IDENTIFYING THE DETERMINANTS OF COEXISTING OVER AND UNDERNUTRITION IN CEBU, PHILIPPINES

by
Anna R Jennings

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Nutrition (Nutritional Epidemiology), School of Public Health

Chapel Hill
2007

Approved by:
Advisor: Linda Adair
Reader: Barry Popkin
Reader: Kelly Evenson
Reader: Penny Gordon-Larson
Reader: David Guilkey

ABSTRACT

Anna R Jennings: Identifying the determinants of coexisting over and undernutrition in Cebu, Philippines
(Under the direction of Dr. Linda Adair)

Obesity has quickly become a worldwide epidemic. Unlike in developed countries, in developing countries obesity is rapidly on the rise while chronic undernutrition remains a pervasive problem. This situation is only further complicated by the finding that over and undernutrition overlap so that in many cases both forms of malnutrition co-occur in the same communities and even households. However, developing countries do not have the healthcare infrastructure, nor do a majority of individuals have the financial means to counteract the negative impact of chronic undernutrition or obesity and its associated chronic diseases. Several studies have identified that there is a divergence of weight status between adults and offspring in countries experiencing rapid modernization but no studies that we know of have explored possible differential weight-related behavior patterns that might explain this difference. This research investigates key factors characterizing discrepant weight mother-offspring pairs in the rapidly transitioning society of Cebu, Philippines. In addition, this research identifies key determinants of diet and physical activity patterns of Filipino mothers and offspring in respond to modernization, including an evaluation of possible generational differences. We used data from multiples years of the Cebu Longitudinal Health and Nutrition Survey. Detailed individual, household, and community-level environmental, socioeconomic, and demographic information was collected at each survey year, which allowed for an exploration of the association between multiple

dimensions of modernization and multiple dimensions of physical activity and diet. Specifically, in this research we identified the urbanicity and socioeconomic (SES) environment where discrepant overweight mother/underweight offspring pairs were most commonly found and explored participation in weight-related behaviors by offspring that might contribute to this dual-burden phenomenon. Second, we explored the impact of urbanicity and SES on the dietary patterns in energy adequacy, percent calories from fat and carbohydrates of mothers compared to offspring over time. Finally, we explored the association of urbanicity and SES with occupational, chores and leisure physical activity of mothers and offspring at multiple times points. This research addresses an important gap in understanding generational differences in weight-related behavior responses to modernization; knowledge necessary to develop effective age and weight-status specific interventions in transitional societies.

To my husband Malcolm Jennings

ACKNOWLEDGEMENTS

I want to first thank my advisor, Dr. Linda Adair who, with endless patience, helped me develop the intellectual clarity and precision necessary to excel as a researcher. To me, Dr Adair embodies the archetypal true researcher: deeply curious, dedicated, and honest with a profound sense of integrity both personally and professionally. I cannot thank her enough for the innumerable hours she spent with me deconstructing roadblocks in my work and helping me see different perspectives both methodologically and theoretically. I would also like to thank and acknowledge my committee members for the invaluable contributions they made throughout the dissertation process. I am a better writer and researcher because of their dedication to detail and quality. I specifically wanted to thank all of my committee members for the continual confidence they displayed in my ability to finish despite medical difficulties during the dissertation process.

My work has been made possible through funding from several sources including the National Institutes of Health and the National Institute of Human Health and Development.

Finally, I want to acknowledge my husband Malcolm who, through his kindness, generosity and encouragement, guided me to the finish line, my mother Paula, who was always there to remind me of my original dream and passion with unconditional love and my friends, Amy, Monal, Janne, my sisters Rebecca and Jenny, Janet, Patricia, Anne, Piku, and Michele for being the independent, quirky, sassy, compassionate and brilliant inspirations in my life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%CHO	percent calories from carbohydrates
%FAT	percent calories from fat
ANOVA	analysis of variance
ARIC	Atherosclerosis Risk in Communities Study
BEE	basal energy expenditure
BMI	body mass index
CI	confidence interval
CLHNS	Cebu Longitudinal Health and Nutrition Survey
cm	centimeter
CPI	consumer price index
CVD	cardiovascular disease
FAO	Food and Agriculture Organization (United Nations)
FM	fat mass
FFM	fat free mass
GEE	generalized estimating equation
IOTF	International Obesity Task Force
kcal	kilocalories
kg	kilogram
m	meter
METS	metabolic equivalents
MV	moderate/vigorous (with respect to activity level)
MVPA	moderate/vigorous physical activity

n	number of observations
NIH	National Institute of Health
NM/OC	normal weight mother/overweight child
NM/NC	normal weight mother/normal weight child
NM/UC	normal weight mother/underweight child
OM/OC	overweight mother/overweight child
OM/NC	overweight mother/normal weight child
OM/UO	overweight mother/underweight offspring: dual-burden pair
OR	odds ratio
p	probability
PA	physical activity
SD	standard deviation
SES	socioeconomic status
SL	sedentary/light (with respect to activity level)
TEE	total energy expenditure
UM/OO	underweight mother/overweight offspring
UM/NO	underweight mother/normal weight offspring
UM/UO	underweight mother/underweight offspring
WHO	World Health Organization

I. Introduction

A. Background

During the past two decades, dramatic increases in overweight and obesity have occurred worldwide. High rates of obesity exist for both adults and adolescents/children in developed countries but as we shift towards countries with a significantly lower national Gross National Product an age disparity in overweight/obesity trends rapidly emerges. Countries still in the earlier stages of the nutrition transition show increasing trends of obesity in adults but not yet in adolescents and children. In fact, in many countries undernutrition, stunting and wasting are still prevalent resulting in the existence of a dual burden of under- and overweight within the same geographic location and in many cases the same household. These observations suggest that factors associated with individual, household, community and national-level development may differentially affect obesity trends in adults as compared to adolescents and children. Given that both chronic over and undernutrition can lead to severe health consequences and an overall reduced quality of life, it is crucial that researchers identify the factors associated with these weight disparities. It is widely recognized that both increasing wealth and urbanization, factors characteristic of modernization, are associated with changes in weight status and weight-related behaviors. We have found no research however, investigating whether these factors differentially affect women versus adolescents and children. Understanding the effect of these factors on weight

status and weight-related behavior patterns of mothers and children may be essential for developing age-specific focused and effective health policies.

In this study we used data from the Cebu Longitudinal Health and Nutrition Survey (CLHNS), a large-scale survey with detailed individual, household and community-level environmental, socioeconomic and demographic information. This survey, which included 17 survey rounds between 1983 and 2005, also included important anthropometric as well as detailed dietary and physical activity information for mothers and offspring. The wealth of data in the CLHNS provided the perfect opportunity to explore the effect of modernization on the weight status and weight-related behavior patterns of mothers and offspring over time during an important economically transitional time period in Cebu, Philippines.

B. Overall objective and specific research aims

The overall goal of this research was to identify key factors characterizing discrepant weight households in a rapidly transitioning society and further, to identify possible generational differences in how key determinants of weight status, diet and physical activity, respond to modernization. Specific aims of this work were as follows:

1. Describe the individual behaviors as well as the demographic and SES factors that characterize households with a discrepant weight pair compared to households where the mother and offspring are both in the same weight category for each cross-section of the CLHNS from 1991 to 2002. We hypothesized that the likelihood of finding a discrepant weight pair increases with greater levels of urbanicity, household income, assets, and higher mother's education. To assess this hypothesis we used multinomial logistic

regression analyses as well as predicted probabilities to assess the magnitude of effect of key exposures.

2. Compare the nature and magnitude of the differential effects of urbanicity and socioeconomic (SES) characteristics on dietary patterns in percent calories from fat and carbohydrates as well as energy adequacy behaviors of mothers and offspring from 1994 to 2005. Given that overweight prevalence was consistently substantially higher in mothers versus offspring we hypothesized that the longitudinal dietary patterns of mothers was significantly more responsive to changes in socioeconomic status and urbanization, resulting in a more obesogenic diet. We used longitudinal random-effects regression to compare the effects of urbanization and SES factors on dietary behaviors of mothers compared to their offspring.
3. Assess the relationship between socioeconomic factors and urbanicity at multiple time points and different dimensions of moderate/vigorous physical activity (MVPA) including occupational, domestic and leisure, for mothers and their offspring. We hypothesized that mothers would show a comparatively greater drop in total physical activity than offspring in response to increased wealth and urbanicity. Ordered logistic regression models assessed sociodemographic predictors of number of maternal MV chores, and relative levels of offspring MV chores and leisure MVPA. Multinomial logistic regressions were used to assess sociodemographic predictors of occupational MVPA for mother and offspring.

II. Review of the literature

A. Extent of the problem - coexisting over and undernutrition

Obesity is recognized as one of the most widespread disease epidemics of our times. Not only is obesity thought to directly reduce the quality of life of individuals but it is also recognized as a risk factor for diseases such as hypertension, cardiovascular disease, diabetes mellitus and several types of cancers (Dietz 1998; Dominguez, Barbagallo et al. 1999; Reddy, Rao et al. 2002). Some of the highest prevalences of obesity still exist in developed countries. However, some of the highest rates of increase currently exist in the developing world where undernutrition, leading to underweight, stunting, decreased mental acuity, and an increased susceptibility to infectious diseases, is still widespread (Gillespie and Haddad 2001; Caballero 2002; Popkin 2002; Popkin 2004; Caballero 2005; Mendez, Monteiro et al. 2005). Given the high costs of both chronic over and undernutrition it is imperative that developing and transitional countries address obesity prevention, while still coping with undernutrition. The complexity of the situation arises from the need to develop interventions which address both forms of malnutrition simultaneously.

B. The coexistence of under and overnutrition is a developing country phenomena

1. The rise of overweight and obesity in developing countries

A key characteristic of a country with advanced levels of obesity is the presence of the disease not only in adults but in adolescents and children as well (Bell, Adair et al. 2002;

Kimm and Obarzanek 2002). Obesity has been of public health significance for adults as well as adolescents and children in developed countries for many decades (Troiano and Flegal 1998; Lahti-Koski, Jousilahti et al. 2001; Flegal, Carroll et al. 2002; Kautiainen, Rimpela et al. 2002; Tremblay, Katzmarzyk et al. 2002; Hedley, Ogden et al. 2004). In some cases, such as in Spain, obesity rates in children have almost matched that now observed in adults (Moreno, Sarria et al. 2001; Moreno, Sarria et al. 2002).

In recent decades we have seen marked shifts towards a more 'westernized' diet structure with higher rates of over vs. undernutrition, higher rates of overweight and obesity and concurrently higher rates of chronic vs. infectious disease in developing countries around the world, phenomena referred to as the epidemiologic and nutrition transitions (Monteiro, Mondini et al. 1995; Popkin and Doak 1998; Albala, Vio et al. 2001; Popkin 2001; Benjelloun 2002; Du, Lu et al. 2002; Evans, Sinclair et al. 2002; Galal 2002; Ghassemi, Harrison et al. 2002). As with developed countries, the prevalence of overweight and obesity are on the rise for populations of adolescents and children for some middle-income countries, particularly in the Middle East, island nations of the Western Pacific, and Latin America (de Onis and Blossner 2000; Filozof, Gonzalez et al. 2001; Dorosty, Siassi et al. 2002).

2. The persistence of undernutrition in developing countries

In some low to middle-income countries where we are only beginning to observe signs of 'westernization', obesity trends are not apparent consistently across age groups. We see examples in South America, Asia and Sub-Saharan Africa where overweight/obesity is not yet occurring among adolescents and children even though high rates of obesity exist among adults (Martorell, Khan et al. 1998; de Onis and Blossner 2000; Martorell, Kettel

Khan et al. 2000). Although we do see a decrease in undernutrition, stunting and wasting in these countries the current prevalence still remains of concern (Ajayi and Akinyinka 1999; Gillespie and Haddad 2001; Ke-You and Da-Wei 2001; Hels, Hassan et al. 2003; Wiwanitkit and Sodsri 2003; Oner, Vatansever et al. 2004; Perez-Cueto and Kolsteren 2004; Wickramasinghe, Lamabadusuriya et al. 2004; Caballero 2005; Foster, Byron et al. 2005).

3. Emergence of the dual-burden problem

Until recently, underweight was a form of malnutrition found primarily among the poor urban and rural populations and overweight was concentrated among the urban wealthy in low-income developing countries (Monteiro, Moura et al. 2004). Researchers are now discovering that there is a significant overlap resulting in households with both an underweight and overweight individual (Doak, Adair et al. 2000; Gillespie and Haddad 2001; Doak, Adair et al. 2002; Popkin 2002; Caballero 2005; Doak, Adair et al. 2005). A study of six developing countries found 22-66% of households with an underweight individual were dual-burden households- defined as households with both an underweight and an overweight member (Doak, Adair et al. 2005). Conversely, 8-60% of those households with an overweight individual also had an underweight individual. Several studies have also found that the shift from underweight to overweight occurs first among adults so that dual-burden pairs are most commonly comprised of an overweight adult and underweight child or adolescent (Gillespie and Haddad 2001; Caballero 2005; Doak, Adair et al. 2005). Another recent study, in The Republic of the Marshal Islands (Micronesia), found that approximately 50% of men were overweight or obese and 75% of all women were overweight or obese while over 35% of the children (many in the same households) were undernourished and

stunted (Gittelsohn, Haberle et al. 2003). Given that the overlap in under and overnutrition is on the rise in developing countries, interventions should be designed to confront both forms of malnutrition simultaneously to avoid exacerbating one or the other of these conditions.

C. Modernization impacts both underweight and overweight trends

To confront the coexistence of under and overnutrition, research must clearly define the environment in which both forms of malnutrition overlap. Within the developing country context, several invaluable studies by Doak have begun the exploration of household and community factors that characterize the dual-burden households. In 2002, Doak et al observed that dual-burden households in China were more urban and had a higher household income than underweight and normal weight combination households (2002). This work was followed in 2005 by a multinational study, which found that in four out of six developing countries (Brazil, Russia, China, Indonesia, Kyrgyzstan, and the United States) dual-burden households where significantly more likely to be urban and come from the highest income third compared to households with an underweight but no overweight individual (Doak, Adair et al. 2005). In Brazil and Russia dual-burden households were more likely to be urban and come from a lower income third. This study suggests that the environment where under and overnutrition overlap may differ depending on the stage of modernization at the country level. Therefore the important first step in identifying the cause of coexisting over and undernutrition is to identify the household and community characteristics associated with this dual-burden phenomenon. In the first stage of this work we took advantage of a large and diverse population-based longitudinal survey of Filipino mothers and offspring to explore the

relationship between household and community characteristics and the dual-burden of over and undernutrition in Cebu, Philippines.

1. Urbanization is associated with a shift from underweight to overweight

A majority of the existing literature on the relationships of urbanization and overweight/obesity are cross-sectional. Although we can not determine a causal relationship, these studies provided important preliminary information on existing associations. Recent studies, for example, in China, Africa, Vietnam, and Thailand found significantly higher levels of obesity concentrated in urban areas in both adult and adolescent/children (Uauy, Albala et al. 2001; Kosulwat 2002; Luo and Hu 2002; Vorster 2002; Nguyen, Beresford et al. 2007). Further, a study of Brazilian adolescents in a nationwide home-based survey found that adolescents in the most industrialized regions were 1.86 times more likely to be overweight or obese than adolescents from the least industrialized regions and that urban males were 1.71 times more likely to be obese then their rural counterparts (Neutzling, Taddei et al. 2000). A multinational study of preschool children in 50 national surveys found overweight consistently more common in urban versus rural locations (Martorell, Kettel Khan et al. 2000). Although, studies do show that urbanization has an effect on overweight and obesity rates for adults as well as adolescents/children, the clustering of dual-burden pairs in urban environments suggests that the rate at which urbanization promotes the shift from under to overnutrition may differ between adults and children/adolescents. However, we found no studies exploring the impact of urbanization on divergent trends in weight status seen between adults and children/adolescents in low-income countries. Understanding the role of urbanization on malnutrition is of particular importance because of the high rate of

immigration from rural to urban centers in the developing world, especially within the lowest income groups (Solomons and Gross 1995; Popkin 1999; Caballero 2001).

2. Changing affluence is associated with a shift from underweight to overweight

As with the literature on urbanization, research in developing countries assessing the influence of changing affluence on overweight and obesity is primarily based on cross-sectional or descriptive trends studies. In general findings show that for low-income countries there is a positive relationship between affluence and overweight/obesity (Popkin 1998; Monteiro, Conde et al. 2004; Fezeu, Minkoulou et al. 2006). However, these studies are typically age specific. No studies were identified which explored a possible differential effect of changing affluence on overweight/obesity between adults and children/adolescents. In this research we explored the association of both urbanization and changing affluence on the coexistence of an overweight mother and underweight offspring pair during an economically transitional 14-year time period.

D. Modernization impacts weight-related behavior patterns

The second phase of this work focused on diet and physical activity (PA) as study outcomes because they are essential components of energy balance (Chockalingam, Balaguer-Vintro et al. 2000; Coitinho, Monteiro et al. 2002; Zhai, Fu et al. 2002). A differential response to modernization in these weight-related behaviors by adults compared to children/adolescents might contribute to the dual-burden of over and underweight in developing countries. Equally important both diet and PA patterns are modifiable behaviors that can be influenced by interventions and health policies. In most developing countries

large shifts in diet and PA patterns have occurred coinciding with urbanization, industrialization and economic development (Hankin and Dickinson 1972; Drewnowski and Popkin 1997; Popkin 1999; Drewnowski 2000; Doak and Popkin 2001; Hakeem, Thomas et al. 2002; Gracey 2003; Rivera, Barquera et al. 2004). Therefore, this work focused explicitly on the effects of urbanization and socioeconomic factors on weight status and weight-related behavior patterns of adults compared to offspring.

1. The influence of urbanization and changing affluence on diet

Dietary structure differs substantially in developing countries depending on the degree of modernization at the national level. As a country becomes more modernized, diet structure shifts through various stages of the nutrition transition. There are five major stages: *collecting food* (hunter-gatherers); *famine* (agricultural society with high fertility and mortality); *receding famine* (societies experiencing industrialization with shifts from high to low fertility and mortality and an increase in diverse 'rich' diets); *nutrition-related non-communicable disease* (industrialized societies with diets high in fat, cholesterol, sugar, and low in complex carbohydrates and fiber concomitant with reduced levels of physical activity); and *behavioral change* (societies engaging in lifestyle modifications to prevent or delay chronic disease onset) (Popkin 1994; Popkin 1998). According to Drewnowski and Popkin (1997), with improved food technology due to modernization, shifts occur in food availability and diversity as well as diet composition (increases in intake as percent fat) in lower income countries. A decrease in the consumption of complex carbohydrates and high fiber foods and increases in energy dense foods high in fat (primarily animal fat) and sweets occur as well.

In developing countries there is evidence of a positive relationship between urbanization, a fundamental characteristic of modernization, and consumption of an obesogenic diet. A small study of rural and urban Indian children, found an increased consumption of processed foods high in sugar and fat, increased levels of animal products and decreases in carbohydrates, fiber, riboflavin and vitamin E among urban compared to rural children (Hakeem, Thomas et al. 1999; Hakeem, Thomas et al. 2002). In Micronesia, where urbanization began as early as the mid-70s, shifts in the diet structure for adults were observed reaching levels far exceeding recommendations for a healthy diet concurrent with dramatic increases in chronic disease rates (Ringrose and Zimmet 1979).

It is widely recognized in the health economic literature that as individual and household income increases the absolute value spent on food expenditure increases (Ma and Popkin 1995). In keeping with this observation, several national trends studies have shown that increased income is associated with dietary shifts towards more expensive animal fats and protein, and away from relatively inexpensive vegetable fat and protein, and sources of carbohydrates and fiber (FAO 1970). A more recent study in China found strong evidence that increases in the consumption of fatty meats and edible oils and decreases in the consumption of carbohydrates occurred most dramatically in response to increasing income among the poor (Du, Mroz et al. 2004). However, a majority of evidence for the influence of changing affluence on diet in developing countries is based from ecological studies of national-level diet shifts in response to national improvements in GNP. Many of these studies have found that the direct relationship with affluence and diet (in the form of energy intake, % animal fat and protein and processed foods) occurs most dramatically in the lowest income countries (Martorell, Khan et al. 2000; Noor 2002; Monteiro, Conde et al. 2004). No studies

to date have explored the relationship between modernization and diet between generations in the same household environment.

2. The influence of urbanization and changing affluence on PA

As with diet, there is a dearth of studies in the developing world exploring the relationship between urbanization and changing affluence and PA patterns of adults compared to children/adolescents. However, a few recent studies exist which provided valuable information to form our hypotheses. With increasing levels of urbanicity in the developing world, we generally observe an increase in sedentary leisure activities and sedentary jobs of the service sector and technologically-advanced industrialized sector, as well as a decrease in agricultural jobs and active forms of transportation (Popkin 2001; Uauy, Albala et al. 2001; Kain, Vio et al. 2003; Monda, Gordon-Larsen et al. 2007). With increased household income in developing countries, we also tend to observe increases in TV ownership, car ownership, and improved household technologies/appliances that all contribute to decreases in daily energy expenditure (Albala, Vio et al. 2002; Kain, Vio et al. 2003). In Chile, for example, car ownership per 1000 inhabitants increased from 38.9 in 1970 to 136.6 in 1998 (Albala, Vio et al. 2002). A longitudinal study in China found a significantly increased odds of both male and female participation in light versus heavy occupational activity with increased urbanization (Monda, Gordon-Larsen et al. 2007). Another study in Cameroon found that urban adults engaged in significantly lower levels of PA due to increased levels of sedentary occupations and modes of transportation (Sobngwi, Mbanya et al. 2002). Consequently higher obesity, hypertension, and diabetes rates were also observed for study participants living in urban areas compared to rural areas in Cameroon. Among a

sample of black women in a province of South Africa, high-income women tended to engage in the least overall PA, which in turn was one of the strongest predictors of obesity (Kruger, Venter et al. 2002). Finally, a more recent study in Tanzania found that overall PA levels from all sources of activity were lower for men and women in urban compared to rural areas (Mbalilaki, Hellenius et al. 2007).

Similar relationships between aspects of modernization and PA are observed for children in the developing world. A small study of children in Cameroon found that rural children engaged in almost twice as much PA as did their urban counterparts (Proctor, Moore et al. 1996). In urban Santiago, Chile over 99% of a small sample of school children watched television on week nights and 20% more than 3 hours/day (Olivares, Albala et al. 1999). China is unique; in the face of modernization, 84% of Chinese youth actively commute to school, 72% engage in moderate/vigorous in-school PA, and only 8% of Chinese school children watch 2>h/day of television (Tudor-Locke, Ainsworth et al. 2003). Although urbanization and changing income affect PA patterns of adults and children/adolescents, it may be that the extent of the effect on these patterns is not uniform between adults and children within a given household (Doak, Adair et al. 2000).

E. Multiple sources of PA are affected by modernization in developing countries

Many studies of physical activity patterns and there association with health outcomes in developed countries focus on leisure-time physical activity (LTPA) (Fung, Hu et al. 2000; Kronenberg, Pereira et al. 2000; Verdaet, Dendale et al. 2004; Pitsavos, Panagiotakos et al. 2005). This focus is appropriate in an environment where there are sufficient resources such as money and time as well as appropriate facilities. Although modernization in developing

countries is associated with an emergence of labor saving household appliances, automated transportation, and processed packaged foods (Popkin 2004), access to these resources is by no means ubiquitous. This is particularly so in rural areas of low-income countries. In addition, outside of professional and school-related sports, leisure-time allocation to physical activity is not a cultural norm in many developing countries, especially for women. A recent study in a developing country context (Nigeria) found that PA was more highly attributed to occupational rather than LTPA (Forrest, Bunker et al. 2001). In China, adults were significantly more likely to perform light versus heavy occupational physical activity as urbanicity level increased (Monda, Gordon-Larsen et al. 2007). Although chores have been documented as an important source of PA in developing countries (Dufour, Reina et al. 2003; Rao, Gokhale et al. 2007), there are few studies that explore the direct relationship between factors of modernizations and PA patterns from chores.

