mentioned before globalization is a major driving force behind the increase in overweight and obesity. Until recently, a majority of the population in Colombia does not have access to industrialized foods and technology from the United States. However, the free trade agreement will most likely affect the nutrition and physical activity environment of the Colombian population. For example, fruits are now available and affordable for most Colombian families; nonetheless, it is likely that an important proportion of the fruit produced in Colombia will now be exported to the US, causing fruit prices to increase. Simultaneously, access to fast food and other imported industrialized foods will become more accessible. Public policy and civil society in Colombia must prepare for these changes in the nutrition and physical activity environments. Surveillance systems, such as ENSIN and DHS, will provide valuable information to assess changes in the population health and behaviors potentially associated with the free trade agreement. These changes will challenge the cultural resilience of the Colombian population. Public policy could take advantage of this resilience and the current perceived value of Colombian traditional diet to try to preserve healthy eating and physical activity behaviors, and assist the general population in adapting to potential changes in the nutrition and physical activity environments.

Public policy plays a very important role in obesity prevention. In depth analyses of surveillance data, such as the one presented in this dissertation, and adequate evaluation components are important to guide public policy and to provide information to the Colombian population.

Implications of Study Findings

The main theme linking all findings of this dissertation is the relevance of utilizing the information available in LMICs, such as these two national nutrition surveys from Colombia, to challenge preconceived beliefs and assess the applicability of recommendations based on studies from HIC or international recommendations, to the specific context and population of interest.

The first study of this dissertation outlined important differences in estimation of overweight and obesity of the three main international BMI classification systems for children and adolescents older than five. International classification systems have two main functions: 1) they are used to compare trends or changes in childhood and adolescent overweight and obesity across countries, and 2) they are used at the country level to identify and target subgroups with high prevalence of overweight and obesity. The lack of consistency in the associations with age and sex across international systems not only complicates global comparisons, but more importantly limits the capacity of policy makers and public health professionals to adequately target groups at higher risk of overweight, obesity, or future chronic diseases. Future studies should focus on identifying the classification system that best reflects body composition and risk of negative health outcomes. In the meantime, the objective and location of the study, as well as the characteristics of the study population should be considered in order to decide which classification system is most appropriate.

The second study described the prevalence of childhood and adolescence overweight and obesity by age, sex, wealth, and population density. Interestingly, there were no significant increases in the prevalence of child and adolescent overweight and obesity in Colombia. If the emphasis of this country on physical activity promotion and obesity prevention has been successful this raises hope for other LMICs undergoing the nutrition transition. Future studies should focus in assessing the specific contributions of local interventions and national policies in Colombia to prevent children and adolescent overweight and obesity. Also, an alternative explanation to these findings is that, because until recently Colombia did not have a free trade agreement with the United States, exposure of Colombian children and adolescents to the obesity-promoting “Western” influences has not been as strong as the exposure of other Latin American countries, such as Mexico or Brazil. If this is the case, future policies and interventions in Colombia should address this new availability of foods and technology which might promote an increase in the prevalence of overweight and obesity.

Finally, the third study identified predictors of overweight and obesity at the individual, familial, and community level. Perhaps the most relevant finding of this study was the importance of the family level predictors of Colombian children weight status. Interventions at the household level could be important to improve the nutritional status of Colombian children and adolescents. An interesting result is the association of extended families with children and adolescents’ overweight and obesity, future analysis could explore the particular influence of specific family members on child and adolescent nutritional status. Moreover, findings from this study outline the importance of social patterning in relation to childhood and adolescence overweight. We found an inverse association with urbanization and a positive association with wealth. Usually, overweight is positively associated with urbanization in both LMICs and HICs. Few exceptions are Sweden, Canada, Finland, and Greenland, which are all HICs. To our knowledge Colombia is the only LMIC were an inverse association between BMI and urbanization in children and adolescents has been described. The positive association of overweight with wealth has been reported in other countries at early stages of the nutrition transition. Results from this third study have the potential to influence public policy in Colombia; further, its applicability in similar contexts, such as other Latin American countries should be assessed. Further, they contribute to the body of knowledge of correlates of child and adolescence overweight and obesity in LMICs.

For this dissertation we used relatively novel data analysis techniques to analyze data from two national nutrition surveys from Colombia. Similar surveys are available from many Latin American countries. Future research should focus on utilizing these data sources to describe the epidemiology of overweight and obesity in the region and link this information to governments and policy makers in order to improve the health and wellbeing of children, adolescents, and the general population.

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