SOCIOECONOMIC STATUS AND OVERWEIGHT: USING A "FUNDAMENTAL CAUSE" PERSPECTIVE TO EXAMINE RELATIONSHIPS ACROSS TIME AND PLACE

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ABSTRACT

Jessica Claire Jones-Smith: Socioeconomic Status and Overweight: Using a "Fundamental Cause" Perspective to Examine Relationships Across Time and Place
(Under the direction of Barry M. Popkin, PhD)

Historically, in lower income countries, women with lower socioeconomic status (SES) have had a lower risk of overweight compared to their higher SES counterparts. However, with increasing rates of overweight worldwide, contemporary data suggest that even in some developing countries, lower SES women now have a higher risk of overweight compared to higher SES women.

We use data from women (n=556,352) in 41 lower income countries to determine whether the prevalence of overweight has increased disproportionately among low SES women compared to high SES women during the last two decades. We also assess whether the direction of the relationship between SES and overweight has changed for women in these countries. Furthermore, we examine whether there are country-level contextual features that are saliently associated with comparatively faster overweight prevalence gains among low SES women.

We find that the relation between SES and overweight has changed direction from positive to inverse in only five countries. However, in approximately 30-50% of the countries, the increases in overweight prevalence over time have been faster in the lowest SES populations compared to the highest SES populations. Country-level economic development was positively associated with faster increases in overweight prevalence among the lower wealth women. The fastest gains in low SES populations were seen in countries that had relatively higher GDP and lower levels of income inequality.

We then use longitudinal data from adults in China (1989-2006) to track trajectories of BMI and overweight according to SES. We find larger increases in BMI and overweight over time for the lowest SES women compared to the highest, resulting in the emergence of a socioeconomic disparity in overweight. Opposite findings are seen for men; high SES men (versus low) have higher odds of overweight by the end of the survey.

Overall, this study indicates that, predominantly, in lower income countries, low SES women are still less likely to be overweight than high SES women. However, a shift in the burden of overweight also appears to be underway, as the rates of overweight prevalence gains among low SES women are currently outpacing those among high SES women in these contexts.

This work is dedicated to:

My mom, Kate, and Damon.

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LIST OF ABBREVIATIONS

BMI	Body Mass Index
CHNS	China Health and Nutrition Survey
DHS	Demographic and Health Survey
GDP	Gross Domestic Product
FCT	Fundamental Cause Theory
HR	Hazard Ratio
IFLS	Indonesia Family Life Survey
Kg	Kilogram
M	Meter
OR	Odds Ratio
RII	Relative Index of Inequality
SII	Slope Index of Inequality
SES	Socioeconomic Status
WHO	World Health Organization

I. INTRODUCTION

Rapid economic and demographic change is often accompanied by shifts in the population burden of disease; as economic development increases, the burden of disease generally transitions from a state in which infectious diseases predominate to a state in which chronic conditions constitute the largest share of disease burden. Despite these large changes in the predominant types of disease, the largest disease burden *across time and place* has continued to fall on populations in the lowest socioeconomic positions. Multiple theories have been formulated to explain the relationships between low socioeconomic status and high burden of disease. One such theory is *fundamental cause theory (FCT)*, which emphasizes the persistence of the relationship between SES and disease over time, despite radical changes in the predominant diseases and their causal intermediates. FCT hypothesizes that higher income groups utilize their flexible resources to respond to changing environments and disease risk, which ultimately results in higher SES groups experiencing a lower disease risk compared to lower SES groups. In addition, fundamental cause theorists assert that, since predominant diseases and their intermediary pathways will likely change, scientific investigation focused on the distal role of social conditions is warranted.

From a fundamental cause perspective, recent shifts in the burden of overweight among social class groups around the world might provide a remarkable example in which we can witness groups with the highest SES begin to experience a decreased risk of the prevailing disease in comparison to those with lower SES. Historically, in lower income countries, women with lower socioeconomic status (SES) have had a lower risk of overweight compared to their higher SES counterparts. However, with increasing rates of overweight worldwide, contemporary data suggest that even in some developing countries, lower SES women now have a higher risk of overweight compared to higher SES women. In comparison to many other chronic diseases, weight gain and overweight can develop over a relatively short period of time. This quality positions weight gain and overweight prevalence as good candidate outcomes to examine how the disease implications for socioeconomic status group change as context changes, over a short, contemporary time period of 5 to 20 years.

Since the above mentioned seminal cross-national studies did not follow the same countries through time, it is unclear whether, within a given country, the burden of disease by socioeconomic status actually changes as economic development increases, or whether these relationships are only seen using cross-sectional snapshots of countries at varying GDP. If longitudinal country-level or individual-level findings are not consistent with previous work from a single point in time, it would challenge the assumptions and theories of the relationship between economic development, socioeconomic status and overweight.

To address these research questions we assembled individual-level data from 41 countries for which we could obtain repeated anthropometric measurements to assess overweight. The majority of these data come from the nationally representative Demographic and Health Surveys. In addition we used data from the Indonesian Family Life Survey and the China Health and Nutrition Survey. Furthermore, we utilize the seven waves of data from the China Health and Nutrition Survey to more closely probe trends in BMI trajectories over time among high and low SES groups during a time of rapid economic development.

II. SPECIFIC AIMS

Motivated by the theoretical framework of fundamental cause theory, the goal of this work was to investigate whether the disease burden of overweight among adults in low-and middle-income countries is actively shifting toward lower SES groups within these countries as well as whether country-level contextual features are associated with a disproportionate burden of overweight among low SES groups.

The specific objectives of this project were to:

1) Describe the time trends in overweight prevalence levels for high and low SES populations in low- and middle-income countries, and to determine how frequently the increases in overweight prevalence are higher for lowest education and wealth populations compared to highest education and wealth groups in each country.

To assess time trends in overweight among women we used repeated cross-sectional, nationally representative data from women aged 18-49 (n=556,352) in 41 low- and middle-income countries to determine the prevalence of overweight (body mass index ≥25) at each survey wave by wealth quintile and educational attainment (separately). We calculate the SES-specific prevalence difference and prevalence growth rate over time for each country and determine which group experienced faster rates of increase in overweight prevalence. We hypothesized that we'd find only a few countries for which the overweight prevalence has become higher among the lowest SES groups, compared to the highest, but that a substantial number of countries would display faster *rates of increase* in overweight prevalence among the lowest SES populations in comparison to the highest.

2) Determine whether relatively a faster rate of overweight prevalence increase among the lower wealth population was associated with level of and change in economic development over time and whether these associations varied by country-level income inequality.

Using the same repeated, cross-sectional data and limiting our analyses to wealth as an indicator of SES, we estimated the overall level of inequality in overweight prevalence between the highest and lowest wealth groups in each country using the regression-based Slope Index of Inequality (SII). Using wealth quintiles as SES categories enabled the interpretation of the change in SII between the first and last survey years dually as the disproportionate increase in overweight prevalence by higher or lower wealth populations. Meta-regression was employed to examine the associations between economic development and disproportionate increases in overweight prevalence by SES, as well as whether these associations varied by country-level income inequality. We hypothesized that economic development and change in economic development would be positively associated disproportionate overweight increases among the low SES populations.

3) Finally, we aimed to examine how BMI trajectories and risk of overweight become different according to SES over time in the context of one rapidly developing country, China. We hypothesized that in 1989 high SES women would have overweight risk higher or equivalent to lower SES women, but that by 2006, high SES women will have a significantly lower overweight risk.

China was one of five countries for which our cross-country comparison of age-standardized overweight prevalence revealed a reversal in the relationship between SES and overweight from direct to inverse during the study time period. We sought to investigate whether this finding was robust to longitudinally collected data from the China Health and Nutrition Survey. We use random-effects linear and logistic models to track BMI and overweight over time. We hypothesized that a social disparity in the relative odds of overweight would have emerged among women since the late 80s in China and we used this as a case study to examine “the social shaping of disease” during rapidly changing conditions.

III. LITERATURE REVIEW

Obesity risk varies by socioeconomic status (SES) in countries around the globe. However, the specific social patterning of obesity risk by SES appears to differ by country-level economic development. Historically, it has been noted that, in lower income countries, populations with lower SES have a lower risk of obesity, while in higher income countries populations with lower SES often have the highest risk of obesity. Recent evidence suggests that even in some low- and middle-income countries, women with low SES now have higher risk of obesity than women with high SES in these countries [1]. Due to lack of country-level longitudinal analyses, it is unclear whether the burden of obesity actually shifts to the lowest SES groups as countries experience increases in economic development, or whether the documented country- level GDP differences are only seen in single time point, cross-sectional, between-country comparisons. We seek to explore whether, and under what conditions, the overweight disease burden disproportionately shifts away from high SES groups and toward lower SES groups within lower- and middle-income countries. We then use longitudinal data from China to track differences in BMI and overweight trajectories according to SES in order to investigate the "social shaping" of overweight among adults during a time of rapid economic development.

The majority of the literature on SES and health is based on cross-sectional work in highly developed countries. From this work, in the fields of public health and epidemiology, multiple theories have been established to explain the sociology and biology behind the persistent relationship between SES and health. Some of these theories include the social gradient, the weathering hypothesis, John Henryism, ecosocial theory and the fundamental cause theory. Specifically related to socioeconomic status and obesity, a less well established "economic hypothesis" has been proposed by Drewnowski, based on ecological observations.[2]

Fundamental cause theory provides theoretical grounding for the hypotheses posed in this proposal. We begin with an overview of fundamental cause theory; then we explore how fundamental cause theory may be a useful framework for examining the relationship between SES and overweight in developing nations over a relatively short contemporary time period. Next, we provide additional background and rationale for testing Aim 1, and subsequently for Aim 2.

A. Socioeconomic Status and Health: A Fundamental Cause Perspective

Low socioeconomic status is associated with increased risk for many leading causes of morbidity and mortality [3-6]. The increased risk for disease among the poor is not a new phenomenon, but rather one that has persisted at least since early enumerations of cause-specific deaths in 1830 by Villerme [7]. Even as countries around the world have undergone epidemiologic transitions, during which the predominant disease burden has shifted from infectious to chronic disease, the largest disease burden continues to fall on those with the lowest socioeconomic position [7].

Multiple theories have been put forward to explain the underlying relationship between low SES and increased risk for morbidity and mortality. One such theory is the fundamental cause theory, which emphasizes the persistence of the association between low socioeconomic status and higher risk for disease throughout time and place [8]. Fundamental cause theory (FCT) distinguishes between distal and proximate causes of disease and asserts that the predominant diseases and their proximate causes have changed, but low socioeconomic status remains a more distal and fundamental cause of disproportionate disease burden [8, 9]. For example, during industrialization in Western societies the nineteenth century, cholera and tuberculosis were the leading causes of death [7]. The initiation and spread of these infectious diseases was linked to unsanitary waste disposal and densely populated living areas. These conditions were more prevalent characteristics of the living conditions of groups with low socioeconomic status, and thus, resulted in higher mortality from the prevailing diseases among the poor [7]. Today, cardiovascular disease is the leading cause of death, and, to a large degree, is attributable to lifestyle factors, such as diet and exercise. Having low socioeconomic status is associated with lack of access to early preventative health care, lack of health knowledge, lack of money to spend on healthful food or exercise facilities, and decreased acceptable outdoor space for exercise, all of which influence healthfulness of lifestyle and prevention of chronic disease [7]. Cardiovascular mortality rates are higher in groups with low SES compared to those with high SES [10]. This example illustrates that although, over time, the predominant disease have changed from infectious to chronic, and their proximate causes from sanitation to lifestyle, low SES continues to be the predisposing distal factor for increased exposure to disease-promoting proximate causes.

Furthermore, FCT asserts that "health enhancing knowledge and technology come to have effects on population health through a thick distribution of social, political and economic circumstances" and that as diseases become more under human control, the disparities in disease outcomes will actually widen because the "uneven distribution of new knowledge and technology results in a powerful social shaping of health disparities" [11 (p 374 & 370)]. SES acts as a distal cause that shapes the level of exposure to health-promoting or health-harming proximate risk factors.

In addition to powerfully shaping exposure to risk factors, FCT suggests that the broad mechanisms by which SES becomes inversely related to the predominant diseases of the day is that groups with the highest socio-economic status command flexible resources, such as knowledge, money, and power that enable them to respond to changing disease risk and stigma, whereas groups that lack such resources cannot make the same types of adjustments with the same ease. Resultantly, these lower SES populations come to experience higher rates of the predominant diseases [6]. This purposeful process has been called a "social shaping of disease", and refers to the changes that higher SES populations make to preserve health or avoid stigma around health behaviors or certain disease states, once medical knowledge, technology or stigma changes [11].

B. Empirical Tests of Fundamental Cause Theory

Phelan and co-authors test the hypothesis that flexible resources play a key role in disease disparities, by examining the socioeconomic disparities in diseases classified as preventable and nonpreventable [6]. The logic behind this empirical test is that, if little is known about the prevention or treatment of a disease, then flexible resources should not alter the incidence of or mortality from such a disease. Using data from the National Longitudinal Mortality Study, Phelan and colleagues found evidence in support of their hypotheses—the relationship between socioeconomic status and mortality was of greater magnitude in the preventable causes of death compared to the generally nonpreventable. These findings were consistent across racial/ethnic groups and gender [6].

Related to the central role of differential access to the flexible resources, Phelan and colleagues argue that the use of these resources to promote health is purposeful, and thus, is responsive to changes in knowledge and stigma attached to certain behaviors[6]. It is also through these processes that disease becomes socially shaped [11]. This part of the theory is best tested in the context of new disease treatments, changes in disease burden or changes in stigma associated with a disease or behavior. Chang and Lauderdale used the introduction of cholesterol-lowering statins as a powerful treatment for hypercholesterolemia to test whether individuals with high SES disproportionately utilize new medical technology and found a drastic reversal in mean cholesterol levels by SES over time was associated with the timing of the market-release of statin drugs. Miech et al test whether the relative proportions of cocaine and marijuana users according to SES changed as public opinion of cocaine and marijuana changed from accepted (in the 1970s and 80s) to stigmatized and unhealthy (in the 1990s) following a prominent anti-drug health campaign [12]. Higher SES groups had higher rates of cessation of drug use and lower rates of initiation in comparison to lower SES groups coinciding with the anti-drug campaign [12]. Link documented the social shaping of cigarette smoking in the US, using National Opinion Polls and time-series prevalence of smoking. As national opinion became unfavorable toward smoking, the prevalence of smoking decreased in the high SES segments, creating a disparity in smoking prevalence whereby low SES groups had significantly higher prevalence than high SES groups [11].

C. Socioeconomic Status and Overweight from a Fundamental Cause Perspective

Recent shifts in the burden of overweight and obesity among social class groups around the world may be a case of fundamental cause “in action”, in which groups with the highest SES begin to experience decreased risk of the prevailing disease in comparison to those with lower SES. Overweight and obesity were once considered diseases of affluence, limited to people in high-income countries or to only people of highest SES in lower- and middle-income countries[13]. In 1989, a review of existing studies from 130 countries with varying levels of development, using data collected between the years 1933 and 1988, found this to be the case, with the most consistent findings among women[13]. The primary conclusions were that among low income countries, higher SES women had higher prevalence of obesity, but among high income countries, higher SES women had lower prevalence of obesity, compared to the lowest SES women[13]. However, this relationship was reexamined in 2004 using contemporary data from 37 low- and middle-income countries, and a different dynamic was noted. Even in some lower- and middle-income countries, the higher SES groups had lower prevalence of obesity compared to the lowest SES groups [1]. Contemporaneously, it was reported that for many countries around the world, even lower income countries, the disease burden of overweight had surpassed the disease burden of underweight [14].

The shifts in the prevalence and social patterning of obesity may reflect the changing social and environmental context for both high and low SES groups and differences in response to these changing contexts. Those in the highest social positions to may adjust based on new health risks and medical knowledge or stigma to lower their risk of disease, while the changes in context may have different meaning and manifestation for those in lower SES groups and these groups may lack the flexible resources to adjust in a health-preserving way to the new contexts.

Changes in the social patterning of overweight in developing countries is particularly interesting since energy-dense processed foods and sedentary occupations are still most accessible to the higher SES segments of the population in most of these contexts [15]. Whereas the price of healthy food and the accessibility of leisure time activity seem to provide a ready explanation for why low SES populations in high income countries have a higher prevalence of overweight [2], these same explanations do not yet hold much weight in most developing countries. If the rates of overweight prevalence increase are faster in low SES populations compared to high, this gives some suggestion of a purposeful process on the part of the higher SES populations to avoid overweight in the face of a changing environment. Documenting changes in the social distribution of overweight in transitional countries can begin to test if a “social shaping” of overweight is underway in these contexts.

Within countries at varying levels of GDP, the SES-obesity relationship could be rapidly changing. In comparison to many other chronic diseases, weight gain and obesity can develop over a relatively short period of time. This quality positions these disease states as good candidate outcomes to examine how different social groups respond to a changing disease burden, over a short, contemporary time period of 5-20 years. If high SES groups adjust their response to changing environments and disease burdens, we’d expect that as countries experience later stages of epidemiologic, demographic and nutrition transitions, the prevalence gains will be experienced disproportionately in the lower SES groups and the higher SES groups will experience smaller gains.

A few recent studies have used repeated cross-sectional studies to begin to investigate the SES-obesity trends in a single country. Repeated cross-sectional data from Brazil indicates that between the 1970s and early 2000s, obesity continued to increase among women in the lower social class groups; however, women in the highest social positions, who once had the highest prevalence of obesity, did not experience any increase in obesity prevalence [16]. As a result, now, among Brazilian women, those in low socioeconomic positions now have the highest prevalence of obesity in some regions and have an equivalent prevalence in others [16, 17]. The abatement of obesity prevalence in the highest socioeconomic status groups coincided with a national health education campaign targeted at preventing obesity [16]. From a fundamental cause perspective, even though this campaign may not have been targeted only at higher socioeconomic groups, perhaps these groups were most able to respond to the new information about changing health risks.

A study of adolescents in the US produced results similar to those of Brazil. Miech and collegues [18] use repeated cross-sectional data from National Examination of Health and Nutrition

Survey (NHANES) in the US between 1971 and 2001 to examine trends in the SES-obesity relationship among US adolescents [18]. They found that, although obesity prevalence increased for almost all racial/ethnic, income and age groups, for older adolescents, the prevalence increased significantly more in the poorest groups [18]. A similar study of US adults also found that in non-Hispanic White women and men, the highest SES groups had the smallest increase in obesity prevalence over time [19].

D. Does Country-level economic development affect how SES is related to overweight?

The two seminal, multinational studies which examined the direction of the relationship between SES and obesity in countries of high and low GDP [1, 13], have done so considering only one point in time. Therefore, it is uncertain whether, within a given country, the SES-obesity risk relationship changes in response to a change in GDP over time, or whether this association is only seen in comparisons between countries. It is also uncertain whether higher GDP countries more often have faster overweight prevalences among the lower SES populations over time.

Increasing national economic productivity and wealth could plausibly be a driving mechanism behind the changing association between SES and obesity. It has previously been hypothesized that low country-level GDP results in an environment of food scarcity and, historically, less ability to import goods and ideas.[13, 20] In this type of environment, people with high socioeconomic status will have greater resources and ability to procure adequate food, and to meet and exceed, caloric needs with their dietary intake. It has also been hypothesized that in many food scarce societies, larger body sizes are desirable, so those who are in the position to become overweight by eating more than their caloric needs, may be satisfied with their larger body size and its meaning[13]. On the other hand, people in low socioeconomic position may not be able to procure adequate food to exceed their daily energy needs, and therefore, less often become overweight. Additionally, in low GDP countries, a larger proportion of the low socioeconomic groups are likely to expend a greater amount energy in their daily work, compared to low SES groups in countries with higher GDP, and compared to their higher income countrymates. As lower GDP countries increase their GDP, food likely becomes relatively cheaper and more abundant for all populations, thus increasing the likelihood of exceeding one's energy needs in all income groups and increasing the overall prevalence of obesity. Increased options for work may draw low SES individuals away from farming and into the formal labor market, which may result in a greater decrease in energy expenditure for this group only.

Further, since the findings of an inverse relationship between SES and obesity risk in higher GDP countries are most consistent for women and not for men, it has been hypothesized that ideal body size is an influential factor in realized body size, and that this is more influential for women then for men [13, 20-22]. Extending this rationale, it is possible that, either ideas about desirable body shapes/sizes change for only higher income individuals, due to greater access to media influences. Alternatively, change in the ideal body shapes could be pervasive for all groups, but only the highest SES groups have the resources to attempt to achieve the thinner body habitus in the new environments.

According to fundamental cause theory, the population-level, differential disease burden associated with low and high SES groups changes as 1) total disease prevalence changes 2) medical and common knowledge about the disease state changes, and/or 3) social perception of the disease or its associated behaviors changes. We might then expect that low SES begins to impart a higher risk for obesity/overweight only after the total prevalence of obesity/overweight has increased to a substantial degree. Increasing GDP is highly correlated with improvements in medical technologies/information, so the pool of knowledge about overweight and obesity—its prevention, treatment and consequences—is likely concurrently increasing as prevalence increases.[23]

If the preceding logic regarding how changes in GDP might drive changes in the SES-obesity risk relationship were indeed true, it would stand to reason that more egalitarian societies would see less of a change in obesity risk imparted by low SES with the transition to higher GDP levels. In other words, under this scenario, income inequality might be an important moderator of the effect of increasing GDP. At the contextual level, low societal income inequality has been associated with greater investment in human capital, higher social cohesion and lower levels of relative deprivation.[24] Perhaps due to factors such as greater investment in human capital and greater societal commitment to provision of public goods, having *low SES* in a country with *low levels of income inequality* might be associated with a lower differential in obesity/overweight by SES group initially, as well as less change in the differential as GDP increase. SES groups may experience less disparate access to media influences and healthcare, and to resources to respond to changing health risks as GDP increases in low income inequality contexts. Having *low SES* in a developing country with *high income inequality* is likely associated with a greater risk for undernutrition when the country has low GDP which would likely result in a higher risk for obesity among the high SES groups and a larger differential in obesity risk, initially. In such a country, if GDP were to increase substantially, basic provisions and changes in livelihood options would likely lead to decreases in the amount of undernutrition and increases in overweight/obesity, particularly among low SES groups. At the same time in this setting, as food access is increased among the low SES groups, high SES groups may experience greater access to health technologies and information [23], which could change the social perception of obesity/overweight and the knowledge pool about causes and prevention of this disease. Perhaps this results in obesity/overweight becoming socially undesirable and, ultimately, in an abatement of prevalence gains in the higher SES groups.