F. Measuring urbanization and changing affluence

Few studies classify urbanicity beyond a simple urban/rural dichotomy. Use of an urban/rural dichotomy however obscures any heterogeneity that may exist within communities defined as urban and rural (Yach, Mathews et al. 1990; Vlahov and Galea 2002). One study measuring food habits and nutrient density in Pakistani children used a five category classification for urbanization and found u-shaped associations for several micronutrients (Hakeem, Thomas et al. 2002). This non-linear association across urban categories would have been completely obscured by using a binary urbanicity classification. Further, an urban/rural dichotomy can only capture change over time if a community that was categorized at one point in time as rural is later classified as urban. Once a community

is categorized as urban it will remain urban over time when using a dichotomous urban/rural classification (assuming that these urban and rural definitions remain constant over time) regardless of any continuing development. If development that does occur has a true influence on the relationship of urbanicity and health this temporal distinction will be lost if urbanicity is dichotomized. In fact, studies based on the data used in our study show that an urban/rural dichotomization is insufficient to distinguish levels of urbanicity and to track the process of urbanization in Cebu, Philippines (McDade and Adair 2001; Dahly and Adair 2007). To capture an effect of urbanization over time, a scale of urbanicity based on 7 community characteristics was used in our study to capture heterogeneity in all communities including households migrating from one community to another.

There is currently no consensus for a standardized measure of changing affluence in developing countries. Few studies exist that systematically compare the relationships between different components of affluence to identify a stable coherent measure within a developing country context. A recent study however, comparing different proxies of economic status in developing countries found that a simple sum of durable goods owned by the household or a principle components score of these goods were the most accurate measures of economic status (Bollen, Glanville et al. 2001). For a majority of studies, affluence is typically based on individual or household income levels although some studies also include an individual's or an individual's parent's education and occupation (Sobal 1991). According to Sobal (1991), all three factors are important components of affluence. It may also be important to consider all three factors since the direction of effect may differ depending on the variables used. For example, a study in Brazil found that there was a positive relationship between income and obesity but a negative relationship between

education and obesity (Monteiro, Conde et al. 2001). To avoid a misrepresentation of the effect of changing affluence on weight status and weight-related behavior patters of mothers and offspring in this study, we included three different measures of affluence: income, maternal education, and an index of household assets.

G. Summary and Significance

The emergence of obesity in adults of transitional countries with continuing prevalence of undernutrition, stunting and wasting in youth creates a dual-burden phenomenon in the developing world. This complex scenario poses substantial difficulties for policy makers since to address one aspect of the coexisting over/underweight combination might exacerbate the problems of the other. A majority of the research to the present date has been ecological, which does not allow for a direct analysis of associations at an individual level; or cross-sectional, which does not allow for an evaluation of cause-and-effect relationships. Our objective was therefore to answer an important, previously unanswered question: "What factors drive the divergent weight trends between adults and children observed in transitional countries?" This question follows the premise that as household members experience improved economic stability and access to commodities, individuals may respond differently in reference to weight-related behaviors.

Overall, studies consistently show that modernization is positively associated with consumption of a more obesogenic diet and a decrease in PA in low to middle-income countries. However, it is unclear whether these changes occur simultaneously for adults and children/adolescents. A recent study documented a lag in the increasing overweight trend of children/adolescents compared to adults in developing countries (Popkin, Conde et al. 2006).

This study provides some evidence of generational differences in weight-related behaviors changes in response to modernization. No studies were found that explore the effect of urbanization or changing affluence on the diet or PA patterns of adults compared to adolescents and children. To fill this gap, the study herein focuses explicitly on these relationships. The information from this study is invaluable for creating targeted age-specific interventions that confront shifts in diet and PA patterns leading to over and undernutrition occurring in developing countries.

Our study used data from a large-scale longitudinal survey of a cohort of mothers and their offspring in Cebu, Philippines. The Philippines, like many developing countries, has experienced rapid growth and modernization in the last few decades. Increases in obesity and chronic disease prevalence in the adult population of the Philippines (Tanchoco, Cruz et al. 2003) have occurred in parallel with the increased movement towards urban settings, shift towards industrial and service oriented jobs and increase in average per capita standard of living. According to research by the Food and Nutrition Research Institute (2001), as of 2000 approximately 30% of all deaths were caused by cardiovascular disease (CVD) and over 21% of the entire population was hypertensive. In contrast, overweight is uncommon among the nations children and undernutrition, with subsequent underweight, is a continued source of public health concern (Cerdena, Lana et al. 2001). The Cebu Longitudinal Health and Nutrition Survey (CLHNS) provides detailed information on a cohort of mothers and their index child (the child born at baseline of the CLHNS) in the Metropolitan area of Cebu during a pivotal period of 'westernization' and economic growth. The survey includes individual and household-level information on nutrition, health, demographic, and SES characteristics as well as contextual community level information on the barangays

(administrative units) included in the study. Detailed information on multiple levels and time points allowed for a longitudinal analysis of the effect of changes in urbanicity and SES characteristics on individual level diet and physical activity behaviors for mothers and offspring, a comparison that has not yet been explored. Longitudinal analyses , such as those in this study, are particular important given that the relationship between factors of modernization and weight-related behavior patterns change depending on the countrywide state of development, (Solomons and Gross 1995).

III. Coexisting over and undernutrition is associated with household wealth and deliberate weight-related behavior changes in Cebu, Philippines

A. Introduction

Until recently, underweight was a form of malnutrition found primarily among poor urban and rural populations in developing countries. In contrast, overweight was concentrated among the urban wealthy (Monteiro, Conde et al. 2004; Monteiro, Moura et al. 2004). As developing countries globalize and adopt new technologies, there has been a rapid shift to processed high fat and sugar diets and sedentary work and leisure activities known as the nutrition transition (Popkin 1994). As a result, a "dual burden" of over and undernutrition in the same community and often the household has emerged and poses new health threats (Doak, Adair et al. 2000; Gillespie and Haddad 2001; Doak, Adair et al. 2002; Popkin 2002; Caballero 2005; Doak, Adair et al. 2005; Garrett and Ruel 2005).

The Philippines, like many developing countries, has experienced rapid growth and modernization in recent decades. Increases in obesity and chronic disease in adults (FNRI 2001; Tanchoco, Cruz et al. 2003) have occurred in parallel with increased urbanization, a shift towards industrial and service oriented jobs, and an increase in average per capita standard of living. In contrast, overweight is uncommon (though increasing) among Filipino children and undernutrition is a continued source of public health concern (Cerdena, Lana et al. 2001).

The negative health consequences of undernutrition (Rice, Sacco et al. 2000; WHO 2004; Nandy, Irving et al. 2005) and overnutrition (WHO 2004) are equally severe and therefore require equal attention. Given the high health costs of chronic disease related to obesity, it is imperative that developing and transitional countries, such as the Philippines, address obesity prevention, while still coping with undernutrition. Traditionally, interventions have been designed to address either under or overnutrition individually. However, in countries experiencing rapid modernization with high levels of dual-burden households, an intervention targeting one condition may exacerbate the other. It is therefore crucial that researchers identify characteristics unique to these dual-burden households in order to develop interventions which simultaneously confront under and overnutrition in these countries.

Few large scale studies have explored characteristics of the dual-burden household. Prior analyses have been cross-sectional with an emphasis on primary characteristics associated with the nutrition transition such as household urbanicity level and income. This work suggests that dual-burden households tend to be from more urban areas and higher income levels (Doak, Adair et al. 2002) although the evidence for income is less conclusive (Doak, Adair et al. 2000; Doak, Adair et al. 2005). For many developing countries the recent influence of 'Western' culture (Field, Cheung et al. 1999; McCabe and Ricciardelli 2003; Ricciardelli and McCabe 2004; Cafri, Thompson et al. 2005; Paxton, Norris et al. 2005) has caused a shift in desired body ideals towards model-thin for young females and ruggedly muscular for young males (Chugh and Puri 2001; Shroff and Thompson 2004; Canpolat, Orsel et al. 2005). To our knowledge, there are no studies that evaluate the association of these sociodemographic characteristics with dual-burden status or that explore possible

weight-related behavioral responses to modernization, which may explain the paradoxical coexistence of underweight in a high-income household with existing overweight.

This study examines trends in the association between dual-burden status and sociodemographic factors over time for a birth cohort of Filipino mothers and their offspring. The Cebu Longitudinal Health and Nutrition Survey (CLHNS) provides detailed information on a cohort of mother and offspring pairs in the Metropolitan area of Cebu during a pivotal period of 'westernization' and economic growth making it an ideal sample for this analysis. The use of a single birth cohort allows tracking of dual-burden patterns through important life cycle periods such as puberty and young adulthood for the offspring. Additionally, we evaluate sex-specific patterns in dual-burden trends and identify diet and physical activity-related behaviors among the offspring that might relate to dual-burden pair status.

B. Methods

1. Study population

The CLHNS used a single-stage cluster sampling procedure to select 17 urban and 16 rural barangays (administrative units) of metropolitan Cebu, Philippines (including Cebu City one of the largest cities in the country). All pregnant women in the selected barangays who gave birth between May 1st, 1983 and April 30th, 1984 were recruited to the study (ages 14.8 to 47.1 years, n=3,327). Detailed individual, household and community-level environmental, socioeconomic and demographic information was collected once during the third trimester of pregnancy, at delivery and bimonthly for 24 months. The survey was extended to include rounds in 1991-2, 1994-5, 1998-2000, 2002, and 2005-6. For

convenience, we refer to these rounds as 1991, 1994, 1998, 2002 and 2005 and the average age of the offspring in each survey was 8.5, 11.5, 15.5, 18.7, and 21.5 years, respectively.

Our sample was restricted at each survey to mother/offspring pairs who were residing in the same house. We excluded pairs if either the mother or the offspring was pregnant at the time of interview, or the offspring was a twin or triplet. The 1983 – 6 surveys were excluded from our analyses because of the small number of overweight individuals (5% for the mothers and <1% for the offspring) in these survey years. Our final analyses included data from mother/offspring pairs in the 1991 (n=2,133), 1994 (n=2,038), 1998 (n=1,937), 2002 (n=1,831), and 2005 (n=1,674) follow-up surveys. The CLHNS protocols were reviewed and approved by the Institutional Review Board of the University of North Carolina at Chapel Hill.

2. Dependent variables

a. Mother-offspring weight status pairs

Weight and height were measured by trained local field staff during an in-home interview. Height was measured to the nearest 0.1 cm and weight was measured to the nearest 0.1 kg. Weight status (under, normal or overweight) was based on body mass index (BMI: kg/m^2). Mothers and offspring ages 18 and older were classified as overweight at a BMI of ≥25 and underweight at a BMI <18.5. For offspring <18 years of age (all those in 1991, 1994, 1998 and 14 in 2002), the International Obesity Task Force (IOTF) sex and age-specific cut points developed by Cole et al were used to determine underweight and overweight (Cole, Bellizzi et al. 2000). Nine unique pairs were created using the underweight, normal weight, or overweight status of the mother and offspring within each

household and an overweight mother/underweight offspring (OM/UO) was identified as a dual-burden pair (Figure 1). We did not separately analyze underweight mother/overweight offspring (UM/OO) dual burden pairs because fewer than 8 households (less than 0.44%) contained this pair type in any given survey year, and the etiology of this combination is likely to be different from the OM/UO pair type. The goal of the present analyses was to identify behavioral and socioeconomic characteristics particular to dual-burden pairs versus other mother-offspring pair combinations.

b. Offspring weight-related behaviors

The 2002 and 2005 surveys included questions on desire to gain or lose weight, and behaviors undertake to achieve those changes. Given that western ideals favor thin girls and muscular boys, we were interested in behavior patterns for girls who became underweight and boys who were no longer underweight by 2005. Binary categorical variables were created to indicate, in each year, whether the participants had engaged in weight loss or weight gain-oriented behaviors. For example, a subject was given a 1 if they participated in at least one of the weight loss-oriented behaviors (e.g. dieting, exercising) and 0 otherwise. The same criteria were used to create the binary weight gain-oriented behavior variable.

3. Community-level independent variables

Urbanicity has traditionally been expressed as a simple binary urban/rural variable. Studies based on the CLHNS show that this dichotomization is insufficient to distinguish levels of urbanicity and to track the process of urbanization (McDade and Adair 2001; Dahly and Adair 2007). An index was therefore created using the following community-level

categories: population size, population density, communication, transportation, healthcare services, education, and market availability each of which was designated a maximum value of 10 so that a score of 70 represented the highest level of urbanicity (Dahly and Adair 2007).

4. Household-level independent variables

Household wealth was represented by household income and assets. Total household income was estimated from cash income and the value of in-kind earnings for each survey year. Respondents were asked to describe the average minutes per day, days per week, and weeks per year each household member worked as well as the average pay received for this time. Using the Philippines consumer price indices (CPIs), income values were deflated to a common time point in 1983 for comparability. The distribution of income at each time point was severely right-skewed and a non-linear association with our outcome was observed using fourths of income. For descriptive analyses, deflated household income was truncated so that right-skewed outliers were given the value at the 99^{th} percentile of the sample income distribution. For regression analyses, indicator variables were created to represent thirds of the income distribution (low, medium, high).

A summary index of twelve household assets, ranging from small items such as electric fans to house ownership and construction material, was created to represent wealth. We chose a simple summation score of assets owned based on recommendations from a previous study evaluating SES specification in a developing country context (Bollen, Glanville et al. 2001). Our final analyses included assets as a continuous variable with possible values from 0 to 12.

5. Individual-level independent variables

Mother's education was expressed as the highest level of education attained. Because of a non-linear association with our study outcome, maternal education was categorized to represent : < primary school graduate, primary school graduate, some high school, and high school graduate and beyond. The effect of maternal and offspring age, offspring gender and number of siblings on the likelihood of being a dual-burden pair was also evaluated. Binary variables were used to classify offspring as either early or late maturers. For girls, early maturation was menarche before age 12.4, and late was menarche after age 13.9 (the 25^{th} and 75^{th} percentiles in the sample). At age 15, boys were classified based on their self-comparison with line drawings depicting stages of pubic hair development (validated on a sub-sample by a comparison of self-report to a clinical assessment by a physician). Boys were classified as early maturers if they were at pubic stage 4 or 5 and late maturers if they were at stage 1 or 2.

6. Imputations for missing data

Missing values were imputed for independent variables by using the output of a regression of the variable in question on covariate that most highly correlated with that variable. Fewer than 2.75% of households were missing information for any of the independent variables included in our analyses. The use of imputed data did not change the results or interpretation of our analyses.

7. Statistical Analyses

a. Trends in overweight and underweight

Trends of overweight among mothers, overweight and underweight among offspring, and trends in the prevalence of dual-burden mother-offspring pairs were investigated. Generalized estimating equations (GEE) were used to test for increasing or decreasing linear trends. At each survey year, means for individual, household and community-level characteristics from OM/UO pairs were compared to means from non-discrepant weight pairs (mother and offspring both underweight, normal weight, or overweight) using analysis of variance (ANOVA) with a Bonferroni adjustment. Our goal was to identify characteristics unique to the OM/UO pair compared to pairs representing chronic undernutrition (UM/UC), relative health (NM/NC), and chronic obesity (OM/OC). We identified characteristic of the OM/UO pairs that differed from the comparison group in at least half (3 of the 5) survey years. For the girls who became underweight between 2002 and 2005 and the boys who were underweight in 2002 but not in 2005, the percentage of individuals who participated in weight-gain and weight-loss related behaviors were identified.

b. Characteristics of dual-burden pairs

The likelihood of being in each of the mother/offspring pair types was assessed using multinomial logistic regression, with the NM/NC pair as the referent. The NM/NC pairs were used as the referent because they accounted for the largest percentage of mother-offspring pairs at all time points (32.0 to 52.0%) and represented a state of relative health for the mother and offspring. In this paper we focus on the comparison between the dual burden OM/UO and NM/NC pairs. Regression analyses were performed using a series of cross-sections since mother-offspring pairs were not comprised of the same individuals over time.

Significance levels for main effects variables were determined at a p value ≤ 0.05. There was a high likelihood that information on maturation, number of siblings, and diet-related behaviors were related to unmeasured characteristics that were in turn related to being a dual-burden pair and therefore, these variables would be endogenous in our models. To avoid estimating biased regression coefficients due to endogeneity, these variables were excluded from our final models. Interactions based on two-variable combinations of the following: urbanicity, household assets, household income, offspring gender, and maternal education, were assessed using partial F tests. We observed a statistically significant interaction ($p \leq 0.10$) at multiple time points between household income and urbanicity as well as assets and urbanicity and therefore these interactions were included in the relevant models. A statistically significant interaction was observed between maternal education and assets at multiple time points but because of small cell sizes these interactions were not included in the final models. To aid in the interpretation of regression coefficients, the predicted prevalence of dual-burden pairs at selected levels of urbanicity, maternal education, household assets and income representing low and high-risk profiles were calculated for boys and girls from 1991 to 2005. Low and high-risk profiles were defined as the 25^{th} or 75^{th} percentile of urbanicity, household assets and income and 75^{th} or 25^{th} percentile of maternal education, respectively.

Since our regression analysis revealed different associations of offspring gender with the likelihood of being a dual burden pair in 1998 versus 2005, gender-specific logistic regression analyses were performed to identify factors that contributed to offspring underweight in 2005. The purpose of this analysis was to identify possible influences of 'westernization' on weight status for girls versus boys in young adulthood. Significance levels

for main effect variables were determined at a p value ≤ 0.05 and as with our multinomial logistic regression models two-variable interaction terms were assessed at a p value ≤ 0.10 using a partial F test. No statistically significant interactions were found. All data analyses were performed using Stata 9.2 (StataCorp 2006).

c. Assessment for selectivity bias

We assessed selectivity bias related to loss-to-follow and study exclusion criteria in two ways. First, we used a two-stage Heckman estimation procedure at each time point (Heckman 1979). Although both stages of the Heckman correction analysis were performed simultaneously using one Stata command, for pedagogical purposes we describe them here as two separate steps. In the first stage a binary outcome (1=in sample year, 0=not in sample year) was regressed on a set of characteristics thought to influence the likelihood of being in the sample. Our selectivity model included individual, household and community independent variables from the baseline survey in 1983. In the second stage a binary outcome (1=NM/NC pair, 0=otherwise) was regressed on a set of variables from the year of interest adjusted for the likelihood of being in the model (estimated in the first stage). We collapsed all categories but the NM/NC group because of the complexity of estimating a two-stage multinomial logistic regression and since this group was the most prevalent it seemed a logical choice for our Heckman analysis. Pairs lost to follow-up or excluded were consistently poorer, with a younger mother and an older offspring who was more likely to be a daughter. However, results from the Heckman models showed no significant selection bias in any of the survey years. In a second test of selectivity bias, an additional category was created to represent all excluded mother/offspring pairs (e.g. those excluded because the

mother or daughter was pregnant). Inclusion of this category in our analyses did not alter any of the regression estimates for our other remaining categories.

C. Results

1. Trends in overweight and underweight

As shown in Figure 2a, the prevalence of overweight increased among mothers from 26.5% in 1991 to 42.9% in 2005 (trend: OR=1.14, CI=1.12,1.16). There was an increasing linear trend over time in overweight for girls (trend: OR=1.56, CI=1.40,1.73) and boys (trend: OR=1.55, CI=1.40,1.72), yet in 2005 prevalences remained low (7.7% and 8.9% respectively). Although there was a decreasing linear trend in underweight for girls (34.4% to 30.1%; trend: OR=0.94, CI=0.91,0.96) and boys (32.3% to 15.5%; trend: OR=0.85, CI=0.83,0.87) the prevalence for both groups remained high in 2005 (Figure 2b). Despite a decrease in underweight for the offspring there was no significant decrease in the prevalence of dual-burden mother/offspring pairs (6.8% in 1991 to 8.1% in 2005) (Figure 2c).

2. Characteristics of dual-burden pairs

Table 1 compares characteristics of OM/UO pairs and non-discrepant weight pairs from 1991 to 2005. Compared to the OM/OC pairs, mothers in the OM/UO pairs had lower levels of education and fewer offspring were early maturers. The OM/OC and OM/UO pairs did not differ by urbanicity level or household assets and only some evidence suggested that the average household income was higher in OM/OC pairs. In contrast, OM/UO pairs had higher average household income and assets, and lived in more urban areas than both

NM/NC and UM/UC pairs. In addition, mothers of OM/UO pairs had a higher level of education and fewer offspring were late maturers compared to UM/UC pairs.

Table 2 shows the likelihood of being an OM/UO pair versus a NM/NC pair from 1991 to 2005 given various individual, household and community-level characteristics. In all five years the likelihood of being an OM/UO pair was positively associated with household assets. From 1991 to 1998 OM/UO pairs were more likely to be an overweight mother and underweight son. This relationship reversed and by 2005 OM/UO pairs were more likely to be an overweight mother and underweight daughter compared to NM/NC pairs. In 2005, the likelihood of being an OM/UO pair was negatively associated with both maternal and offspring age. Although level of urbanicity increased the likelihood of being an OM/UO pair, it was only significant in 1991. Maternal education was not associated with being a dual-burden pair, however having some high school education tended to decrease this likelihood. No consistent or precise associations were observed for household income and the likelihood of being a dual-burden pair.

To aid in the interpretation of regression coefficients, the predicted prevalence of dual-burden pairs was calculated in low and high-risk profiles among girls and boys from 1991 to 2005 (Figure 3). Within the high-risk profile, the predicted prevalence of dual-burden pairs for girls started at a low (6.8%) and increased through to 2005 (13.4%). The highest predicted prevalence of dual-burden pairs occurred for boys in 1994 (13.2%) and consistently decreased through to 2005 (7.0%). Within the low-risk profile the predicted prevalence of the dual burden pairs followed similar patterns for both boys and girls. A further analysis of offspring underweight showed that girls in 2005 were more likely to be underweight if they were older (OR=1.68, CI=1.01,2.81) and from at least a middle income

family (OR=1.68, CI=1.09,2.59) (Table 3). In contrast, boys were more likely to be underweight if they were younger (OR=0.56, CI=0.32,0.95) and from a low compared to a high-income family (OR=0.65, CI=0.43,0.97).

3. Gender-specific weight-related behavior patterns for offspring

We examined behavior patterns aimed at weight loss and gain from 2002 to 2005. Among girls who became underweight between 2002 and 2005 (n=85), 17.7% (n=15) were trying to lose weight in 2002 and 9.4% (n=8) were trying to lose weight in 2005. For boys who were underweight in 2002 but were no longer underweight by 2005 (n=146), 41.8% (n=61) were actively trying to gain weight in 2002. By 2005, 24.7% (n=36) of these boys were still trying to gain weight.

D. Discussion

Our study documents a consistent and dramatic increase in overweight in a cohort of adult Filipino women with a concomitant decrease in underweight among their offspring from 1991 to 2005. With a substantial increase in maternal overweight and only a moderate decrease in offspring underweight we would expect an increase in the prevalence of dual-burden pairs; instead we found a relatively constant prevalence of dual-burden pairs over time. This suggests that the dual occurrence of overweight in mothers and underweight in a cohort of their offspring in Cebu, Philippines is not due simply to chance (i.e. combined probabilities) and that there may be factors jointly influencing these two trends. Our comparison of mean characteristics showed that dual-burden pairs were different from all non-discrepant weight pairs with respect to maternal education but otherwise they had similar

characteristics to pairs where both the mother and offspring were overweight. Since dual-burden pairs occur in environments similar to those of overweight mother-offspring pairs, there is an increased possibility of negative repercussions of interventions focused exclusively on obesity in this population.

Our regression analyses showed that greater household assets, representing long-term wealth, most consistently predicted the likelihood of being a dual-burden pair. These results are similar to findings in previous studies linking dual-burden households with a more wealthy setting in developing countries (Vorster, Bourne et al. 1999; Doak, Adair et al. 2002; Doak, Adair et al. 2005). The increase in overweight prevalence observed for mothers in our study may have been a result of increased food availability and variety, changes commonly observed for countries in intermediate stages of the nutrition transition (Popkin 2001; Popkin 2004). An increase in sedentary forms of transportation and increase in service oriented versus agricultural jobs in more urban areas may also have prompted an increase in overweight in mothers (Popkin 1996; Adair 2004). In contrast to overweight mothers, offspring in our study may have made dietary and physical activity-behavioral changes that placed them in a negative energy balance in response to increases in household wealth. This theory is supported by several study findings. First, approximately 10% of daughters who became underweight by 2005 were participating in diet and physical activity-related behaviors in order to lose weight. Secondly, girls were more likely to be underweight if they were from at least a middle-income family compared to a low-income family. Finally, not only did underweight in daughters remain high over time but the prevalence of dual-burden pairs with a daughter increased over time.