However, it must be noted that much of the theory and testing of income inequality, social environments and health effects has been predominantly focused on high-income countries. Whether income inequality works in similar ways in lower-income countries is less certain. In middle-income countries, it is conceivable that lower levels of income inequality give lower income individuals better access to newly obesogenic environmental features [15].

We examine whether countries with higher GDP with be most likely to exhibit faster overweight prevalence increases among the lower SES groups in comparison to higher SES groups. We also explore whether as countries experience change in their economic wealth (as indicated by GDP), the risk relationship between SES and obesity changes. Just as a “threshold” of GDP was noted in the cross-sectional studies, we hypothesize that, due to the concurrent risk of underweight in the extremely poor groups in poor nations, these changes in relationship between SES and obesity emerge only after a certain threshold of economic development has been surpassed. We also hypothesize that globalization and urbanization processes may be actively lowering the “threshold” at which exceeding caloric needs is easily achievable for all groups. We also test whether nations with more egalitarian distribution of income and resources, have smaller disparities in overweight prevalence by SES.

Our multinational comparisons will have the unique ability to provide clues about the role of changing nation wealth, the pervasiveness of obesity health disparities by social class in countries around the world, and about the conditions in which these disparities are most prevalent (for example, income inequality). Tracking changes in the social patterning of obesity using this multicountry, repeated cross-sectional design enables exploration into how changes in economic and social contexts affect the obesity risk conferred by social class.

E. The Social Shaping of Overweight during a period of rapid development in China

A comparative study between China and the U.S. using data from 1993 found that, in China, those with the highest SES reported the most unhealthy lifestyle patterns, while the opposite was true for the US [25]. However, there are more recent indications that the chronic disease burden is shifting toward the poor in China [26-28]. And, in fact, it has been reported that socioeconomic status (represented by education) is inversely related to poor health, suggesting a gradient as seen higher income countries [29].

These previous studies in China suggest that the relationship between SES and overweight is might be changing over time. Theory suggests that social disparities may emerge where none previously existed because higher SES populations more readily adjust their preferences, choices and behaviors based on new stigma, new medical knowledge and treatments [11], while lower SES populations face more constraints in making the same health-preserving adjustments [7, 8]. This process of emerging and widening disparities under such conditions has been referred to as a “social shaping of disease” [11] that can best be investigated under conditions of large changes in disease burden, new diseases, new treatments for diseases or new stigma associated with disease [11].

We use China as a case study to investigate the “social shaping of disease” (in this case, overweight) in a rapidly developing country [11]. The dramatic increase in overweight prevalence in China over the past 20 years provides an excellent opportunity to investigate how the burden of overweight by social class may have changed over time [30]. China has experienced extremely rapid increases in economic development and national wealth over the last 20 years [31]. With this economic growth and market restructuring have come major changes in food and physical activity environments and norms [26, 32, 33]. Economic development has been associated with improved medical knowledge and technologies as well as exposure to Western media, which is believed to influence desired body size, especially among women [21].

We hypothesize that a social disparity in the relative odds of overweight has emerged since the late 80s in China. Since an inverse relationship between SES and overweight seems to be particularly robust among women in developed countries around the world [13], we anticipate higher BMIs and overweight in women of high SES in the that in the late 80s and early 90s, high SES women will have higher or equal mean body mass index (BMI) and odds of overweight, transitioning to higher mean BMI and higher odds of overweight in low SES women by 2006. Furthermore, we hypothesize continual gains in BMI among individuals of low SES, and reduced gains or a leveling-off of gains over time among individuals of high SES. We further hypothesize sex differences with higher or equivalent gains in BMI and overweight risk for high SES men compared to lower SES men.

F. SUMMARY

This research intends to investigate changes in the relationship between individual socioeconomic status and obesity risk in countries of varying levels of economic development in order to test whether the burden of overweight increasing disproportionately among low SES populations across the developing world. The use of multinational comparisons allow us to examine the between and within-country changes and investigate the role of macro-level processes on the shifting burden of disease by social class. We will determine whether disproportionate overweight prevalence gains among the low SES populations are associated with country-level GDP and whether this association varies by country-level income inequality. Finally, our use of longitudinal individual-level data from China, during a period of rapid development, enables a deeper examination of how socioeconomic status is related to BMI trajectories and obesity risk, and how these relationships become socially shaped over time.

IV. METHODS

A. Data Source and Study Population for Specific Aims 1 & 2

We identified 41 countries for which data are publically available, which contained the key variables of interest, and in which there were repeated measurements over time (≥2 surveys). Data for these analyses come from several sources. The majority of the data (39 out of 41 countries) are from Demographic and Health Surveys (DHS), which use a multistage cluster sample design to obtain a nationally representative household sample, and are administered primarily in lower- and middle-income countries. The surveys involve repeated cross-sections, are performed approximately every five years, and collect information about key demographic characteristics, fertility, contraception, health and nutrition. The DHS questionnaires contain a standardized core questionnaire, to enable cross-country comparisons, while still being tailored for each country in other subsections [34]. Additionally, we used data from the Indonesian Family Life Survey (IFLS) and the China Health and Nutrition Survey (CHNS). These surveys each use a multistage cluster sample, and are they are representative of a large portion of the countries in which they are conducted. IFLS is representative of half of the provinces in Indonesia, while CHNS is representative of 9 provinces (out of 22 provinces total) in China.

For nearly all of our sample countries, anthropometric measurements are available only for women, so the analyses were limited to women. Since we are interested in weight trajectories, we exclude women who were pregnant during the survey measurement, due to the fluctuation in weight associated with pregnancy. We also restrict the sample to adults between the ages of 18-50, since the DHS surveys only include anthropometric for women under age 50. Finally, most of the DHS surveys have repeated anthropometric measurements for women who have children under age 5. To maintain sample comparability over time, we restrict our main analyses for these countries to this subset of women.

B. MEASUREMENT OF KEY VARIABLES FOR SPECIFIC AIMS 1 & 2

ANTHROPOMETRY

In all surveys, height and weight were measured by trained technicians using standard techniques [35, 36]. We used Body Mass Index (BMI) (kg/m^2) to classify people as overweight (BMI≥25) according to WHO guidelines [37]. Although lower BMI cutpoints have been established as "action points" for disease risk in Asian populations, it is still recommended to use the standard cutpoints to enable international comparisons of overweight and obesity prevalence [38]; therefore we use the cutpoint BMI≥25 for main analyses. We focused our analyses on overweight rather than obesity because obesity prevalence was extremely low in many of our sample countries and since overweight has been associated with increased cardiometabolic disease risk [39].

AGE

Age was collected for each individual in all surveys and controlled for by direct standardization using the WHO standard world population [39, 40] to allow greater comparability between countries and within countries over time. Direct standardization is recommended for cross-country comparisons due to widely varying population age structures across countries. To obtain age-standardized overweight prevalence rates, we applied the each country's age-specific obesity rates to a standard population structure [40].

SOCIOECONOMIC INDICATORS

Individual socioeconomic status was represented by wealth and education, in separate analyses, in order to explore the robustness of the results to different indicators of SES.

Wealth. Wealth indicators were queried in all of the surveys. A wealth index has been created for the countries that implement the DHS survey [41]. This index is comprised of assets that were asked in all surveys, as well as some country-specific variables. Principal components analysis was used to weight each of the components and generate a total wealth score for each family in each country in each survey wave [41]. The Indonesian Family Life Survey and the China Health and Nutrition Survey also collected information regarding household assets and these were entered into country-specific and year-specific principal components analysis to create a wealth index comparable to the DHS index for each of these countries in each survey wave. For the analyses, the country and survey-year specific quintiles of wealth score were used to create a categorical variable for wealth.

Edcuation. All the surveys contain information about the participant's highest level of educational attainment. Education was categorized based on the educational milestones: no formal schooling, primary school, secondary school, tertiary school when appropriate. If less than 2% of the population attended tertiary school in any of the survey waves for each country, the tertiary category was combined with the secondary category to avoid unstable estimates. Secondary education was then treated as the highest education group in these countries.

SES-Specific Overweight Prevalence Increases

For each country and each survey year (referred to henceforth as country-year), we subtract the overweight prevalence in the highest wealth quintile from that in the lowest wealth quintile to find the prevalence difference. To calculate the net overweight prevalence growth rate for each wealth quintile, we subtracted the prevalence in the earliest country-year from the prevalence in the most recent country-year. To determine whether this wealth-specific prevalence growth rate was higher in the lowest quintile compared to the highest, we subtracted the net prevalence growth in the highest wealth quintile from that of the lowest. A positive difference in prevalence growth rates indicated that the lowest wealth quintile had a higher rate of prevalence growth rate than did the highest wealth quintile. We repeated these analyses for each country by education group, with the lowest education groups being those with no formal schooling and the highest education group being those with a tertiary school education, except in countries in which too few people obtained tertiary education, in which case the highest education group is secondary school.

We use absolute differences in prevalence by SES group, absolute change in prevalence over time within each SES group, and absolute difference in prevalence growth rates between SES groups. We chose absolute measures rather than relative because each one-point increase in the percent of the population with overweight is meaningful and interpretable. Additionally, there were a number of countries with a very low prevalence in the lowest SES group and a fairly high prevalence in the highest SES group; this combination means that fairly small absolute increases the low prevalence groups equate to large relative increases that could not be matched in the high prevalence groups except by tremendous absolute increases. Take, for example, Chad: the lowest education group has a prevalence of ~4% in 1996 and ~7.5% in 2004, for an absolute change of 3.5 points and a relative change of 87%. The highest education group has a prevalence of ~35% in 1996 and to experience a similar relative change of 87%, they would have to increase absolute prevalence by 30 points by 2006. We therefore felt that the more reasonable and meaningful comparisons would be in the difference in the absolute increase in prevalence in each group.

SLOPE INDEX OF INEQUALITY (SII)

To summarize the level of inequality in overweight prevalence by SES group, we estimated the SII. The SII is a recommended measure for quantifying the absolute level of inequality in a health outcome when within country time trends and cross-country comparisons are of interest [23]. The SII accounts for the mean level of health by socioeconomic group as well as the proportion of the population in each group [23]. It is a regression-based measure that is obtained by regressing the mean health status of each SES group on the fractional rank of each SES group (ridit score), ranked highest to lowest; it assumes a linear relationship between SES group and the health outcome.

In our case, we regressed the age-standardized overweight prevalence for each wealth group on the fractional rank of each wealth group:

$$(\text{Age-standardized overweight prevalence} \mid \text{country, year})_j = \alpha + \beta_1(\text{SES group ridit score})_j + \varepsilon,$$

where j denotes wealth group. Every individual in the same wealth group is assigned the same ridit score and age-standardized overweight prevalence so that the regression is self-weighted by the number of individuals in each SES group [42]. The resulting regression coefficient β_1 is the SII and represents the difference in overweight prevalence moving from the highest (0) to the lowest (1) group. The SII was calculated for each country in each survey year.

CHANGE IN SLOPE INDEX OF INEQUALITY

We estimated the change in the SII between the first and the last survey year for each country with the following model:

$$\text{(Age-standardized overweight prevalence| country)}_{jt} = \alpha + \beta_1(\text{ridit score}_{jt}) + \beta_2(\text{middle survey year}_t) + \beta_3(\text{last survey year}_t) + \beta_4((\text{ridit score}_{jt})*(\text{middle survey year}_t)) + \beta_5((\text{ridit score}_{jt})*(\text{last survey year}_t)) + \varepsilon.$$

In this model, j denotes wealth group, t denotes the year in which the cross-sectional survey was performed, and survey year is represented with indicator variables. The coefficient on the ridit score (β_1) gives SII in the first survey year. The change in the SII between the first and last survey years is represented in the interaction between ridit score and last survey year, coefficient β_5. The change in the SII is the change in the magnitude of inequality in overweight levels. It also is indicative of the differential rate of increase in overweight prevalence between the high and low wealth groups, since it is calculated within countries and, by using wealth quintiles, we've constrained the amount of change that could be due to change in proportion in each wealth group.

COUNTRY-LEVEL ECONOMIC DEVELOPMENT

We use gross domestic product (GDP) per capita adjusted for purchasing power parity (PPP) and inflated to the 2005 international dollar value (referred to henceforth as GDP for short) to represent country-level economic development. Purchasing power parity is a method for adjusting GDP to reflect the difference in relative prices of goods and services across countries [43]. This value was obtained for all years between the first and last survey wave for each country from the World Bank World Indicators Database [44].

Change in Economic Development. To capture the level of change in economic development over the survey period we calculated the average annual percent change in GDP per capita (PPP).

COUNTRY-LEVEL INCOME INEQUALITY

We used the Gini coefficient to represent country-level income inequality, which is a commonly used indicator [45]; it assesses the proportion of the income shared by the proportion of the population [46]. The Gini coefficient ranges from 0 to 1, where 0 would mean that everyone in the population had the same income and 1 means that 1 person has 100% of the income. We used the average Gini coefficient across the survey period for each country, obtained from the World Bank Indicators Database [31]

C. DATA SOURCE AND STUDY POPULATION FOR SPECIFIC AIMS 3

For Aim 3, data were from the China Health and Nutrition Survey (CHNS) which began data collection in 1989 and has been implemented every 2 to 3 years since, resulting in 7 observational periods and the most recently available data coming at 2006. The CHNS uses a multistage cluster sample design to survey individuals within nine provinces in China. To obtain the sample from these nine provinces, the counties inside the provinces were stratified by income then a weighted sample of four cities or counties was selected. Within these areas, neighborhoods were randomly selected and within the neighborhoods, households were selected randomly from a community household roster and all members in each household were interviewed. The household roster was used to follow up each of the originally sampled households as well as new households formed from previous households for subsequent survey panels. The baseline sample was representative of each province but over time, loss-to-follow up has occurred [48]. The study protocols have been approved by the University of North Carolina at Chapel Hill and the Chinese Center for Disease Control Internal Review Boards.

The CHNS includes individual, household, and community level surveys conducted by trained field workers; the current analysis utilizes information from each of these surveys.

Our analyses are limited to non-pregnant women and men who were surveyed at least one time and were younger than 50 years at their first included measurement and older than 18 years during at least one of the survey waves (measurements from age 18 and above are included for individuals who aged into our eligible sample).

D. Measurement of Key Variables for specific Aim 3

In addition to anthropometry and education described above for Specific Aims 1 & 2, Specific Aim 3 utilized the following measures:

Calendar Time

We include calendar year to represent time and interact it with education group in the regression models to assess the education group-specific growth in BMI/overweight risk over time. Calendar time is recoded from 0 (1989) to 17 (2006) and is used as an ordinal variable.

Birth Cohort

Due to the fact that China has undergone major upheavals and social change during distinct historical periods, such as the Great Leap Forward and Famine in the 1950s, the Cultural Revolution in from the mid-1960s to 1970s and then the post-Maoist reforms from the late 1970s onward [49] we hypothesize that growing up in different eras may modify the SES-overweight relation and its change over time. Birth cohort was categorized into 2 levels to keep adequate sample size yet distinguish between populations growing up during different periods in China. The sample was divided between participants born between 1939-1959 (inclusive) and those born in 1960 or later.

Urbanicity

Urbanicity has been an important dimension along which health outcomes have varied in the developing world and in China in particular [30, 50-54], so we hypothesize that the SES-overweight relation and its change over time might also vary by level of urbancity. If the relationship of interest did not vary by urbanicity, we consider it a confounder since it is likely associated with education attainment and BMI levels.

We use our own urbanicity scale, which we have assessed for validity and reliability, to indicate community-level urbanicity represented by infrastructure, sanitation, transportation, social services, occupations and wages, commercial markets and communications [51]. Each community receives a time-varying urbanicity value ranging potentially from 0-130 points, which is used in its continuous form in the analyses.

SMOKING

Current smoking habits were ascertained in each survey except the first survey in 1989. Since smoking is quite rare among women in this context and since its inclusion results in the loss of observations from 1989, we include smoking as a covariate in the male analyses only.

V. IS THE BURDEN OF OBESITY SHIFTING TO THE POOR ACROSS THE GLOBE? TIME TRENDS AMONG WOMEN IN 41 LOWER- AND MIDDLE INCOME COUNTRIES (1992-2007)

A. ABSTRACT

Objective: Assess trends in the prevalence difference of overweight by socioeconomic status (SES) group and test if the overweight prevalence growth rate over time is higher for the lowest SES group compared to the highest SES group. Further, assess whether higher national wealth is associated with a higher growth rate in overweight prevalence for the lowest SES group compared to the highest SES group.

Methods: Repeated cross-sectional, nationally representative data from women aged 18-49 (n=556,352) in 41 low- and middle-income countries were used to determine the prevalence of overweight (body mass index ≥25) at each survey wave by wealth quintile and educational attainment (separately). The SES-specific prevalence difference and prevalence growth rate over time for each country were compared for the lowest and highest SES groups.

Results: In the majority of country-years the highest wealth and education groups still have the highest age-standardized prevalence of overweight and obesity (97 out of 111 total country-years). However, in approximately half of the countries (21 out of 41), the increases in prevalence over time have been greater in the lowest SES group compared to the highest SES group. Higher country-level Gross Domestic Product per capita (GDP) is associated with a higher overweight prevalence growth rate for the lowest wealth group compared to the highest ($\beta_{GDPper\ capita/1000}$= 0.24; 95% CI -0.015, 0.46).

Conclusions: Currently, higher SES groups have more overweight than lower SES groups across most countries. Nevertheless, half the countries show a faster growth rates in overweight in the

lowest SES groups, indicative of an ongoing shift in the burden toward lower SES groups. Across countries, this shift toward faster overweight growth among lower wealth groups is associated with higher GDP.

B. BACKGROUND

Low socioeconomic status (SES) is associated with higher rates of chronic disease in high-income countries [3-6]. In low- and middle-income countries, chronic disease has only recently become a leading cause of morbidity and mortality [55], and less is known about the social patterning of emerging chronic diseases in these contexts. In the past, overweight and obesity were relatively uncommon in low- and middle-income countries and were positively associated with socioeconomic status [13]. However, the prevalence of overweight and obesity has increased dramatically in many low- and middle-income countries around the world over the last 5-15 years [56-58]. As the burden of nutrition-related disease has shifted toward overnutrition and away from undernutrition in low- and middle-income countries [14], it is unknown whether the burden of these emerging disease is becoming relatively heavier among lower SES groups.

Only under conditions of faster overweight prevalence growth rates for the low SES groups, could the relationship between high SES and obesity eventually become inverse in countries with previously positive relationships. Such a shift of the burden of obesity to low SES groups in countries progressing through epidemiologic transitions would be consistent with the fundamental cause theory of disease [8, 9]. This theory is often invoked to explain health disparities and highlights the overall persistance of the relationship between socioeconomic status and poor health over time [6, 7, 12, 59]. Fundamental cause theory asserts that despite changes in the types of predominant diseases, low SES groups consistently bear the largest burden of disease across time. Under this theory the mechanism by which high SES populations avert disease is by using the flexible resources that accompany higher SES (e.g. wealth, knowledge, power) to fend off disease while lower SES groups lack the resources to adjust to the changing burden of disease and ultimately experience higher rates of the predominant diseases [9].

A recent cross-national comparison found evidence that low SES groups were bearing a larger burden of obesity than high SES groups even in some middle income countries [1, 60], however this study looked only at one point in time and conclusions about whether the social patterning of overweight or obesity is changing within countries over time cannot be drawn. To determine whether overweight prevlanece is growing at a faster rate among the lowest SES groups, data from multiple time points are needed. Brazil is one of the few middle-income countries in which the changes over time in the SES-specific overweight prevalence have been reported. Analyses using repeated cross-sectional nationally-representative data between 1975 and 2003 show that, among women, the lowest income groups have experienced much more rapid gains in obesity prevalence compared to highest SES groups [16]. Another study using only the two most populous regions in Brazil between 1975 and 1997 found the obesity prevalence for the lowest income group has actually surpassed that the highest income group [17]. The pattern of change in SES-specific obesity rates seen in Brazil is consistent with a shifting burden of obesity to the poor and with the fundamental cause theory. However, it is unclear whether this pattern of more rapid growth in overweight prevalence among lower SES groups is unique to one country or if this is a common phenomenon experienced by many lower- and middle-income countries.

Additionally, recent studies in developing countries have focused only on obesity and have ignored the risk of overweight. Our study investigates overweight prevalence (body mass index (BMI)≥25) since metabolic risk factors, such as high blood pressure, cholesterol, and blood glucose occur below the BMI obesity cutpoint (BMI≥30) [39, 61-63]. Additionally, obesity is still fairly uncommon in many lower-income countries, and stratification by SES results in very small and sometimes zero prevalences.

Furthermore, although the results from the above mentioned cross-national study found an association between country-level GDP and the odds of having an inverse relationship between obesity and SES, it is uncertain what role country-level economic development plays in any shift in the burden of obesity from high SES to low SES groups, since previous research captures only a single point in time and lacks the ability to determine whether the burden of obesity is truly undergoing dynamic changes between social classes in association with economic development.

Our study uses repeated cross-sectional, nationally representative data on adult women from 41 lower- and middle-income countries to 1) determine the prevalence difference in overweight between social class group in each survey year, 2) test whether the net change in overweight prevalence over time is higher for those in the lowest socioeconomic status group compared to the highest socioeconomic status group. Two indicators of socioeconomic status, wealth and education, will be tested separately to see if results are robust to the indicator for socioeconomic status. 3) Finally, we will test whether higher national wealth is associated with a higher growth rate in overweight prevalence for the lowest SES group compared to the highest SES group.

C. METHODS

DATA SOURCES

Data for these analyses come from several sources of publicly available datasets that include anthropometric data and at least two repeated measures over time. Each of the data sources uses a multistage cluster sample design and is either nationally representative or representative of a large portion of the country surveyed. The majority of the data are from Demographic and Health Surveys (DHS), nationally representative household surveys administered primarily in lower- and middle-income countries. The surveys entail repeated cross-sections, approximately every five years and collect information about key demographic characteristics, fertility, contraception, health and nutrition. The DHS questionnaires are standardized to a certain degree, to enable cross-country comparisons, while still being tailored for each country [64]. Additionally, we will use data from the Indonesian Family Life Surveys (IFLS), representative of 83% of the Indonesia, and the China Health and Nutrition Survey (CHNS) is conducted in 9 provinces in China, which contain approximately 56% of the Chinese population.

For the majority (39 out of 41) of our sample countries, anthropometric measurements were available in repeated surveys only for women under 50 years old, so our analyses were limited to adult women age 18-50 in all countries. Since earlier years of the DHS survey only collected anthropometrics on women who had children between ages of 0-5 years, we limited our main analyses to this subgroup to keep the repeated cross-sections over time comparable, but we also provide main results for the full sample for comparison. We exclude women who were pregnant during the survey measurement, due to the fluctuation in weight associated with pregnancy. Appendix A displays the included countries and the years in which each was surveyed, sample sizes and selected sample characteristics.

KEY VARIABLES

Anthropometrics. In all surveys, height and weight were measured by trained technicians using standard techniques [35, 36]. Body mass index (kg/m^2) was used to classify people as obese or overweight according to WHO guidelines [37]. The prevalence of overweight or obesity (BMI≥25) according to socioeconomic status was calculated for each country at each survey wave.

Age. Age was collected for each individual in all surveys and controlled for by direct standardization using the WHO standard world population [40] to allow greater comparability between countries and within countries over time.

Socioeconomic Indicators. Individual socioeconomic status was represented by wealth and education, in separate analyses, in order to explore the robustness of the results to different indicators of SES.

Wealth. Wealth indicators were queried in all of the surveys. A wealth index has been created for the countries that implement the DHS survey [41]. This index is comprised of assets that were asked in all surveys, as well as some country-specific variables. Principal components analysis was used to weight each of the components and generate a total wealth score for each family in each country in each survey wave [41]. The Indonesian Family Life Survey and the China Health and Nutrition Survey also collected information regarding household assets and these were entered into country-specific principal components analysis to create a wealth index comparable to the DHS index for each of these countries in each survey wave. For the analyses, the country and survey-year specific quintiles of wealth score were used to create a categorical variable for wealth.

Edcuation. All the surveys contain information about the participant's highest level of educational attainment. Education was categorized based on the educational milestones: no formal schooling, primary school, secondary school, tertiary school when appropriate. If less than 2% of the population attended tertiary school in any of the survey waves for each country, the tertiary category was combined with the secondary category to avoid unstable estimates. Secondary education was then treated as the highest education group in these countries.

Economic Development. We use gross domestic product (GDP) per capita adjusted for purchasing power parity (PPP) and inflated to the 2005 international dollar value (referred to henceforth as GDP for short) to represent country-level economic development. The PPP equalizes the purchasing power of different currencies in their home countries for a given basket of goods. This value was obtained for all years between the first and last survey wave for each country from the World Bank World Indicators Database [44]. The average GDP for the included years for each country is used in the regression analyses in its continuous form. This is divided by 1000 so the interpretation is an increase in $1000 per capita GDP.

STATISTICAL ANALYSES

Age-standardized overweight prevalence was determined for each country by survey year (referred to henceforth as country-year) and SES group. Sample weights to account for complex survey design were used in all analyses. We look separately by: 1) wealth quintile, 2) education group. For each country-year, we subtract the overweight prevalence in the highest wealth quintile from that in the lowest wealth quintile to find the prevalence difference; statistical significance was determined with the Wald test [65]. To calculate the net overweight prevalence growth rate for each wealth quintile, we subtracted the prevalence in the earliest country-year from the prevalence in the most recent country-year. To determine whether this wealth-specific prevalence growth rate was higher in the lowest quintile compared to the highest, we subtracted the net prevalence growth in the highest wealth quintile from that of the lowest. A positive difference in prevalence growth rates indicated that the lowest wealth quintile had a higher rate of prevalence growth rate than did the highest wealth quintile. Statistical significance of this difference is again determined by the Wald test. We repeat these analyses for each country by education group, with the lowest education groups being those with no formal schooling and the highest education group being those with a tertiary school education, except in countries in which too few people obtained tertiary education, in which case the highest education group is secondary school.

We use absolute differences in prevalence by SES group, absolute change in prevalence over time within each SES group, and absolute difference in prevalence growth rates between SES groups. We chose absolute measures rather than relative because each one-point increase in the percent of the population with overweight is meaningful and interpretable. Additionally, there were a number of countries with a very low prevalence in the lowest SES group and a fairly high prevalence in the highest SES group; this combination means that fairly small absolute increases the low prevalence groups equate to large relative increases that could not be matched in the high prevalence groups except by tremendous absolute increases. Take, for example, Chad: the lowest education group has a prevalence of ~4% in 1996 and ~7.5% in 2004, for an absolute change of 3.5 points and a relative change of 87%. The highest education group has a prevalence of ~35% in 1996 and to experience a similar relative change of 87%, they would have to increase absolute prevalence by 30 points by 2006. We therefore felt that the more reasonable and meaningful comparisons would be in the difference in the absolute increase in prevalence in each group.

For sensitivity analyses, we re-ran the analyses on the full sample, including all women with measured weight and height in any survey year to assess whether the difference in prevalence growth rate results would change substantially if we included the full sample instead of conservatively restricting the sample to only mothers of young children to retain sample comparability through time. Additionally, the threshold at which some Asian populations experience increased metabolic risk factors appears to be lower than the BMI 25 cutpoint [38]. For the Asian countries in our sample, we perform the main analyses using BMI ≥25 and then we perform a sensitivity analysis using the suggested BMI ≥23 as a cut-off point for overweight [38].

Finally, a country-level linear regression was used to examine the association between the country-level difference in overweight prevalence growth rate for the lowest versus the highest wealth quintile and country-level GDP per capita and, subsequently, for the lowest versus the highest education group and country-level GDP per capita. The difference in prevalence growth rates for each country were divided by the number of years between the first and last year for an annualized growth rate. GDP per capita/1000 was entered as a continuous variable. A squared term to allow for a curvilinear relationship was tested for significance and excluded from both models due to $p>0.05$.

Alpha was set at 0.05 for all analyses and all tests were 2-sided. All analyses were performed with Stata (Version 11, 2009, Stata Corporation, College Station, TX)

D. RESULTS

SAMPLE CHARACTERISTICS

Analyses included data from 556,352 women with complete data on covariates in 41 countries each with an average of 2.7 surveys per country between 1991 and 2008. There were eight country-years from four countries in which the DHS wealth index was not available. This resulted in eight fewer estimates of prevalence difference by wealth compared to education and four fewer estimates of difference in prevalence growth rates within countries.

WEALTH RESULTS

Table 1 provides the age-standardized overweight prevalence differences between the lowest and highest wealth group for each country-year (N=103) and the annualized difference in prevalence growth rates between highest and lowest wealth group in each country (n=37).

Overweight/obese prevalence difference by wealth. In 92% of the country-years (N=95), the highest wealth group had the highest prevalence of overweight. In the remaining 8% (n=8), the age-standardized prevalence in the lowest wealth quintile was greater than the prevalence in the highest wealth quintile.

Overweight/obese difference in prevalence growth rate by wealth. The overweight prevalence growth rate was greater for the lowest wealth quintile in 27% of the countries (N=10). In the remaining 73% (N=27) of the countries, the prevalence growth rate was greater in the highest wealth quintile.

EDUCATION RESULTS

Table 2 displays the age-standardized overweight prevalence differences between the lowest and highest education group for each country-year (N=111) and the annualized difference in prevalence growth rates between highest and lowest education group in each country (n=41).

Overweight/obese prevalence difference by education. In 90% of the country-years (n=100), the highest education group had a higher overweight prevalence than the lowest education group. In the remaining 10% (n=11), the lowest group had a higher prevalence of overweight compared to the highest education group.

*Overweight/obese difference in prevalence growth rate by education (*Table 2*).* In 49% of the countries (n=20), the overweight prevalence growth rate was higher in the lowest education group compared to the highest education group. In the remaining 21 countries, the prevalence growth rate was higher in the highest education group compared to the lowest education group.

COMPARING WEALTH AND EDUCATION RESULTS

The general conclusions of the country-year prevalence differences by wealth and education are similar, with approximately 90% of the country-years in both analyses showing greater overweight prevalence among the highest SES group.

In both the wealth and education analyses, even though the prevalence difference in overweight still favors the low SES groups in most country-years, when we look at the difference in prevalence growth rates, we see more countries displaying a pattern of faster growth rates among the lowest wealth and education groups (27% and 49%, respectively). Nearly all of the countries that had higher prevalence growth rates among the lowest wealth group also had higher growth rates in the lowest education group, so the difference in numbers come mainly from an additional set of countries in which lowest education group's growth rate surpassed that of the highest education group.

SENSITIVITY ANALYSES

Impact of sample restrictions. Our primary analysis was restricted to women that had children under 5 years old to ensure sample comparability over the years; however, the more recent DHS surveys obtain anthropometrics on all surveyed women. In an additional sensitivity analysis we included all measured women in the recent years and determined the difference in prevalence growth rates by wealth and education on this broader sample. The results from examination of differences in prevalence gains by SES from the full sample are largely similar in direction and significance to those from the restricted sample, particularly for the analyses that use wealth as a proxy for SES (results not shown).

Asian BMI cutpoint. Using the Asian-specific BMI cutpoints [38] for overweight (BMI≥23) for the countries with a primarily Asian population (China, India, Bangladesh, Nepal, Cambodia) produced largely consistent in direction with the results using a cut-off point of BMI≥25 (Table 1).

COUNTRY-LEVEL ECONOMIC DEVELOPMENT

The country-level difference in the annualized prevalence growth for the lowest wealth group compared to the highest is plotted against country level GDP in Figure 1 and the analogous relation for education groups is plotted in Figure 1 Country-level GDP was positively associated with faster annualized prevalence growth of overweight for the lowest wealth quintile compared to the highest quintile (β= 0.24; 95% CI -0.015,0.46; regression line shown in Figure 1), but not for the lowest versus the highest education groups (β= -0.03; 95% CI -0.25, 0.19; regression line shown in Figure 2).

E. DISCUSSION

Chronic disease has emerged as leading cause of morbidity and mortality in low- and middle-income countries, yet the implications of socioeconomic status for chronic disease and any potential changes in these implications over time are understudied. Trends in higher income countries and theories of health inequalities predict that low socioeconomic status will become associated with higher risk of chronic disease even in instances in which it was previously associated with lower risk of these same diseases. To our knowledge, this is the first multiregional study to examine changes in the relationship between socioeconomic status and overweight over time. In the majority of country-years the highest wealth and education groups still have the highest age-standardized prevalence of overweight and obesity. However, consistent with a shifting of disease burden to the lower SES groups within countries, a trend toward faster overweight prevalence growth rates for the lowest SES groups compared to the highest SES groups is apparent in approximately 50% of the countries studied (N=21 out of 41).

Our finding of a positive relationship between SES and overweight is opposite of what is seen in many studies of higher-income countries [66-69], but is consistent with the historical review by Sobal and Stunkard [13], which found a positive SES-overweight relationship in 91% of lower -and middle- income countries. In contrast, Monteiro et al. [1] find a positive relationship between SES and overweight in only76% of the survey waves. Differences between our findings and the findings of Monteiro et al. could be due to real changes over time, different outcomes (BMI≥25 vs. BMI≥30) or the different classification of low and high education groups (milestone groups vs. tertiles). Our study improves upon the previous work by Monteiro by examining the changes over time within and across a large sample of low- and middle-income countries.

Despite the overwhelmingly positive association between SES and overweight, we also find that a shift in the burden of disease is occurring, evidenced by faster prevalence growth rates among the lowest wealth or education group compared to the highest in half of our sample countries. Only a few other studies examine the time trends in overweight or obesity in low- or middle- income countries. As mentioned previously, Brazil also displays faster rate of growth in overweight prevalence among the lowest income group compared to the highest income group [16]. Among sub-Saharan African countries, Ziraba et al. [50] find that the growth in overweight prevalence among the urban low education groups has outpaced that of the urban high education groups and that this trend is more pronounced. Among high-income countries, similar reports of faster growth rates among the lowest education groups are seen in France [70] and among the lowest income groups of non-Hispanic white women in the US [19]. However, a faster rate of growth in overweight prevalence among the lowest SES group compared to the highest SES group was not seen when US white women are grouped by education [71]. Our findings are consistent with these reports, but since our results cover many more countries, they also highlight the heterogeneous patterns of change in the SES-obesity relationship between countries.

A number of factors might explain the propensity for greater growth rate of overweight prevalence among the lowest SES groups in many low- and middle-income countries. Fundamental cause proponents posit that higher SES groups use their resources respond to increasing stigma and/or health concerns associated with the predominant disease states [8]. Increased stigma around larger body sizes in these settings might come from increasing Western media exposure. Increasing prevalence of overweight may promote health concerns and the health knowledge to stem its occurrence. Potentially higher SES groups are more able to engage in health promoting behaviors and slow their overweight prevalence growth rate. There is some evidence that low SES populations in lower income countries display higher preferences for purchasing energy dense foods per dollar increase in income, compared to higher income counterparts [28]. Also, degree of occupational activity and use of labor saving devices may be changing disproportionately for lower SES populations [33]. Under fundamental cause theory, while higher SES groups adjust to these changing environments in health promoting ways, for the lowest SES groups, changes in food accessibility and required daily activity may not be countered by behavior change adjustments to prevent overweight.

An alternative explanation for these findings is one of entirely differential timing of exposure, rather than a difference in SES-specific adjustment to current conditions. It is possible that low SES groups are just more recently experiencing the same environmental changes that high SES groups in the same country experienced 10-20+ years ago (i.e. surplus calories and change in activity demands of daily life). Under this hypothesis, the low SES groups might be experiencing faster prevalence growth rates now, but these could slow when they approach the absolute prevalence of the high SES group. A strong test of fundamental cause would require that the growth rates ultimately lead to a higher overall prevalence, which cannot yet be observed in these countries, but will become possible in the future as prevalence in the low SES groups catch up to those in the high SES groups. Following the trends in these data over the years to come will provide an opportunity for a strong test of competing hypotheses.

In terms of country-level factors, increasing country-level economic development could be associated with changes in food environments and daily activity demands as well as the differential exposure and/or response to these changes by SES group. Previous literature suggests that among low and middle income countries, those with relatively higher GDPs more often have an inverse relationship between SES (represented by education) and obesity [1]. We briefly test whether higher country-level GDP differentiates countries with a greater overweight prevalence growth rate among the lowest wealth and education groups and find evidence in support of this bivariate relationship for wealth. However, no statistically significant relationship was found when we used education as the indicator of individual-level SES. This lack of association which is contrary to our hypothesis is likely due to the group of fairly low income countries that exhibit faster overweight prevalence growth for the lowest education groups (and not when grouped by wealth).

As mentioned above, the primary difference in the results between education and wealth as indicators of socioeconomic was that there was an additional set of mostly lower income countries in which the overweight prevalence growth rate was higher for the lowest SES group than for the highest SES group when education is used rather than wealth. One potential concern could be that this finding is due changes in the distribution education over time or differences between countries. We employ a few additional tests to begin to rule out this possibility. First, we regressed (separately) the difference in overweight prevalence growth on the proportion of the population in the lowest and highest education groups and on the percent change in the proportion lowest education group. None of these variables are statistically associated with the difference in prevalence growth rates. Additionally, we calculate the slope index of inequality which accounts for the distribution of the population in each SES group and we assess the change in the SII over the survey years within countries and compare this to our difference in prevalence growth rates. Findings using the difference in SII across survey years are similar to our primary results (results not shown). These additional tests help to rule out the possibility that the education results are due solely to a change in the distribution of education over the survey years. Whether there are other characteristics that distinguish these countries is an area for future research.

In a recent review of cross-sectional studies of SES and overweight by country-level economic development, McLaren [1, 60] also indicates that more inverse relationships between SES and body weight status were reported when education was used as the indicator of SES, compared to income or wealth, although the wealth and education indicator comparisons were typically not within the same populations. Findings in the US, when comparing income and education as indicators of SES within the same nationally representative population, also give differing conclusions; however, in general, income is associated with increased rate of growth in obesity while education is not [19, 71].

Limitations of our study should be noted. Our primary sample is limited to women with children under 5 years old to maintain sample comparability over time since DHS surveys originally measured anthropometrics primarily for these women. However, changes in procedure have led to the measurement of all women in recent survey years and our sensitivity analyses incorporate this full sample and show generally similar findings. We therefore have confidence that our findings may be generalizable to women of childbearing age in our sample countries. Our sample of 41 low- and middle-income countries is not random, but rather based on the public availability of repeated cross-sectional anthropometric data for women, mostly from DHS surveys. However, we also have no reason to think they are systematically different as a group.

CONCLUSIONS

Our results add to the literature on the social distribution of chronic disease in low- and middle-income countries. We demonstrate that although the prevalence of disease is still currently higher in the highest SES groups, the growth rate in low SES groups has surpassed that of the high SES groups in many countries. This implies that, for overweight, a chronic condition in itself and a risk factor for many other chronic diseases, the implications of socioeconomic status on disease risk are actively changing in many low and middle-income countries. These findings also suggest that socioeconomic status affects the impact of environmental changes, such as those that accompany globalization and modernization, on disease risk in these contexts. These findings have important implications for future trends in the social distribution of chronic disease in low- and middle-income countries and for the targeting of interventions and prevention programs.

Table 1. Age-standardized overweight prevalence difference between lowest and highest wealth quintile† for each country in each year (country-year, N=103) and difference in annualized prevalence growth rate between lowest and highest wealth quintile over survey period in each country (N=37)††

Country Year	Prevalence Difference	Prevalence Growth Difference	Country Year	Prevalence Difference	Prevalence Growth Difference	Country Year	Prevalence Difference	Prevalence Growth Difference
Armenia 2005	6.5	0.7	Egypt 2005	**-23.4**	**1.9**	Morocco 2003	**-24.9**	**0.9**
Armenia 2000	2.9		Egypt 2003	**-18.4**		Morocco 1992	**-34.4**	
Bangladesh 2007	**-29.7**	**-1.5**	Egypt 2000	**-31.7**		Mozambique 2003	**-32.3**	-1
Bangladesh 2004	**-21.7**		Egypt 1995	**-42.1**		Mozambique 1997	**-26.3**	
Bangladesh 1999	**-24.2**		Ethiopia 2005	**-8.5**	-0.5	Namibia 2006	**-40.9**	-0.1
Bangladesh 1996	**-12.2**		Ethiopia 2000	**-5.8**		Namibia 1992	**-40.1**	
Benin 2006	**-32.2**	**-1.2**	Ghana 2003	**-49.1**	**-2.2**	Nepal 2006	**-23.6**	**-1.6**
Benin 2001	**-38.0**		Ghana 1998	**-43.4**		Nepal 2001	**-17.5**	

Benin 1996	**-20.4**		Ghana 1993	**-27.1**		Nepal 1996	**-7.3**	
Bolivia 2003	**-23.5**	0.1	Guatemala 1998	**-47.6**	**-6**	Nicaragua 2001	**-28.2**	-0.9
Bolivia 1998	**-13.1**		Guatemala 1995	**-29.7**		Nicaragua 1997	**-24.7**	
Bolivia 1994	**-24.1**		Guinea 2005	**-25.3**	**0.9**	Niger 2006	**-34.6**	-0.5
Burkina Faso 2003	**-29.1**	**-1.2**	Guinea 1999	**-30.9**		Niger 1998	**-28.1**	
Burkina Faso 1998	**-12.9**		Haiti 2005	**-35.4**	-0.6	Peru 2000	**-24.8**	-0.7
Burkina Faso 1992	**-16.3**		Haiti 2000	**-40.9**		Peru 1996	**-28.4**	
Cambodia 2005	**-17.9**	-1.1	Haiti 1994	**-29.3**		Peru 1992	**-18.8**	
Cambodia 2000	**-12.3**		Indonesia 2007	1.9	0.4	Rwanda 2005	**-14.9**	0.2
Cameroon 2004	**-41.9**	**-1.9**	Indonesia 1997	-2.2		Rwanda 2000	**-16**	
Cameroon 1998	**-30.4**		Jordan 2007	3.3	1	Tanzania 2004	**-33.9**	**-1.4**

Cote d'Ivoire 1998	**-36.2**	-0.5	Jordan 2002	4.3		Tanzania 1996	**-23.1**	
Cote d'Ivoire 1994	**-34.2**		Jordan 1997	**-6.5**		Turkey 2003	0.8	**1.2**
Chad 2004	**-20.2**	**-0.9**	Kazakhstan 1999	**-11.6**	-1	Turkey 1998	1.2	
Chad 1996	**-13**		Kazakhstan 1995	**.7**		Turkey 1993	-11.6	
China 2006	**-9.8**		Kenya 2003	**-39.2**		Uganda 2006	**-30.4**	
China 2004	-5.1		Kenya 1998	**-31.2**	**-1.3**	Uganda 2000	**-29.3**	**-1.4**
China 2000	**-10.6**		Kenya 1993	**-25.8**		Uganda 1995	**-14.6**	
China 1997	**-6.5**	-0.6	Madagascar 2003	**-12.8**	-0.5	Zambia 2007	**-39**	
China 1993	**-5.8**		Madagascar 1997	**-9.5**		Zambia 2001	**-29.1**	**-1.5**
China 1991	**-7.1**		Malawi 2004	**-20.1**		Zambia 1996	**-22.4**	
China 1989	-0.6		Malawi 2000	**-16.7**	-0.3	Zimbabwe 2005	**-36.9**	
Colombia 2005	**-5.5**	**1.3**	Malawi 1992	**-16.2**		Zimbabwe 1999	**-30.9**	**-1.4**

Colombia 2000	3.2	
Colombia 1995	**-18.4**	
Mali 2006	**-33.3**	**-0.8**
Mali 2001	**4.4**	
Mali 1995	**-24.4**	
Zimbabwe 1994	**-21.5**	

Bold signifies $p<0.05$

† Prevalence difference is the age-standardized prevalence in highest wealth quintile (5th) subtracted from that in lowest wealth quintile (1st) in each year.