Unlike some dual-burden studies (Doak, Adair et al. 2000; Doak, Adair et al. 2002), we did not find that dual-burden pairs were consistently more likely to occur in urban areas. An increase in urbanicity over time may have increased the uniformity of food availability throughout metropolitan Cebu, accounting for the decreased impact of urbanicity on being a dual-burden pair from 1991 to 2005. In 2005, offspring age was negatively associated with being a dual-burden pair. Our logistic regression results showed an increased risk of being underweight at younger ages only among boys. Given that boys mature later than girls this age effect may simply be a function of late maturation. Our multinomial regression results also showed that being a dual-burden pair in 2005 was negatively associated with maternal age. Since the age range for mothers in 2005 ranged from 35 to 66 years of age, weight loss for older women may be driving this negative association.

Unique to our study was the finding that through adolescence and young adulthood (1998 to 2005), the prevalence of the dual-burden phenomenon was different in households with a daughter versus a son. The drop in risk for dual-burden pairs having an underweight son between 1998 and 2005 was likely a partial response to post-pubertal increases in muscle mass in males. Additionally, in wealthier households, social and cultural pressures, similar to those in more developed countries, may have been responsible for changes in body size due to boys desire to be 'bigger and stronger' and girls desire to be thin (Field, Cheung et al. 1999; Furnham, Badmin et al. 2002; McCabe and Ricciardelli 2003; Chow 2004; Eisenberg, Neumark-Sztainer et al. 2005). The persistent desire to lose weight even for underweight girls and the continued desire to gain weight for boys observed in our study indicates the influence of social pressures. We did not find any studies that explored the relationship of social pressures and body image issues among boys in other Asian countries. However,

multiple Asian studies were found that support our finding that some girls in Cebu, Philippines engaged in weight-loss related behaviors in response to a social pressure to be thin (Matsuhashi 2000; Chugh and Puri 2001; Sakamaki, Amamoto et al. 2005). These cultural influences may not have as great an impact on mothers who grew up when chronic undernutrition was a predominant fear and therefore a "plump" figure was equated with health and desirability (Martorell, Khan et al. 2000; Mendez, Monteiro et al. 2005; Subramanian and Smith 2006). Therefore, the contrast in body image ideals between generations might also be a contributing factor to the presence of dual-burden pairs in developing countries. Overall, the emergence of social pressure for girls to be thin adds to the complexity of simultaneously addressing underweight and overweight. From our findings it seems clear that a successful intervention must not only simultaneously address underweight and overweight in the household but must also take into consideration the complex biological, environmental as well as the social factors leading to the dual-burden phenomenon.

As with any study based on longitudinal data there is the concern that final risk estimates will be biased due to selective loss to follow-up. In the CLHNS baseline survey, households that were lost due to death of the offspring were from poorer more rural areas. In contrast, those lost due to refusal to continue in the study, or migration from the study area were from more urban areas and the parents had higher education levels. For the more recent survey years (1991 to 2005) the pool of households lost due to deaths, refusal, and migration rates were also socioeconomically and demographically heterogenous. We did not therefore expect significant selection bias due to loss to follow-up. Because our analysis focused on mother-offspring pairs, our study sample was restricted to households where both the mother

and offspring were living together. Additionally, since our outcome was weight status we could not include any mothers or daughters who were pregnant at the time of the interview. Formal tests for selection bias however, showed that these exclusions did not significantly bias our results.

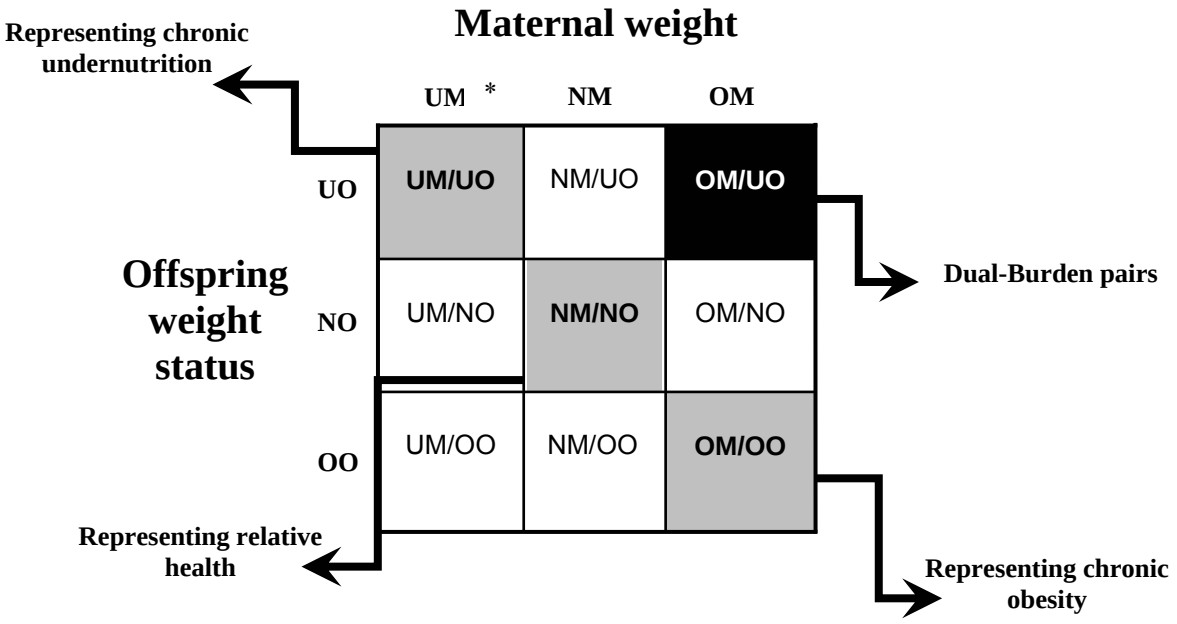
Since we used a birth cohort, we cannot be certain that the observed trends were related to time versus age effect. Therefore, findings from this study can not be used to make inferences about dual-burden time trends for the entire country. We do however, have a heterogenous age group for the mothers and were therefore able to control for maternal age. Additionally, studies show that the nutrition transition and modernization in the developing world has an impact on both adult males and females (James, Leach et al. 2001). However, since our dataset only includes complete information for mothers and one offspring, we cannot include the fathers in our analyses. If there were dual-burden pairs in our sample with an overweight father and underweight offspring but not an overweight mother they were misclassified in our study. Additionally, we could not fully assess individual factors related to the father, which may be important predictors of the dual-burden phenomenon. As one mitigating factor, we used household income in our analyses, which is highly correlated with father's income.

There is substantial socioeconomic and demographic heterogeneity within this study population, which includes Cebu City, one of the largest cities and cultural centers in the country. The richness of this data increased our ability to assess the impact of these factors on the likelihood of being a dual-burden pair. Additionally, the detailed individual, household and community-level data spanning several decades makes the CLHNS ideal for studying intergenerational behavioral responses to the many aspects of globalization. Most

important, we were able to study these intergenerational behavioral responses over an 11-year time span. Finally, without longitudinal data we would not have observed the dramatic change in dual-burden pairs from predominantly mothers and sons to mothers and daughters between 1998 and 2005. This finding led to our discovery that social pressures, similar to those found in developed countries, may play an important role in the presence of underweight in households with an overweight individual.

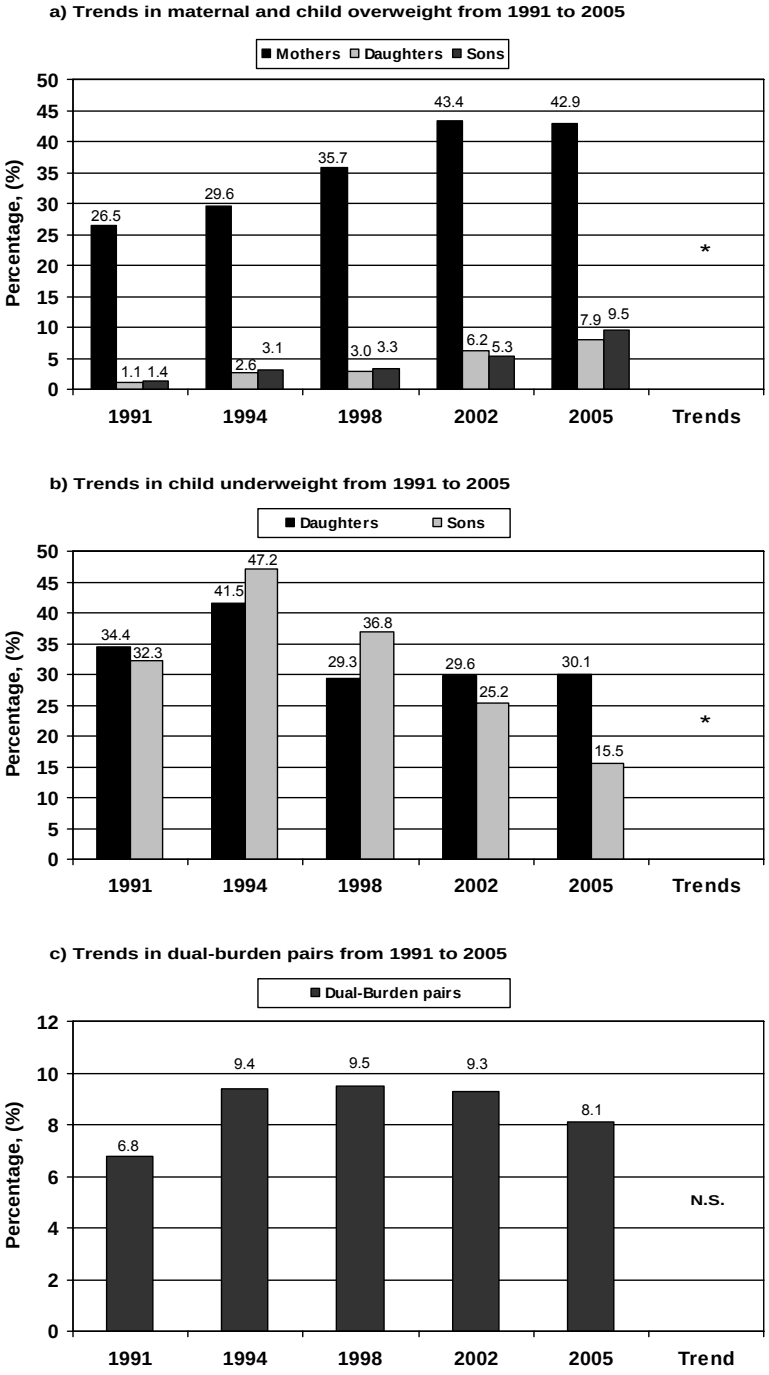
In conclusion, the health consequences compounded by the economic costs of underweight and overweight pose particular problems for economically unstable developing countries. Interventions to limit both forms of malnutrition are therefore crucial. However, interventions that focus exclusively on underweight or overweight may exacerbate the condition not directly targeted by the intervention. In this study we found that dual-burden pairs are more common in wealthier households. We also discovered that offspring in our study sample were using dietary and physical activity behaviors to obtain a desired body size, which may be a response to social pressures. Given that these are modifiable behaviors that can be influenced by interventions and health policies (Chockalingam, Balaguer-Vintro et al. 2000; Coitinho, Monteiro et al. 2002; Zhai, Fu et al. 2002), a logical future study might be to explore possible differential behavioral responses of mothers and offspring to modernization. This information may provide key insights for a focused and effective intervention that can jointly address underweight an overweight coexisting within a single household context.

Figure 1. Mother and offspring pair combinations based on the underweight, normal weight, and overweight status of the mother and offspring within each household.



* UM=underweight mother, NM=normal weight mother, and OM=overweight mother. This coding scheme is repeated for the offspring using UO, NO, and OO.

Figure 2. Trends over time in the prevalence (%) of maternal and offspring overweight, underweight, and dual-burden pairs.



* Indicates an increasing linear trend at P<0.0001. Trend was assessed using XTGEE regression models predicting a) percentage of overweight mothers, daughters and sons, b) percentage of underweight daughters and sons, and c) percentage of dual-burden pairs with an overweight mother and underweight offspring, by year (1991 – 2005). All overweight and underweight trends were significant. No significant trend was observed for dual-burden pairs.

Table 1. Comparison of Characteristics (Mean ± SD) between dual-burden pairs and non-discrepant weight mother-offspring pairs from 1991 to 2005 in Cebu, Philippines

	dual-burden	both overweight	both normal weight	both underweight
		1991		
N	130	14	820	78
Offspring gender (% male)	59.2[a]	50.0[a]	55.0[a]	43.6[a]
Early maturer (%)	33.6 ± 47.8[a]	83.3 ± 38.9[b]	34.4 ± 47.5[a]	14.3 ± 35.2[c]
Late maturer (%)	21.3 ± 41.4[a]	0 ± 0[a]	22.0 ± 41.4[a]	35.7 ± 48.2[b]
Maternal age (years)	36.2 ± 6.0[a]	37.2 ± 6.1[a]	35.4 ± 6.1[a]	36.5 ± 6.6[a]
Maternal education (years)	8.6 ± 3.8[a]	11.5 ± 3.7[a]	7.4 ± 3.8[b]	6.7 ± 3.9[b]
Urbanicity (1 to 70)	37.9 ± 12.2[a]	45.2 ± 6.6[a]	32.4 ± 14.7[b]	30.5 ± 14.1[b]
Household assets (0 to 11)	5.0 ± 2.2[a]	6.4 ± 2.5[a]	3.8 ± 2.3[b]	3.1 ± 2.0[c]
Household income (pesos/wk)	466.3 ± 374.8[a]	583.3 ± 355.3[a,b]	372.0 ± 344.3[b,c]	283.5 ± 171.5[c]
		1994		
N	176	33	588	128
Offspring gender (% male)	55.7[a]	45.5[a]	50.2[a]	50.0[a]
Early maturer (%)	27.7 ± 44.9[a]	72.7 ± 45.2[b]	40.6 ± 49.2[c]	14.4 ± 35.3[d]
Late maturer (%)	19.1 ± 39.4[a]	3.0 ± 17.4[a]	17.3 ± 38.0[a]	37.6 ± 48.6[b]
Maternal age (years)	38.7 ± 5.7[a,b]	39.3 ± 6.2[a,b]	38.2 ± 6.0[b]	39.9 ± 6.9[a]
Maternal education (years)	8.2 ± 3.8[a]	10.3 ± 4.4[b]	7.7 ± 3.8[a]	6.1 ± 3.8[c]
Urbanicity (1 to 70)	38.3 ± 12.1[a]	42.7 ± 6.9[a]	35.3 ± 13.5[b]	32.1 ± 13.9[b]
Household assets (0 to 11)	4.8 ± 2.0[a]	5.7 ± 2.4[a]	3.9 ± 2.2[b]	3.1 ± 1.8[c]
Household income (pesos/wk)	550.7 ± 354.5[a]	808.3 ± 700.8[b]	472.3 ± 388.9[a,c]	390.0 ± 289.6[c]
		1998		
N	168	33	619	74
Offspring gender (% male)	60.0[a]	60.6[a]	50.0[a]	46.0[a]
Early maturer (%)	28.0 ± 45.0[a,c]	66.7 ± 47.9[b]	34.9 ± 47.7[a]	13.5 ± 34.4[c]
Late maturer (%)	25.6 ± 43.8[a]	3.0 ± 17.4[b]	18.1 ± 38.5[a,b]	45.9 ± 50.2[c]
Maternal age (years)	42.2 ± 5.5[a]	42.6 ± 6.0[a,b]	42.3 ± 6.0[a]	45.0 ± 7.0[b]
Maternal education (years)	8.3 ± 4.0[a]	9.9 ± 4.8[a]	7.3 ± 3.8[b]	6.8 ± 3.8[b]
Urbanicity (1 to 70)	41.0 ± 11.9[a]	44.4 ± 9.8[a]	37.1 ± 14.6[b]	35.0 ± 15.5[b]
Household assets (0 to 11)	5.5 ± 2.0[a]	6.2 ± 2.5[a]	4.5 ± 2.1[b]	3.6 ± 1.7[c]
Household income (pesos/wk)	654.9 ± 481.0[a]	828.0 ± 653.3[a]	517.9 ± 388.7[b]	380.2 ± 212.0[c]
		2002		
N	149	59	508	48
Offspring gender (% male)	53.7[a]	47.5[a]	59.6[a]	48.9[a]
Early maturer (%)	29.9 ± 46.0[a]	59.3 ± 49.5[b]	35.8 ± 47.9[a]	22.2 ± 42.0[a]
Late maturer (%)	23.1 ± 42.3[a]	3.4 ± 18.3[b]	21.1 ± 40.8[a]	35.6 ± 48.4[a]
Maternal age (years)	45.7 ± 5.6[a,b]	43.6 ± 5.2[b]	45.8 ± 6.0[a]	47.0 ± 7.2[a]
Maternal education (years)	8.0 ± 3.7[a]	9.6 ± 4.2[b]	7.3 ± 3.9[a,c]	6.3 ± 3.7[c]
Urbanicity (1 to 70)	43.9 ± 12.2[a,b]	46.9 ± 11.2[b]	39.7 ± 14.8[c]	39.8 ± 14.5[a,c]
Household assets (0 to 11)	5.9 ± 1.9[a]	6.2 ± 1.7[a]	4.9 ± 2.0[b]	4.0 ± 1.7[c]
Household income (pesos/wk)	648.7 ± 508.4[a]	746.3 ± 604.6[a]	529.2 ± 442.3[b]	365.7 ± 217.1[b]
		2005		
N	105	68	459	37
Offspring gender (% male)	36.2[a]	54.4[a,b]	61.9[b]	48.6[a,b]
Early maturer (%)	26.9 ± 44.6[a,c]	63.2 ± 48.6[b]	34.0 ± 47.4[a]	11.1 ± 31.9[c]
Late maturer (%)	20.2 ± 40.3[a,b]	4.4 ± 20.7[a]	24.0 ± 42.8[b]	41.7 ± 50.0[b,c]
Maternal age (years)	47.7 ± 5.9[a]	47.2 ± 5.5[a]	49.1 ± 5.9[a]	49.1 ± 7.4[a]
Maternal education (years)	7.9 ± 3.8[a]	10.1 ± 4.0[b]	7.4 ± 3.8[a]	7.1 ± 3.7[a]
Urbanicity (1 to 70)	41.0 ± 12.3[a,b]	44.3 ± 9.5[a]	39.1 ± 14.1[b]	37.9 ± 16.2[a,b]
Household assets (0 to 11)	5.8 ± 1.7[a]	6.8 ± 1.6[b]	5.2 ± 1.9[c]	4.9 ± 1.5[c]
Household income (pesos/wk)	598.0 ± 493.8[a]	830.9 ± 650.4[b]	546.5 ± 481.5[a]	412.5 ± 288.1[a]

[a,b,c,d] Values that differ from one another by ANOVA at $p < 0.05$ are noted with different letters.

Table 2. The likelihood of being a dual-burden versus a normal weight mother and offspring pair: adjusted βs, 95% CI from cross-sectional multinomial logistic regressions at multiple time points in Cebu, Philippines[§]

	1991	1994	1998	2002	2005
N	2,133	2,038	1,937	1,831	1,674
Community characteristics					
Urbanicity (1 to 70)	**0.08*** (0.05,0.10)**	**0.01 (-0.00,0.03)**	**0.01† (-0.00,0.03)**	**0.01 (-0.00,0.03)**	**-0.01 (-0.04,0.02)**
Household characteristics					
Household income					
Low income third	**Ref[a]**	**Ref**	**Ref**	**Ref**	**Ref**
Middle income third	**1.39** (0.39,2.39)**	**0.26 (-0.27,0.80)**	**-0.17 (-0.73,0.38)**	**0.04 (-0.40,0.47)**	**-0.25 (-1.42,0.92)**
High income third	**0.44 (-1.08,1.96)**	**0.41 (-0.09,0.91)**	**0.12 (-0.32,0.57)**	**0.07 (-0.44,0.58)**	**-1.51† (-3.17,0.16)**
Middle income*urbanicity‡	**-0.03* (-0.06,-0.00)**	**---**	**---**	**---**	**---**
High income*urbanicity‡		**---**	**---**	**---**	**0.04† (-0.00,0.08)**
Household assets (1 to 11)	**0.53*** (0.29,0.77)**	**0.15* (0.03,0.26)**	**0.18** (0.08,0.29)**	**0.25*** (0.14,0.35)**	**0.18** (0.06,0.31)**
Assets*urbanicity‡	**-0.01** (-0.02,-0.00)**	**---**	**---**	**---**	**---**
Individual characteristics					
Offspring gender					
Female	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
Male	**0.14 (-0.32,0.61)**	**0.20 (-0.14,0.53)**	**0.64* (0.03,1.24)**	**-0.22 (-0.58,0.13)**	**-1.01*** (-1.35,-0.67)**
Offspring age (years)	**-0.45 (-5.54,4.65)**	**-0.17 (-0.54,0.20)**	**-0.24 (-0.73,0.25)**	**-0.45 (-1.12,0.14)**	**-0.70* (-1.30,-0.11)**
Maternal age (years)	**0.02 (-0.01,0.06)**	**0.01 (-0.01,0.03)**	**-0.01 (-0.03,0.01)**	**-0.00 (-0.03,0.02)**	**-0.04† (-0.08,0.00)**
Maternal education					
<Primary school graduate	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
Primary school graduate	**0.12 (-0.41,0.64)**	**-0.21 (-0.64,0.22)**	**0.06 (-0.50,0.63)**	**0.06 (-0.45,0.58)**	**-0.24 (-0.82,0.33)**
Some high school	**-0.07 (-0.75,0.62)**	**-0.35* (-0.67,-0.02)**	**-0.16 (-0.67,0.36)**	**-0.24 (-0.74,0.27)**	**-0.45 (-1.00,0.10)**
High school graduate+	**-0.07 (-0.68,0.54)**	**-0.41 (-0.98,0.16)**	**0.09 (-0.46,0.65)**	**-0.11 (-0.76,0.54)**	**-0.02 (-0.91,0.88)**

[a]Ref = referent category

†P<0.10

*P<0.05

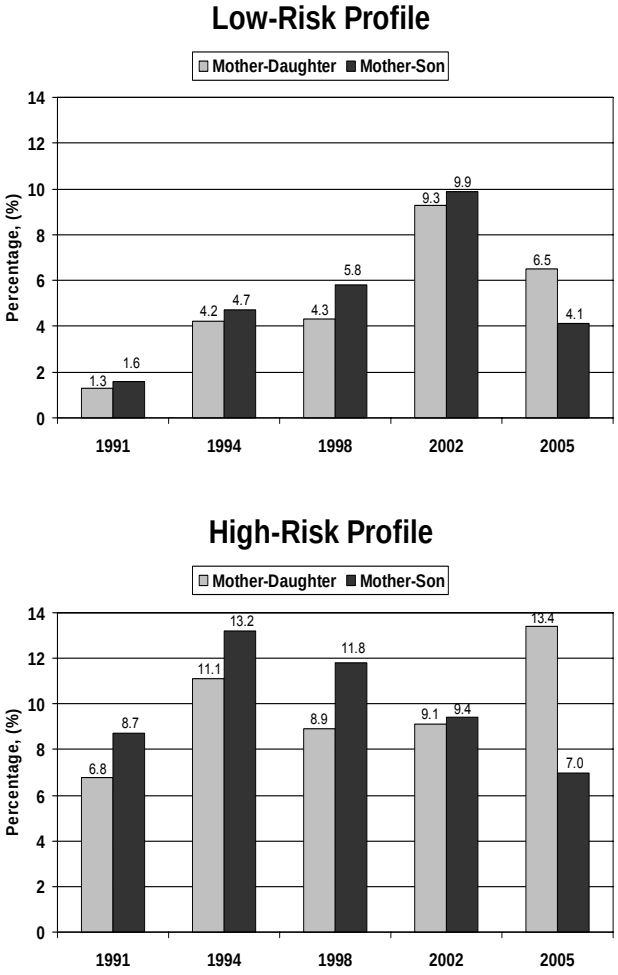
**P<0.01

***P<0.0001

[§]Cross-sectional multinomial logistic regression analyses were performed comparing all mother-offspring pair combinations of under, normal, or overweight status using the normal weight mother and offspring pair as the referent group. However, we present here only the likelihood of being a dual-burden overweight mother-underweight offspring pair.

[‡]Indicates a significant interaction between two variables using a $p < 0.10$. Beta-coefficients were only reported if there was a significant interaction. An interaction was observed between maternal education and assets at multiple time points but because of insufficient cell sizes these interactions were not included in the final models.

Figure 3. Predicted prevalence of dual-burden pairs at selected levels of urbanicity, maternal education, household assets and income representing low and high-risk profiles* from 1991 to 2005 in Cebu, Philippines.



*Low-risk profile= 25th percentile of urbanicity, household assets and income and 75th percentile of maternal education. High-risk profile= 75th percentile of urbanicity, household assets and income and 25th percentile of maternal education.