†† Annualized difference in prevalence growth rate is net change in prevalence over the survey period (last year minus first year) for the highest wealth quintile subtracted from that in the lowest wealth quintile divided by the number of years between the first and last survey years in each country.

Excluded country-years: Niger 1992, Nigeria 1999, Senegal 1992, Tanzania 1992, India 1998, Dominican Republic 1991, Egypt 1992.

Table 2. Age-standardized overweight prevalence difference between lowest and highest education group† for each country in each year (country-year, N=111) and difference in annualized prevalence growth rate between lowest and highest wealth quintile over survey period in each country (N=41) ††

Country Year	Prevalence Difference	Prevalence Growth	Country Year	Prevalence Difference	Prevalence Growth	Country Year	Prevalence Difference	Prevalence Growth
Armenia 2005	6.7	2.1	Egypt 2005	**-11.7**	0.7	Morocco 2003+	**-9.1**	**1.2**
Armenia 2000	-4		Egypt 2003	**-9.7**		Morocco 1992+	**-22.2**	
Bangladesh 2007	**-28.8**	-0.6	Egypt 2000	**-21**		Mozambique 2003+	**-34.4**	**2.9**
Bangladesh 2004	**-34.6**		Egypt 1995	**-25.4**		Mozambique 1997+	**-51.8**	
Bangladesh 1999	**-34.8**		Egypt 1992	**-20.4**		Namibia 2006+	**-18.8**	-0.1
Bangladesh 1996	**-22.3**		Ethiopia 2005+	**-28.7**	1	Namibia 1992+	**-18**	
Benin 2006+	**-26.4**	0.5	Ethiopia 2000+	**-33.7**		Nepal 2006+	**-14.7**	-0.6
Benin 2001+	**-32.2**		Ghana	**-23.9**	0.4	Nepal 2001+	**-22.5**	

			2003+					
Benin 1996+	**-31.5**		Ghana 1998+	**-17.4**		Nepal 1996+	-8.7	
Bolivia 2003	-4.4		Ghana 1993+	**-27.9**		Nicaragua 2001	**-9.6**	-0.3
Bolivia 1998	**-12.8**	-0.3	Guatemala 1998+	**-16.7**	-0.4	Nicaragua 1997	**-8.3**	
Bolivia 1994	-1.3		Guatemala 1995+	**-15.5**		Niger 2006+	**-44**	
Burkina Faso 2003+	**-38.3**		Guinea 2005+	**-18**	0.5	Niger 1998+	**-38.4**	-0.1
Burkina Faso 1998+	**-23**	-0.9	Guinea 1999+	**-21.2**		Niger 1992+	**-42.4**	
Burkina Faso 1992+	**-28.5**		Haiti 2005+	**-21.8**		Nigeria 2003	**-23.6**	-2.4
Cambodia 2005+	**-11.9**	**-2**	Haiti 2000+	**-25.5**	**1.1**	Nigeria 1999	-14.1	
Cambodia 2000+	-2.1		Haiti 1994+	**-33.7**		Peru 2000	**-17.2**	-0.5
Cameroon	**-34.6**	-1.5	India 2005	**-22**	-0.3	Peru 1996	**-10.2**	

2004+								
Cameroon 1998+	**-25.6**		India 1998	**-19.7**		Peru 1992	**-13.1**	
Cote d'Ivoire 1998+	-8		Indonesia 2007	-1.8		Rwanda 2005+	**-14.3**	
		3.4			0.6			0.7
Cote d'Ivoire 1994+	**-21.6**		Indonesia 1997	**-8.2**		Rwanda 2000+	**-17.9**	
Chad 2004+	**-33.4**		Jordan 2007	-5.2		Senegal 2005+	**-16.6**	
		-0.3						0.2
					0.3			
Chad 1996+	**-30.8**		Jordan 2002	0.5		Senegal 1992+	**-19.5**	
China 2006	4.5		Jordan 1997	-7.8		Tanzania 2004+	**-25.3**	
								1
China 2004	6.6		Kazakhstan 1999	**-12.8**		Tanzania 1996+	**-27.6**	
					-3.6			
		0.5						
China 2000	0.7		Kazakhstan 1995	1.5		Tanzania 1992+	**-37.2**	
China 1997	4		Kenya 2003+	**-27**		Turkey 2003	**18.1**	
China 1993	-0.7		Kenya 1998+	**-8.9**	-0.1	Turkey 1998	**18.9**	0.5
China 1991	**-5.9**		Kenya 1993+	**-26.3**		Turkey 1993	**12.9**	

China 1989	-3.3		Madagascar 2003+	**-10.6**	**-1.1**	Uganda 2006+	**-21.8**	
Colombia 2005	-2.6		Madagascar 1997+	-4.3		Uganda 2000+	**-25.3**	**-1.2**
Colombia 2000	0.7	0.6	Malawi 2004+	**-21.3**		Uganda 1995+	**-8.7**	
Colombia 1995	-9.1		Malawi 2000+	**-24.4**	**1.4**	Zambia 2007+	**-27.4**	
Dominican Republic 1996	**-13.2**	0	Malawi 1992+	**-37.6**		Zambia 2001+	**-19.1**	**-0.7**
Dominican Republic 1991	**-13.1**		Mali 2006+	**-31.2**		Zambia 1996+	**-10.7**	
			Mali 2001+	**-25.8**	0.2	Zambia 1992+	**-16.7**	
			Mali 1995+	**-33.9**		Zimbabwe 2005+	**-23.1**	-0.1
						Zimbabwe 1999+	**-26.4**	

Zimbabwe		
1994+	**-21.8**	

Bold signifies p<0.05

† Prevalence difference is the age-standardized prevalence in highest education group (tertiary school or secondary school) subtracted from that in lowest education group (no formal schooling) in each year.

†† Annualized difference in prevalence growth rate is net change in prevalence over the survey period (last year minus first year) for the highest education group subtracted from that in the lowest education group divided by the number of years between the first and last survey years in each country.

+Indicates that due to a very small percentage of the population completing tertiary school (<2%), tertiary school was combined with secondary school to form the highest education group.

Table 3. Comparison of difference in annualized prevalence growth rate† between lowest and highest SES groups over survey period in each Asian country using standard BMI cutpoint (BMI≥25) to Asian-specific cutpoint for Asian countries (BMI≥23)

	SES Indicator: Wealth Quintile		SES Indicator: Education Group	
	BMI Cutpoint≥25	BMI Cutpoint≥23	BMI Cutpoint≥25	BMI Cutpoint≥23
Country	Prevalence Growth	Prevalence Growth	Prevalence Growth	Prevalence Growth
Bangladesh	**-1.5 (-2.1, -1.0)**	-0.6 (-1.2, 0.0)	-0.6 (-1.7, 0.5)	-.6 (-1.7, 0.5)
Cambodia	-1.1 (-2.4, 0.2)	-1.3 (-2.8, 0.22)	**-2.0 (-3.6, -0.3)**	-2.0 (-3.7, 0.01)
China	-0.6 (-1.2, 0.2)	0.1 (-0.9, 1.1)	0.5 (-0.2, 1.2)	0.6 (-0.2, 1.4)
India	NA	NA	-0.3 (-0.9, 0.2)	**-1.3 (-1.8, -0.7)**
Nepal	**-1.6(-2.5, -0.8)**	**-2.2 (-3.1, -1.4)**	-0.6 (-1.8, 0.6)	-0.6 (-2.1, 0.8)

Bold signifies p<0.05

† Annualized difference in prevalence growth rate is net change in prevalence over the survey period (last year minus first year) for the highest wealth (education) group subtracted from that in the lowest wealth (education) group divided by the number of years between the first and last survey years in each country.

Figure 1. Annualized difference in overweight prevalence growth rate between lowest and highest wealth group by country-level GDP per capita (with regression line)

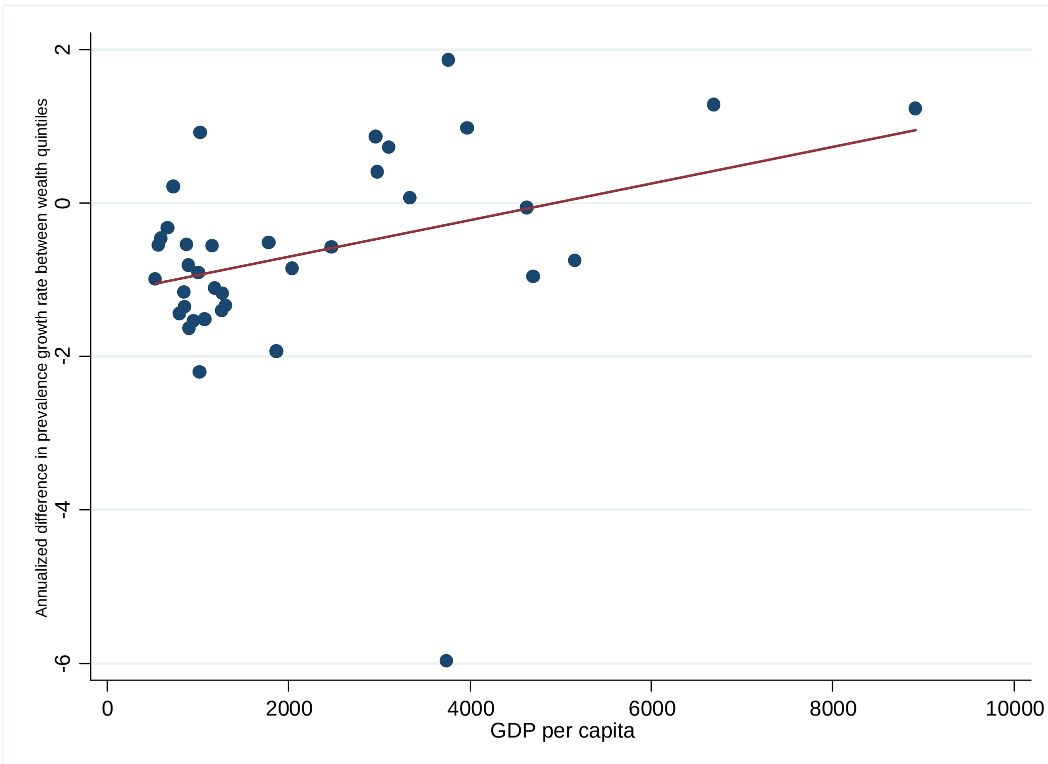
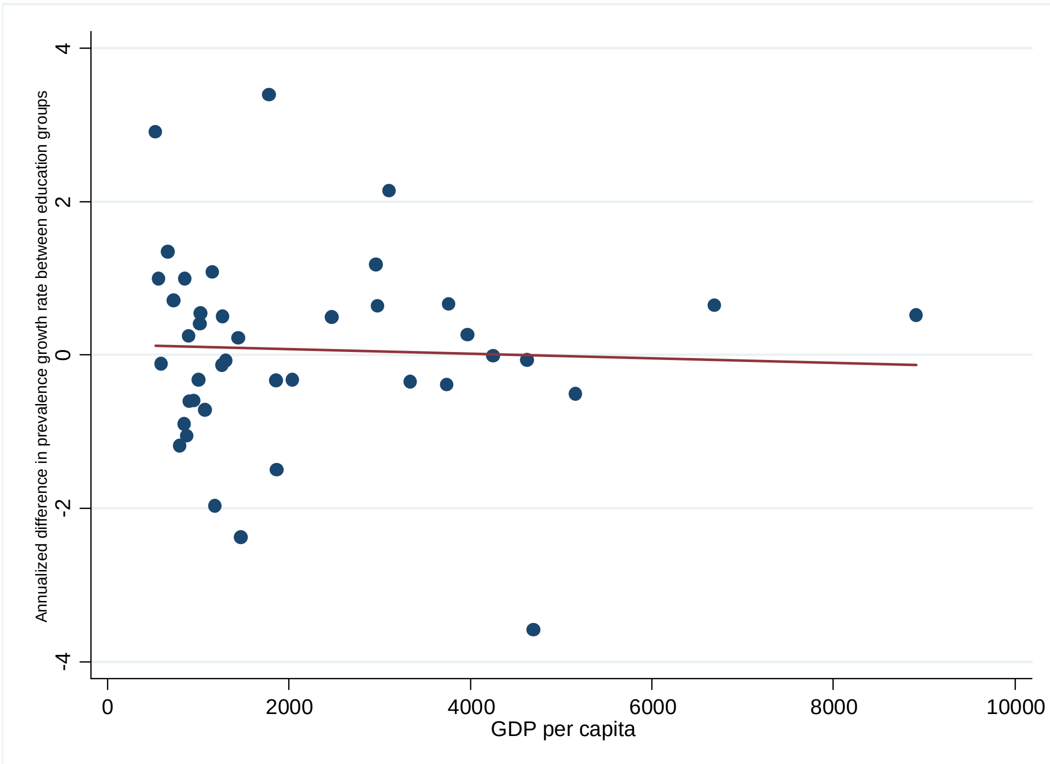


Figure 2. Annualized difference in overweight prevalence growth rate between lowest and highest education group by country-level GDP per capita (with regression line)



VI. CROSS-NATIONAL COMPARISON OF TIME TRENDS IN OVERWEIGHT INEQUALITY BY SOCIOECONOMIC STATUS IN 37 COUNTRIES (1991-2007)

A. ABSTRACT

Background: Country-level contextual factors, such as level of economic development and income inequality, are associated with overweight prevalence and with direction of the relationship between individual socioeconomic status (SES) and overweight. Investigating whether such characteristics are also associated with faster overweight prevalence increases for low SES individuals (compared to high) over time is critically important in order to rigorously interrogate the role of such features in the development of SES-based disparities.

Methods: Repeated cross-sectional data from women aged 18-49 years in 37 low- and middle-income countries were used to assess within-country trends in overweight inequalities by SES over the past 15 years. An assets-based wealth index was used to measure SES, Gross Domestic Product (GDP) was used to measure economic development, and the slope index of inequality (SII) was used to assess the direction and magnitude of the inequality in overweight prevalence at each time point. Change in the SII between time points represented disproportionate growth in overweight prevalence for higher or lower SES groups. Meta-regression was employed to examine the associations between GDP and disproportionate increases in overweight prevalence by SES, with additional testing for patterns by country-level income inequality.

Results: In 10 out of 37 countries the rate of overweight was increasing faster among the low (versus high) wealth groups. GDP was positively related to faster increases in overweightrevalence among the lower wealth groups. Among higher GDP countries, higher income inequality was associated with a faster increase in overweight among the wealthy, whereas low income inequality was associated with a faster overweight growth among the poor.

Conclusions: While increased economic development and decreased income inequality certainly hold benefits for population health, our analyses indicate that progress on these measures may have the unintended consequence of disproportionate increases in overweight among women of childbearing age in the lowest wealth groups

B. BACKGROUND

Overweight prevalence has increased rapidly in developing countries around the globe [72]. County-level contextual factors, such as economic development and income inequality are associated with both the prevalence of overweight and the direction of the relationship between individual socioeconomic status (SES) and overweight [13, 73]. Whether such country-level contextual factors are associated with faster increases in overweight prevalence over time for low SES individuals compared to high SES individuals in developing countries is unclear. Yet, investigating these relationships is critically important in order to more rigorously interrogate the role of such features in the development of SES-based disparities in overweight prevalence and to provide information about the contextual circumstances in which lower SES becomes a risk factor for overweight.

Level of economic development has previously been associated with body mass index (BMI) and with the distribution of overweight by socioeconomic status (SES) [13, 73]. Higher income countries tend to have higher mean BMI levels and an inverse relationship between SES and overweight while, in lower income countries, mean BMI is lower and the relationship between SES and overweight tends to be positive [1, 13]. Economic development may promote total overweight prevalence through greater abundance of foods, increased exposure to the global food market, access to labor-saving devices, and changes in occupational options [15, 33, 74].

Aspects of economic development, such as media exposure, medical technologies and changes in the price of energy dense foods, may also promote differential increases in overweight prevalence by SES [1, 13, 16, 75], which might ultimately promote a lower risk of overweight among high SES groups compared to lower SES populations within a country.

However, particularly among developing countries, there are very few documented within country time trends of the overweight prevalence by SES. Tracking rates of SES-specific overweight prevalence over time in relation to economic development would provide stronger evidence for the role of economic development as a driving factor in development of low SES as a risk factor for overweight.

Furthermore, the effect of economic development on changes in the relationship between SES and overweight might vary by country-level income inequality. Higher country-level income inequality has previously been positively associated with higher total rates of obesity among high income countries [76, 77]. Additionally, income inequality has been associated with the magnitude of inequality in overweight between low and high SES groups. Due et al used the slope index of inequality (SII) to examine whether the overall level of inequality in overweight prevalence among adolescents in middle and high income European countries was associated with country-level income inequality [78]. For high-income countries, higher income inequality was associated with higher inequality in overweight prevalence between low and high SES adolescents, whereas in middle-income countries, higher income inequality was associated with a lower level of inequality in overweight prevalence between SES groups. These findings from a single point in time could be attributed to the fact that, in the middle income countries, overweight prevalence might have grown at a faster rate among the low SES groups, catching up to the overweight prevalence in the higher SES groups [79]. Consequently, while the level of inequality is decreasing, this masks the fact that the overweight levels are increasing faster for the lowest SES groups and the decrease in inequality may be driven by low SES groups catching up to the overweight prevalence in the higher SES groups, likely not the desired outcome.

Recent cross-country comparisons have used the SII and the Relative Index of Inequality (RII) to focus on the steepness of the “gradient” between low and high SES groups at a single point in time [78, 80]. In these studies flatter gradients indicate less overall social inequality in health outcomes. We build on this work and tailor it for a low-income country context by using the SII from multiple time points in our cross-country comparison to assess the trends in inequality within countries and to assess the relative growth rates in overweight prevalence by social class. When looking longitudinally among lower income countries where the relationship between SES and overweight has been positive, a flattening of the gradient within countries is indicative of the growth in overweight among the low SES groups outpacing that among the higher SES group.

Our study uses a cross-national comparison of repeated cross-sectional measurements among women in 37 lower and middle income countries to investigate whether economic development and change in economic development is associated with a disproportionately faster growth in overweight prevalence among the lowest wealth groups. Additionally, we investigate whether the relationship between GDP and differential rates of increase in overweight prevalence by SES varies by country-level of income inequality.

C. METHODS

DATA SOURCES

Data came from several publicly available sources and, for each country, included at least two measures of anthropometric data at different time points. Each of the data sources used a multistage cluster sample design and was either nationally representative or representative of a large portion of the country surveyed. The majority of the data are from Demographic and Health Surveys (DHS), nationally representative household surveys administered primarily in lower- and middle-income countries. The surveys entailed repeated cross-sections, approximately every five years; the DHS questionnaires are standardized to a certain degree, to enable cross-country comparisons [64, 81]. Additionally, we used data from the Indonesian Family Life Surveys (IFLS), and the China Health and Nutrition Survey (CHNS) is conducted in 9 provinces in China.

For the majority (35 out of 37) of our sample countries, anthropometric measurements were available in repeated surveys only for women under 50 years old, so our analyses were limited to adult women age 18-49 in all countries. Since earlier years of the DHS survey only collected anthropometrics on women who had children between ages of 0-5 years, we limited our main analyses to this subgroup to keep the repeated cross-sections over time comparable. We excluded women who were pregnant during the survey measurement.

KEY VARIABLES

Individual-Level Variables

Anthropometrics. In all surveys, height and weight were measured by trained technicians using standard techniques [35, 82]. Body mass index (kg/m^2) was used to classify people as obese or overweight according to WHO guidelines [37]. The prevalence of overweight (BMI≥25) according to socioeconomic status was calculated for each country at each survey wave. We utilize this BMI cutpoint because, although lower BMI thresholds demonstrate disease risk in some Asian populations, the WHO still recommends the cutpoint of BMI≥25 for international comparisons of overweight [38].

Socioeconomic Indicator. Individual socioeconomic status was represented by a wealth index derived from assessment of household assets. Wealth was chosen to represent socioeconomic status because in the context of lower income countries, assets-based wealth indices are considered a superior measure of financial resources compared to income since income can be highly fluctuating, come from multiple sources (the entirety of which may be difficult to query in a survey) and often items are bartered and this can be hard to translate into income [41]. We chose to utilize wealth rather than education since the distribution of education was quite different among our countries with some countries having too few people completing tertiary school to enable stable estimates. The use of wealth indices is uncommon in cross-country comparisons, particularly among highly developed countries; however, it is not uncommon in single-country studies in developing countries. The DHS data include a constructed wealth index which is comprised of assets that were asked in all surveys, as well as some country-specific variables [41]. Principal components analysis was used to generate a total wealth score for each family in each country in each survey wave [41]. The Indonesian Family Life Survey and the China Health and Nutrition Survey also collected information regarding household assets and we ran a country-specific principal components analysis to create a wealth index comparable to the DHS index for each of these countries in each survey wave. For the analyses, the country and survey-year specific quintiles of wealth score were used to create a categorical variable for wealth.

Age. Age was collected in all surveys and controlled for by direct standardization, in which we applied each country's overweight rates to the WHO world standard population age structure [40] to control for different age structures across countries. This allows greater comparability between countries and within countries over time.

Country-level variables

Economic Development. We used gross domestic product (GDP) per capita adjusted for purchasing power parity (PPP) and inflated to the 2005 international dollar value (referred to henceforth as GDP for short) to represent country-level economic development. Purchasing power parity is a method for adjusting GDP to reflect the difference in relative prices of goods and services across countries [43]. This value was obtained for all years between the first and last survey wave for each country from the World Bank World Indicators Database [31]. The baseline survey year GDP for each country is used in the regression analyses in its continuous, log transformed form.

Change in Economic Development. To capture the level of change in economic development over the survey period we calculated the average annual percent change in GDP per capita (PPP).

Income inequality: We used the Gini coefficient to represent country-level income inequality, which is a commonly used indicator; it assesses the proportion of the income shared by the proportion of the population [45]. The Gini coefficient ranges from 0 to 1, where 0 would mean that everyone in the population had the same income and 1 means that 1 person has 100% of the income. We used the average Gini coefficient across the survey period for each country, obtained from the World Bank Indicators Database [31].

STATISTICAL ANALYSES

Slope Index of Inequality (SII)

To summarize the level of inequality in overweight prevalence by SES group, we estimated the SII. The SII is a recommended measure for quantifying the absolute level of inequality in a health outcome when within country time trends and cross-country comparisons are of interest [23]. The SII accounts for the mean level of health by socioeconomic group as well as the proportion of the population in each group [23]. It is a regression-based measure that is obtained by regressing the mean health status of each SES group on the fractional rank of each SES group (ridit score), ranked highest to lowest; it assumes a linear relationship between SES group and the health outcome.

In our case, we regressed the age-standardized overweight prevalence for each wealth group on the fractional rank of each wealth group:

$$(\text{Age-standardized overweight prevalence} \mid \text{country, year})_j = \alpha + \beta_1(\text{SES group ridit score})_j + \varepsilon,$$

where *j* denotes wealth group. Every individual in the same wealth group is assigned the same ridit score and age-standardized overweight prevalence so that the regression is self-weighted by the number of individuals in each SES group [42]. The resulting regression coefficient β_1 is the SII and represents the difference in overweight prevalence moving from the highest (0) to the lowest (1) group. The SII was calculated for each country in each survey year.

Change in Slope Index of Inequality

We estimated the change in the SII between the first and the last survey year for each country with the following model:

(Age-standardized overweight prevalence| country)$_{jt}$= α +β_1(ridit score$_{jt}$) + β_2(middle survey year$_t$) + β_3(last survey year$_t$) + β_4((ridit score$_{jt}$)*(middle survey year$_t$)) + β_5((ridit score$_{jt}$)*(last survey year$_t$)) + ε.

In this model, *j* denotes wealth group, *t* denotes the year in which the cross-sectional survey was performed, and survey year is represented with indicator variables. The coefficient on the ridit score (β_1) gives SII in the first survey year. The change in the SII between the first and last survey years is represented in the interaction between ridit score and last survey year, coefficient β_5. The change in the SII is the change in the magnitude of inequality in overweight levels. It also is indicative of the differential rate of increase in overweight prevalence between the high and low wealth groups, since it is calculated within countries and, by using wealth quintiles, we've constrained the amount of change that could be due to change in proportion in each wealth group. This is illustrated in Figure 3.

Relative Index of Inequality

Whereas the SII estimates the level of absolute inequality in a health outcome, the relative index of inequality (RII) is a regression-based measure that estimates the relative level of inequality in a health outcome by socioeconomic status group. We estimated the RII in an analogous fashion to the SII, except that Poisson regression of the overweight prevalence rate on the SES group ridit score is used to give a relative measure of inequality, rather than an absolute difference between the highest and lowest SES groups. We present the RII for the first and last survey year in each country and as well as the change in the RII between the survey years for comparison. We leave the estimates log transformed so that the negative and positive values have the same substantive directional interpretation mentioned above for the SII. These are presented in tabular form for comparison, but our analyses focus on the SII as an outcome. We chose this focus because of the very large within-country differences in overweight prevalences by wealth quintile (i.e. prevalence <5% in lowest wealth quintile and prevalence >30% in highest). A small increase in absolute prevalence in a group with extremely low prevalence equates to quite a large relative increase for this group that could not be matched in the higher prevalence group except by extreme absolute increase.

Meta-regression to explore country-level factors associated with a faster rate of prevalence growth among lower SES groups

Next, we used the change in the inequality in overweight prevalence over the survey period (i.e. the change in the SII, from above) to represent the differential growth rates in overweight prevalence between the low and high SES groups as the outcome in a country-level meta-regression. Change in SII was annualized to account for the different number of years between surveys between countries. The meta-regression used a random effects regression model to estimate the relationships of interest and the proportion of the between-study variance that is explained by the independent variables [83]. We estimated the crude association between each GDP and percent change in GDP and change in the SII. We then test whether the effects of GDP vary by percent change in GDP by interacting these two variables. GDP and GDP change are both included in their continuous form. Based on residual diagnostics, GDP was log transformed for the analyses.

Subsequently, we tested whether the association between GDP and the change in SII varies by country-level income inequality, represented by the Gini coefficient. We test the interaction using the continuous form of the variable as well as with tertiles of GDP and a dichotomized version the Gini coefficient.

Sensitivity Analyses

For sensitivity analyses, we calculated the difference in the growth rates of overweight prevalence for the lowest and the highest wealth quintiles (referred to as “the range” measure in studies of health inequalities). We ran the regression analyses with this measure as an outcome instead of the change in the SII to ensure that they approximately give the same results. Additionally, we re-ran the meta-regressions using change in the RII as the outcome measure.

Sample weights to account for complex survey design were used the micro-level analyses which derived the country-level SES-specific overweight prevalences and the SII/RII. *Alpha* was set at 0.05 for all main effects and 0.20 for all interactions; all tests were 2-sided. The alpha for the interaction was intentionally set liberally since we have relatively few observations and are substantively interested in detecting any interactions that exist. Since the test of interaction has low power, one alternative is to increase *alpha* [65]. All analyses were performed with Stata (Version 11, 2009, Stata Corporation, College Station, TX).

D. RESULTS

Selected descriptive characteristics are provided in Table 4. The GDP per capita ranged from $451 to $9,505 and annual percent change in GDP ranged from -1.2 (Haiti) to 19.5 (China). Age-standardized prevalence of overweight ranged from 2.5% in Ethiopia in 2000 to 76% in Eygpt in 2005.

Mean absolute inequality level for overweight prevalence (represented by SII) was -23.3, meaning at this level the lowest SES group would have an overweight prevalence approximately 23 points lower than the highest SES group. A negative SII indicates higher overweight prevalence in the higher wealth groups, whereas a positive SII means higher levels of overweight prevalence in the lower wealth groups. The level of relative overweight inequality (represented by the RII) is in the same direction as the absolute level of overweight inequality for nearly all of the surveys.

The mean annualized change in absolute inequality in overweight was -1.0 (range -6.0 – 1.9). Since all of the countries except Indonesia have a negative SII for overweight in the first survey year, a *negative change* in SII indicates an *increase* in the magnitude of overweight inequality by SES. We can deduce that this increase in magnitude is brought about by a faster increase in overweight prevalence for the higher wealth groups compared to the lower wealth groups (see Figure 3), since wealth is categorized by quintiles, which assures that the proportion in each wealth group is not changing dramatically. Conversely, a *positive change* in the overweight inequality indicates a *decrease* in the magnitude of the overweight inequality by SES, brought about by a faster increase in overweight among the lower wealth groups compared to the higher wealth groups. In other words, positive change in overweight inequality (SII) indicates a faster increase in overweight prevalence among the lower wealth groups but also a decrease in the magnitude of the inequality in overweight in most cases. As such, in the remainder of the results we interpret the change in the overweight inequality as the differential rate of increase in overweight prevalence comparing lower and higher wealth groups.

GDP and SES-specific rates of increase in overweight prevalence

Figure 4 displays a forest plot of the annualized change in the overweight inequality over the survey period for each country, listed in order of initial GDP. Ten out of 37 countries had a positive change in the overweight inequality, indicating a faster overweight prevalence increase among the lower wealth groups. This faster increase in overweight prevalence for low (vs. high) wealth appears to be concentrated in the countries with higher initial GDPs.

The meta-regression of the change in the inequality in overweight prevalence on GDP confirms a positive, statistically significant association. A one unit increase in log GDP is associated with an increase of 0.93 units (95% CI 0.29, 1.56) in overweight inequality change score. This finding indicates higher GDP is associated with greater likelihood of a country having a relatively higher rate of increase in overweight prevalence among lower wealth group (Table 5, Model 1).

The association of annual percent change in GDP on overweight inequality over the survey period was positive but was not statistically significant ($\beta = 0.09$ (95% CI -0.04, 0.23) (Table 5, Model 2). When both baseline GDP and percent change in GDP were include in the model, GDP remained significantly positively associated and percent change in GDP was positively, but only marginally significantly, related to level of overweight inequality (Table 5, Model 3). We found no significant interaction between baseline GDP and level of change in GDP (*p* for interaction: 0.60) in the model of change in overweight inequality (Table 5, Model 4). Using the equation with GDP and GDP change (Table 5, Model 3), the level of baseline GDP at which the overweight growth rate is predicted to be faster for the low wealth groups compared to the higher is approximately $5611. Alternatively a baseline GDP of approximately $3394 with a 3% annual percent change in GDP also predicts a positive change in SII. The variance decomposition from the random effects meta-regression indicates that country-level GDP alone accounts for 17.9% of the between-country variance in the change in SII, the addition of change in GDP increases the variance explained to 23.5%.

INCOME INEQUALITY AS A MODIFIER OF THE RELATION BETWEEN GDP AND SES-SPECIFIC RATES OF INCREASE IN OVERWEIGHT

The interaction between economic development (GDP tertile) and income inequality (dichotomous Gini coefficient) was statistically significant (*p*-0.01). Among countries in the highest GDP tertile, a lower country-level income inequality was associated with a predicted annual change in overweight inequality of 1.13 (95% CI 0.11, 2.15), indicating faster increase in overweight prevalence for the lower wealth groups compared to the wealthier group (Figure 5). Conversely for countries in the highest income tertile but with high income inequality, the predicted annual change in the overweight inequality was -0.91(95% CI -2.12, 0.29), indicating a slower overweight prevalence growth among the lower wealth groups in comparison to wealthier groups (*p* for difference between high and low income inequality =0.01). Among countries in the two lowest income tertiles, the predicted change in overweight inequality is not statistically significantly different according to level of income inequality, and, in all four categories, the predicted change in overweight inequality is negative, indicative of a faster rate of overweight increase among the wealthier groups (Figure 5). The proportion of the between-country variance explained in the model that interacted GDP and the Gini coefficient was 33%.

We interpret these results with caution since the interaction was not robust to specification in its continuous form, but since theory and prior research suggests a strong rationale for an interaction, we probed the interaction further and tested by categories.

SENSITIVITY ANALYSES

We also ran the analyses using the difference in the prevalence rate gains between the highest and the lowest wealth quintiles. We found similar results; specifically, baseline GDP was positively associated with higher overweight prevalence growth in the least wealthy compared to the wealthiest, and the interaction between GDP and income inequality was significant. This supports our use of change in SII as an indicator to disproportionate change in overweight prevalence among wealth categories. Additionally, we ran the analyses with change in the RII and the results were similar with this specification as well. Specifically, GDP was positively associated with change in RII, but was only marginally statistically significant (p =0.06). However, the interaction between GDP and the Gini coefficient was not statistically significant.

E. DISCUSSION

Our findings from 37 countries around the world suggest that economic development and income inequality are significantly related to faster rates of overweight prevalence increases for lower SES groups compared to higher SES groups. Our cross-national comparison is the first to investigate country-level contextual factors in relation to within-country time trends of SES-based inequalities in overweight prevalence in lower income countries. In general, we observed that higher GDP per capita was associated with a higher rate of overweight prevalence growth among low wealth groups in comparison to higher wealth groups. However, we find that the association between GDP and propensity for faster overweight increases in low wealth groups varies by country-level income inequality. Specifically, the country-level combination of high GDP and lower income inequality is associated with the greatest likelihood of disproportionately fast increase in overweight prevalence for the lower wealth groups compared to higher wealth groups. While increased economic development and decreased income inequality certainly hold benefits for population health, our analyses indicate that progress on these measures may have the unintended consequence of a disproportionate growth in overweight among the lowest wealth groups.

Among the 37 countries, we observed two predominant patterns of change in overweight inequality. First is the pattern of increasing inequality in overweight prevalence, driven by a disproportionate increase in overweight prevalence among the wealthy. The second pattern is a decrease in overall inequality of overweight status, but driven by a disproportionate increase of overweight among the poor. Additionally, one country displays the aberrant pattern of increasing inequality driven by disproportionate overweight prevalence growth among the poor (Armenia). In all cases, a positive change in the overweight inequality over the survey period is indicative of a disproportionate rate of overweight prevalence increase among the lower wealth groups in comparison to the higher wealth groups.

ECONOMIC DEVELOPMENT

We found that higher GDP was associated with a significantly greater disproportionate increase in overweight prevalence among the low wealth persons. Our work builds on previous work relating higher GDP to an inverse relationship between obesity and SES [1, 73], and adds to this body of work by investigating the SES-specific overweight prevalence accrual process over time.

Stronger causal evidence for the role of GDP could be claimed if change in GDP were strongly associated with the disproportionate overweight prevalence increases in the lower wealth groups compared to the higher; however, the estimate was only marginally statistically significant. The lack of a statistically significant association between GDP change and overweight prevalence growth by SES group could be due to a relatively small range of GDP change or our small sample size (i.e. n=37 in the country-level analyses). Alternatively, perhaps the relationship between GDP and disproportionately faster increase in overweight prevalence among the poor is spurious rather than causal. It could be that many aspects other than GDP also differ between these countries, and that GDP is merely a marker for other driving forces/causal agents.

There are, however, reasons to think that national wealth plays a role in the SES-specific overweight prevalence. Low country-level GDP results in an environment of food scarcity [13, 20] and in this type of environment, people with high socioeconomic status will have greater resources and ability to procure adequate food, and to exceed caloric needs. It has also been hypothesized that in many food scarce societies, larger body sizes are desirable [13]. Consequently, those who are in the position to become overweight may be satisfied with their larger body size and its meaning [13]. On the other hand, people in low socioeconomic position may not be able to procure adequate food to exceed their daily energy needs, and therefore, less often become overweight. Additionally, in low GDP countries, a larger proportion of the low socioeconomic groups are likely to expend a greater amount energy in their daily work, compared to low SES groups in countries with higher GDP, and compared to their higher income countrymates. As lower GDP countries increase their GDP, food likely becomes relatively cheaper and more abundant for all populations.

These explanations give rationale for an increasing prevalence of overweight among the poor, but they do not address why lower wealth groups would actually have faster rates of increase in overweight than the higher wealth groups. Faster overweight prevalence increases could stem from a contextual change felt disproportionately by lower income groups, such as occupational change with changing economies. Increased options for work may draw low SES individuals away from farming and into the formal labor market, which may result in a greater decrease in energy expenditure for this SES group only.

Alternatively, perhaps the differential increase stems from a different response to the same environment. Overweight may become an undesired outcome in the context of development [13, 20]. Ideas about desirable body shapes/sizes might change for only higher income individuals, due to greater access to media influences [21]. Or, change in the ideal body shapes are pervasive for all groups, but only the highest SES groups have the resources to attempt to achieve the thinner body habitus in the new environments. A change in the desirability/stigma associated with overweight might drive wealthier groups to respond to the same environment differently and attempt to halt overweight prevalence increases. This is one of the mechanisms by which theorists suggest that low SES groups come to bear a larger burden of predominant preventable diseases, even when the types of predominant disease change over time, while high SES groups become relatively protected [11, 12].

INCOME INEQUALITY

Furthermore, we find some evidence that the association between country-level GDP and SES-specific increases in overweight prevalence growth varies by country-level of income inequality. Among our countries in the highest income tertile, having high income inequality (ie Bolivia, Peru, Guatemala, Namibia, and Columbia) was associated with a significantly higher overweight prevalence growth among the *higher* wealth individuals. For countries in the highest income tertile, having lower income inequality (eg Armenia, Egypt, Indonesia, Jordan, Morocco, Turkey, Kazahkstan) was actually associated with a higher overweight prevalence growth among the *low* wealth individuals.

These findings among the highest wealth groups in relatively higher income countries of varying levels of income inequality suggest that the increased resources and knowledge that most likely accompanying wealth do not have universal effect on a given health outcome, even at the same level of economic development. As speculated previously, a third factor, such as the perceived social stigma around a behavior or disease, likely shapes the application of knowledge and resources imparted by wealth and together these determine the SES-disease relationship [11, 12]. In our case, we'd speculate that the social perception of overweight as desirable or undesirable might factor into the distribution of overweight by social class [22].

Despite plausible mechanisms and consistency with other findings, we should interpret these results conservatively since the significance of the interaction between GDP and income inequality was not apparent when the variables were entered in their continuous form. Explanations for the different findings with different model specification may be due to one country acting as an influential point. Guatemala has highest magnitude of negative change in overweight inequality and falls into the highest income, high inequality category. Although we do not see any reason to exclude Guatemala from the main analyses, we did probe the interaction to see if the results were robust to the exclusion of Guatemala. The interaction remained significant at the 0.20 level and the high income/high inequality still had lower predicted rates of overweight prevalence increase of for the lower wealth groups compared to that of high income/low inequality countries (0.23 (-0.74, 1.20) versus 1.13 (0.40, 1.87); however, the predicted rates in the high income/high inequality were positive rather than negative.

To our knowledge, no published studies have examined whether income inequality is associated with SES-specific changes in overweight prevalence over time. One recent study did examine the relationship between level of inequality in overweight prevalence between SES groups and country-level income inequality at a single point in time [78]. Although not directly comparable, these results differ from a recent study that examined the relationship between level of inequality in overweight prevalence between SES groups and country-level income inequality at a single point in time among adolescents in Europe and North America [78]. Among the middle income countries in that study (comparable to higher income countries in our study), countries with higher income inequality had lower magnitude of inequality in overweight compared to those with lower income inequality [78]. We further examined only the most recent survey wave among our higher income countries, and, contrary to the findings from Due et al, countries with higher income inequality have higher magnitude of inequality in overweight levels (mean SII =-35.3 (-53.6, -17.1)) compared to those with lower income inequality (mean SII = -8.9 (-22.8, 5.1)). Differences could be due to the age of the populations studied (adolescents versus adults) or the fact that the highest income countries in our sample still have higher overweight prevalence in the higher SES groups, whereas the opposite is true among girls in Due et al. Additionally, our middle income countries are concentrated in Latin America and Northern Africa/Middle East, while theirs are in Central Europe.

LIMITATIONS

Limitations should be noted. First, we use an assets-based wealth index to represent SES; this covers only one realm of the various dimensions that constitute SES. Additionally, although the an assets based wealth index is commonly used and believed to be superior to income in lower income countries (due to the highly fluctuating nature of income in these settings [41], it still is an imperfect measure and does not perfectly capture a family's level of financial resources. Next, we use GDP per capita to represent country-level economic development. Certainly, GDP does not encompass all aspects of development and alternative measures such as the Human Development Index exist. However, we chose to use country-level GDP since most of the previous literature also uses GDP and this eases comparisons among studies. Use of the Gini coefficient provided by the World Bank to represent income inequality also is an imperfect measure; however, it is a commonly used indicator the literature in this field. In addition, the SII assumes a linear relationship between mean health status and the SES categories. Visual examination of the plotted data reveals that this assumption is reasonable.

Additionally, our meta-regression analyses are conducted at the country-level, and this results in a small sample size of 37 countries. Consequently, we have limited ability to control for multiple confounders. Also, our primary sample is limited to women with children under 5 years old to maintain sample comparability over time since DHS surveys originally measured anthropometrics primarily for these women. Generalizability of these results should be limited to women with young children in low and middle countries. Future work could compare the sensitivity of the results to these sample restrictions since changes in the DHS protocol have led to the measurement of all women in recent survey years. Next, our sample of 37 low- and middle-income countries is not random, but rather based on the public availability of repeated cross-sectional anthropometric data for women, mostly from DHS surveys. However, we also have no reason to think they are systematically different as a group.

CONCLUSIONS

Using a large multinational sample and following countries over time, we find that country-level GDP is associated with a decrease in level of overweight inequality. Unfortunately, however, this decrease in inequality is brought about by a disproportionately faster increase in overweight prevalence among the lower wealth groups in comparison to the higher wealth groups. In these counties, the less wealthy are catching up to and potentially surpassing the overweight prevalence to the wealthy. Countries with higher GDPs and low levels of income inequality have the fastest increases in overweight prevalence among the lower wealth groups. These findings indicate that country-level contextual features are significantly associated with the distribution of overweight by social class and the changes in these distributions over time.

Achieving higher nation wealth and lower income inequality may have the unintended consequence of increasing the burden of overweight among lower SES women in developing countries. To stave off these unfavorable consequences, health campaigns and policies addressing prevention of chronic disease in lower income countries should be targeted for lower SES populations in order to avoid simply trading SES-based disparities in undernutrition for disparities in overnutrition.

Table 4. Countries included and years surveyed and selected country-level sample characteristics.