Table 3. The likelihood of being underweight for boys and girls in 2005 using logistic regression (adjusted ORs, 95% CI)[§] in Cebu, Philippines

	Girls	**Boys**
N	736	868
Community characteristics		
Urbanicity, (1 to 70)	1.00 (0.99,1.02)	1.03[†] (1.00,1.08)
Household characteristics		
Household income		
Low income third	Ref[a]	Ref
Middle income third	1.68* (1.09,2.59)	1.09 (0.76,1.54)
High income third	1.44 (0.83,2.50)	0.65* (0.43,0.97)
Household assets, (1 to 11)	1.04 (0.93,1.17)	1.33[†] (0.97,1.82)
Individual characteristics		
Offspring age, (years)	1.68* (1.01,2.81)	0.56* (0.32,0.95)
Maternal age, (years)	1.00 (0.97,1.03)	0.99 (0.96,1.02)
Maternal education		
<Primary school graduate	Ref	Ref
Primary school graduate	0.72 (0.44,1.17)	1.02 (0.65,1.60)
Some high school	0.91 (0.54,1.51)	0.87 (0.57,1.32)
High school graduate+	0.96 (0.51,1.81)	1.08 (0.50,2.31)

[a]Ref = referent category

[†]P<0.10

*P<0.05

[§]No interactions were observed so results are presented here as odds ratios instead of beta-coefficients

IV. Offspring consume a more obesogenic diet than mothers in response to modernization in Cebu, Philippines

A. Introduction

Developing countries experiencing modernization, are experiencing concurrent increases in the consumption of processed foods, animal fats, and simple sugars, as well as an overall increase in total energy intake known as the nutrition transition (Popkin 1994). Simultaneously, modernization leads to a shift from active to sedentary occupations, domestic chores, and forms of transportation. These changes in diet and physical activity ultimately lead to the emergence of overweight and obesity in countries with historically high levels of chronic undernutrition (Monteiro, Conde et al. 2004; Mendez, Monteiro et al. 2005). Several studies have shown that these trends toward positive energy balance tend to occur first among the wealthy and/or urban subpopulations in developing countries (Popkin 1999; Neutzling, Taddei et al. 2000; Uauy, Albala et al. 2001; Albala, Vio et al. 2002; Benjelloun 2002; Monteiro, Moura et al. 2004; Monda, Gordon-Larsen et al. 2007). However, there may be substantial heterogeneity, with respect to dietary changes in response to modernization, within strata of socioeconomic status or urbanicity. A recent multi-country study found that obesity rates initially increased among adults before children in developing countries (Popkin, Conde et al. 2006) provoking another series of important questions. Does this reflect generational or cohort differences? Is it an effect of aging or a differential response to changing environmental and economic circumstances? Answering these questions can help in

the development of targeted and effective interventions for overweight populations in a context where chronic undernutrition is still a serious concern.

The Philippines, like many developing countries, has experienced rapid modernization in recent decades. There is also evidence that the nutrition transition has affected this population. A study based on data from the Cebu Longitudinal Health and Nutrition Survey (CLHNS) found that the prevalence of overweight increased significantly among mothers and a cohort of their offspring during a 14 year period (Jennings et al, unpublished). However, in 2005, the prevalence of overweight for mothers (43%) was greater than 4 times that observed for their sons (10%) and daughters (8%) (Jennings et al, unpublished). This suggests that Filipino mothers and offspring may not be responding to the nutrition transition in the same way. Thus, further exploration of these longitudinal data may provide important insights into whether there are generational differences in how key determinants of weight status, namely diet and physical activity, respond to rapidly changing social, economic, and environmental circumstances. One study based on the CLHNS examined moderate to vigorous physical activity patterns and found that occupational, domestic and leisure moderate to vigorous activity decreased from 1998 to 2005 for both mothers and offspring (Jennings et al, unpublished). To examine the other side of the energy balance equation, we use the CLHNS data to explore the differential effects of changing income, assets, maternal education, and urbanicity on three characteristics of maternal and offspring diet that may affect obesity risk: percentage of calories from fat, percentage of calories from carbohydrates and estimated energy adequacy. Given that overweight is currently substantially higher in mothers than offspring, we hypothesized that the

longitudinal dietary changes of mothers would be significantly more obesogenic than offspring in response to changes in socioeconomic status and urbanization.

B. Methods

1. Study population

Participants were recruited from metropolitan Cebu, Philippines, which includes Cebu City (the second largest city in the country) and several smaller urban as well as mountainous and coastal rural communities. All pregnant women in 17 urban and 16 rural randomly selected barangays (administrative units) were invited to participate in the study (ages 14.8 to 47.1 years, n=3,327). Between May 1st, 1983 and April 30th, 1984 there were 3,080 singleton births identified. Information was collected once during the third trimester of pregnancy, at delivery and bimonthly for 24 months. The survey was extended to include rounds in 1991-2, 1994-5, 1998-2000, 2002, and 2005-6 where the average age of the index offspring were 8.5, 11.5, 15.5, 18.7, and 21.5 years, respectively. For convenience, we refer to these rounds as 1991, 1994, 1998, 2002 and 2005. The analysis samples were restricted to mother/offspring pairs living together in the same household, and included cases where the offspring was a singleton, and neither the mother nor the offspring was pregnant, incapacitated or institutionalized. Our final samples included mother/offspring pairs in 1994 (n=1,884), 1998 (n=1,781), 2002 (n=1,615), and 2005 (n=1,349). The CLHNS protocols were reviewed and approved by the Institutional Review Board of the University of North Carolina at Chapel Hill.

2. Dependent variables

Dietary information was collected using 24-hour dietary recalls. One day of intake was recorded from mothers in all years and from offspring in 1994. From 1998 to 2005, two days of dietary recall are available for offspring. Data were collected during in-home interviews performed by highly trained local field staff. All data were checked by editors, and implausible intake values were verified by sending interviewers back to question respondents. To minimize loss of information and maximize the probability of obtaining unbiased estimates (Willet 1998), offspring intakes are represented by 2-day average intakes for each year from 1998 through 2005.

a. Energy intake - kilocalories/Basal Energy Expenditure (Kcal/BEE)

Total energy intake (kcal) for both mothers and offspring was calculated using year-appropriate Philippines Food Composition Tables from the Food and Nutrition Research Institute. To create a comparable measure of total energy for mothers and offspring, total intake was divided by BEE to adjust for body size. BEE was estimated using the following most recent WHO/FAO equations based on doubly labeled water studies (Institute of Medicine of the National Academies 2005), which account for adolescent energy requirements for growth and development:

(1) Normal weight mother BEE: (255 - 2.35*age + 361.6*height + 10.12*weight)

(2) Overweight mother BEE: (247 - 2.67*age + 401.5*height + 8.60*weight)

(3) Normal weight daughter BEE: (189 - 17.6*age + 625*height + 7.9*weight)

(4) Overweight daughter BEE: (515.8 - 26.8*age + 347*height + 12.4*weight)

(5) Normal weight son BEE: (68 - 43.3*age + 712*height + 19.2*weight)

(6) Overweight son BEE: (419.9 - 33.5*age + 418.9*height + 16.7*weight)

where age was in years, both height (m) and weight (kg) were measured by trained field staff. Height was measured to the nearest 0.1 cm using portable stadiometers and weight was measured to the nearest 0.1 kg using portable scales. Overweight was defined for mothers and children ages 18 and older as a BMI of ≥25. For children <18 years of age (all those in 1994, 1998 and 14 in 2002), the International Obesity Task Force (IOTF) sex and age-specific cut points developed by Cole et al were used to determine overweight (Cole, Bellizzi et al. 2000). Any change in weight over time for mothers was due primarily to an increase in fat mass. To avoid an artificial increase in energy requirement, maternal weight in 1994 was used to calculate BEE in subsequent years. This method assumes that weight change over time due to changes in lean body mass was negligible. The final variable for mothers and offspring was expressed as a proportion (kcal/BEE) which represents estimated energy adequacy.

b. Diet composition - fat and carbohydrate consumption

Percentage of calories from fat (%FAT) or carbohydrates (%CHO) were calculated by multiplying the total gram intake from the 24-hr recalls by 9 (kcal per 1-unit gram) and 4 respectively and dividing by the total 24-hour kcal intake. Both %FAT and % CHO were represented in the final models as continuous variables.

3. Independent variables

a. Maternal education

For each round of the CLHNS, maternal education was recorded as the highest year of education completed. Based on the distributions, indicator variables were created to represent: less than primary school graduate, primary school graduate, some high school, and high school graduate and beyond. However, few women attained additional education after the 1983 baseline survey so there is minimal change over time in maternal education.

b. Household income

Total household income included the sum of both cash income from all household members over 6 years of age and the value of in-kind earnings. For comparability over time, income values were deflated to January 1983 values using year-appropriate Philippines consumer price indices from 1994 to 2005. For all analyses, a continuous variable of household income was truncated so that right-skewed outliers were given the value at the 99th percentile of the sample income distribution.

c. Household assets

Household assets are represented by the sum of the number of selected possessions ranging from small items such as electric fans to house ownership and construction material. The resulting index took on values from 0 to 11. Previous research has shown that a simple summation of ownership of material goods is an accurate and robust estimate of SES in a developing country context (Bollen, Glanville et al. 2001).

d. Urbanicity

Recent studies based on the CLHNS have found substantial heterogeneity in the common urban-rural dichotomy (McDade and Adair 2001; Dahly and Adair 2007), To minimize misclassification and allow for an exploration of changes in urbanicity over time, an urbanicity index score was assigned to each barangay based on 7 criteria: population size, population density, communication, transportation, healthcare services, education, and market availability (Dahly and Adair 2007). Each category was created with values from 1 to 10 so that a maximum score of 70 represented the most urban community. The urbanicity score was included in our final models as a continuous variable.

e. Household member status

A binary variable indicated whether the participant was a mother (0) or offspring (1). Within each household there were a maximum of 4 observations per household member (one per survey year).

f. Time

Given that the four survey years included in this study were not equally spaced, a series of indicator variables were created to represent 1994, 1998, 2002 and 2005.

4. Statistical analysis

Descriptive statistics (number of participants, means, standard deviations, and proportions) were used to describe general sample characteristics in 1994 - 2005. Our aim was to identify whether aspects of modernization associated with the nutrition transition, namely increasing SES and urbanicity, had a differential effect on diet patterns of mothers

versus offspring. To directly compare the dietary patterns of mothers and offspring over time a dataset was created for both mothers and offspring so that there was a maximum of 4 observations per person representing the 4 survey years included in this analysis. The two datasets were then appended so that one outcome variable for energy adequacy, %FAT, and %CHO were created. A binary indicator household member variable was created to identify the intake value as belonging to the mother or the offspring. This member variable was included in our regressions to test whether dietary intakes differed between mothers and offspring.

We used random-effects models to explore the effect of several indicators of SES and urbanicity on energy intake, %FAT and %CHO in which, the intercept and slope (rate of change in diet with increasing SES and urbanicity conditioned on household member status) were modeled as random effects. The coefficients for main effects in each model represented the effect of independent variables on maternal diet. Interactions between each independent variable and household member were included in each model and represented the added effect of independent variables on diet outcomes associated with being the offspring versus the mother within the household. Preliminary analyses showed a significant interaction between offspring gender and household member status on diet outcomes, therefore analyses were stratified by offspring gender. Results were considered significant at a p value ≤ 0.05 for main effects, and interactions between time and the independent variables were assessed using partial F tests and considered significant at $p \leq 0.10$. To avoid artificially large standard errors of interaction terms due to substantial covariance, backwards deletion was used to eliminate interaction terms with minimal impact (T-statistic $<|1.0|$). All models were adjusted for maternal age using both a continuous and squared age term due to a curvilinear

relationship between maternal age and all three diet outcomes. Given that changes in SES and urbanicity characteristics tend to co-occur, simulations were performed to present the predicted prevalence of each outcome under contrasting circumstances: a high SES-urbanicity (90^{th} percentile of sample level of income, assets and urbanicity and maternal education level = high school graduate+), and low SES-urbanicity (10^{th} percentile of income, assets and urbanicity and maternal education level = primary school graduate). All analyses were adjusted for clustering at the community level and performed using Stata 9.2 (StataCorp 2006).

C. Results

Table 4 presents individual and household characteristics. In general, energy intake and the percent of calories from fat increased and the percent of calories from carbohydrates decreased over time for daughters and sons. For mothers, there were small decreases over time in energy intake and percent calories from fat between 1998 and 2005 but percent calories from carbohydrates remained relatively constant. Table 4 also depicts changes in SES and urbanicity over time. There was an overall increase in average household assets, income and community urbanicity but not maternal education.

In **Table 5** we show results for the effect of SES and urbanicity over time on energy intake for mothers versus offspring. Mothers of both daughters and sons were more likely to have a higher estimated energy adequacy if they were more educated, from a higher income and assets household, and lived in a more urban environment. Maternal energy intake decreased consistently over time. Contrary to our hypothesis, compared to mothers,

daughters and sons were likely to have a greater increase in energy intake with the same increase in household assets and daughters with the same level of community urbanicity.

With respect to diet composition, mothers were more likely to consume a diet with a higher %FAT (**Table 6**) and lower %CHO (**Table 7**) if they were more educated, from a higher income and assets household, and lived in a more urban environment. For mothers, the %FAT decreased over time but the %CHO remained relatively constant. In general, compared to mothers, offspring were likely to have a greater increase in dietary fat and carbohydrates with the same increase in household income and in households where the mother had a higher level of education. This is indicated by the consistently significant value of the household member variable and associated interaction terms in the regressions.

Figure 4 presents the predicted dietary trends over time for Filipino mothers and offspring in contrasting SES-urbanicity environments. Mothers and offspring consume substantially more kilocalories as well as a higher %FAT and lower %CHO in a high versus a low SES-urbanicity environment. However, the predicted energy adequacy and the %FAT decreased over time for mothers but increased over time for offspring. Additionally, the predicted %CHO remained relatively constant for mothers but decreased substantially for offspring. Over time, the divergence in energy adequacy between mothers and sons was greater than the divergence observed between mothers and daughters. In contrast, the divergence in %FAT and decrease in %CHO between mothers and daughters was greater than the divergence observed between mothers and sons.

D. Discussion

Our objective was to explore the differential effect of changes in socioeconomic status and urbanization on the diet patterns of Filipino mothers compared to their offspring.

We found with increasing socioeconomic status and urbanization, mothers as well as offspring were consistently more likely to consume more calories relative to basal needs as well as a higher percent of calories from fat and a lower percent from carbohydrates. This is reminiscent of dietary changes observed in low-income developing countries experiencing rapid modernization (Drewnowski and Popkin 1997; Vorster, Bourne et al. 1999; Kosulwat 2002; Weng, Liu et al. 2007). Additionally, similar to findings in other developing countries (Galal 2002; Doak, Adair et al. 2005), overweight increased to a greater extent among Filipino mothers than there offspring (Jennings et al, unpublished). Therefore, we expected that mothers' dietary patterns would become more obesogenic than that of their offspring in response to increases in wealth and urbanicity. However, contrary to our hypothesis, offspring consumed a significantly more obesogenic diet than mothers experiencing the same increases in wealth and urbanicity. These results suggest that modernization has a greater impact on the diet of younger generations in the Philippines. There may be an age effect to weight gain such that growth and development may counteract the effect of an obesogenic lifestyle among adolescents. Once the period of growth and development is complete for these Filipino offspring, will the rate of increase in the prevalence of overweight far exceed the rates observed for older generations?

Previous research suggests that Filipino offspring may be at an increased risk for substantial increases in overweight as they enter in to adulthood. Using the CLHNS, we observed a modest but steady increase in overweight and a decrease in underweight among Filipino offspring from 1991 to 2005 (Jennings et al, unpublished). Additionally, we have observed a steady drop in the number of offspring participating in physical activity (Jennings et al, unpublished). This new information on obesogenic dietary behaviors among offspring

suggests a future increase in overweight among Filipino youth, particularly among the wealthy urban subpopulation. Unless interventions are designed to address this problem now, overweight may far exceed the high levels observed among older generations. Given that overweight and its associated diseases are already a serious public health problem among Filipino adults (FNRI 2001; Tanchoco, Cruz et al. 2003), interventions should be developed at the family level. These interventions should focus on a healthy balanced diet versus calorie restriction given that dual-burden households with an overweight mother and underweight offspring tend to exist in wealthy urban environments where we expect to observe continual increases in offspring overweight.

This study has a number of limitations, primarily concerning the method for creating the energy adequacy outcome. Use of BEE in lieu of total energy expenditure (TEE) may have biased our estimates. We did not have data to estimate physical activity duration and intensity and therefore could not accurately estimate energy expenditure from physical activity. Previous findings using the CLHNS data show that a greater number of sons participate in occupational and leisure moderate/vigorous activity than mothers and daughters suggesting that use of BEE may have inflated the extent to which energy need was exceeded in this study, particularly for sons. Further, because weight gain for mothers was due primarily to increases in fat mass versus fat free mass we used mothers' weight from 1994 to estimate BEE for subsequent years. The assumption that there were no changes in fat free mass may have been violated, particularly for older women with age-related decreases in fat free mass (Svendsen, Hassager et al. 1995). However, the models were adjusted for maternal age; therefore the likelihood that this violation biased our estimates was minimized. According to the Institute of Medicine (2005), different equations are necessary to calculate

BEE for overweight versus normal or underweight individuals. However, because the 1994 weight was used to estimate energy need at all time points the equation for underweight and normal weight individuals was used for all mothers who became overweight after 1994. These equations were designed to measure BEE across a population of individuals with varying weights and not necessarily for individuals with changing weight over time. It is unlikely that there was a substantial shift in energy need for mothers as they passed the BMI=25 kg/m2 threshold; therefore we did not change equations for women who became overweight between 1994 and 2005. Our results show a decrease in energy adequacy over time for mothers despite a continued increase in overweight. This brings in to question our method for creating the energy adequacy variable for mothers. However, we also observed a decrease over time in %FAT, a variable which is not determined based on weight status. The discrepancy between energy intake and weight status may therefore, be a result of a disproportionately greater decrease in energy expenditure through physical activity compared to energy intake which would result in a continued weight gain over time.

In our study BEE was calculated using estimation equations based on data from an American population. Previous studies have found that Asians tend to have higher fat mass and less fat free mass compared to Americans with the same BMI; therefore the estimation equations may have overestimated actual BEE (fat mass is less metabolically active than fat free mass). However, since our population is ethnically homogenous the extent to which BEE may be overestimated is probably consistent across the sample and therefore we do not expect significant differential misclassification in the ranking of individuals by BEE levels. Further, there are no studies that validate the extent to which the BEE equations accurately assess energy need for adults as compared to offspring (the R-squared may be higher for

adults than offspring which could introduce bias to my models comparing mothers and offspring). A final possible limitation of this study was the assumption that reporting adequacy was the same for both mothers and offspring. In developed countries, studies have found that overweight and obese individuals are more likely to underreport calorie and fat intakes possibly in response to social pressures to be thin (Lafay, Basdevant et al. 1997; Voss, Kroke et al. 1998; Samaras, Kelly et al. 1999; Scagliusi, Polacow et al. 2003; Yannakoulia, Panagiotakos et al. 2007). However, given that mothers and offspring consume a more obesogenic diet in response to increased wealth and urbanicity, non-random misreporting of dietary behaviors between mothers and offspring is unlikely.

There are several unique strengths of this study. Previous research has documented dietary behavior changes in developing countries such as increased total calorie from processed foods high in sugar and fat intake from animal sources. However no studies to date have explored a possible differential response in dietary behaviors of adults and offspring to modernization that might explain discrepant weight status. Because of the detailed environmental, socioeconomic, and demographic information of the CLHNS from individual, household and community-levels, we had the unique opportunity in this study to explore intergenerational responses to modernization. Additionally, the wealth of data of the CLHNS allowed for a detailed exploration of multiple dimensions of diet. Finally, this study documents dietary trends through important period of development from adolescence to adulthood for offspring.

In conclusion, several studies to date have identified the coexistence of overweight and underweight in developing countries (Khor and Sharif 2003; Doak, Adair et al. 2005; Garrett and Ruel 2005). However, few studies have explored the possible differential effect

of modernization on weight-related behavior patterns that might lead to this dual-burden phenomenon. Given that the overweight individual is commonly an adult and the underweight individual an offspring in these dual-burden pairs, it is a logical assumption to believe that there is a generational difference in behavioral responses to modernization. With modernization comes increased access to western cultural beliefs and pressures especially for the urban wealthy and perhaps younger generations are more susceptible to these pressures. However, our findings suggest that Filipino offspring are as likely, if not more likely, as mothers to adopt an obesogenic lifestyle in response to increased wealth and urbanicity. It may be that the Philippines has not reached a level of modernization to observe large-scale dietary modification among the urban wealthy that is often observed in developed countries. Therefore, it may be prudent for Filipino public health officials to prepare for a continued shift towards an obesogenic lifestyle and a likely increase in the overweight trend among the urban wealthy.

Table 4. Individual, household and community characteristics (Mean ± SD) of mother-offspring pairs from 1994 to 2005 in Cebu, Philippines[a]

Year	**1994**	**1998**	**2002**	**2005**
No. of households	1,884	1,781	1,615	1,311
Dietary characteristics:				
Mothers				
Energy adequacy, (Kcal/BEE)[a]	1.1	1.2	1.1	1.0
Percent calories from CHO[a], (%)	69.0	68.2	67.8	68.1
Percent calories from fat, (%)	15.8	17.1	16.0	15.7
Offspring - Females				
Energy adequacy, (Kcal/BEE)	1.1	1.1	1.3	1.4
Percent calories from CHO, (%)	68.4	64.0	56.0	55.6
Percent calories from fat, (%)	17.2	22.1	26.6	25.8
Offspring - Males				
Energy adequacy, (Kcal/BEE)	1.2	1.4	1.5	1.6
Percent calories from CHO, (%)	68.4	64.3	60.5	60.0
Percent calories from fat, (%)	16.9	21.8	22.2	21.6
Individual characteristics:				
Mothers				
Age, (years)	38.7 ± 6.1	42.7 ± 6.1	45.9 ± 6.0	48.6 ± 5.9
Education, (years)	7.5 ± 3.9	7.6 ± 3.9	7.6 ± 3.9	7.7 ± 3.9
Gender of Offspring (% male)	51.6	53.0	55.7	56.5
Offspring - No. of Females	912	837	720	571
Age, (years)	11.5 ± 0.4	14.9 ± 0.4	18.7 ± 0.3	21.5 ± 0.3
Education, (years)	3.7 ± 1.0	7.8 ± 1.5	10.8 ± 2.0	12.1 ± 3.1
Offspring - No. of Males	968	944	895	740
Age, (years)	11.5 ± 0.4	16.1 ± 0.3	18.7 ± 0.3	21.5 ± 0.3
Education, (years)	3.4 ± 1.2	7.8 ± 1.5	9.5 ± 2.9	10.7 ± 3.9
Household characteristics:				
Household income, (pesos/wk)	501.0 ± 407.8	543.3 ± 407.4	578.1 ± 468.8	601.4 ± 555.0
Household assets, (1 to 11)	4.0 ± 2.2	4.8 ± 2.2	5.3 ± 2.0	5.5 ± 1.9
Community characteristics:				
Urbanicity, (1 to 70)	35.7 ± 13.3	39.0 ± 13.7	41.9 ± 13.8	41.0 ± 13.4

[a]*Notes:* SD = Standard Deviation, Kcal = kilocalories, BEE = Basal Energy Expenditure, CHO = Carbohydrate

Table 5. Coefficients and 95% confidence intervals from a longitudinal random-effects regression predicting total dietary calories/Basal Energy Expenditure (BEE) for Filipino mothers versus offspring[a]

Model	Mother vs. Daughter	Mother vs. Son
Maternal education:		
<Primary school graduate	*Ref*[b]	*Ref*
Primary school graduate	0.06 (0.01,0.10)**[d]	0.08 (0.04,0.12)***
Some high school	0.13 (0.08,0.18)***	0.13 (0.08,0.18)***
High school graduate+	0.22 (0.15,0.28)***	0.21 (0.15,0.28)***
Household income, (per 100 pesos)	0.003 (-0.002,0.008)	0.006 (0.002,0.01)**
Household assets, (1 to 11)	0.02 (0.006,0.03)**	0.007 (-0.006,0.02)
Urbanicity, (1 to 70)	0.004 (0.002,0.006)***	0.005 (0.003,0.006)***
Time:		
1994	*Ref*	*Ref*
1998	-0.05 (-0.08,-0.009)*	0.12 (0.07,0.18)***
2002	-0.07 (-0.13,-0.008)*	-0.003 (-0.06,0.06)
2005	-0.15 (-0.20,-0.09)***	-0.10 (-0.15,-0.05)***
Household member:		
Mother	*Ref*	*Ref*
Offspring	-0.24 (-0.34,-0.15)***	0.02 (-0.10,0.05)
Interactions[c]:		
Offspring*Assets	0.02 (0.008,0.03)**	0.02 (0.004,0.03)*
Offspring*Urbanicity	0.003 (0.000,0.005)*	----------
Offspring*1998	0.02 (-0.03,0.06)	0.06 (-0.01,0.14)[†]
Offspring*2002	0.21 (0.12,0.30)***	0.29 (0.19,0.39)***
Offspring*2005	0.37 (0.27,0.46)***	0.54 (0.43,0.66)***

[a]All models are adjusted for maternal age

[b]*Notes:* Ref = referent category

[c]Interactions that were significant in at least one of the mother-offspring comparisons were retained in both models

[c†]P<0.10, *P<0.05, **P<0.01, ***P<0.0001

Table 6. Coefficients and 95% confidence intervals from a longitudinal random-effects regression predicting the level of percent of dietary calories from fat for Filipino mothers versus offspring[a]

Model	Mother vs. Daughter	Mother vs. Son
Maternal education:		
<Primary school graduate	*Ref*[b]	*Ref*
Primary school graduate	1.05 (0.11,1.98)*[d]	1.76 (0.74,2.79)**
Some high school	3.30 (2.10,4.50)***	2.99 (1.92,4.06)***
High school graduate+	5.41 (3.79,7.02)***	6.50 (5.06,7.95)***
Household income, (per 100 pesos)	0.28 (0.11,0.45)**	0.17 (0.07,0.28)**
Household assets, (1 to 11)	1.00 (0.81,1.19)***	0.89 (0.69,1.10)***
Urbanicity, (1 to 70)	0.09 (0.05,0.13)***	0.09 (0.06,0.13)***
Time:		
1994	*Ref*	*Ref*
1998	-0.88 (-1.94,0.19)	1.79 (0.75,2.84)**
2002	-1.69 (-3.16,-0.21)*	-0.72 (-2.18,0.74)
2005	-1.67 (-3.22,-0.12)*	-1.55 (-2.51,-0.58)**
Household member:		
Mother	*Ref*	*Ref*
Offspring	2.25 (1.40,3.09)***	2.14 (0.91,3.37)**
Interactions[c]:		
Offspring*Primary school graduate	----------	-0.78 (-1.91,0.35)
Offspring*Some high school	----------	-0.95 (-2.24,0.33)
Offspring*High school graduate+	----------	-2.18 (-3.43,-0.93)**
Offspring*Household income	-0.16 (-0.32,0.01)[†]	-0.08 (-0.18,0.02)[†]
Offspring*1998	5.02 (3.80,6.24)***	2.58 (1.16,4.00)***
Offspring*2002	9.31 (7.49,11.12)***	5.25 (3.72,6.77)***
Offspring*2005	8.28 (6.59,9.97)***	5.33 (4.02,6.65)***

[a]All models are adjusted for maternal age

[b]Ref = referent category

[c]Interactions that were significant in at least one of the mother-offspring comparisons were retained in both models

[d†]P<0.10, *P<0.05, **P<0.01, ***P<0.0001

Table 7. Coefficients and 95% confidence intervals from a longitudinal random-effects regression predicting the level of percent of dietary calories from carbohydrates for Filipino mothers versus offspring[a]

Model	Mother vs. Daughter	Mother vs. Son
Maternal education:		
<Primary school graduate	*Ref*[b]	*Ref*
Primary school graduate	-0.92 (-2.09,0.24)	-1.64 (-2.87,-0.42)**[d]
Some high school	-3.50 (-4.79,-2.20)***	-2.88 (-4.09,-1.67)***
High school graduate+	-6.06 (-7.84,-4.27)***	-6.89 (-8.48,-5.30)***
Household income, (per 100 pesos)	-0.36 (-0.52,-0.19)***	-0.24 (-0.36,-0.11)***
Household assets, (1 to 11)	-1.06 (-1.27,-0.86)***	-1.01 (-1.22,-0.81)***
Urbanicity, (1 to 70)	-0.08 (-0.13,-0.04)***	-0.09 (-0.13,-0.05)***
Time:		
1994	*Ref*	*Ref*
1998	1.18 (-0.05,2.41)†	-1.19 (-2.27,-0.10)*
2002	0.55 (-1.13,2.34)	-0.24 (-1.75,1.26)
2005	0.63 (-1.09,2.34)	0.49 (-0.65,1.62)
Household member:		
Mother	*Ref*	*Ref*
Offspring	-2.52 (-3.73,-1.32)***	-2.24 (-3.57,-0.91)**
Interactions[c]:		
Offspring*Primary school graduate	0.07 (-1.27,1.40)	0.77 (-0.47,2.00)
Offspring*Some high school	1.15 (-0.02,2.32)†	1.45 (0.05,2.85)*
Offspring*High school graduate+	1.63 (0.02,3.25)*	2.77 (0.98,4.56)**
Offspring*Household income	0.20 (0.03,0.38)*	0.14 (0.02,0.27)*
Offspring*1998	-4.73 (-6.17,-3.29)***	-2.38 (-3.96,-0.80)**
Offspring*2002	-11.17 (-13.29,-9.04)***	-6.88 (-8.26,-5.49)***
Offspring*2005	-11.44 (-13.10,-9.78)***	-8.20 (-9.61,-6.79)***

[a]All models are adjusted for maternal age

[b]Ref = referent category

[c]Interactions that were significant in at least one of the mother-offspring comparisons were retained in both models

[d†]P<0.10, *P<0.05, **P<0.01, ***P<0.0001

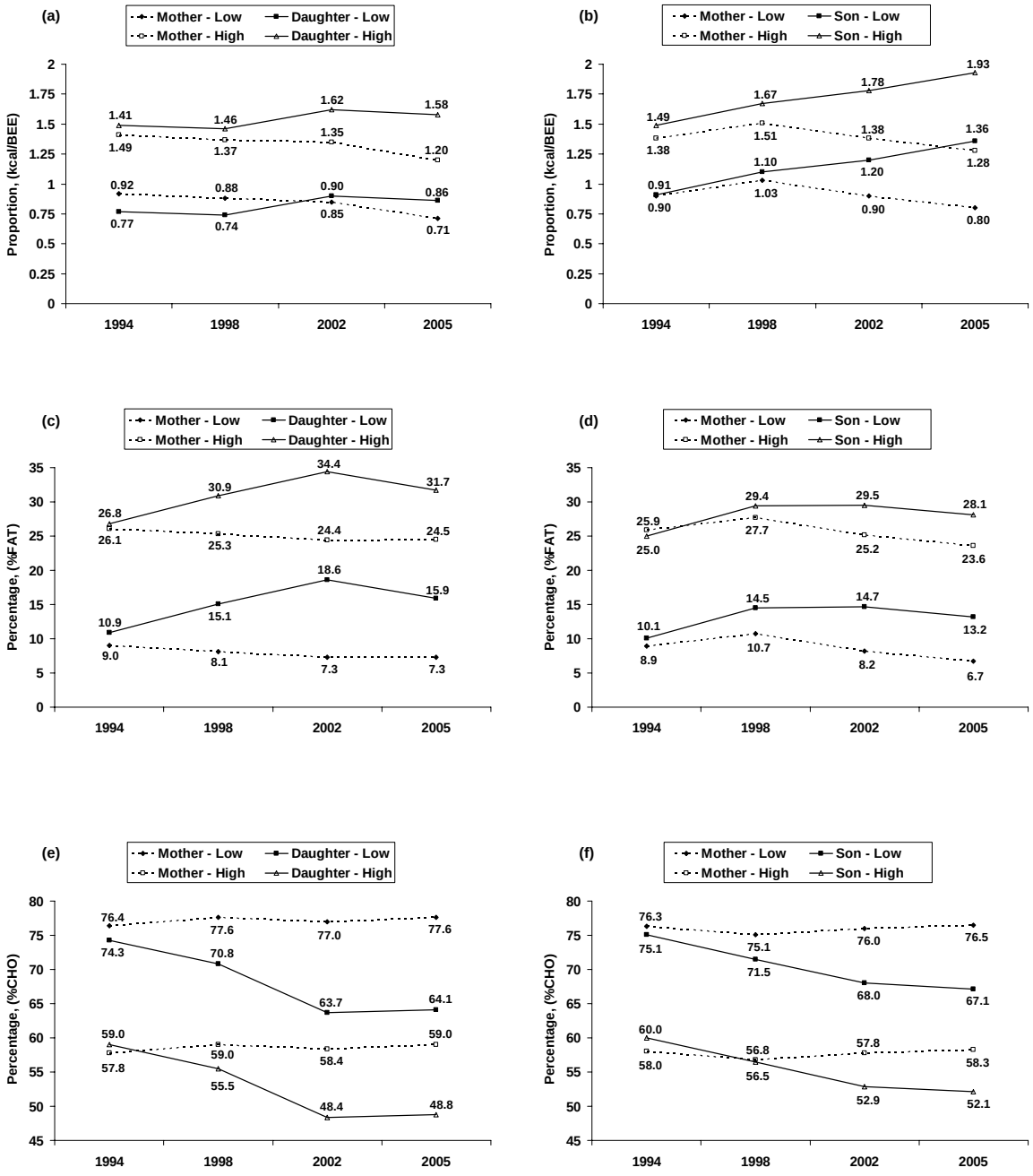


Figure 4. Predicted prevalence of (a) total calories as a proportion of basal energy expenditure for mothers versus daughters in both a high and Low SES-urbanicity environment, (b) total calories as a proportion of basal energy expenditure for mothers versus sons in both a high and Low SES-urbanicity environment, (c) proportion of total calories from fat for mothers versus daughters in both a high and Low SES-urbanicity environment, (d) proportion of total calories from fat for mothers versus sons in both a high and Low SES-urbanicity environment, (e) proportion of total calories from carbohydrates for mothers versus daughters in both a high and Low SES-urbanicity environment, (f) proportion of total calories from carbohydrates for mothers versus sons in both a high and Low SES-urbanicity

environment. As noted in the text, a high SES-urbanicity environment is represented jointly by the 90th percentile of income, assets and urbanicity and maternal education level = high school graduate+, and low SES-urbanicity is represented jointly by the 10th percentile of income, assets and urbanicity and maternal education level = primary school graduate.

V. Modernization is associated with decreases in occupational, chores and leisure physical activity for mothers and offspring in Cebu, Philippines

A. Introduction

As developing countries experience rapid modernization, they face a complex problem of increasing obesity in adults (Popkin and Doak 1998; Doak and Popkin 2001; James, Leach et al. 2001) while undernutrition remains prevalent among children and adolescents (Vorster, Bourne et al. 1999; Doak, Adair et al. 2000; Gillespie and Haddad 2001; Caballero 2005; Popkin, Conde et al. 2006). Frequently these trends coexist resulting in overweight adults and underweight offspring living in the same household (Doak, Adair et al. 2000; Doak, Adair et al. 2005; Garrett and Ruel 2005) a phenomenon which makes addressing either overweight or underweight substantially more complicated. The mechanism by which modernization leads to the emergence of coexisting over and undernutrition is unclear. Given that overweight adults and underweight offspring share both genes and a common household environment, the weight difference may be a result of divergent weight-related behavior patterns such as physical activity.

Several studies describing the nutrition transition in developing countries have identified decreases in physical activity occurring as environments become more urban and affluent (Popkin 2001; Uauy, Albala et al. 2001; Albala, Vio et al. 2002; Rodriguez-Ojea, Jimenez et al. 2002; Kain, Vio et al. 2003; Monda, Gordon-Larsen et al. 2007). As urbanicity levels increase, a concomitant shift from active agricultural to sedentary industrial or service sectors jobs as well as an increase in sedentary leisure activities and modes of transportation,

seem to occur. Additionally, with increased household wealth in developing countries there is an increase in household technologies/appliances that contribute to decreases in domestic physical activity. However, decreases in physical activity may not occur equally for both adults and offspring. A differential response in physical activity patterns as a result of increasing wealth and urbanicity may contribute to the emergence of households with both an overweight adult and underweight offspring. We found no studies evaluating the relationship between physical activity trends and modernization for adults compared to their offspring living in the same household environment. To fill this gap, this study assesses the impact of socioeconomic factors and urbanicity at multiple time points on different dimensions of moderate/vigorous physical activity (MVPA) including occupational, domestic and leisure, for a cohort of mothers and their offspring.

B. Methods

1. Study Population

Data come from the Cebu Longitudinal Health and Nutrition Survey (CLHNS). A single-stage clustering sample procedure was used to select 17 urban and 16 rural barangays (administrative units) from the metropolitan area of Cebu, Philippines. All pregnant women from these barangays were invited to participate and were included in the longitudinal study if they gave birth between May 1983 and April 1984 (ages 15 to 47, n=3,327). The original survey included one round of interviews at approximately 6 months gestational age, one at the point of delivery, and bimonthly for the first 24 months of life. The project was extended to include surveys rounds in 1991-2, 1994-5, 1998-2000, 2002, and 2005. For convenience, we refer to these rounds as 1991, 1994, 1998, 2002 and 2005. All surveys included detailed

individual, household, and community-level environmental, socioeconomic, and demographic information. Comparable physical activity information was collected for mothers and offspring starting in 1998. Our sample was restricted to mother/offspring pairs who were both available for the full interview, were residing in the same house, the offspring was from a singleton birth and neither the mother nor offspring were pregnant, institutionalized, or incapacitated. Our final sample included mother-offspring pairs from the 1998 (n=1,781, offspring ages: 14-16), 2002 (n=1,615, offspring ages: 17-19), and 2005 (n=1,349, offspring ages: 21-22) survey years. Protocols for the CLHNS were approved by the Institutional Review Board of the University of North Carolina at Chapel Hill.

2. Dependent variables

In our study, we used moderate to vigorous (MV) occupational activity and MV chores to represent MVPA for mothers. Although the mothers did record participating in leisure time activities, all activities reported for all years were sedentary to light (e.g., reading, watching TV, and talking to neighbors). For offspring, patterns of MVPA in occupational activity, chores, and leisure physical activity were evaluated. Detailed individual information on MVPA in transportation or any other type of activity was not collected and therefore was not included in this analysis. To develop consistency across all activity measures, activity levels were defined for both mothers and offspring as sedentary/light= <5 metabolic equivalents (METS), moderate= ≥5 and <7 METS, and vigorous= 7+ METS (1 MET=3.5 ml O_2/kg/min and represents the amount of energy expended during 1 minute at rest). These cut point values were selected because they

approximate the absolute intensity levels observed for adults 20-39 years of age (≤4.7 very light/light, 4.8-7.1 moderate, ≥7.2 hard/very hard) (Pollock, Gaesser et al. 1998).

a. Occupational activity

For all survey years, occupational codes for mothers and offspring were matched to occupational codes from the Atherosclerosis Risk in Communities (ARIC) study (Evenson, Rosamond et al. 2003). Sedentary/light (SL) or moderate/vigorous (MV) PA levels were previously assigned to each ARIC job code by two trained exercise physiologists and these were used to categorize the matched job codes from the CLHNS sample. To create homogenous categories, we divided workers into SL and MV occupations. However, since our study focus is MVPA our results focus on the MV occupations. Examples of occupations classified as SL were: teachers (except for kindergarten), physicians, office clerks, sales people, apparel and related product makers, bakers, barbers and hairdressers, and directors and managers. Examples of occupations classified as MV included: surveyors, market vendors and traveling salespeople, farm workers, fishermen, loggers, drivers of pedaled vehicles, metal and leather product workers, welders, carpenters, winemakers, butchers, valets, gardeners and athletes. To explore the use of a United States based coding scheme for a Filipino population, we compared the agreement between PA levels determined by the ARIC scheme and levels of PA reported by CLHNS offspring for each occupation type, since exertion data was not collected for the mothers. In 2002 and 2005, offspring were asked to identify main tasks performed in their occupation. Using a PA compendium (Ainsworth, Haskell et al. 1993; Ainsworth, Haskell et al. 2000) these tasks were coded as either 1 (MV activity) or 0 (SL activity). We compared the level of agreement between the ARIC PA

levels and the PA levels of tasks reported by offspring in both 2002 and 2005 per occupation type to assess agreement between the two sets of occupation classifications and the extent of MVPA variability within occupation classifications. If, for a given occupation, a majority (greater than 50%) of offspring reported a level of PA different from the PA level determined by ARIC in both 2002 and 2005 the PA level was changed to match the level most commonly reported in the CLHNS. If disagreement was greater than 50% for only one of the two years then the assigned PA level was changed if the change maximized the total number of individuals correctly classified irrespective of year. Out of 204 total occupation types, the level of PA was decided for 30 using this method. These coding assignments were checked by a trained exercise physiologist and disagreements were resolved. Individuals were classified based on their primary occupation (self-identified based on time allocation) if they had two reported occupations. The final occupation variable consisted of three levels: 0=non-workers, 1=workers in a SL occupation, 2=workers in a MV occupation.

b. Activity through chores

Physical activity in household chores was represented by a summation of chores identified from the mother questionnaires. Respondents were asked to identify household members responsible for a variety of chores. Among a list of 11 household chores, seven were identified as MVPA according to a physical activity compendium (Ainsworth, Haskell et al. 1993; Ainsworth, Haskell et al. 2000): washing clothes, buying groceries, gathering wood, fetching water, tending the garden, feeding farm animals, and performing household repairs. To reduce potential misclassification of mothers as physically active through household chores, they were only considered physically active when washing clothes if there

was no washing machine in the house. Additionally, mothers were considered physically active when buying groceries only if they reported walking to the market and the market was reported to be at least 30 minutes from the home based on internationally recognized daily PA recommendations (Pate, Pratt et al. 1995; U.S. Department of Health and Human Services 1996). For each mother, a summation score was created from the number of chores for which she was the primary responsible household member. Approximately 3-6% of women across the three survey administrations were responsible for more than 4 household chores. To normalize the distribution, the final variable was collapsed so that values ranged from 0 to 4+ chores. This information was not available for offspring at all survey years. However, an open-ended questionnaire of usual activities was collected for offspring from 1998 to 2005, which included chores activity (see appendix 1).

In the Philippines, chores are a mandatory and graded activity in high school. Therefore, in 1998, offspring were asked to list activities performed during school hours, how many times per week and how many minutes per bout. This information was also collected for activities performed after school. Using a physical activity compendium (Ainsworth, Haskell et al. 1993; Ainsworth, Haskell et al. 2000) MV chores (e.g., sweeping and scrubbing floors, cleaning the classroom/house and fetching water) were identified. A summation of hours/week of MV chores was then calculated for each offspring in 1998. The questionnaire was modified for 2002 and 2005. For these surveys, offspring reported physical activities irrespective of schooling status, how many times per month and how many minutes per bout. A summation score was created based on the number of hours/month of MV chores. Because the time scale differed between 1998 and 2002-5, a relative ranking of offspring MV chores per year was created by dividing total hours of MV chores into sex-

specific thirds. A final sex-specific four-level variable was created for each year including a reference category of offspring who reported zero hours of MV chores.

c. Leisure activity

Leisure PA for offspring was assessed based on the same open-ended questionnaire used to create the MVPA variable of chores. In the context of this study, leisure activities were defined as those which were not work or school-related. The most common examples of MV included dancing and playing volleyball for girls, and playing basketball, soccer, baseball and softball for boys. Sex-specific thirds of leisure MVPA were created and were used to create a four-level variable of leisure MVPA for each year including those who reported zero hours of leisure MVPA as the referent.

3. Independent variables

a. Maternal education

For each round of the CLHNS, maternal education was recorded as the highest year of education completed. Due to clustering around specific levels of education, a set of indicator variables were created at each time point: < primary school graduate, primary school graduate, some high school, and high school graduate and beyond. However, few women attained additional education after the 1983 baseline survey so there is minimal change over time in maternal education.

b. Household income

Total household income was constructed based on both cash income from all household members over 6 years of age and the value of in-kind earnings. For comparability over time, income values were deflated to January 1983 values using the Philippines consumer price indices for 1998, 2002, and 2005. For descriptive analyses, household income was truncated so that right-skewed outliers were given the value at the 99th percentile of the sample income distribution. We were particularly interested in the effect of household economic status on MVPA choices for mothers and offspring. To avoid spurious associations between household income and MVPA activity, a household variable excluding mothers' income was included in regression analyses for mothers. A second set of household income variables were created excluding offspring income for analyses assessing offspring MVPA. A non-linear relationship of household income and physical activity measures was observed for both the mothers and offspring. Indicator variables from thirds of household income were therefore included in the final regression models with the low-income third as the referent.

c. Household assets

A summary score was created representing household assets owned including: house, jeepney (minibus often used for privately owned busing services), car, refrigerator, air conditioning unit, electric fan, electric iron, tape recorder, and television ownership as well as quality of housing construction. Previous research has shown that a simple summation of ownership of material goods is an accurate and robust estimate of SES in a developing country context (Bollen, Glanville et al. 2001). For all three time points the variable took on values from 0 to 11.

d. Urbanicity

Several recent studies based on the CLHNS have found high levels of heterogeneity within commonly used binary urban-rural categories which are often based on single criteria such as population density (McDade and Adair 2001; Dahly and Adair 2007). To minimize misclassification, an urbanicity index score was assigned to each barangay based on 7 criteria: population size, population density, communication, transportation, healthcare services, education, and market availability (Dahly and Adair 2007). Each category was created with values from 1 to 10 so that a maximum score of 70 represented the most urban community. Preliminary exploratory analyses revealed a non-linear relationship between urbanicity and several PA components therefore indicator variables from thirds of urbanicity were included in our final models. For simplicity, we refer to the low third as rural, the middle third as semi-urban, and the high third as urban.

4. Statistical analyses

Descriptive statistics (number of participants, means, standard deviations, and proportions) were used to elucidate general sample characteristics in 1998 - 2005. Generalized estimating equation (GEE) models were used to describe changes over time in our main household and community-level exposures of interest: maternal education, household income and assets, and community urbanicity.

a. Occupational activity

The likelihood of performing occupational MVPA was assessed using cross-sectional multinomial regression analyses (used to separate the SL and MV occupational activity) in 1998 - 2005 with non-workers as the referent.

b. Activity through chores

Given that maternal MV chores was an ordinal variable, multiple cross-sectional ordered logistic regression analyses in 1998 - 2005 were used to evaluate the factors associated with adding higher relative to lower numbers of MV chores to a mother's household responsibilities. Ordered logistic regression analyses were also used to assess the likelihood of performing higher relative to lower levels of MVPA chores for offspring in 1998. Minimal participation in MV chores in 2002 - 2005 prohibited formal analyses of offspring chores for these years.

c. Leisure activity

Like offspring MV chores, leisure activity was a 4-level ordinal variable, therefore cross-sectional ordered logistic regression analyses were used to assess the likelihood that sons participated in higher compared to lower levels of leisure MVPA in 1998 - 2005. Parallel analyses of leisure MVPA for daughters were restricted to 1998 due to minimal participation in 2002 - 2005.

d. Model building

Significance levels were determined at a p value ≤ 0.05. All models were adjusted for maternal age. Additionally, models assessing offspring MVPA were adjusted for

offspring age. Interactions based on two-variable combinations of urbanicity, household assets, household income, and maternal education, were assessed using partial F tests and were considered significant at $p \leq 0.10$. No consistent interactions were observed across all time points for any of the models. Further, inclusion of interactions that were significant caused substantial increases in the size of confidence intervals due to small sample sizes and therefore were not included in the final models. Offspring school attendance was identified as a likely important determinant of offspring MVPA. However, there was a high probability that offspring school attendance was also correlated with unmeasured individual characteristics and household/community environmental factors and therefore endogenous to offspring MVPA models. Results from a set of diagnostic models including schooling resulted in small attenuation of the main effects coefficients but did not change the interpretation of the results. Thus, final models did not include schooling. All data analyses were adjusted for clustering at the community level and performed using Stata 9.2 (StataCorp 2006).

e. Assessment of selectivity bias

There was potential for bias due to selectivity as a result of both loss to follow-up and active exclusion of particular subgroups (e.g., pregnant mothers and offspring). We used a two-stage Heckman estimation procedure for each activity performed by mothers and offspring at each time point in order to assess potential selectivity bias (Heckman 1979). In effect, using the Heckman procedure, selected models were adjusted for the likelihood of being in the sample in a given year. For diagnostic purposes, models with Heckman adjustments were performed for each type of MVPA to identify possible selection bias.