	Year	Sample Size	GDP §	Annualized percent change in GDP	Gini coefficient	Age-standardized percent overweight §§	Slope Index of Inequality in overweight (SII)†	Relative Index of Inequality (RII) (log)	Relative Index of Inequality	Annualized Change in SII††	Annualized Change in Prevalence difference††	Annualized change in log RII
Armenia	2000	1,723	2294			43.8	-0.6	0.0	0.99			
Armenia	2005	1,433	4098	15.7	34.7	45.4	7.3	0.2	1.17	1.6	0.7	0.034
Bangladesh	1996	3,536	781			2.7	-11.4	-5.4	0.00			
Bangladesh	2007	5,320	1178	4.6	30.8	11.5	-34.8	-3.8	0.02	-2.1	-1.5	0.145
Benin	1996	2,222	1173			11.7	-18.5	-1.6	0.19			
Benin	2006	10,089	1315	1.2	38.6	18.4	-39.3	-2.3	0.10	-2.1	-1.2	-0.062
Bolivia	199	2,183	3118	1.1	58.8	34.9	-33.9	-0.9	0.41	0.4	0.1	0.032

	4											
Bolivia	2003	8,142	3426			50.6	-30.6	-0.6	0.55			
Burkina Faso	1992	3,262	737			7.2	-17.9	-2.7	0.07			
Burkina Faso	2003	7,737	982	3.0	45.7	8.8	-30.0	-4.2	0.01	-1.1	-1.2	-0.144
Cambodia	2000	3,231	1009			6.3	-13.0	-2.2	0.11			
Cambodia	2005	3,649	1443	8.6	41.9	10.0	-21.8	-2.3	0.10	-1.8	-1.1	-0.031
Cameroon	1998	1,498	1765			21.9	-42.5	-2.0	0.13			
Cameroon	2004	2,826	1957	1.8	44.6	30.3	-55.3	-1.9	0.15	-2.1	-1.9	0.025
Chad	1996	3,430	904			5.2	-13.4	-2.7	0.07			
Chad	2004	2,714	1407	6.9	39.8	8.7	-20.1	-2.5	0.08	-0.8	-0.9	0.028
China	199	2,599	1099	19.5	41.5	11.6	-4.5	-0.1	0.94	0.4	-0.6	0.033

	0											
China	2006	2,467	4524			19.2	-0.4	0.002	1.00			
Colombia	1995	3,189	6700			46.6	-13.0	-0.3	0.76			
Colombia	2005	14,618	7231	0.8	57.5	47.0	-6.2	-0.1	0.88	0.7	1.3	0.014
Cote d'Ivoire	1994	2,867	1656			16.0	-38.0	-2.5	0.08			
Cote d'Ivoire	1998	1,607	1871	3.3	40.2	21.1	-47.4	-2.3	0.10	-2.3	-0.5	0.044
Egypt	1995	6,365	3221			52.8	-51.0	-1.0	0.38			
Egypt	2005	10,085	4319	3.4	31.7	76.1	-27.9	-0.4	0.69	2.3	1.9	0.059
Ethiopia	2000	7,265	528			2.5	-5.5	-2.3	0.10			
Ethiopia	2005	3,326	633	4.0	29.9	3.6	-7.5	-2.2	0.11	-0.4	-0.5	0.020
Ghana	199	1,691	943	1.8	40.8	12.8	-33.1	-2.6	0.07	-2.5	-2.2	0.016

	3											
Ghana	2003	2,826	1116			25.2	-58.3	-2.5	0.08			
Guatemala	1995	4,778	3664			36.3	-39.8	-1.1	0.33			
Guatemala	1998	2,288	3860	1.8	55.7	46.9	-56.5	-1.2	0.31	-5.6	-6.0	-0.023
Guinea	1999	3,133	990			12.5	-31.8	-2.7	0.07			
Guinea	2005	2,422	1056	1.1	43.3	13.5	-29.5	-2.2	0.11	0.4	0.9	0.083
Haiti	1994	1,727	1226			11.3	-30.7	-2.8	0.06			
Haiti	2005	2,492	1068	-1.2	59.5	23.2	-43.4	-1.9	0.15	-1.2	-0.6	0.083
Indonesia	1997	2,147	3075			19.9	0.1	0.0	1.01			
Indonesia	2007	3,270	3504	1.4	39.4	30.4	-1.9	-0.1	0.94	-0.2	0.4	-0.007
Jordan	199	2,930	3520	3.6	37.7	65.0	-9.9	-0.2	0.86	1.5	1.0	0.023

	7											
Jordan	2007	2,915	4775			59.9	4.6	0.1	1.08			
Kazakhstan	1995	1,302	4499	2.3		38.5	-8.1	-0.2	0.81			
Kazakhstan	1999	674	4909		35.3	31.3	-11.3	-0.3	0.71	-0.8	-1.0	-0.034
Kenya	1993	3,143	1307			15.7	-30.7	-1.9	0.14			
Kenya	2003	3,986	1279	-0.2	42.3	24.2	-47.4	-2.0	0.14	-1.7	-1.3	-0.004
Madagascar	1997	2,419	873			4.2	-7.0	-1.7	0.18			
Madagascar	2003	3,771	847	-0.5	44.6	6.3	-14.6	-2.4	0.09	-1.3	-0.5	-0.108
Malawi	1992	2,100	601			10.0	-16.5	-1.7	0.18			
Malawi	2004	6,521	648	0.7	44.7	15.0	-24.1	-1.6	0.19	-0.6	-0.3	0.005
Mali	199	3,970	762	3.1	39.5	9.0	-24.0	-2.8	0.06	-1.5	-0.8	0.050

	5											
Mali	2006	8,476	1025			18.9	-40.9	-2.2	0.11			
Morocco	1992	2,795	2746			32.8	-48.9	-1.5	0.23			
Morocco	2003	6,555	3395	2.1	40.0	42.3	-30.6	-0.7	0.48	1.7	0.9	0.068
Mozambique	1997	3,012	451			10.3	-29.9	-2.9	0.06			
Mozambique	2003	6,736	606	5.8	45.8	15.5	-39.7	-2.9	0.06	-1.6	-1.0	0.000
Namibia	1992	2,029	4305			22.2	-53.3	-2.5	0.08			
Namibia	2006	4,841	5669	2.3	74.3	32.5	-49.2	-1.6	0.21	0.3	-0.1	0.065
Nepal	1996	3,187	829			1.7	-5.8	-3.4	0.03			
Nepal	2006	5,003	976	1.8	42.5	7.8	-25.9	-3.7	0.02	-2.0	-1.6	-0.028
Nicaragua	199	6,887	1925	2.9	52.1	47.0	-30.6	-0.7	0.52	-1.3	-0.9	-0.003

	7											
Nicaragua	2001	6,278	2145			54.3	-35.7	-0.7	0.52			
Niger	1998	3,173	607			8.3	-27.3		1.00			
Niger	2006	2,909	597	-0.1	40.5	14.9	-39.5	-3.0	0.05	-2.8	-0.5	-0.217
Peru	1992	4,986	4359			42.1	-30.5	-0.7	0.49			
Peru	2000	12,155	5513	3.3	45.6	51.4	-33.7	-0.7	0.52	-0.4	-0.7	0.006
Rwanda	2000	5,092	658			13.5	-15.9	-1.2	0.31			
Rwanda	2005	2,918	793	4.1	46.7	11.8	-16.5	-1.4	0.24	-0.1	0.2	-0.051
Tanzania	1996	3,597	826			13.3	-24.9	-1.9	0.15			
Tanzania	2004	5,776	990	2.5	34.2	18.2	-39.7	-2.2	0.11	-3.1	-1.4	-0.281
Turkey	199	2,222	8434	1.3	42.1	51.6	-21.2	-0.4	0.67	1.9	1.2	0.037

	3											
Turkey	2003	2,897	9505			61.5	-2.1	0.0	0.97			
Uganda	1995	2,968	666			9.4	-14.7	-1.6	0.20			
Uganda	2006	1,616	966	4.1	42.1	17.2	-37.6	-2.3	0.10	-2.1	-1.4	-0.066
Zambia	1996	3,558	1149			14.8	-26.2	-1.8	0.17			
Zambia	2007	3,981	1212	0.5	49.7	21.1	-47.6	-2.4	0.09	-1.9	-1.5	-0.056
Zimbabwe	1994	1,779	--			26.4	-28.6	-1.14	0.32			
Zimbabwe	2005	4,698	--	--	50.1	28.4	-47.1	-1.673	0.19	-1.7	-1.4	-0.048

§GDP is per capita and adjusted by the purchasing power parity method and adjusted for inflation using the $2005 International dollar as a base

§§Overweight is defined by BMI≥25 [37]

†A negative SII (log RII) indicates lower levels of overweight in the lower wealth groups, whereas a positive SII (log RII) means the lower levels of overweight in the higher wealth groups.

†† A positive change in the SII indicates a faster increase in overweight prevalence among the lower wealth groups and a decrease in the magnitude of the inequality in overweight in most cases (exception is Armenia). A negative change in SII indicates a faster increase in overweight prevalence among the higher wealth groups and an increase in the overall inequality in overweight. Annualized change in SII (log RII) is the SII (log RII) in the most recent year minus the SII in the initial survey year, divided by the number of years between the two measurements.

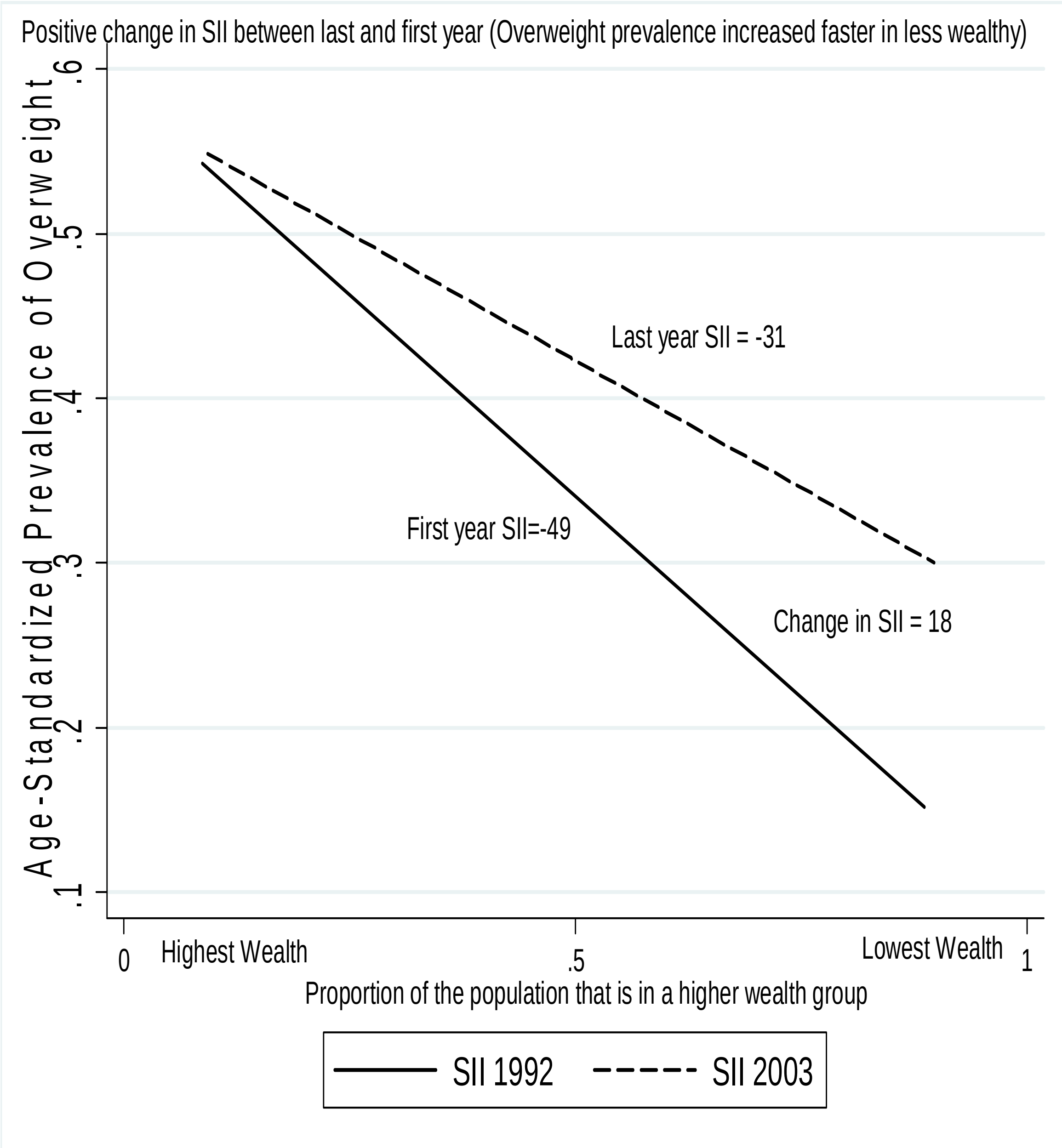
†††Annualized change in prevalence difference is the overweight prevalence in the first year minus that in the second year for the lowest wealth group minus the same prevalences in the highest wealth group.

Table 5 . Meta-regression of change in slope index of inequality for overweight on GDP+ and percent change in GDP

	Beta Coefficients (95% Confidence Interval)			
Variables	Model 1	Model 2	Model 3	Model 4
Baseline GDP (log)	0.93 (0.29, 1.56)	--	0.98 (0.37, 1.60)	0.86 (-0.08, 1.80)
Annualized Percent Change in GDP	--	0.09 (-0.04, 0.23)	0.11 (-0.01, 0.23)	-0.26 (-2.25, 1.74)
Baseline GDP (log) X Annualized Percent Change in GDP	--	--	--	0.05 (-0.23, 0.33)
Constant	-7.69 (-12.36, -3.02)	-1.22 (-1.91, -0.53)	-8.46 (-13.05, -3.87)	-7.52 (-14.44, -0.60)
N	37	37	37	37
Proportion of Between Study Variance Explained	17.9%	2.5%	23.5%	21.5%

+GDP is Gross Domestic Product per capita and adjusted by the purchasing power parity method and adjusted for inflation using the $2005 International dollar as a base

Figure 3. Illustration of SII, Change in SII and indications for SES-specific growth rates over time.



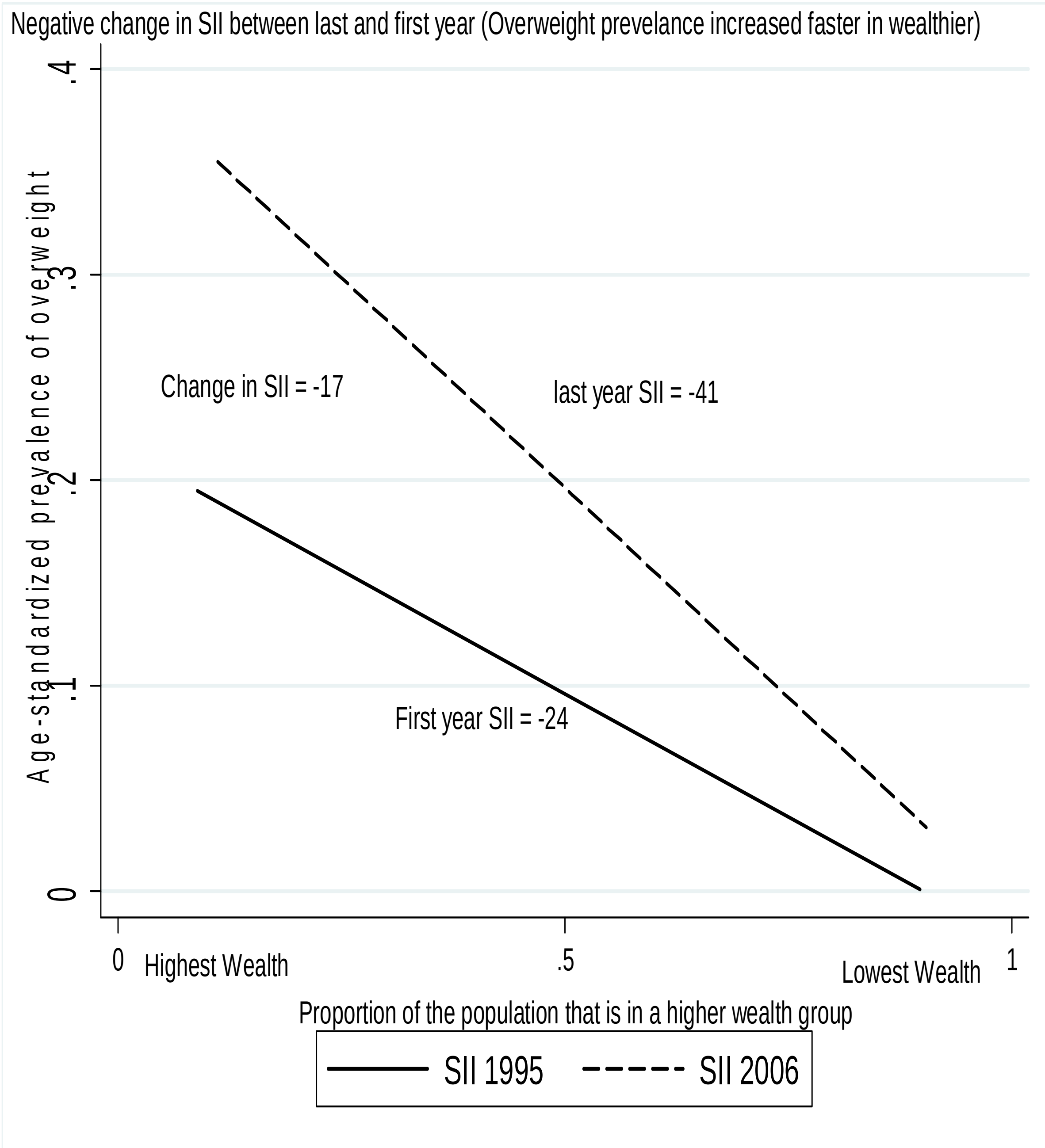

Negative change in SII between last and first year (Overweight prevelance increased faster in wealthier)
Age-standardized prevalence of overweight
0
.1
.2
.3
.4
Change in SII = -17
last year SII = -41
First year SII = -24
0
Highest Wealth
.5
Lowest Wealth
1
Proportion of the population that is in a higher wealth group
SII 1995
SII 2006

Figure 4. Annualized change in slope index of inequality for overweight between first and last survey year and 95% confidence interval, ordered according to first year GDP.

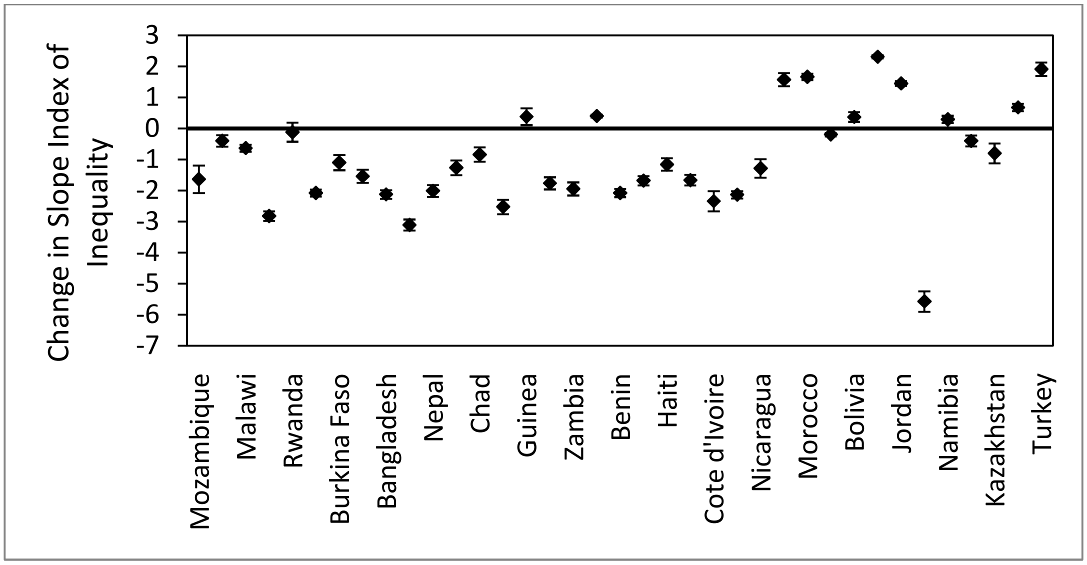
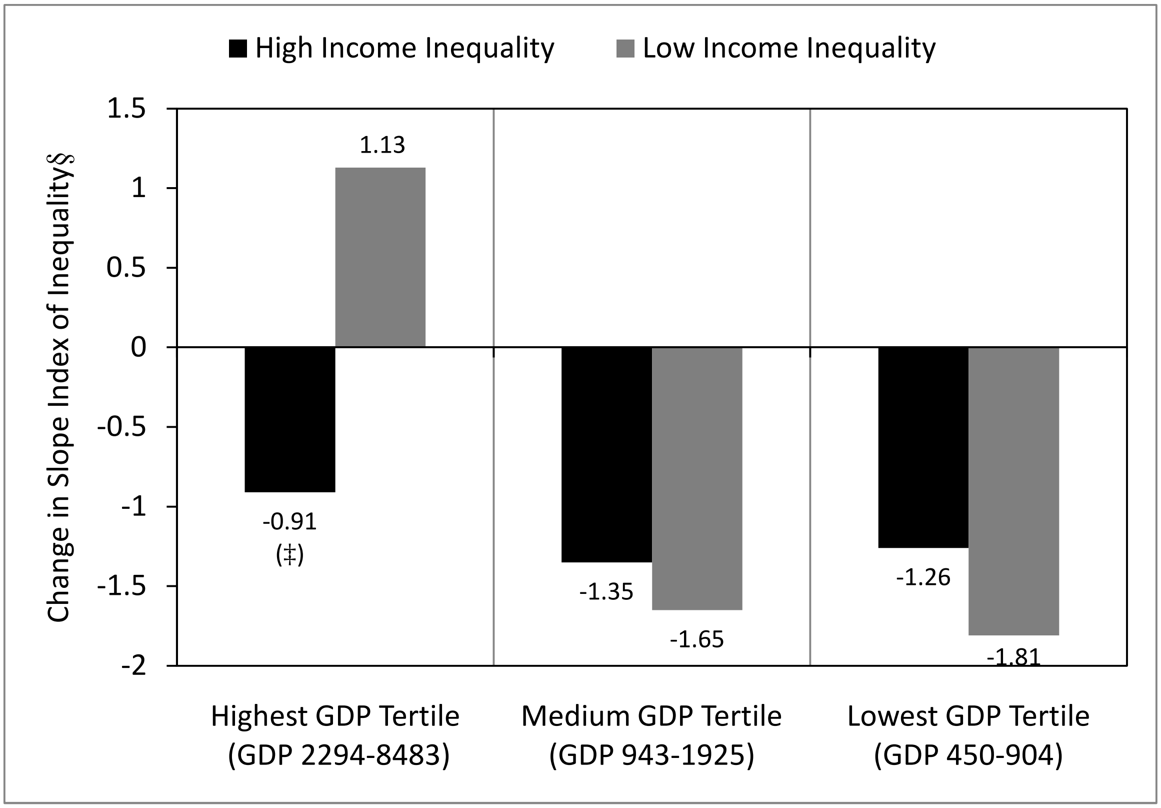


Figure 5. Predicted change in slope index of inequality in overweight by country-level GDP† and country-level of income inequality††.



†GDP is Gross Domestic Product per capita and adjusted by the purchasing power parity method and adjusted for inflation using the $2005 International dollar as a base. Baseline GDP was used to create GDP tertiles.

††Income inequality was represented by the Gini coefficient and dichotomized; low income inequality ranged 29.8-42.1 and high income inequality ranged 42.2-74.3.

‡ Estimate for highest GDP tertile & high income inequality countries is significantly different from estimate for highest GDP tertile & low income inequality.

§Negative change in the slope index of inequality in overweight represents faster overweight increase among higher wealth groups, while a positive change indicates faster increase in overweight among the lower wealth groups.

Sample countries fall into the following categories: Highest GDP Tertile/High Income Inequality: Bolivia, Colombia, Guatemala, Namibia, Peru; Highest GDP Tertile/Low Income Inequality:Armenia, Egypt, Indonesia, Jordan, Morocco, Turkey, Kazahkstan; Middle GDP Tertile/High Income Inequality: Cameroon, Guinea, Haiti, Kenya, Nicaragua, Zambia, Zimbabwe; Middle GDP Tertile/Low Income Inequality: Benin, Cambodia, China, Cote d'Ivoire, Ghana; Lowest GDP Tertile/High Income Inequality: Burkina Faso, Madagascar, Malawi, Mozambique, Nepal, Rwanda, Uganda; Lowest GDP Tertile/Low Income Inequality: Bangladesh, Chad, Ethiopia, Mali, Tanzania, Niger.

VII. THE EMERGENCE OF A DISPARITY IN OVERWEIGHT STATUS IN CHINA (1989-2006)

A. ABSTRACT

Background: Overweight prevalence has increased dramatically in China over the last 20 years. We test whether a disparity by socioeconomic status in overweight status has emerged among adult women and men in this context.

Objective: To longitudinally track the mean BMI and prevalence of overweight by socioeconomic status among Chinese adults (baseline age 18-50) from 1989 to 2006 to determine whether lower SES groups have experienced a disproportionately faster increase in BMI and overweight prevalence than those of high SES and to assess the Additionally, to test whether prospective odds of overweight between low and high SES groups change in direction or magnitude between the beginning and end of the survey.

Methods: Data from the China Health and Nutrition Survey from 7,314 women and 6,492 men are used to determine the unadjusted mean BMI, prevalence of overweight (BMI≥25) and odds of overweight by socioeconomic status (represented by educational attainment) for each survey wave. Random-effects models estimate the adjusted trajectories of BMI and odds of overweight by SES over the survey period (1989-2006). Models are sex-stratified and interactions by birth cohort (before or after 1960) are included.

Results: Overweight prevalence has doubled for women and tripled for men. Among women, the likelihood of overweight was not statistically significantly different for the highest versus the lowest either birth cohort in 1989; however, the rate of increase over time for mean BMI and the overweight were significantly lower for the highest education group compared to the lowest, such

that, by 2006, odds of overweight were significantly lower for the highest education group in both the younger (OR= 0.22; CI 0.11, 0.47) and older (OR=0.19; CI 0.09, 0.41) birth cohorts. The reverse trend is seen for men, who also begin with no difference in odds of overweight by SES, but by 2006, the odds ratio for the highest versus lowest education group was OR=3.5, CI 1.46, 8.13) (younger cohort) and OR=4.3, CI 1.86, 9.85 (older cohort).

Conclusions: The social distribution of overweight has changed over time in China such that low SES has become associated with higher BMI and likelihood of overweight factor for overweight among Chinese women, while high SES remains a risk factor for overweight among Chinese men.

B. BACKGROUND

Overweight prevalence varies by socioeconomic status in countries around the globe; however, the direction of this relationship appears to differ based on country-level economic development [13, 60]. In high-income countries, a robust inverse association between socioeconomic status and overweight prevalence among women has been established, while in lower income countries a positive association between overweight and SES predominates [1, 13, 60]. Recent studies suggest a tendency for the relatively higher burden of overweight to transition to low socioeconomic groups in association with economic development [1, 79]. If overweight does become inversely associated with socioeconomic status in transitioning societies it is of particular interest because, often in these societies, obesogenic environmental exposures are still more readily accessible to higher SES groups. The emergence of a disparity in overweight in such contexts would be consistent with a larger social process whereby predominant diseases persistently are associated with low socioeconomic status [8].

Theory suggests that social disparities may emerge where none previously existed because higher SES populations more readily adjust their preferences, choices and behaviors based on new stigma, new medical knowledge and treatments [11], while lower SES populations face more constraints in making the same health-preserving adjustments [7, 8]. This process of emerging and widening disparities under such conditions has been referred to as a "social shaping of disease" [11] that can best be investigated under conditions of large changes in disease burden, new diseases, new treatments for diseases or new stigma associated with disease [11]. For example, the epidemic increase in overweight among older adolescents in the US between the 1970s and 2000s was associated with the emergence of a social disparity in overweight prevalence by income among older teens where differences by income had previously not existed. In the early 1970s the prevalence of overweight was not significantly different, but by the early 2000s, the lowest SES individuals had a significantly higher prevalence [18]. Other examples of emerging health disparities in connection with a significant change in medical technology or behavior-related stigma, respectively, have been documented for smoking [8], cholesterol levels [84] and cocaine use [12].

We use China as a case study to investigate the “social shaping of disease” (in this case, overweight) in a rapidly developing country [11]. The dramatic increase in overweight prevalence in China over the past 20 years provides an excellent opportunity to investigate how the burden of overweight by social class may have changed over time [30]. China has experienced extremely rapid increases in economic development and national wealth over the last 20 years [31]. With this economic growth and market restructuring have come major changes in food and physical activity environments and norms [26, 32, 33]. Economic development is associated with improved medical knowledge and technologies as well as exposure to Western media, which is believed to influence desired body size, especially among women [21]. Conversely, researchers have documented a null or a positive association between SES and obesity among men [13, 20].

We hypothesize that a social disparity in the relative odds of overweight has emerged since the late 80s in China. Since an inverse relationship between SES and overweight seems to be particularly robust among women in developed countries around the world [13], we anticipate higher BMIs and overweight in women of high SES in the that in the late 80s and early 90s, high SES women will have higher or equal mean body mass index (BMI) and odds of overweight, transitioning to higher mean BMI and higher odds of overweight in low SES women by 2006. Furthermore, we hypothesize continual gains in BMI among individuals of low SES, and reduced gains or a leveling-off of gains over time among individuals of high SES. We further hypothesize sex differences with higher or equivalent gains in BMI and overweight risk for high SES men compared to lower SES men.

C. METHODS

STUDY POPULATION

Data come from the China Health and Nutrition Survey (CHNS) which began data collection in 1989 and has been implemented every 2 to 3 years since, resulting in 7 observational periods and the most recently available data coming at 2006. The CHNS uses a multistage cluster sample design to survey individuals within nine provinces in China. To obtain the sample from these nine provinces, the counties inside the provinces were stratified by income then a weighted sample of four cities or counties was selected. Within these areas, neighborhoods were randomly selected and within the neighborhoods, households were selected randomly from a community household roster and all members in each household were interviewed. The household roster was used to follow up each of the originally sampled households as well as new households formed from previous households for subsequent survey panels. The baseline sample was representative of each province but over time, loss-to-follow up has occurred [48]. The study protocols have been approved by the University of North Carolina at Chapel Hill and the Chinese Center for Disease Control Internal Review Boards.

The CHNS includes individual, household, and community level surveys conducted by trained field workers; the current analysis utilizes information from each of these surveys.

Our analyses are limited to non-pregnant women and men who were surveyed at least one time and were younger than 50 years at their first included measurement and older than 18 years during at least one of the survey waves (measurements from age 18 and above are included for individuals who aged into our eligible sample). Of the 7789 eligible women, 7314 (94%) were included in the analyses; missingness was due to BMI (n=372), education (n=95), age (n=8). For men, of the 7141 eligible, 6492 (91%) were included in the analysis; missingness was due to BMI (n=345), education (n=27), age (n=10), and smoking (266). The average number of measurements per person is 3.2 for women and 2.9 for men.

DEPENDENT VARIABLES

Height and weight were directly measured using standard techniques and portable equipment. BMI (weight (kg)/(height (m)^2)) was used in its continuous form and also for overweight (BMI≥25) classification according to WHO guidelines [37]. The prevalence of overweight (BMI≥25) according to socioeconomic status was calculated for each survey wave. Although lower BMI cutpoints have been established as “action points” for disease risk in Asian populations, it is still recommended to use the standard cutpoints to enable international comparisons of overweight and obesity prevalence [38].

INDEPENDENT VARIABLES

Key Explanatory Variables

Our key independent variables of interest are SES and time. We use education level to represent SES in our main analyses since, in general, education is believed to generally reflect social circumstance, particularly in lower income countries where the most disadvantaged groups may attend very little formal schooling [85]. Additionally, attained education is typically correlated to some degree with earnings another indicator of socioeconomic status [85]. Furthermore, there was a great deal of fluctuation into and out of income tertiles among families over the survey period, so we chose to focus on education as our indicator of SES, since it is more stable within individuals over the survey period. Highest level of education was ascertained for each individual at each survey wave. Categories of education attainment were formed as follows: 1) less than primary school completed 2) primary school completed 3) secondary school completed 4) more than secondary school completed.

Since our hypothesis concerns the rate of BMI/overweight increase over time, we include calendar year to represent time and interact it with education group in the regression models to assess the education group-specific growth in BMI/overweight risk over time. In the regression analyses, calendar time is recoded from 0 (1989) to 17 (2006) and is entered as an ordinal variable. Descriptive means, lowess curves and the testing of a squared term examined the assumption of a linear increase in BMI over time.

EFFECT MEASURE MODIFIERS AND COVARIATES

Age was calculated from birthdate by adjusting all birthdates to the Western calendar. We hypothesized that birth cohort and urbanicity might modify the effect of SES on obesity. Due to the fact that China has undergone major upheavals and social change during distinct historical periods, such as the Great Leap Forward and Famine in the 1950s, the Cultural Revolution in from the mid-1960s to 1970s and then the post-Maoist reforms from the late 1970s onward [49] we hypothesize that growing up in different eras may modify the SES-overweight relation and its change over time. Birth cohort was categorized into 2 levels to keep adequate sample size yet distinguish between populations growing up during different periods in China. The sample was divided between participants born between 1939-1959 (inclusive) and those born in 1960 or later.

Urbanicity has been an important dimension along which health outcomes have varied in the developing world and in China in particular [30, 50-54], so we hypothesize that the SES-overweight relation and its change over time might also vary by level of urbancity. If the relationship of interest did not vary by urbanicity, we consider it a confounder since it is likely associated with education attainment and BMI levels.

We use our own urbanicity scale, which we have assessed for validity and reliability, to indicate community-level urbanicity represented by infrastructure, sanitation, transportation, social services, occupations and wages, commercial markets and communications [51]. Each community receives a time-varying urbanicity value ranging potentially from 0-130 points, which is used in its continuous form in the analyses.

Current smoking habits were ascertained in each survey except the first survey in 1989. Since smoking is quite rare among women in this context (see Table 6 for smoking prevalence among women in 2006) and since its inclusion results in the loss of observations from 1989, we include smoking as a covariate in the male analyses only.

STATISTICAL ANALYSES

We determined sex-stratified prevalence of overweight for each education group determined by dividing the number of participants with BMI≥25 by the total eligible sample for each survey wave. Bivariate odds ratios of overweight for each survey wave were estimated by logistic regression of overweight status on education group (modeled with indicator variables) in sex-stratified models.

To estimate the average BMI growth rate over time according to education group, we employ random-effects linear models of repeated BMI measurements over the survey period. We used comparable random-effects logistic regression models to estimate the education-specific increase in overweigh over the study time period. Random-effects models maximize the number of observations and people included in our models since these models do not require that every participant has outcome measurements at all time points; they incorporate all available measurements from each subject and do not exclude subjects who might be missing one or more measurements. These models do assume that the covariates are exongenous. For time-varying variables, the random effects generalized least squares estimator employs a weighted average of the between and within cluster effects [86]. In our models the “cluster” is each individual, inside which, repeated measurements are nested. Additional clustering by household and community are accounted for with the use of the Huber-White robust standard errors [86, 87]. Descriptive means, lowess curves and the testing of a squared term were used to examine the assumption of linear increases in BMI over time.

Finally, given demonstrated variation in the association between SES and BMI by sex [13, 20], we stratify our analyses by sex.

Our main variables of interest are education category (represented by indicator variables) and its interaction with time (represented by ordinal calendar year recoded from 0-17) in order to test whether the average BMI growth over time differs by educational category. Subject-specific mean age and mean age squared over the survey time period were entered as covariates. Mean age was used rather than actual age at each time point so that the effect of age is the between-subject effect of age. The coefficient on calendar time then reflects the passage of time within and between subjects.

Since we hypothesized that birth cohort and/or urbanicity might modify the effect of the education specific growth rates, we tested the significance of a three-way interaction between birth cohort and education and time as well urbanicity, education and time. In addition to the three-way interactions, we included all the lower order two-way interactions between the three variables and their main effects along with the covariates. We also interacted age and age squared with birth cohort and birth cohort with urbanicity. Neither of the three-way interactions were significant, so we tested the remaining two-way interactions against the model with all two-way interactions included. After retaining the significant interactions, we tested the assumption that the between and within effects for the time-varying variables of time, time by education group, and urbanicity were not statistically different by including the original variable and the person-specific mean of each variable and testing the significance of the coefficient on the person-specific mean variable [86]. The coefficient on the variable for the person-specific mean represents the difference between the between and within effects for each variable. These tests address the assumption of random effects models that the between and within subject effect are equivalent [86].

The final linear and logistic regression models for women and men differ slightly based on the significance of the various interaction terms in each model. For women, all of the interactions between birth cohort and education, urbanicity, age and age squared were retained due to statistical significance. The tests of statistical equivalence of the between and within effects for time and urbanicity led to the inclusion of both the main effect and the between effect for urbanicity and time. The final model for females is shown in the following equation (for simplicity, we describe only the linear model, while the logistic model follows the same specification), where *i* indicates subject and *t* indicates occasion, and ζ is the between-subject error term while ε is the within subject residual error

$$
\begin{aligned}
BMI_{it} &= \alpha + \beta_1(primaryschool)_{it} + \beta_2(\sec ondaryschool)_{it} + \beta_3(>\sec ondaryschool)_{it} + \beta_4(time)_t \\
&+ \beta_5(timeXprimary)_{it} + \beta_6(timeX\sec ondary)_{it} + \beta_7(timeX>\sec ondary)_{it} + \beta_8(\overline{age})_i \\
&+ \beta_8(\overline{agesquared})_i + \beta_9(cohort)_i + \beta_{10}(\overline{age}Xcohort)_i + \beta_{11}(\overline{agesquared}Xcohort)_i \\
&+ \beta_{12}(cohortXprimary)_i + \beta_{13}(cohortX\sec ondary)_i + \beta_{14}(cohortX>\sec ondary)_i \\
&+ \beta_{15}(urbanicity)_{it} + \beta_{16}(\overline{urbanicity})_i + \beta_{17}(cohortXurbanicity)_{it} + \beta_{18}(cohortX\overline{urbanicity})_i \\
&+ \beta_{19}(\overline{time})_i + \zeta_i + \varepsilon_{it}
\end{aligned}
$$

For males, the interaction between birth cohort and time was retained while the interactions between birth cohort and age and age squared were not included. Additionally, for males, we included smoking as a covariate and we included a quadratic term for time to allow for curvilinearity due to statistical significance of this term. We retained the person mean and occasion-specific deviation from the cluster mean for urbanicity only.

The random effects model included a random intercept for each participant to account for the correlation between BMI measurements within the same person over time. Robust standard errors accounted for the potential correlation of BMI between people of the same household or community and for heteroskedasticity of residuals at the lowest level (occasion) [86, 87]. Cluster-level standardized residuals were approximately normally distributed.

Again, random effects logistic regression models with the same specifications as linear models for female and male models were used to estimate the education-specific growth rate in the odds of overweight over the study time period. Model coefficients and post-estimation tests of confidence intervals were used to graph the predicted odds of overweight by education group.

SENSITIVITY ANALYSES

For sensitivity analyses, we add per capita household income as a covariate to the final linear and logistic models to see if the results change after controlling for income. Our interest in doing this was as a basic test that the association between SES, represented by education, was not entirely attributable to a different SES dimension, income. However, we weren't necessarily interested in isolating the effect of education independent of income, and, further, income is arguably at least partially a result of education, and therefore potentially on the causal pathway between education and BMI. The CHNS queried multiple sources of income and these were combined and adjusted for inflation to form the per capita measure of household income.

Additionally, we calculated sex-stratified overweight incidence density (cases/person-years at risk) and ran an unadjusted Cox proportional hazards model to see whether the overweight incidence density and hazard rates were in the same direction and of same significance to the prevalence rates at the end of the survey. We chose to focus the main analyses on prevalence odds ratios and BMI trajectories over time since our research question specifically is concerned with tracking trends over time and since focusing on incidence substantially decreased the sample size, due to the elimination of all new prevalent cases at each wave.

All analyses were performed in Stata 11 [88]. *Alpha* was set at 0.05 for main effects and 0.10 for interactions. For linear models, model estimation was performed using *xtreg* with generalized least squares random-effects estimation and robust standard errors. *Gllamm* was used to check the distribution of level-1 and level-2 standardized residuals [86]. For logistic models, *gllamm* with adaptive quadrature was used for the final models [86]; the number of integration points for the adaptive quadrature were increased until estimates in last two consecutive models and the log likelihoods were almost identical (most models required 28 integration points).

D. RESULTS

Overweight more than doubled in women and more than tripled in men from baseline to final follow-up (Table 6). Household income (adjusted for inflation) also increased for all education groups, as did community level urbanicity.

Among women, unadjusted mean BMI levels also increased for all education groups, but least so for the highest education group (Table 7). Similarly, the education specific prevalence of overweight increased over the survey period for all groups, with the largest increase in those with less than a primary school education. Additionally, the bivariate odds ratios for overweight were not statistically significantly different between all education groups in1989, but by 2006 the highest education group had a statistically significantly lower odds of overweight compared to each other education group.

Quite different trends were seen among men. Mean BMI and overweight increased for all education groups; however, in men, the highest education group had the largest increases in BMI and overweight. Likewise, during every survey year, the unadjusted odds for overweight was significantly higher in the highest education group (Table 8).

BMI AND OVERWEIGHT FINDINGS IN FEMALES

Does the increase in BMI differ by education level for females?

Using longitudinal random effects regression models we estimated of the education-specific BMI increases per year while controlling for confounders and used these estimates to plot predicted BMI trajectories (Figure 6).

Among women in both cohorts, the predicted rate of increase in BMI was lower in those of highest versus lowerst education ($ß_{year*highest\ ed}$: -0.03 (CI -0.08, -0.01) (Table 9). Additionally, the predicted BMI growth rate among those with the highest education was also lower than those with only secondary school education (ß -0.06 (CI -0.09, -0.03) and those with only primary school (ß -0.05 (CI -0.08, -0.03).

At the beginning of the survey, the predicted BMI for the highest education compared to the lowest was 0.41 (CI -0.80, -0.02) units lower for the younger cohort and not significantly lower for the older cohort (ß -0.30 (CI -0.77, 0.17). This difference increased to almost one BMI unit lower for the young cohort by 2006 (ß -0.92 (CI-1.29, -0.56) and 0.81 BMI units lower for the older cohort (ß -0.81 (CI -1.26, -0.36)) (Figure 6).

Does the increase in overweight per year differ by education level for females?

We found similar results for the rate of increase in the odds of overweight by education group for women (Table 10). Again, the highest education group experienced a significantly lower rate of increase (8% lower) in the odds of overweight compared to other education groups. At baseline, the odds of overweight between the highest and lowest education groups were not significantly different for the younger (OR 0.93 (CI 0.37, 2.3) or the older (OR 0.79 (CI 0.31, 2.02) cohorts. However, by 2006, odds ratio for overweight for the highest versus the lowest education groups was OR 0.22 (CI 0.11, 0.47) for the younger cohort and OR 0.19 (CI 0.09, 0.41) for the older cohort. The predicted trajectories of the odds ratio of overweight for women in the highest education group compared to each other education group are plotted in Figure 7.

BMI AND OVERWEIGHT FINDINGS IN MALES

Does the growth rate of BMI differ by education level for males?

Among men the predicted rate of increase in BMI is higher per year for the highest education group compared to the lowest education group ($ß_{year*highest\ ed}$ 0.07 (CI 0.04, 0.10) (Table 9). The growth rate for highest education group is also statistically significantly higher than that of the primary school (ß 0.03 (CI 0.003, 0.06)) and secondary school (ß 0.03 (CI 0.002, 0.06)). At baseline, predicted mean BMIs for men with the highest versus lowest education are not statistically different (younger cohort: ß -0.28 (CI -0.76, 0.19) and older cohort: ß 0.08 (CI -0.39, 0.56)). However, by 2006, the mean in BMI for men with the highest versus the lowest education is nearly a whole BMI unit higher (ß 0.90 (CI 0.44, 1.35) for the younger cohort and 1.27 units higher for the older cohort (CI 0.81, 1.72) (Figure 8).

Does the increase in overweight per year differ by education level for males?