C. Results

Table 8 presents descriptive individual and household demographic characteristics. From 1998 to 2005 the sample size decreases from n=1,781 to n=1,349. An increase in the proportion of male to female offspring in the sample was observed from 1998 to 2005 due to pregnancy and a possible disproportionate numbers of daughters moving to a different household (e.g., household of employer or spouse). Table 8 also depicts socioeconomic and urban development over time. Results from the GEE analyses identified significantly increasing linear trends in household assets, and community urbanicity but not maternal education. An increasing linear trend was observed for household income but the substantial variance made the test for time trend uninterpretable.

Table 9 shows participation in occupational, chores, and leisure MVPA for mothers and offspring from 1998 to 2005. Although the number of mothers working in MV occupations stayed relatively constant the percentage of working mothers decreased from 81.5% in 1998 to 74.4% in 2005. Additionally, the number of women reporting doing MV chores decreased during this period. There was a substantial decrease in the proportion of daughters in MV occupations, performing MV chores, and participating in leisure MVPA. Although not as severe, a decrease in total MVPA was also observed for sons. **Figure 5** shows an overall decrease in the number of both mothers and offspring reporting any occupational, chores or leisure MVPA. There was a 5.5% decrease in the number of mothers reporting any occupational and chores MVPA. Additionally, there was a 78.8% and 46.5% decrease in the number of daughters and sons respectively reporting any occupational, chores, and leisure MVPA between 1998 and 2005.

a. Occupational activity

Mothers were less likely to do occupational MVPA if they were at least a high school graduate, were from a higher income and assets household and lived in a more urban environment (**Table 10**). These findings were consistent over time. Similar findings were observed for sons who were less likely to participate in occupational MVPA if they were from higher SES households. The association of maternal education with occupational MVPA for sons was even greater than that observed for mothers. Sons were significantly less likely to participate in occupational MVPA if the mother was at least a primary school graduate. However the relationship between urbanicity and occupational MVPA was less clear for sons. Sons were less likely to participate in occupational MVPA if they lived in a semi-urban environment in 1998 and 2002 but there was no association in the highly urban setting. As with the mothers and sons, daughters were less likely to participate in occupational MVPA if they came from a higher SES household. However, the strength of the association decreased between over time. Although there was some evidence that higher maternal education was associated with a decreased likelihood of participating in occupational MVPA for daughters, results were not consistent over time.

b. Activity through chores

Mothers who were at least high school graduates, were from higher SES households, and lived in semi-urban and urban settings were consistently less likely to do high levels of MV household chores (**Table 11**). Similarly, sons and daughters were less likely to do higher levels of MV chores if they were from higher SES households in 1998 (**Table 12**).

Additionally, sons were less likely to do higher level of MV chores if the mother was at least a high school graduate and they were from at least a semi-urban environment.

c. Leisure activity

In 1998, daughters were more likely to participate in higher levels of leisure MVPA if the mother had at least some high school education, they were from a higher SES household and they were from at least a semi-urban environment (**Table 13**). There were no consistent significant predictors of leisure MVPA for sons.

d. Assessment of Selectivity bias

Results from the Heckman adjusted models showed that, consistently, households where the mother was younger and less educated were less likely to be in included in the study samples. For models of maternal MVPA, even where the models were identified as significantly biased due to selectivity, the results differed only modestly from the unadjusted models. In general, the estimated effect of maternal education was attenuated and the effect of urbanicity was inflated compared to the Heckman adjusted models. For the offspring activity models, the estimated effects of maternal education, household income and assets, and community urbanicity were modestly inflated in the unadjusted models, however the direction of effect and significance levels remained the same when adjusting for selectivity (Heckman adjusted models not shown).

D. Discussion

Cebu, Philippines, like many developing country settings, has experienced rapid modernization accompanied by substantial increases in overweight among adult women (42% in 2005) (Adair 2004). However, overweight remains low (daughters: 8%, sons: 10%) and underweight relatively high (daughters: 30%, sons: 16%) among a cohort of their offspring (Jennings et al. unpublished). As in many developing countries (Doak, Adair et al. 2000; Doak, Adair et al. 2005), the coexistence of an overweight mother and underweight offspring have been found to occur in higher SES Filipino households (Jennings et al., unpublished). We hypothesized that a divergence in the level of physical activity between the mothers and offspring in response to modernization might be a possible contributor to the weight divergence in the Philippines. We did observe a decrease in occupational MVPA and chores activity for mothers from wealthier and more urban environments. Additionally, similar to trends observed in developed countries (Wilcox, Castro et al. 2000; Eyler, Wilcox et al. 2002; Haase, Steptoe et al. 2004; Lethbridge-Cejku, Schiller et al. 2004; Patterson, Moore et al. 2004; Martin, Kirkner et al. 2005; Ward, Tarasuk et al. 2007), our findings show that daughters were more likely to participate in higher levels of leisure MVPA if they were from a wealthier, more urban household. However, this increase among wealthy urban female offspring occurred only in 1998. Insufficient numbers of female offspring participated in leisure MVPA past 1998 to do a formal analysis. Overall, similar to the mothers, offspring from a wealthy urban environment were less likely to participate in MVPA. This suggests that different MVPA patterns for mothers and offspring may not be contributing to the discrepant weight patterns observed in Cebu, Philippines.

Despite the increased likelihood of leisure MVPA among wealthy urban female offspring in 1998, our study found that over time the total number of mothers and offspring

participating in any MVPA decreased. Given the number of offspring reporting zero minutes of occupational, chores, and leisure MVPA, our study suggests that a majority are not meeting recommended activity levels to minimize risk of obesity and associated chronic diseases (WHO 2002; WHO/FAO 2003). The substantial decrease over time in MVPA among offspring may be a harbinger of future obesity rates similar to those observed in mothers. Additionally, although the percent of mothers performing occupational MVPA remained relatively constant and a majority consistently reported doing MVPA through chores, the high rates of overweight (Adair 2004) suggest that the time and intensity of activity did not meet PA recommendations. Given that MVPA decreased over time for both mothers and offspring, interventions developed to increase MVPA levels in the Philippines should be developed at the household level.

As in many developing countries, both mothers and offspring from wealthier, more educated and urban households were less likely to participate in high levels of occupational MVPA and chores. Based on previous findings in developing countries, with continued modernization, chores and occupational MVPA will likely continue to decrease for both mothers and offspring (Popkin 2001). In the face of these changes, interventions aimed at increasing leisure physical activity may be the most effective method to increase total MVPA. However, for cultural and possibly other environmental constraints (e.g. hot and humid tropical climate), leisure physical activity is still uncommon in the Philippines; particularly among older generations (e.g., zero percent of mothers reported leisure MVPA at any point during this study period). For offspring, a substantial number participated in leisure physical activity during high school but participation dropped sharply in the years following graduation. A family-based intervention aimed at increasing leisure MVPA in the Philippines

should therefore include steps to address cultural barriers to MVPA, as well as steps to help adolescents maintain leisure MVPA during the transition from high school to adulthood.

There were several important offspring gender differences in the pattern of MVPA trends over time. There was a dramatic decrease in the number of daughters participating in all forms of measured MVPA from 1998 to 2005. Most surprisingly, domestic activity, which is often a major source of MVPA for females in developing countries (Benefice, Garnier et al. 2001; Dufour, Reina et al. 2003; Rao, Gokhale et al. 2007), was negligible for daughters post high school.

Although there was a decline in MVPA for sons, it was substantially less than the decline observed for daughters. There are several possible reasons for this gender difference. Like many developing countries, women do not work in many of the physically demanding occupations such as construction workers, carpenters, garbage collectors, electricians, and janitors. Additionally, a majority of women do not participate in moderate to vigorous sports past high school. In contrast, basketball, the most popular sport among Filipino males, is played at all socioeconomic and urbanicity levels. This may explain the lack of association between leisure MVPA for sons with both wealth and urbanicity. Overall, these findings suggest that compared to sons, daughters may be at a higher risk of future adverse body weight and subsequent health outcomes associated with chronically insufficient levels of physical activity.

Despite the inherent strengths of using a longitudinal dataset, there is the risk that final estimates are biased due to selectivity. Results from our Heckman analyses indicated that there were minimal changes in point estimates after adjusting for the probability of being in the sample for a given year. However, the finding that households where the mother was

younger and less educated were consistently less likely to be included in the sample, most likely reflects the inclusion criteria that mothers and offspring live in the same household. This is the case because offspring marrying at a relatively young age (which often equates with leaving the mother's home) is more common in low SES households. As a result the findings in our study may not be generalizeable to the 1983 baseline study population. Additionally, because we used a birth cohort of offspring for this study we cannot distinguish between offspring age trends and secular changes in physical activity patterns in response to modernization. Because we used multiple time points for this analysis, we were however, able to distinguish consistent trends in physical activity patterns versus age-specific activities. For example, in a recent paper based on the CLHNS, children were reported to be performing high levels of MVPA from chores (Tudor-Locke, Ainsworth et al. 2003). Our study clarifies that high levels of activity through chores was primarily a function of school requirements. Once the offspring graduated from high school, MVPA from chores became negligible.

Although collection for the CLHNS began in 1983, complete detailed physical activity data collection did not begin for both mothers and offspring until 1998. A majority of weight gain observed for mothers occurred before 1998 (Adair 2004). It is possible that substantial changes in MVPA occurred concurrently with changes in weight status. The aim of this study was to assess possible discrepancies in physical activity patterns in response to modernization that would explain divergent weight patterns between mothers and offspring. Data from the 1998 to 2005 surveys were sufficient to compare trends in maternal and offspring MVPA.

Several aspects of the CLHNS physical activity questionnaires limited the scope of the analysis for this study. Active transportation may provide a valuable source of MVPA in this population; however this information was not consistently available for mothers and offspring over time. Many studies in developing countries have documented a decrease in active forms of transportation with increases in household wealth and community urbanicity suggesting that those at highest risk of insufficient levels of MVPA in our study may also utilize passive forms of transportation as well (Popkin 1999; Bell, Ge et al. 2002). In addition to the lack of transportation MVPA information, we were unable to assess duration or intensity of our activities measures. Due to data limitations we were also unable to explore patterns of inactivity. Several studies have shown that time spent in sedentary activities is positively associated with overweight independent of physical activity (Gortmaker, Must et al. 1996; Hernandez, Gortmaker et al. 1999; Martinez-Gonzalez, Martinez et al. 1999; Crespo, Smit et al. 2001; Gordon-Larsen, Adair et al. 2002). Without information on inactivity and TEE we cannot formally assess the impact of activity patterns on health outcomes for our study population. However, the total number of Filipino mothers and offspring reporting no occupational, chores and leisure activity suggests the need for policies to encourage engagement in more active lifestyles.

With respect to occupational MVPA, a respondent with multiple occupations was classified based on the activity level of their primary occupation. However, the number of respondents where there was disagreement in physical activity level between the primary and secondary occupations was small (maximum observed discrepancy, 7.0% for mothers, 1.5% for daughters, and 3.5% for sons). Given the method of aggregation of occupations into PA levels there were two possible sources of heterogeneity within activity levels. First, there was

the possibility of heterogeneity in PA intensity between individuals within the same occupation. Second, the average PA intensity may have differed between occupations within our occupational PA categories. There also may have been a discrepancy between the PA intensity levels determined by the ARIC study and the actual PA intensity levels for occupations in the Philippines. Although we did not have information on exertion levels for mothers, exertion levels during working hours for offspring indicated that heterogeneity of both duration and intensity within occupational PA categories may have affected the precision and ultimately the interpretation of regression estimates. Additionally, we cannot distinguish the extent to which occupational MVPA is a result of personal choice of occupation with specific activity levels. However, the factors determining selection of an occupation with high levels of MVPA are likely socioeconomic in origin (e.g. economic and education restraints frequently lead to increased participation in manual labor occupations). Therefore, choice of occupation is likely in the conceptual pathway between socioeconomic and demographic factors and occupational MVPA level rather than a confounder.

According to the American College of Sports Medicine, cut points at which activities are considered moderate and vigorous occur at lower METS values for older ages (Pollock, Gaesser et al. 1998). For comparability, we used cut points for the 20-39 yr age group for both mothers and offspring at all time points. This may have caused a systematic underestimation of MVPA for the mothers most of whom were older than 39 yrs old by 1998.

A detailed investigation of physical activity patterns in a developing country context are uncommon, even more uncommon are studies that include adolescent activity patterns. This study documents trends in physical activity patterns through an important period of

offspring development from adolescence to adulthood and therefore offers insights into MVPA levels that are robust to life course changes. Additionally, use of the CLHNS enabled a comparison of MVPA trends between generations within the household environment. Most important we were able to explore differences between mothers and offspring in multiple dimensions of activity.

In conclusion, few studies have explored the relationship between socioeconomic factors and urbanicity with MVPA in a developing country experiencing rapid modernization. According to our findings, there was a decreasing trend over time in occupational and domestic MVPA for Filipino mothers and offspring, particularly among the urban wealthy. This emphasizes the need for a family-based versus an individual-based intervention to increase MVPA for both mothers and offspring. Additionally, the observed decreases in occupational and domestic activity, intrinsic to modernization, underscore the need for alternate MVPA opportunities. Previous findings indicate that younger Filipino generations, in response to emerging western cultural influences, may be receptive to interventions aimed at increasing leisure MVPA (Jennings et al, unpublished). However, as in many developing countries, older generations of Filipino women do not participate in leisure MVPA particularly sports, therefore policies and interventions need to include education to confront cultural barriers. Given that our findings show MVPA decreased to a greater extent for offspring then mothers, future research should explore other weight-related behaviors of Filipino mothers and offspring, such as diet, which may be contributing to the high levels of overweight among mothers and persistent underweight among offspring.

Table 8. Individual, household and community characteristics (Mean ± SD) and test for time trend (RR, 95% CI) of mother-offspring pairs from 1998 to 2005 in Cebu, Philippines

Year	**1998**	**2002**	**2005**	**Test for time trend[§]**
No. of pairs	1,789	1,615	1,349	
Individual characteristics:				
Mothers				
Age, (years)	42.7 ± 6.1	45.9 ± 6.0	48.6 ± 5.9	
Education, (years)	7.6 ± 3.9	7.6 ± 3.9	7.7 ± 3.9	1.00 (0.99,1.02)
Gender of Offspring, (% male)	53.0	55.4	56.3	
Offspring - Females				
Age, (years)	14.9 ± 0.4	18.7 ± 0.3	21.5 ± 0.3	
Education, (years)	7.8 ± 1.5	10.8 ± 2.0	12.1 ± 3.1	
Offspring - Males				
Age, (years)	16.1 ± 0.3	18.7 ± 0.3	21.5 ± 0.3	
Education, (years)	7.8 ± 1.5	9.5 ± 2.9	10.7 ± 3.9	
Household characteristics:				
Household income, (pesos/wk)	543.3 ± 407.4	578.1 ± 468.8	601.4 ± 555.0	--------*
Household assets, (1 to 11)	4.8 ± 2.2	5.3 ± 2.0	5.5 ± 1.9	1.32** (1.27,1.37)
Community characteristics:				
Urbanicity, (1 to 70)	39.0 ± 13.7	41.9 ± 13.8	41.0 ± 13.4	2.71** (2.33,3.15)

[§]Generalized estimating equations (GEE) were used to test for increasing or decreasing linear time trends in our main exposures of interest: maternal education, household income and assets, and community urbanicity

*The magnitude of the variance for household income made the test for time trend uninterpretable

**P<0.0001

Table 9. Physical activity participation for a sample of mothers and their offspring from 1998 to 2005 in Cebu, Philippines

Year (No. of mother/offspring pairs)	**1998 (n=1,781)**	**2002 (n=1,615)**	**2005 (n=1,349)**
	N (%)	N (%)	N (%)
Mother			
No. who reported working	1,452 (81.5)	1,279 (79.2)	1,003 (74.4)
No. with occupational MVPA* among workers	273 (18.8)	249 (19.5)	197 (19.6)
No. reporting doing any household chores	1,562 (87.8)	1,352 (83.7)	1,104 (81.8)
Offspring - No. of Females	837	720	590
No. attending school	737 (88.1)	341 (47.4)	123 (20.9)
No. who reported working	264 (31.5)	370 (51.4)	341 (57.8)
No. attending school and working	214 (25.6)	115 (16.0)	22 (3.7)
No. with occupational MVPA among workers	67 (25.4)	84 (22.7)	31 (9.1)
No. reporting any household/school chores	734 (87.7)	52 (7.2)	12 (2.0)
No. reporting any leisure/sports MVPA	432 (51.6)	132 (18.3)	62 (10.5)
Offspring - No. of Males	944	895	759
No. attending school	667 (70.7)	397 (44.4)	160 (21.1)
No. who reported working	459 (48.6)	494 (55.2)	470 (61.9)
No. attending school and working	252 (26.7)	133 (14.9)	44 (5.8)
No. with occupational MVPA among workers	227 (49.5)	244 (49.4)	202 (43.0)
No. reporting any household/school chores	819 (86.8)	69 (7.7)	4 (0.5)
No. reporting any leisure/sports MVPA	836 (88.6)	373 (41.7)	261 (34.4)

*MVPA=moderate to vigorous level of physical activity

Figure 5. Percent of mothers and offspring reporting any occupational, chores, and leisure MVPA in Cebu, Philippines from 1998 to 2005

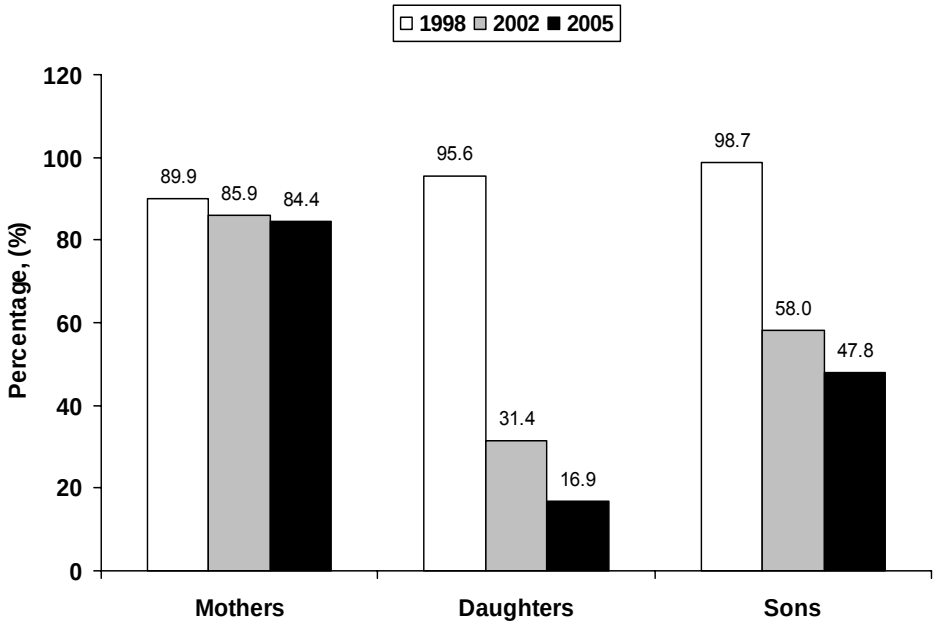


Table 10. The likelihood of having a moderate/vigorous job compared to non-working mothers and their offspring: adjusted ORs, 95% CI from cross-sectional multinomial logistic regressions at multiple time points in Cebu, Philippines[§]

Year	1998	2002	2005
		Mothers	
N	n=1,781	n=1,615	n=1,349
Maternal education			
<Primary school graduate	*Ref*	*Ref*	*Ref*
Primary school graduate	0.88 (0.61,1.25)	0.96 (0.65,1.41)	1.12 (0.73,1.72)
Some high school	0.57* (0.34,0.96)	0.62* (0.41,0.95)	0.56* (0.40,0.78)
High school graduate+	0.95 (0.51,1.77)	0.59 (0.31,1.13)	0.78 (0.41,1.47)
Household income:			
Low income third	*Ref*	*Ref*	*Ref*
Middle income third	0.32*** (0.20,0.52)	0.61** (0.43,0.86)	0.54** (0.35,0.84)
High income third	0.25*** (0.16,0.39)	0.49*** (0.36,0.67)	0.51** (0.33,0.78)
Household assets, (1 to 11)	0.89** (0.82,0.97)	0.91* (0.84,0.99)	0.91 (0.81,1.03)
Urbanicity:			
Rural	*Ref*	*Ref*	*Ref*
Semi-urban	0.73 (0.44,1.23)	0.56* (0.33,0.98)	0.75 (0.48,1.19)
Urban	0.53* (0.33,0.86)	0.61[†] (0.37,1.02)	0.60* (0.37,0.97)
		Daughters	
N	n=837	n=720	n=590
Maternal education			
<Primary school graduate	*Ref*	*Ref*	*Ref*
Primary school graduate	1.30 (0.57,2.99)	1.13 (0.66,1.95)	2.04 (0.72,5.79)
Some high school	0.89 (0.43,1.85)	0.76 (0.43,1.36)	1.93 (0.69,5.35)
High school graduate+	1.82 (0.68,4.84)	0.37[†] (0.12,1.11)	0.52 (0.09,3.06)
Household income:			
Low income third	*Ref*	*Ref*	*Ref*
Middle income third	1.12 (0.63,2.00)	1.08 (0.63,1.85)	0.84 (0.23,3.02)
High income third	1.19 (0.58,2.45)	0.75 (0.31,1.82)	0.80 (0.21,3.04)
Household assets, (1 to 11)	0.67*** (0.60,0.75)	0.84* (0.70,1.00)	0.94 (0.77,1.16)
Urbanicity:			
Rural	*Ref*	*Ref*	*Ref*
Semi-urban	0.77 (0.35,1.69)	0.55* (0.31,1.00)	1.24 (0.43,3.57)
Urban	0.73 (0.32,1.68)	1.08 (0.62,1.89)	1.20 (0.31,4.68)
		Sons	
N	n=944	n=895	n=759
Maternal education			
<Primary school graduate	*Ref*	*Ref*	*Ref*
Primary school graduate	0.59* (0.39,0.91)	0.65* (0.43,0.98)	0.98 (0.56,1.72)
Some high school	0.38*** (0.24,0.60)	0.40*** (0.26,0.61)	0.73 (0.42,1.26)
High school graduate+	0.20*** (0.09,0.43)	0.20*** (0.09,0.46)	0.26*** (0.13,0.52)
Household income:			
Low income third	*Ref*	*Ref*	*Ref*
Middle income third	0.66* (0.45,0.97)	0.72[†] (0.51,1.00)	0.87 (0.58,1.29)
High income third	0.72[†] (0.49,1.06)	0.45** (0.28,0.72)	0.87 (0.60,1.27)
Household assets, (1 to 11)	0.78*** (0.69,0.89)	0.79*** (0.72,0.86)	0.76*** (0.66,0.87)
Urbanicity:			

Rural	*Ref*	*Ref*	*Ref*
Semi-urban	0.61[†] (0.36,1.03)	0.59[†] (0.33,1.05)	0.74 (0.46,1.20)
Urban	0.61 (0.29,1.27)	0.74 (0.49,1.10)	1.05 (0.58,1.92)

[a]Ref = referent category

[†]P<0.10

*P<0.05

**P<0.01

***P<0.0001

[§]Cross-sectional multinomial logistic regression analyses were performed comparing workers in sedentary/light and moderate/vigorous (MV) jobs to non-workers. However, we present here only the likelihood of having a MV job for mothers, sons and daughters. Mother models are adjusted for maternal age and offspring models are adjusted for both maternal and offspring age.

Table 11. The likelihood that mothers are responsible for higher levels of moderate/vigorous chores: adjusted ORs, 95% CI from cross-sectional ordered logistic regressions at multiple time points in Cebu, Philippines§

Year	**1998 (n=1,781)**	**2002 (n=1,615)**	**2005 (n=1,349)**
Maternal education			
<Primary school graduate	*Ref*	*Ref*	*Ref*
Primary school graduate	1.18 (0.95,1.46)	1.13 (0.87,1.47)	1.04 (0.73,1.47)
Some high school	0.95 (0.73,1.24)	0.78† (0.60,1.01)	0.79 (0.56,1.12)
High school graduate+	0.71* (0.53,0.97)	0.70* (0.50,10.98)	0.58** (0.42,0.80)
Household income:			
Low income third	*Ref*	*Ref*	*Ref*
Middle income third	1.18 (0.95,1.46)	1.12 (0.92,1.36)	1.38† (0.99,1.93)
High income third	1.15 (0.91,1.46)	0.97 (0.77,1.22)	1.11 (0.85,1.49)
Household assets, (1 to 11)	0.97 (0.92,1.02)	0.90** (0.85,0.96)	0.91** (0.86,0.96)
Urbanicity:			
Rural	*Ref*	*Ref*	*Ref*
Semi-urban	0.63* (0.42,0.96)	0.59* (0.38,0.91)	0.61** (0.43,0.87)
Urban	0.51** (0.32,0.81)	0.63* (0.43,0.91)	0.52*** (0.36,0.74)

[a]Ref = referent category

†P<0.10

*P<0.05

**P<0.01

***P<0.0001

§All models are adjusted for maternal age

Table 12. The likelihood of doing higher relative to lower levels of moderate/vigorous chores for sons and daughters in 1998: adjusted ORs, 95% CI from cross-sectional ordered logistic regressions in Cebu, Philippines[§]

Year	**Daughters (n=837)**	**Sons (n=944)**
Maternal education		
<Primary school graduate	*Ref*	*Ref*
Primary school graduate	1.21 (0.90,1.62)	1.14 (0.85,1.55)
Some high school	0.97 (0.69,1.35)	0.87 (0.62,1.22)
High school graduate +	0.67 (0.40,1.11)	0.42*** (0.29,0.61)
Household income:		
Low income third	*Ref*	*Ref*
Middle income third	1.02 (0.76,1.36)	0.84 (0.63,1.10)
High income third	0.80 (0.58,1.22)	0.65* (0.45,0.94)
Household assets (1 to 11)	0.80*** (0.74,0.86)	0.82*** (0.74,0.89)
Urbanicity:		
Rural	*Ref*	*Ref*
Semi-urban	0.71 (0.47,1.08)	0.47*** (0.34,0.65)
Urban	0.84 (0.58,1.22)	0.55*** (0.42,0.74)

[a]Ref = referent category

[†]P<0.10

*P<0.05

**P<0.01

***P<0.0001

[§]All models are adjusted for maternal and offspring age

Table 13. The likelihood of doing higher relative to lower levels of moderate/vigorous leisure physical activity for daughters (1998 only) and sons (1998 - 2005): adjusted ORs, 95% CI from cross-sectional ordered logistic regressions in Cebu, Philippines[§]

	Daughters	Sons		
Year	1998 (n=837)	1998 (n=944)	2002 (n=895)	2005 (n=759)
Maternal education				
<Primary school graduate	*Ref*	*Ref*	*Ref*	*Ref*
Primary school graduate	1.12 (0.82,1.54)	1.19 (0.90,1.57)	0.91 (0.64,1.29)	0.91 (0.58,1.44)
Some high school	1.68** (1.15,2.43)	1.18 (0.88,1.58)	1.00 (0.72,1.39)	0.86 (0.59,1.24)
High school graduate+	1.66* (1.05,2.64)	1.84* (1.11,3.05)	1.31 (0.84,2.04)	0.95 (0.57,1.59)
Household income:				
Low income third	*Ref*	*Ref*	*Ref*	*Ref*
Middle income third	0.82 (0.55,1.20)	1.11 (0.85,1.46)	0.84 (0.61,1.14)	0.99 (0.64,1.51)
High income third	1.11 (0.67,1.84)	1.16 (0.87,1.53)	0.79[†] (0.60,1.04)	1.35 (0.89,2.06)
Household assets, (1 to 11)	1.08* (1.00,1.17)	1.10** (1.03,1.17)	1.01 (0.94,1.08)	0.94[†] (0.85,1.01)
Urbanicity:				
Rural	*Ref*	*Ref*	*Ref*	*Ref*
Semi-urban	1.42** (1.10,1.83)	1.27 (0.94,1.71)	0.86 (0.56,1.31)	1.29 (0.89,1.87)
Urban	1.90** (1.28,2.82)	1.12 (0.83,1.52)	0.89 (0.56,1.42)	1.63[†] (0.98,2.70)

[a]Ref = referent category

[†]P<0.10

*P<0.05

**P<0.01

***P<0.0001

[§]All models are adjusted for maternal and offspring age

VI. Synthesis

A. Overview of findings

This research investigates key factors characterizing discrepant weight mother-offspring pairs in the rapidly transitioning society of Cebu, Philippines. In addition, this research identifies key determinants of diet and physical activity patterns of mothers and offspring in response to modernization, including an evaluation of possible generational differences. We used data from multiples years of the Cebu Longitudinal Health and Nutrition Survey. Detailed individual, household, and community-level environmental, socioeconomic, and demographic information was collected at each survey year, which allowed for an exploration of the association between multiple dimensions of modernization and multiple dimensions of physical activity and diet. This research identified generational differences in weight-related behavior responses to modernization which can be used to develop effective age and weight-status specific interventions. In the first phase of this research we identified the urbanicity and socioeconomic (SES) environment where discrepant overweight mother/underweight offspring pairs were most commonly found and explored participation in weight-related behaviors by offspring that might contribute to this dual-burden phenomenon. Second, we explored the impact of urbanicity and SES on the dietary patterns in energy adequacy, percent calories from fat and carbohydrates of mothers compared to offspring over time. Finally, we explored the association of urbanicity and SES with occupational, chores and leisure physical activity of mothers and offspring at multiple times points. In the section below, we summarize and provide a synthesis of our findings.

1. Coexisting over and undernutrition is associated with household wealth and deliberate weight-related behavior changes in Cebu, Philippines

Using data from the 1991, 1994, 1998, 2002, and 2005 survey years of the CLHNS, our objective was to describe the individual behaviors as well as the urbanicity and SES factors that characterized discrepant weight mother-offspring pairs. We hypothesized that discrepant weight mother-offspring pairs would be most common in wealthy urban environments. Multinomial logistic regressions were used to identify the environment characterizing the dual-burden pairs over time. Additionally, logistic regressions were used to identify the individual characteristics as well as the urbanicity and SES environment associated with offspring underweight in 2005.

Descriptively we identified that, although there was a consistently increasing trend in overweight among both mothers and offspring from 1991 to 2005, the prevalence for mothers was 4 times that for offspring. Underweight decreased over this time period for offspring but remained relatively high, especially for daughters. Despite these changes the prevalence of dual-burden overweight mothers and underweight offspring (an indicator of a country being in the intermediary phase of the nutrition transition) remained constant during this time period. These dual-burden pairs were more likely to occur in wealthy, urban environments similar to pairs where both the mother and offspring were overweight.

A particularly interesting outcome of this research was the finding that dual-burden pairs more commonly consisted of an overweight mother and underweight son during offspring adolescence, but post-puberty dual-burden pairs more commonly consisted of an overweight mother and underweight daughter. This was supported by the finding that by

2005, both daughters and sons were more likely to be underweight in higher versus lower income households but the risk was higher for daughters if they were older and sons if they were younger. Further, evidence suggests that this switch may be influenced by participation in weight-related behavior modification by girls to loose weight and boys to gain weight.

The presence of overweight mother-underweight offspring pairs in wealthy urban environments, combined with the finding that underweight offspring in this environment were participating in weight-related behaviors to reach a perceived ideal body weight suggests the emergence of a generational difference in response to modernization. In developed countries there is a tremendous social pressure for women to be thin and for men to be muscular. Consequently, the higher the disposable income a household has, the greater the likelihood of spending time and money to reach these ideals. As a result, the risk of overweight/obesity is lower for wealthy versus poor households. A similar trend may be emerging in developing countries but may not occur to the same extent in older versus younger generations. Findings from this study lead to the hypothesis that offspring may be more responsive to emerging western ideals accompanying modernization and therefore may modify weight-related behaviors to a greater extent then mothers over time. In the next two phases of our study we explored the validity of this hypothesis.

2. Offspring consume a more obesogenic diet than mothers in response to modernization in Cebu, Philippines

Using data from the 1994, 1998, 2002, and 2005 survey years of the CLHNS, our objective was to identify a possible differential response in dietary behaviors of mothers versus offspring in response to modernization. Given that overweight increased to a greater

extent for mothers versus offspring during the study period, we hypothesized that mothers would consume a more obesogenic diet than offspring in response to modernization. The impact of socioeconomic factors and urbanicity on dietary behaviors (energy adequacy, percent fat and carbohydrates) of mothers compared to offspring were examined using longitudinal random-effects regressions.

Our results showed that mothers and offspring were consistently more likely to consume more calories relative to basal needs as well as a higher percent of calories from fat and a lower percent from carbohydrates with increasing socioeconomic status and urbanization. Despite the substantially higher rates of overweight among mothers compared to offspring, offspring consumed a significantly more obesogenic diet than mothers experiencing the same increases in wealth and urbanicity. Further contrary to our hypothesis, we found that the average energy intake and percent calories from fat for mothers decreased over time.

There are several possible explanations for the finding that a substantially greater number of mothers are overweight compared to offspring yet the offspring are consuming a more obesogenic diet. First, there may be an age effect. Simply, increases in overweight for offspring may not have matched that observed in mothers because they were still in a period of growth and development. If this is the case then, in adulthood, overweight and obesity among offspring may reach levels far surpassing those currently observed among the mothers. Secondly, given that energy intake is only one half of the energy balance equation, divergent weight status between mothers and offspring may have been a result of a differential response to modernization with respect to physical activity behaviors. Although we found mothers decreased their dietary energy adequacy and %FAT, if they had a

comparatively greater decrease in energy expenditure during this time period, this would account for the continued increase in overweight prevalence. Alternately, the offspring may have participated in a comparatively greater amount of physical activity in response to modernization compared to the mothers. This might account for the notably lower prevalence of overweight and possibly the persistence in underweight if the increase in energy expenditure exceeded the increase in energy intake. To investigate this possibility, the last stage of this study explored the physical activity patterns of mothers compared to offspring during this time period.

3. Modernization is associated with decreases in occupational, chores and leisure physical activity for mothers and offspring in Cebu, Philippines

Using data from the 1998, 2002, and 2005 survey years of the CLHNS, our objective was to describe moderate/vigorous physical activity (MVPA) trends for Filipino mother-offspring pairs. Further, we aimed to identify SES and urbanicity correlates of multiple dimensions of physical activity that might contribute to the discrepant mother-offspring weight trends. We hypothesized that mothers would show a comparatively greater decrease in total physical activity than offspring in response to increased wealth and urbanicity. Ordered logistic regression models assessed SES and urbanicity predictors of number of maternal MV chores, and relative levels of offspring MV chores and leisure MVPA. Multinomial logistic regressions were used to assess SES and urbanicity predictors of occupational MVPA for mother and offspring.

Descriptively, we found that the number of mothers participating in MVPA chores and occupations decreased over 7 years so that the percentage of mothers reporting any

MVPA from these activities decreased from 89.9% to 84.4%. Offspring participation in chores, occupational, and leisure MVPA decreased resulting in a substantial decrease of offspring reporting any MVPA from these activities (sons: 98.7 to 52.2%, daughters: 95.6 to 16.9%). From our regression analyses, we found that mothers who were at least secondary school graduates, from higher SES households, or who lived in semi-urban and urban settings were less likely to do high levels of MV chores or occupational MVPA from 1998 to 2005. Similar results were observed for sons and daughters with respect to occupational MVPA and chores. In contrast, daughters were more likely to participate in higher levels of leisure MVPA in 1998 if the mother had at least some high school education, they were from a higher SES household and they were from at least a semi-urban environment. Insufficient number of daughters participated in leisure MVPA after 1998 to do a formal analysis. However, the increased likelihood of MPVA participation for wealthy urban female offspring provides some evidence to support our first-phase finding that these offspring may be engaging in weight-related behaviors to loose weight. There were no significant consistent predictors of leisure MVPA for sons.

Overall, findings from the first phase of this study suggest that Filipino mothers and offspring may respond differently to modernization with respect to weight-related behaviors. However our subsequent exploration of diet and physical activity behaviors do not support this hypothesis. Given that mothers are substantially more overweight than offspring and many of the offspring are still underweight, we expected that mothers would respond to modernization by developing a more obesogenic lifestyle than offspring. On the contrary, we found that, in response to modernization, offspring were likely to consume a more obesogenic diet than mothers and there was a greater drop in the number of offspring

performing physical activity than mothers. An age effect may be buffering the impact of an obesogenic lifestyle for offspring. However, if this is the case then we can expect to see substantial increases in overweight/obesity as these offspring enter into adulthood. Further, based on these findings the obesity problem for offspring may surpass that currently observed for mothers. Finally, we did observe that dual-burden households tend to occur in wealthy urban environments similar to the environment where we find the greater likelihood that both mothers and offspring follow obesogenic lifestyles. Although the trend suggests that on average there may be substantial increases in overweight in urban wealthy settings in the Philippines there is still an underweight subpopulation in this environment. Therefore, interventions created to address overweight should focus on a healthy balance between energy intake and expenditure rather than energy restriction in order to address overweight without exacerbating underweight in this population.

B. Strengths and limitations

There were several challenges that we faced in this study. First, since the CLHNS is a study of mothers and a single birth cohort, we were only able to identify dual-burden pairs based on the weight status of the mother and only one offspring in the household. If the mother was not overweight but another adult member of the household was or if another offspring besides the one in this study was underweight these households would have been incorrectly classified which may have attenuated our estimates. Additionally, it was impossible to distinguish between age and secular trends because we used a single birth cohort. For example, a change over time in physical activity may be a result of aging versus a secular change in physical activity behaviors for offspring.

Another challenge of this research is the accurate assessment of diet. We used 24-hour recall questionnaires to assess energy adequacy, and percent energy from fat and carbohydrates. Because of economic and time feasibility, this method is widely used for large scale studies and is generally considered acceptable for epidemiologic assessments of macronutrients. However, there are studies that have found that one 24-hour recall is insufficient to capture usual intake for an individual. Only one 24-hour recall was collected for mothers for all years. For offspring two 24-hour recalls were collected from 1998-2005 and both were used to create average values for our dietary outcomes. Using an average of two versus one day of data has been found to increase the correlation between macronutrient intakes estimated from a 24-recall and estimates from objective food records.

Assessment of physical activity is equally challenging. Due to data availability, we used different questionnaire methodologies to capture the different sources of physical activity. For example, we used occupation type to determine the level of occupational activity for mothers and offspring. This method assumes that all individuals that perform the same job have the same level of physical exertion. Reported exertion levels during working hours for offspring indicated that heterogeneity of both duration and intensity within occupational activity categories may have affected the precision and ultimately the interpretation of regression estimates. This method also assumes that all occupations classified as MV have the same level of physical exertion. If there was a systematic difference in the level of exertion for the occupational jobs classified as MV performed by mothers versus offspring this difference would not have been detected by our classification method. Chores for mothers were measured by the number of MV chores the mother said she was responsible for in the household but there was no information on duration of chores

except for walking to the market. Although duration and intensity could be measured for the chores and leisure MPA for offspring in 1998 the unit of time changed for the 2002 and 2005 so we were not able to use the full duration and intensity information for offspring. Because of these data limitation we were unable to identify the total minutes of MVPA for each person by combining activity from all sources. As a result, we could not run a formal analysis directly comparing changes in the physical activity of mothers versus offspring in response to modernization. We did however detect consistent decreasing trends in the number of mothers and offspring performing any MVPA (occurring to a greater extent among offspring) as well as consistent decreases in the likelihood of participating in MVPA among the urban wealthy.

The limitations we found with constructing the physical activity variables also lead to challenges in creating an estimate of energy adequacy for mothers and offspring. Often an estimate of energy adequacy is estimated by total calories consumed/total energy expenditure (TEE). There are equations to estimate TEE but they include an estimate of expenditure from physical activity. For this reason we were restricted to using basal energy expenditure (which does not included PA) to estimate energy adequacy. From our physical activity study, we showed that the number of offspring participating in any MVPA decreased to a greater extent among offspring compared to mothers therefore the regressions using an energy adequacy based on only basal metabolic needs may have lead to biased estimates. However, the findings using %FAT as the outcome were similar to those observed for energy adequacy validating to some extent the findings of the latter estimates.

Despite these stated limitations this study has numerous strengths. While there has been an increase in attention and research identifying patterns of dual-burden over and undernutrition in transitional societies, our study is the first that we know of which attempts

to understand the behavioral mechanism influencing these divergent weight patterns. Not only were we able to track the dual-burden trend over time for a generation of mothers asd well as their offspring but we captures an important transitional period from adolescent to adulthood. Additionally, the wealth of data in multiple years of the CLHNS allowed for a longitudinal analysis to evaluate the casual effect of modernization on differential dietary behaviors of mothers and offspring. Although some of our aims used multiple cross-sections versus a formal longitudinal analysis, this enabled us to identify lasting versus transient behaviors (such as the high level of chores performed while still in school but not post graduation).

The wealth of data in the CLHNS also allowed for an evaluation of multiple aspects of modernization. Several studies have demonstrated that income, a commonly used estimate of SES, is insufficient as a marker of household wealth. In this study we were able to evaluate the effect of income, assets and maternal education. Many studies including several based on the CLHNS data have found substantial amounts of heterogeneity between the urban rural dichotomies so that estimated effects of urbanicity are often underestimated. Therefore, instead of a dichotomous variable, we used an index based on 7 different urbanicity constructs.

Finally, many studies in the developed world focus exclusively on leisure physical activity but for economic and cultural reasons this is inappropriate for many developing countries. Although there is an increase in some subpopulations of leisure activity (e.g. Filipino males playing basketball), for many developing countries other sources more often provide the main outlet for physical activity such as occupational and domestic activities. In this study we were able to focus our analysis on multiple aspects of physical activity

including leisure, occupational and chores activities. Equally important, we studied the differential response in multiple aspects of maternal and offspring dietary behaviors in response to modernization including both energy intake as well as diet composition.

C. Public health significance

Obesity has quickly become a worldwide epidemic. Unlike in developed countries, in developing countries obesity is rapidly on the rise while chronic undernutrition remains a pervasive problem. This situation is only further complicated by the finding that over and undernutrition overlap so that in many cases both forms of malnutrition co-occur in the same communities and even households. However, developing countries do not have the healthcare infrastructure, nor do a majority of individuals have the financial means to counteract the negative impact of chronic undernutrition or obesity and its associated chronic diseases. Several studies have identified that there is a divergence of weight status between adults and offspring in countries experiencing rapid modernization but no studies that we know of have explored possible differential weight-related behavior patterns that might explain this difference. Understanding the behavior patterns that lead to malnutrition is essential for developing effective policies and interventions to improve overall health. This study identifies obesogenic behaviors, both in diet and physical activity, for mothers that help explain the increasing overweight among mothers. Further, this study identifies weight-related behavior of underweight offspring that may contribute to the troubling dual-burden of overweight and underweight in wealthy urban environments. Finally, this study documents the increase in obesogenic diet and physical activity behaviors among wealthy urban offspring that may lead to substantial future increases in overweight and obesity.

Without this work, policies and interventions may have been designed to address solely the increasing overweight among adults, particularly because there is some evidence of a decrease in underweight among offspring. Given the results of this study, policies and interventions should be designed to address adult overweight but that also confront the obesogenic lifestyle of many Filipino adolescents that may lead to an even greater future obesity problem. To be successful however, these interventions will need to be tempered with a mechanism to address the underweight trend among some adolescents in wealthy urban settings.

Finally, unlike studies of dietary behaviors, there are very few studies currently evaluating physical activity patterns in developing countries experiencing rapid modernization. Further no studies were identified that evaluate trends in multiple sources of physical activity for multiple generations experiencing the same environmental changes due to modernization. This work underscores the need for large scale longitudinal studies to identify physical activity trends for all age groups in transitional societies which may be contributing to the rapid rise in overweight/obesity.

D. Direction for future research

There are several important steps that should be taken following these findings. Although we made some initial important strides towards understanding the trends in physical activity behaviors of mothers versus offspring in response to modernization we were unable to do a direct longitudinal comparison. Currently field staff are recoding parts of the CLHNS that will allow for the calculation of time and intensity of activities. Once this is complete a longitudinal analyses, like those used to estimate the differential dietary response

of mothers and offspring to modernization, can be performed for physical activity. This information may provide additional valuable information to explain the discrepant weight patterns observed between Filipino mothers and offspring. Additionally, this is the first study we know of that has looked at possible generational differences in response to modernization that might account for discrepant weight trends. Therefore future studies should be undertaken to evaluate whether this work is replicable in other developing countries.

There is sufficient evidence from this study to indicate that overweight and obesity is likely to rise sharply in the future for offspring particularly in urban wealthy environments where there is a high prevalence of maternal overweight. Interventions should be created at the household level to improve the diet and physical activity choices of both mothers and offspring. Given that a majority of adolescents go to middle and high school in the Philippines, healthy lifestyle choices can be taught to students and programs can be formed to include family participation based around the context of school and education. Further, if in fact there is a secular trend towards decreasing physical activity for younger generations; interventions should focus on promoting tracking of physical activity patterns established in childhood. In our study, we found that the number of offspring participating in leisure physical activities was notably higher while they were in high school than post graduation. An intervention aimed at educating middle and high school students to the benefits of physical exercise as well as the incorporation of organized activity in schools as a national program may increase the number of Filipino youth who continue exercising into adulthood.

REFERENCES

(2001). Clinical Facts and Figures. Philippine Nutrition: Facts & Figures. Taguig, Metro Manila, Philippines, Food and Nutrition Research Institute.

Adair, L. S. (2004). "Dramatic rise in overweight and obesity in adult filipino women and risk of hypertension." Obes Res **12**(8): 1335-41.

Ainsworth, B. E., W. L. Haskell, et al. (1993). "Compendium of physical activities: classification of energy costs of human physical activities." Med Sci Sports Exerc **25**(1): 71-80.

Ainsworth, B. E., W. L. Haskell, et al. (2000). "Compendium of physical activities: an update of activity codes and MET intensities." Med Sci Sports Exerc **32**(9 Suppl): S498-504.

Ajayi, I. O. and O. O. Akinyinka (1999). "Evaluation of the nutritional status of first year school children in Ibadan, Southwest Nigeria." Afr J Med Med Sci **28**(1-2): 59-63.

Albala, C., F. Vio, et al. (2001). "Nutrition transition in Latin America: the case of Chile." Nutr Rev **59**(6): 170-6.

Albala, C., F. Vio, et al. (2002). "Nutrition transition in Chile: determinants and consequences." Public Health Nutr **5**(1A): 123-8.

Bell, A. C., K. Ge, et al. (2002). "The road to obesity or the path to prevention: motorized transportation and obesity in China." Obes Res **10**(4): 277-83.

Bell, C. A., L. S. Adair, et al. (2002). "Ethnic differences in the association between body mass index and hypertension." Am J Epidemiol **155**(4): 346-53.

Benefice, E., D. Garnier, et al. (2001). "High levels of habitual physical activity in west African adolescent girls and relationship to maturation, growth, and nutritional status: results from a 3-year prospective study." Am J Hum Biol **13**(6): 808-20.

Benjelloun, S. (2002). "Nutrition transition in Morocco." Public Health Nutr **5**(1A): 135-40.

Bollen, K., J. Glanville, et al. (2001). Economic status proxies in studies of fertility in developing countries: Does the measure matter? Chapel Hill, NC, University of North Carolina at Chapel Hill. Carolina Population Center. Measure Evaluation Project: http://www.cpc.unc.edu/measure/publications/pdf/wp-01-38.pdf.

Caballero, B. (2001). "Introduction. Symposium: Obesity in developing countries: biological and ecological factors." J Nutr **131**(3): 866S-870S.

Caballero, B. (2002). "Global patterns of child health: the role of nutrition." Ann Nutr Metab **46 Suppl 1**: 3-7.

Caballero, B. (2005). "A nutrition paradox--underweight and obesity in developing countries." N Engl J Med **352**(15): 1514-6.

Cafri, G., J. K. Thompson, et al. (2005). "Pursuit of the muscular ideal: Physical and psychological consequences and putative risk factors." Clin Psychol Rev **25**(2): 215-39.

Canpolat, B. I., S. Orsel, et al. (2005). "The relationship between dieting and body image, body ideal, self-perception, and body mass index in Turkish adolescents." Int J Eat Disord **37**(2): 150-5.

Cerdena, C. M., R. D. Lana, et al. (2001). "Philippine Nutritional Facts & Figures Supplement 1:

2001 Update of the Nutritional Status of 0-10 Year-Old Filipino Children." from http://www.fnri.dost.gov.ph/facts/factsfigsupplement.pdf.

Chockalingam, A., I. Balaguer-Vintro, et al. (2000). "The World Heart Federation's white book: impending global pandemic of cardiovascular diseases: challenges and opportunities for the prevention and control of cardiovascular diseases in developing countries and economies in transition." Can J Cardiol **16**(2): 227-9.

Chow, J. (2004). "Adolescents' perceptions of popular teen magazines." Journal of Advanced Nursing **48**(2): 132-139.

Chugh, R. and S. Puri (2001). "Affluent adolescent girls of Delhi: eating and weight concerns." Br J Nutr **86**(4): 535-42.

Coitinho, D., C. A. Monteiro, et al. (2002). "What Brazil is doing to promote healthy diets and active lifestyles." Public Health Nutr **5**(1A): 263-7.

Cole, T. J., M. C. Bellizzi, et al. (2000). "Establishing a standard definition for child overweight and obesity worldwide: international survey." BMJ **320**(7244): 1240-1243.

Crespo, C. J., E. Smit, et al. (2001). "Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994." Arch Pediatr Adolesc Med **155**(3): 360-5.

Dahly, D. L. and L. S. Adair (2007). "Quantifying the urban environment: A scale measure of urbanicity outperforms the urban-rural dichotomy." Soc Sci Med **64**(7): 1407-19.

de Onis, M. and M. Blossner (2000). "Prevalence and trends of overweight among preschool children in developing countries." Am J Clin Nutr **72**(4): 1032-9.

Dietz, W. H. (1998). "Health Consequences of Obesity in Youth: Childhood Predictors of Adult Disease." Pediatrics **101**(3): 518-525.

Doak, C., L. Adair, et al. (2002). "The underweight/overweight household: an exploration of household sociodemographic and dietary factors in China." Public Health Nutr **5**(1A): 215-21.

Doak, C. and B. Popkin (2001). The Emerging Problem of Obesity in Developing Countries. Nutrition and Health in Developing Countries. M. W. B. Richard D. Semba. Totowa, NJ, Humana Press Inc.**:** 447-464.

Doak, C. M., L. S. Adair, et al. (2005). "The dual burden household and the nutrition transition paradox." Int J Obes Relat Metab Disord **29**(1): 129-36.

Doak, C. M., L. S. Adair, et al. (2000). "Overweight and underweight coexist within households in Brazil, China and Russia." J Nutr **130**(12): 2965-71.

Dominguez, L. J., M. Barbagallo, et al. (1999). "Cardiovascular risk factors in South America and the Caribbean." Ethn Dis **9**(3): 468-78.

Dorosty, A. R., F. Siassi, et al. (2002). "Obesity in Iranian children." Arch Dis Child **87**(5): 388-91; discussion 388-91.

Drewnowski, A. (2000). "Nutrition transition and global dietary trends." Nutrition **16**(7-8): 486-7.

Drewnowski, A. and B. M. Popkin (1997). "The nutrition transition: new trends in the global diet." Nutr Rev **55**(2): 31-43.

Du, S., B. Lu, et al. (2002). "A new stage of the nutrition transition in China." Public Health Nutr **5**(1A): 169-74.

Du, S., T. A. Mroz, et al. (2004). "Rapid income growth adversely affects diet quality in China--particularly for the poor!" Soc Sci Med **59**(7): 1505-15.

Dufour, D. L., J. C. Reina, et al. (2003). "Physical activity of poor urban women in Cali, Colombia: a comparison of working and not working women." Am J Hum Biol **15**(4): 490-7.

Eisenberg, M. E., D. Neumark-Sztainer, et al. (2005). "The role of social norms and friends' influences on unhealthy weight-control behaviors among adolescent girls." Social Science & Medicine **60**(6): 1165-1173.

Evans, M., R. C. Sinclair, et al. (2002). "Diet, health and the nutrition transition: some impacts of economic and socio-economic factors on food consumption patterns in the Kingdom of Tonga." Pac Health Dialog **9**(2): 309-15.

Evenson, K. R., W. D. Rosamond, et al. (2003). "Occupational physical activity in the atherosclerosis risk in communities study." Ann Epidemiol **13**(5): 351-7.

Eyler, A. E., S. Wilcox, et al. (2002). "Correlates of physical activity among women from diverse racial/ethnic groups." J Womens Health Gend Based Med **11**(3): 239-53.

Fezeu, L., E. Minkoulou, et al. (2006). "Association between socioeconomic status and adiposity in urban Cameroon." Int J Epidemiol **35**(1): 105-11.

Field, A. E., L. Cheung, et al. (1999). "Exposure to the mass media and weight concerns among girls." Pediatrics **103**(3): E36.

Filozof, C., C. Gonzalez, et al. (2001). "Obesity prevalence and trends in Latin-American countries." Obes Rev **2**(2): 99-106.

Flegal, K. M., M. D. Carroll, et al. (2002). "Prevalence and trends in obesity among US adults, 1999-2000." Jama **288**(14): 1723-7.

FNRI (2001). Clinical Facts and Figures. Philippine Nutrition: Facts & Figures. Taguig, Metro Manila, Philippines, Food and Nutrition Research Institute.

Forrest, K. Y., C. H. Bunker, et al. (2001). "Physical activity and cardiovascular risk factors in a developing population." Med Sci Sports Exerc **33**(9): 1598-604.

Foster, Z., E. Byron, et al. (2005). "Physical growth and nutritional status of Tsimane' Amerindian children of lowland Bolivia." Am J Phys Anthropol **126**(3): 343-51.

Fung, T. T., F. B. Hu, et al. (2000). "Leisure-time physical activity, television watching, and plasma biomarkers of obesity and cardiovascular disease risk." Am J Epidemiol **152**(12): 1171-8.

Furnham, A., N. Badmin, et al. (2002). "Body image dissatisfaction: gender differences in eating attitudes, self-esteem, and reasons for exercise." J Psychol **136**(6): 581-96.

Galal, O. M. (2002). "The nutrition transition in Egypt: obesity, undernutrition and the food consumption context." Public Health Nutr **5**(1A): 141-8.

Garrett, J. and M. T. Ruel (2005). "The coexistence of child undernutrition and maternal overweight: prevalence, hypotheses, and programme and policy implications." Matern Child Nutr **1**(3): 185-96.

Ghassemi, H., G. Harrison, et al. (2002). "An accelerated nutrition transition in Iran." Public Health Nutr **5**(1A): 149-55.

Gillespie, S. and L. Haddad (2001). Attacking the Double Burden of Malnutrition in Asia and the Pacific. Manilla, Philippines, Asian Development Bank and IFPRI.

Gittelsohn, J., H. Haberle, et al. (2003). "Macro- and microlevel processes affect food choice and nutritional status in the republic of the marshall islands." J Nutr **133**(1): 310S-313S.

Gordon-Larsen, P., L. S. Adair, et al. (2002). "Ethnic Differences in Physical Activity and Inactivity Patterns and Overweight Status." Obes Res **10**(3): 141-149.

Gortmaker, S. L., A. Must, et al. (1996). "Television viewing as a cause of increasing obesity among children in the United States, 1986-1990." Arch Pediatr Adolesc Med **150**(4): 356-62.

Gracey, M. (2003). "Child health implications of worldwide urbanization." Rev Environ Health **18**(1): 51-63.

Haase, A., A. Steptoe, et al. (2004). "Leisure-time physical activity in university students from 23 countries: associations with health beliefs, risk awareness, and national economic development." Prev Med **39**(1): 182-90.

Hakeem, R., J. Thomas, et al. (1999). "Rural-urban differences in food and nutrient intake of Pakistani children." J Pak Med Assoc **49**(12): 288-94.

Hakeem, R., J. Thomas, et al. (2002). "Food habits and nutrient density of diets of Pakistani children living in different urban and rural settings." J Health Popul Nutr **20**(3): 255-63.

Hakeem, R., J. Thomas, et al. (2002). "Urbanisation and activity pattern of south Asian children." J Pak Med Assoc **52**(9): 402-7.

Hankin, J. H. and L. E. Dickinson (1972). "Urbanization, diet, and potential health effects in Palau." Am J Clin Nutr **25**(3): 348-53.

Heckman, J. J. (1979). "Sample selection bias as a specification error." Econometrica **47**(1): 153-161.

Hedley, A. A., C. L. Ogden, et al. (2004). "Prevalence of overweight and obesity among US children, adolescents, and adults, 1999-2002." Jama **291**(23): 2847-50.

Hels, O., N. Hassan, et al. (2003). "Food consumption, energy and nutrient intake and nutritional status in rural Bangladesh: changes from 1981-1982 to 1995-96." Eur J Clin Nutr **57**(4): 586-94.

Hernandez, B., S. L. Gortmaker, et al. (1999). "Association of obesity with physical activity, television programs and other forms of video viewing among children in Mexico city." Int J Obes Relat Metab Disord **23**(8): 845-54.

Institute of Medicine of the National Academies (2005). Dietary reference intakes for energy, carbohydrates, fiber, fat, fatty acids, cholesterol, protein and amino acids. Washington, D.C., The National Academies Press.

James, P. T., R. Leach, et al. (2001). "The worldwide obesity epidemic." Obes Res **9 Suppl 4**: 228S-233S.

Kain, J., F. Vio, et al. (2003). "Obesity trends and determinant factors in Latin America." Cad Saude Publica **19 Suppl 1**: S77-86.

Kautiainen, S., A. Rimpela, et al. (2002). "Secular trends in overweight and obesity among Finnish adolescents in 1977-1999." Int J Obes Relat Metab Disord **26**(4): 544-52.

Ke-You, G. and F. Da-Wei (2001). "The magnitude and trends of under- and over-nutrition in Asian countries." Biomed Environ Sci **14**(1-2): 53-60.

Kimm, S. Y. S. and E. Obarzanek (2002). "Childhood Obesity: A New Pandemic of the New Millennium." Pediatrics **110**(5): 1003-1007.

Kosulwat, V. (2002). "The nutrition and health transition in Thailand." Public Health Nutr **5**(1A): 183-9.

Kronenberg, F., M. A. Pereira, et al. (2000). "Influence of leisure time physical activity and television watching on atherosclerosis risk factors in the NHLBI Family Heart Study." Atherosclerosis **153**(2): 433-43.

Kruger, H. S., C. S. Venter, et al. (2002). "Physical inactivity is the major determinant of obesity in black women in the North West Province, South Africa: the THUSA study. Transition and Health During Urbanisation of South Africa." Nutrition **18**(5): 422-7.

Lafay, L., A. Basdevant, et al. (1997). "Determinants and nature of dietary underreporting in a free-living population: the Fleurbaix Laventie Ville SantÃ© (FLVS) study." International Journal of Obesity & Related Metabolic Disorders **21**(7): 567.

Lahti-Koski, M., P. Jousilahti, et al. (2001). "Secular trends in body mass index by birth cohort in eastern Finland from 1972 to 1997." Int J Obes Relat Metab Disord **25**(5): 727-34.

Lethbridge-Cejku, M., J. S. Schiller, et al. (2004). "Summary health statistics for U.S. adults: National Health Interview Survey, 2002." Vital Health Stat 10(222): 1-151.

Luo, J. and F. B. Hu (2002). "Time trends of obesity in pre-school children in China from 1989 to 1997." Int J Obes Relat Metab Disord **26**(4): 553-8.

Ma, H. and B. M. Popkin (1995). "Income and food-consumption behaviour in China: A structural-shift analysis." Food and Nutrition Bulletin **16**(2): 155-165.

Martin, S. L., G. J. Kirkner, et al. (2005). "Urban, rural, and regional variations in physical activity." J Rural Health **21**(3): 239-44.

Martinez-Gonzalez, M. A., J. A. Martinez, et al. (1999). "Physical inactivity, sedentary lifestyle and obesity in the European Union." Int J Obes Relat Metab Disord **23**(11): 1192-201.

Martorell, R., L. Kettel Khan, et al. (2000). "Overweight and obesity in preschool children from developing countries." Int J Obes Relat Metab Disord **24**(8): 959-67.

Martorell, R., L. K. Khan, et al. (1998). "Obesity in Latin American women and children." J Nutr **128**(9): 1464-73.

Martorell, R., L. K. Khan, et al. (2000). "Obesity in women from developing countries." Eur J Clin Nutr **54**(3): 247-52.

Matsuhashi, Y. (2000). "Thinness: drives and results." J Adolesc Health **27**(3): 149-50.

Mbalilaki, J. A., M. L. Hellenius, et al. (2007). "Physical activity and blood lipids in rural and urban Tanzanians." Nutr Metab Cardiovasc Dis **17**(5): 344-8.

McCabe, M. P. and L. A. Ricciardelli (2003). "Body image and strategies to lose weight and increase muscle among boys and girls." Health Psychol **22**(1): 39-46.

McCabe, M. P. and L. A. Ricciardelli (2003). "Sociocultural influences on body image and body changes among adolescent boys and girls." J Soc Psychol **143**(1): 5-26.

McDade, T. W. and L. S. Adair (2001). "Defining the "urban" in urbanization and health: a factor analysis approach." Soc Sci Med **53**(1): 55-70.

Mendez, M. A., C. A. Monteiro, et al. (2005). "Overweight exceeds underweight among women in most developing countries." Am J Clin Nutr **81**(3): 714-21.

Monda, K. L., P. Gordon-Larsen, et al. (2007). "China's transition: the effect of rapid urbanization on adult occupational physical activity." Soc Sci Med **64**(4): 858-70.

Monteiro, C. A., W. L. Conde, et al. (2004). "Obesity and inequities in health in the developing world." Int J Obes Relat Metab Disord **28**(9): 1181-6.

Monteiro, C. A., W. L. Conde, et al. (2001). "Independent effects of income and education on the risk of obesity in the Brazilian adult population." J Nutr **131**(3): 881S-886S.

Monteiro, C. A., W. L. Conde, et al. (2004). "The burden of disease from undernutrition and overnutrition in countries undergoing rapid nutrition transition: a view from Brazil." Am J Public Health **94**(3): 433-4.

Monteiro, C. A., L. Mondini, et al. (1995). "The nutrition transition in Brazil." Eur J Clin Nutr **49**(2): 105-13.

Monteiro, C. A., E. C. Moura, et al. (2004). "Socioeconomic status and obesity in adult populations of developing countries: a review." Bull World Health Organ **82**(12): 940-6.

Moreno, L. A., A. Sarria, et al. (2001). "Sociodemographic factors and trends on overweight prevalence in children and adolescents in Aragon (Spain) from 1985 to 1995." J Clin Epidemiol **54**(9): 921-7.

Moreno, L. A., A. Sarria, et al. (2002). "The nutrition transition in Spain: a European Mediterranean country." Eur J Clin Nutr **56**(10): 992-1003.

Nandy, S., M. Irving, et al. (2005). "Poverty, child undernutrition and morbidity: new evidence from India." Bull World Health Organ **83**(3): 210-6.

Neutzling, M. B., J. A. Taddei, et al. (2000). "Overweight and obesity in Brazilian adolescents." Int J Obes Relat Metab Disord **24**(7): 869-74.

Nguyen, M. D., S. A. Beresford, et al. (2007). "Trends in overweight by socio-economic status in Vietnam: 1992 to 2002." Public Health Nutr **10**(2): 115-21.

Noor, M. I. (2002). "The nutrition and health transition in Malaysia." Public Health Nutr **5**(1A): 191-5.

Olivares, S., C. Albala, et al. (1999). "Television publicity and food preferences of school age children of the Metropolitan Region." Revista Medica De Chile **127**(7): 791-799.

Oner, N., U. Vatansever, et al. (2004). "Prevalence of underweight, overweight and obesity in Turkish adolescents." Swiss Med Wkly **134**(35-36): 529-33.

Pate, R. R., M. Pratt, et al. (1995). "Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine." Jama **273**(5): 402-7.

Patterson, P. D., C. G. Moore, et al. (2004). "Obesity and physical inactivity in rural America." J Rural Health **20**(2): 151-9.

Paxton, S. J., M. Norris, et al. (2005). "Body dissatisfaction, dating, and importance of thinness to attractiveness in adolescent girls.(study)." (study) **53**(9-10): 663(13).

Perez-Cueto, F. J. and P. W. Kolsteren (2004). "Changes in the nutritional status of Bolivian women 1994-1998: demographic and social predictors." Eur J Clin Nutr **58**(4): 660-6.

Pitsavos, C., D. B. Panagiotakos, et al. (2005). "Epidemiology of leisure-time physical activity in socio-demographic, lifestyle and psychological characteristics of men and women in Greece: the ATTICA Study." BMC Public Health **5**(1): 37.

Pollock, M. L., G. A. Gaesser, et al. (1998). "ACSM Position Stand: The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Healthy Adults." Med Sci Sports Exerc **30**(6): 975-991.

Popkin, B. M. (1994). "The nutrition transition in low-income countries: an emerging crisis." Nutr Rev **52**(9): 285-98.

Popkin, B. M. (1996). "Understanding the nutrition transition." Urban Health Newsl(30): 3-19.

Popkin, B. M. (1998). "The nutrition transition and its health implications in lower-income countries." Public Health Nutr **1**(1): 5-21.

Popkin, B. M. (1999). "Urbanization, lifestyle changes and the nutrition transition." World Development **27**(11): 1905-1916.

Popkin, B. M. (2001). "The nutrition transition and obesity in the developing world." J Nutr **131**(3): 871S-873S.

Popkin, B. M. (2002). "The shift in stages of the nutrition transition in the developing world differs from past experiences!" Public Health Nutr **5**(1A): 205-14.

Popkin, B. M. (2004). "The nutrition transition: an overview of world patterns of change." Nutr Rev **62**(7 Pt 2): S140-3.

Popkin, B. M., W. Conde, et al. (2006). "Is there a lag globally in overweight trends for children compared with adults?" Obesity (Silver Spring) **14**(10): 1846-53.

Popkin, B. M. and C. M. Doak (1998). "The obesity epidemic is a worldwide phenomenon." Nutr Rev **56**(4 Pt 1): 106-14.

Proctor, M. H., L. L. Moore, et al. (1996). "Risk profiles for non-communicable diseases in rural and urban schoolchildren in the Republic of Cameroon." Ethn Dis **6**(3-4): 235-43.

Rao, S., M. Gokhale, et al. (2007). "Energy costs of daily activities for women in rural India." Public Health Nutr: 1-9.

Reddy, K. K., A. P. Rao, et al. (2002). "Socioeconomic status and the prevalence of coronary heart disease risk factors." Asia Pac J Clin Nutr **11**(2): 98-103.

Ricciardelli, L. A. and M. P. McCabe (2004). "A biopsychosocial model of disordered eating and the pursuit of muscularity in adolescent boys." Psychol Bull **130**(2): 179-205.

Rice, A. L., L. Sacco, et al. (2000). "Malnutrition as an underlying cause of childhood deaths associated with infectious diseases in developing countries." **78**(10): 1207.

Ringrose, H. and P. Zimmet (1979). "Nutrient intakes in an urbanized Micronesian population with a high diabetes prevalence." Am J Clin Nutr **32**(6): 1334-41.

Rivera, J. A., S. Barquera, et al. (2004). "Nutrition transition in Mexico and in other Latin American countries." Nutr Rev **62**(7 Pt 2): S149-57.

Rodriguez-Ojea, A., S. Jimenez, et al. (2002). "The nutrition transition in Cuba in the nineties: an overview." Public Health Nutr **5**(1A): 129-33.

Sakamaki, R., R. Amamoto, et al. (2005). "A comparative study of food habits and body shape perception of university students in Japan and Korea." Nutr J **4**: 31.

Samaras, K., P. J. Kelly, et al. (1999). "Dietary underreporting is prevalent in middleaged British women and is not related to adiposity (percentage body fat)." International Journal of Obesity & Related Metabolic Disorders **23**(8): 881.

Scagliusi, F. B., V. O. Polacow, et al. (2003). "Selective underreporting of energy intake in women: Magnitude, determinants, and effect of training." Journal of the American Dietetic Association **103**(10): 1306-1313.

Shroff, H. and J. K. Thompson (2004). "Body image and eating disturbance in India: media and interpersonal influences." Int J Eat Disord **35**(2): 198-203.

Sobal, J. (1991). "Obesity and socioeconomic status: a framework for examining relationships between physical and social variables." Med Anthropol **13**(3): 231-47.

Sobngwi, E., J. C. Mbanya, et al. (2002). "Physical activity and its relationship with obesity, hypertension and diabetes in urban and rural Cameroon." Int J Obes Relat Metab Disord **26**(7): 1009-16.

Solomons, N. W. and R. Gross (1995). "Urban nutrition in developing countries." Nutr Rev **53**(4 Pt 1): 90-5.

StataCorp (2006). Stata Statistical Software. College Station, TX, STATA Corporation. **Stata/SE 9.2**.

Subramanian, S. V. and G. D. Smith (2006). "Patterns, distribution, and determinants of under- and overnutrition: a population-based study of women in India." Am J Clin Nutr **84**(3): 633-40.

Tanchoco, C. C., A. J. Cruz, et al. (2003). "Prevalence of metabolic syndrome among Filipino adults aged 20 years and over." Asia Pac J Clin Nutr **12**(3): 271-6.

Tremblay, M. S., P. T. Katzmarzyk, et al. (2002). "Temporal trends in overweight and obesity in Canada, 1981-1996." Int J Obes Relat Metab Disord **26**(4): 538-43.

Troiano, R. P. and K. M. Flegal (1998). "Overweight children and adolescents: description, epidemiology, and demographics." Pediatrics **101**(3 Pt 2): 497-504.

Tudor-Locke, C., B. E. Ainsworth, et al. (2003). "Physical activity and inactivity in Chinese school-aged youth: the China Health and Nutrition Survey." Int J Obes Relat Metab Disord **27**(9): 1093-9.

Tudor-Locke, C., B. E. Ainsworth, et al. (2003). "Physical activity in Filipino youth: the Cebu Longitudinal Health and Nutrition Survey." Int J Obes Relat Metab Disord **27**(2): 181-90.

U.S. Department of Health and Human Services (1996). Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.

Uauy, R., C. Albala, et al. (2001). "Obesity Trends in Latin America: Transiting from Under- to Overweight." J. Nutr. **131**(3): 893S-899.

Verdaet, D., P. Dendale, et al. (2004). "Association between leisure time physical activity and markers of chronic inflammation related to coronary heart disease." Atherosclerosis **176**(2): 303-10.

Vlahov, D. and S. Galea (2002). "Urbanization, urbanicity, and health." J Urban Health **79**(4 Suppl 1): S1-S12.

Vorster, H. H. (2002). "The emergence of cardiovascular disease during urbanisation of Africans." Public Health Nutr **5**(1A): 239-43.

Vorster, H. H., L. T. Bourne, et al. (1999). "Contribution of nutrition to the health transition in developing countries: a framework for research and intervention." Nutr Rev **57**(11): 341-9.

Voss, S., A. Kroke, et al. (1998). "Is macronutrient composition of dietary intake data affected by underreporting? results from the." European Journal of Clinical Nutrition **52**(2): 119.

Ward, H., V. Tarasuk, et al. (2007). "Socioeconomic patterns of obesity in Canada: modeling the role of health behaviour." Appl Physiol Nutr Metab **32**(2): 206-16.

WHO (2002). Global strategy on diet, physical activity and health. The world health report: Reducing risks, promoting healthy life. Geneva, World Health Organization**:** 1-21.

WHO (2004). Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. Geneva, World Health Organization.

WHO/FAO (2003). Diet, Nutrition and the Prevention of Chronic Diseases: Report of a joint WHO/FAO expert consultation. WHO Technical Report Series. Geneva, World Health Organization**:** 1-160.

Wickramasinghe, V. P., S. P. Lamabadusuriya, et al. (2004). "Nutritional status of schoolchildren in an urban area of Sri Lanka." Ceylon Med J **49**(4): 114-8.

Wilcox, S., C. Castro, et al. (2000). "Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States." J Epidemiol Community Health **54**(9): 667-72.

Willet, W. (1998). Nutritional Epidemiology. Oxford, Oxford University Press.

Wiwanitkit, V. and P. Sodsri (2003). "Underweight schoolchildren in a rural school near the Thai-Cambodian border." Southeast Asian J Trop Med Public Health **34**(2): 458-61.

Yach, D., C. Mathews, et al. (1990). "Urbanisation and health: methodological difficulties in undertaking epidemiological research in developing countries." Soc Sci Med **31**(4): 507-14.

Yannakoulia, M., D. B. Panagiotakos, et al. (2007). "Low Energy Reporting Related to Lifestyle, Clinical, and Psychosocial Factors in a Randomly Selected Population Sample of Greek Adults: The ATTICA Study." J Am Coll Nutr **26**(4): 327-333.

Zhai, F., D. Fu, et al. (2002). "What is China doing in policy-making to push back the negative aspects of the nutrition transition?" Public Health Nutr **5**(1A): 269-73.