For males, the rate of increase in odds of overweight over the survey period for the highest education group was positive, but not statistically significantly higher than that of the lowest education group. At baseline, for the younger cohort men, the odds of overweight were not statistically significantly different for the highest versus the lowest education groups (Table 10), and by 2006 the odds were statistically significantly higher for the highest education group compared to the lowest (OR 3.5 (CI 1.46, 8.13)). However, for the older cohort, by 2006, the odds of overweight in the highest education group were statistically significantly higher than that in the lowest education group (OR 4.3 (CI 1.86, 9.86)) (Figure 9).

SENSITIVITY ANALYSES

Controlling for income in all analyses resulted in virtually no change to model estimates (Table 9 for linear; results not shown for logistic). This reassures us that the association we are attributing to education as a marker of SES is not better attributed to income.

The overweight incidence density over the survey period was 2.1 cases per 100 person-years for the highest education group and 2.8 cases per 100 person-years for the lowest education group. The unadjusted hazard ratio of overweight was lower for the highest education group versus the lowest education group (HR 0.72 (CI 0.54, 0.97) for women. In men, those with the highest versus the lowest education had a higher hazard of overweight (HR 3.43 (CI 2.64, 4.46)) for men. The incidence results are consistent in terms of direction and significance with our primary analyses of prevalence.

E. DISCUSSION

Over the last 2 decades, Chinese women experienced an emergence of a disparity in overweight by SES. Whereas there were no disparities in overweight in 1989, by 2006, the disparity was readily evident with higher overweight in women with lower education levels. For men, we observe the opposite, with the most educated men having higher levels of overweight by 2006.

Aside from research in Brazil, China is the only other large lower income country in which body size dynamics have been rigorously studied [16]. Our study adds to a small body of literature that traces the social distributions of various conditions over time within a given population to investigate the emergence of health disparities and to document the persistence of SES as a persistent determinant of disease, despite changes in the predominant diseases [6, 12, 18, 84]. These types of studies enhance a large body of literature that documents a robust cross-sectional inverse relationship between socioeconomic status and disease at a given point in time by providing a dynamic view and a “natural history” of how health disparities emerge in situations of changing disease burden, medical technologies and/or stigma. New disparities in overweight/obesity in which the higher SES classes now have lower rates of overweight, have been documented in the US among adolescents [18] and among women in Brazil [16]. Our study improves upon these important studies by following individuals longitudinally over time rather than relying solely on repeated cross-sectional data. Our findings among women are similar to these repeated cross-sectional cases in which, concomitant with the rapid increase in total overweight/obesity, the growth of overweight/obesity prevalence over time in the lowest SES groups outpaces that of the highest and results in an inverse relationship between SES and overweight, where the relationship had previously been positive or null.

Potential explanations for our findings would have to account for the male-female difference in the trends among high SES individuals as well as the high-low SES trends among women. Specifically, the ready explanation that relies on exposure to risk factors for obesity, such as sedentary work and lifestyle and energy-dense foods does not seem to offer a great explanation by itself. Specifically, the high income men and women are likely exposed to relatively similar access to energy-dense foods, sedentary occupations and energy-saving modern conveniences, yet high SES women experienced a slowed growth rate while high SES men experienced an increased rate of growth BMI gains odds of overweight. Access to energy-dense foods, sedentary occupations, and labor-saving devices is likely still more limited for the low SES women in comparison to the high SES women in this context. Taken together, the divergent patterns among high income men and women and high versus low SES women seem to implicate other factors motivating the purposeful behavior to curb BMI growth among high SES women. Women with high SES might enact behaviors to limit BMI gains due to either health concerns and health knowledge or to stigma associated with larger BMI. Changing health concerns could prompt changes in women's behavior before men's, but we speculate that stigma around body size might be the initial motivating factor among women in this context.

We speculate that stigma around larger body sizes likely exists for women and that highly educated women have the means to achieve thinner body shapes in what has become an increasingly obesogenic environment in modern China [30, 33, 89]. The role of sex-specific stigma and desired body size has previously been speculated as a rationale for the difference in the associations between SES and body size between males and females [13, 90]. This study did not directly test this speculation; however, limited evidence suggests that the desired body size among Chinese women has been for a tall and thin body since the 1970s [91] and that Chinese girls currently on average express a desire for a thinner body [90, 92]. The CHNS began asking children aged 6-18 to identify their ideal body shape from a series of nine silhouettes in 2000 ranked from thinnest to least thin. Among girls, the mean response was 3.8 (0.035) in 2000 and decreased to 3.5 (0.05) in 2006, a statistically significant decrease. It's possible that stigma around larger body sizes for men does not exist, is not as strong, or has come into existence only recently

The emergence of this disparity in overweight by education group among women, during a time in which the overall prevalence of overweight doubled for women and in which the food and physical activity environments rapidly changed, seems to implicate a difference in response to a rapidly changing food environment by socioeconomic status group. One prominent sociological theory regarding the formation of health disparities, fundamental cause theory, has proposed that health disparities emerge in part because the highest SES groups purposefully utilize their resources to prevent or treat disease in response to changing disease burden or changing stigma associated with disease [8, 11]. The slower growth in BMI and overweight risk among the highly educated women while all other groups, including men, experienced substantially higher gains is consistent with this hypothesis and seems to implicate a purposeful process in this group. It will be informative to continue to follow the social distribution of overweight among men in this context in future years to see if the higher SES men eventually also experience a lower odds of overweight. Further research that explores how these same changes are linked with dietary and physical activity patterns as well as other BMI-related behaviors (e.g. smoking) is also needed.

Limitations of this study should be noted. First, although this is a longitudinal study, not every participant was interviewed at every survey wave. Attrition occurred due to loss-to-follow-up as well as to a natural disaster that resulted in the loss of one province from the sample in 1997. An advantage of CHNS is that new participants were recruited to the study to replace those lost by following the same random sampling procedures as the initial sample selection. Our use of random effects statistical analysis allows us to incorporate all available measurements from all participants, thereby decreasing the possibility of attrition bias since participants with 1-7 measurements and covariates are all included in the analyses (we include 94% of eligible women and 91% of eligible men; those excluded have no measurements with full covariates). The trade-off is that the effect estimates are obtained from a weighted average of the between subject (cross-sectional) and within-subject (longitudinal) effects and the assumption that these are equal is made. We employ checks of these assumptions as described in the methods, which are satisfied.

Second, education is our measure of SES, which only addresses one aspect of SES; future work to explore additional dimensions of SES in this context will be informative. We tested whether our results would remain the same if we added an additional control for income, finding virtually unchanged estimates. Although mean income does increase with education level, income and education have a correlation of only 0.25, which does not preclude inclusion of both in our models.

CONCLUSION

The doubling and tripling of overweight prevalence in women and men, respectively, in China has been accompanied by a shift in the social distribution of this overweight among women. We found women of lower education had rate of increase in BMI that was 0.03-0.06 BMI units higher per year compared to those with the highest education levels. Our work concurs with other predictions that the burden of chronic diseases, such as overweight, might shift toward the lowest social classes even in developing countries where higher SES individuals have historically had higher comparative risks for such diseases. Low SES populations in low-income countries are particularly vulnerable to the deleterious consequences of comorbidities associated chronic disease since they lack access to adequate medical coverage and other health-promoting resources.

Table 6. Selected Sample Characteristics for First and Last Survey Year by Sex (1989 & 2006)

Women

1989	**Overall**	**<Primary School**	**Primary School**	**Secondary school**	**>Secondary school**
N	2642	844	1362	316	120
Age	32 (0.2)	35 (0.3)	30 (0.3)	29 (0.3)	30 (0.8)
BMI	21.8 (0.1)	22.0 (0.1)	21.8 (0.1)	21.4 (0.2)	21.4 (0.2)
Overweight %(N)*	11 (290)	12 (101)	12 (163)	11 (35)	9 (28)
Obese %(N)*	1 (26)	1 (8)	1 (14)	0 (0)	3 (9)
Urban Index	44 (1.2)	36 (1.0)	45 (1.3)	54 (1.4)	63 (1.5)
Household Income per capita (Yuan)+	2,587 (99)	2,124 (141)	2,643 (112)	3,152 (188)	3,719 (260)
Current Smoker	NA	NA	NA	NA	NA

2006					
N	3663	881	1866	460	456
Age	44 (0.2)	52 (0.3)	42 (0.3)	42 (0.5)	37 (0.8)
BMI	23.4 (0.1)	23.8 (0.2)	23.5 (0.1)	23.3 (0.3)	21.9 (0.2)
Overweight %(N)	27 (989)	33 (290)	29 (541)	25 (115)	13 (59)
Obese%(N)	5 (183)	4 (35)	6 (112)	4 (4.6)	2 (0.09)
Urban Index	63 (1.4)	54 (1.6)	60 (1.4)	74 (1.5)	82 (1.3)
Household Income per capita (Yuan)	7,222 (349)	5,621 (442)	6,405 (278)	7,739 (531)	13,086 (1,193)
Current Smoker %(N)	5 (183)	9 (79)	5 (93)	3 (14)	2 (9)

Men

1989					
N	2191	303	1401	303	141
Age	32 (0.2)	35 (0.5)	32 (0.2)	30 (0.3)	34 (0.8)
BMI	21 (0.1)	21 (0.1)	21 (0.1)	21 (0.1)	22 (0.2)
Overweight %(N)	7 (153)	5 (15)	6 (84)	8 (24)	11 (15)
Obese %(N)	0.3 (7)	0 (0)	0.4 (6)	0.3 (1)	0 (0)
Urban Index	43 (1.2)	36 (1.2)	42 (1.2)	48 (1.7)	64 (1.6)
Household Income per capita	2,499	1,835	2,501	2,837	
(Yuan)	(100)	(140)	(114)	(161)	3,364 (144)
Current Smoker %(N)	NA	NA	NA	NA	NA
2006					
N	3307	314	1845	609	539
Age	43 (0.3)	51 (0.6)	44 (0.3)	42 (0.5)	39 (0.8)
BMI	23.4 (0.1)	22.6 (0.2)	23.2 (0.1)	23.6 (0.1)	24.2 (0.2)
Overweight%(N)	27 (893)	18 (56)	25 (461)	30 (183)	37 (199)
Obese%(N)	4 (132)	2 (6)	4 (74)	4 (24)	6 (32)
Urban Index	63 (1.4)	54 (1.9)	59 (1.4)	68 (1.5)	80 (1.4)
Household Income per capita	7,574	5,173	6,306	8,036	
(Yuan)	(355)	(576)	(289)	(484)	12,767 (968)
Current Smoker%(N)	79 (2612)	88 (276)	82 (1512)	77 (469)	67 (361)

*Overweight defined as BMI≥25 and Obese as BMI≥30 [37]

+Household income is adjusted for inflation

Table 7. Mean BMI, Prevalence of Overweight* and Unadjusted Odds Ratios for Overweight for Women by Education and Year

Year (N)	**1989** (n=2642)	**1991** (n=3229)	**1993** (n=3079)	**1997** (n=3211)	**2000** (n=3679)	**2004** (n=3565)	**2006** (n=3663)
Mean BMI							
<Primary	22.03 (0.12)	22.08 (0.14)	22.28 (0.14)	22.68 (0.16)	23.22 (0.15)	23.67 (0.20)	23.76 (0.16)
Primary school	21.77 (0.09)	21.77 (0.10)	21.92 (0.10)	22.44 (0.10)	22.98 (0.11)	23.45 (0.13)	23.55 (0.13)
Secondary	21.43 (0.17)	21.17 (0.15)	21.47 (0.17)	22.04 (0.15)	22.68 (0.17)	22.97 (0.25)	23.32 (0.26)
>Secondary	21.37 (0.24)	21.69 (0.25)	21.57 (0.28)	21.80 (0.20)	21.84 (0.21)	22.34 (0.28)	21.94 (0.22)
Proportion							
<Primary	0.12 (0.01)	0.14 (0.02)	0.17 (0.02)	0.22 (0.02)	0.27 (0.02)	0.32 (0.02)	0.33 (0.02)
Primary school	0.12 (0.01)	0.13 (0.01)	0.13 (0.01)	0.19 (0.01)	0.24 (0.01)	0.28 (0.01)	0.29 (0.01)
Secondary	0.11 (0.02)	0.11 (0.02)	0.12 (0.02)	0.13 (0.02)	0.19 (0.02)	0.23 (0.02)	0.25 (0.02)
>Secondary	0.09 (0.03)	0.14 (0.03)	0.12 (0.03)	0.13 (0.02)	0.15 (0.02)	0.17 (0.02)	0.13 (0.02)
Odds Ratios							
<Primary	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Primary school	0.97 (0.74, 1.27)	0.93 (0.74, 1.18)	**0.69 (0.55, 0.86)**	0.84 (0.68, 1.02)	0.87 (0.72, 1.04)	0.82 (0.68, 0.98)	0.82 (0.69, 0.98)
Secondary	0.97 (0.64, 1.45)	0.78 (0.54, 1.12)	0.67 (0.47, 0.95)	**0.54 (0.38, 0.75)**	**0.63 (0.47, 0.83)**	0.62 (0.47, 0.81)	0.69 (0.54, 0.89)
>Secondary	0.76 (0.39, 1.46)	1.00 (0.59, 1.69)	**0.62 (0.35, 1.09)**	0.55 (0.36, 0.84)	**0.47 (0.33, 0.66)**	**0.42 (0.31, 0.58)**	**0.31 (0.23, 0.43)**

*Overweight defined as BMI≥25

Table 8. Mean BMI, Prevalence of Overweight* and Unadjusted Odds Ratios for Overweight for Men by Education and Year

Year (N)	1989 (n=2191)	1991 (n=2938)	1993 (n=2846)	1997 (n=3092)	2000 (n=3440)	2004 (n=3330)	2006 (n=3307)
Education Level							
Mean BMI (SE)							
<Primary School	21.23 (0.14)	21.16 (0.14)	21.43 (0.15)	21.74 (0.17)	22.21 (0.19)	22.08 (0.22)	22.59 (0.17)
Primary school	21.21 (0.10)	21.31 (0.09)	21.54 (0.08)	21.93 (0.10)	22.45 (0.10)	23.11 (0.13)	23.19 (0.12)
Secondary school	21.46 (0.14)	21.53 (0.14)	21.83 (0.13)	22.51 (0.15)	23.02 (0.15)	23.50 (0.16)	23.64 (0.15)
>Secondary school	21.77 (0.21)	22.13 (0.19)	22.54 (0.26)	23.17 (0.26)	23.52 (0.20)	24.14 (0.23)	24.20 (0.24)
Proportion Overweight (SE)							
<Primary School	0.05 (0.01)	0.06 (0.01)	0.08 (0.02)	0.11 (0.02)	0.14 (0.02)	0.16 (0.03)	0.18 (0.02)
Primary school	0.06 (0.01)	0.07 (0.01)	0.09 (0.01)	0.12 (0.01)	0.18 (0.01)	0.23 (0.01)	0.25 (0.01)
Secondary	0.08	0.09	0.12	0.20	0.25	0.31	0.30

school	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
>Secondary school	0.11 (0.02)	0.14 (0.02)	0.21 (0.03)	0.28 (0.03)	0.36 (0.03)	0.34 (0.03)	0.37 (0.02)
Odds Ratios (95% CI)							
<Primary School	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Primary school	1.38 (0.80, 2.39)	1.19 (0.77, 1.85)	1.05 (0.67, 1.62)	1.20 (0.81, 1.77)	1.37 (0.94, 1.99)	1.57 (1.05, 2.35)	1.52 (1.12, 2.07)
Secondary school	1.86 (0.97, 3.54)	1.52 (0.91, 2.54)	1.48 (0.90, 2.43)	**2.15 (1.41, 3.28)**	**2.07 (1.38, 3.11)**	**2.44 (1.59, 3.73)**	1.92 (1.37, 2.69)
>Secondary school	**2.64 (1.28, 5.44)**	**2.39 (1.34, 4.27)**	**3.03 (1.75, 5.26)**	**3.31 (2.09, 5.23)**	**3.48 (2.30, 5.28)**	**2.80 (1.81, 4.34)**	**2.60 (1.86, 3.64)**

*Overweight defined as BMI≥25

Table 9. Random effects linear regression models of the association between education and BMI over survey period

	Females		Males	
	Final Model	Final Model + Income	Final Model	Final Model + Income
	ß (95% Confidence Interval)	ß (95% Confidence Interval)	ß (95% Confidence Interval)	ß (95% Confidence Interval)
<Primary School	Referent	Referent	Referent	Referent
Primary School	-0.23 (-0.46, 0.01)	-0.21 (-0.44, 0.02)	-0.42 (-0.73, -0.11)	-0.41 (-0.74, -0.09)
Secondary School	-0.59 (-0.92, -0.27)	-0.58 (-0.91, -0.25)	-0.19 (-0.56, 0.17)	-0.19 (-0.56, 0.18)
>Secondary School	-0.41 (-0.80, -0.02)	-0.39 (-0.79, 0.01)	-0.28 (-0.76, 0.19)	-0.23 (-0.72, 0.26)
Time X Primary School	0.02 (0.01, 0.04)	0.02 (0.01, 0.04)	0.04 (0.02, 0.06)	0.04 (0.02, 0.06)
Time X Secondary School	0.03 (0.01, 0.05)	0.03 (0.00, 0.05)	0.04 (0.02, 0.06)	0.04 (0.02, 0.06)
Time X >Secondary School	-0.03 (-0.06, -0.01)	-0.03 (-0.06, -0.01)	0.07 (0.04, 0.10)	0.06 (0.03, 0.09)
Time	0.11 (0.09, 0.12)	0.11 (0.10, 0.12)	0.15 (0.12, 0.19)	0.16 (0.12, 0.19)
Mean* Time	-0.09 (-0.11, -0.07)	-0.09 (-0.11, -0.07)	-	-

Time Squared	-	-	-0.002 (-0.004, -0.001)	-0.002 (-0.004, -0.001)
Birth Cohort (1= before 1960)	-7.25 (-13.75, -0.75)	-6.93 (-13.44, -0.41)	-1.34 (-1.92, -0.76)	-0.30 (-0.68, 0.09)
Birth Cohort X Time	-		-0.06 (-0.08, -0.04)	-1.30 (-1.89, -0.72)
Birth Cohort X Primary School	0.10 (-0.18, 0.38)	0.10 (-0.19, 0.38)	0.32 (-0.03, 0.67)	-0.06 (-0.08, -0.04)
Birth Cohort X Seconday School	0.38 (-0.13, 0.90)	0.37 (-0.15, 0.89)	0.46 (0.03, 0.88)	0.31 (-0.05, 0.67)
Birth Cohort X >Secondary School	0.11 (-0.40, 0.62)	0.10 (-0.42, 0.62)	0.37 (-0.18, 0.91)	0.42 (-0.01, 0.86)
Urbanicity	0.01 (0.00, 0.02)	0.01 (0.00, 0.02)	0.01 (0.00, 0.02)	0.01 (0.00, 0.02)
Mean* Urbancity	-0.02 (-0.03, -0.01)	-0.02 (-0.03, -0.01)	-0.01 (-0.02, 0.00)	0.03 (0.02, 0.05)
Birth Cohort X Urbanicity	-0.01 (-0.01, 0.00)	-0.01 (-0.01, 0.00)	-0.01 (-0.02, 0.00)	-0.01 (-0.02, 0.00)
Birth Cohort X Mean* Urbanicity	0.04 (0.03, 0.05)	0.04 (0.03, 0.05)	0.03 (0.02, 0.05)	0.03 (0.02, 0.05)
Person-specific Mean* Age	0.21 (0.07, 0.34)	0.22 (0.09, 0.35)	0.37 (0.32, 0.43)	0.36 (0.27, 0.45)

Person-specific Mean* Age Squared	-0.001 (-0.003, 0.001)	-0.001 (-0.004, 0.001)	-0.004 (-0.005, -0.003)	-0.004 (-0.005, -0.003)
Birth Cohort X Mean* Age	0.27 (-0.04, 0.58)	0.25 (-0.06, 0.56)	-	-
Birth Cohort X Mean* Age Squared	-0.004 (-0.007, 0.000)	-0.003 (-0.01, 0.00)	-	-
Current Smoker	-	-	-0.30 (-0.40, -0.20)	-0.30 (-0.40, -0.20)
Household Income per capita	-	0.002 (-0.006, 0.010)		0.010 (-0.001, 0.020)
Intercept	17.19 (15.32, 19.05)	17.00 (15.15, 18.85)	13.99 (12.92, 15.06)	13.57 (12.63, 14.51)
Number of Observations	23,068	22,747	18,693	18,256
N	7,314	7,287	6,492	6,452

*Variable means are the person-specific mean value for these variables over the survey period. The coefficient on the variable for the person-specific mean represents the difference between the between and within effects for each variable. These are included for time-varying variables for which the between and within coefficients were significantly different.

Table 10. Random effects logistic regression models of the association between education and overweight (BMI≥25) over survey period

	Females	Males
	Odds Ratio (95% Confidence Interval)	Odds Ratio (95% Confidence Interval)
<Primary School	1.0	1.0
Primary School	0.83 (0.48, 1.43)	0.53 (0.21, 1.35)
Secondary School	0.78 (0.37, 1.61)	1.22 (0.44, 3.41)
>Secondary School	0.93 (0.38, 2.31)	2.24 (0.72, 7.02)
Time X Primary School	1.02 (0.99, 1.05)	1.06 (1.00, 1.12)
Time X Secondary School	0.99 (0.95, 1.03)	1.03 (0.97, 1.10)
Time X >Secondary School	0.92 (0.87, 0.97)	1.04 (0.97, 1.09)
Time	1.17 (1.14, 1.20)	1.22 (1.16, 1.29)
Mean Time	0.91 (0.87, 0.94)	-
Time Squared	-	0.99 (0.99, 0.99)
Birth Cohort (1= before 1960)	0.85 (0.25, 2.92)	1.14 (0.43, 3.02)
Birth Cohort X Time	-	0.90 (0.87, 0.93)
Birth Cohort X Primary School	1.18 (0.69, 2.01)	1.59 (0.68, 3.67)
Birth Cohort X Seconday School	1.24 (0.55, 2.77)	1.35 (0.51, 3.57)
Birth Cohort X	0.85 (0.33, 2.24)	1.23 (0.42, 3.63)

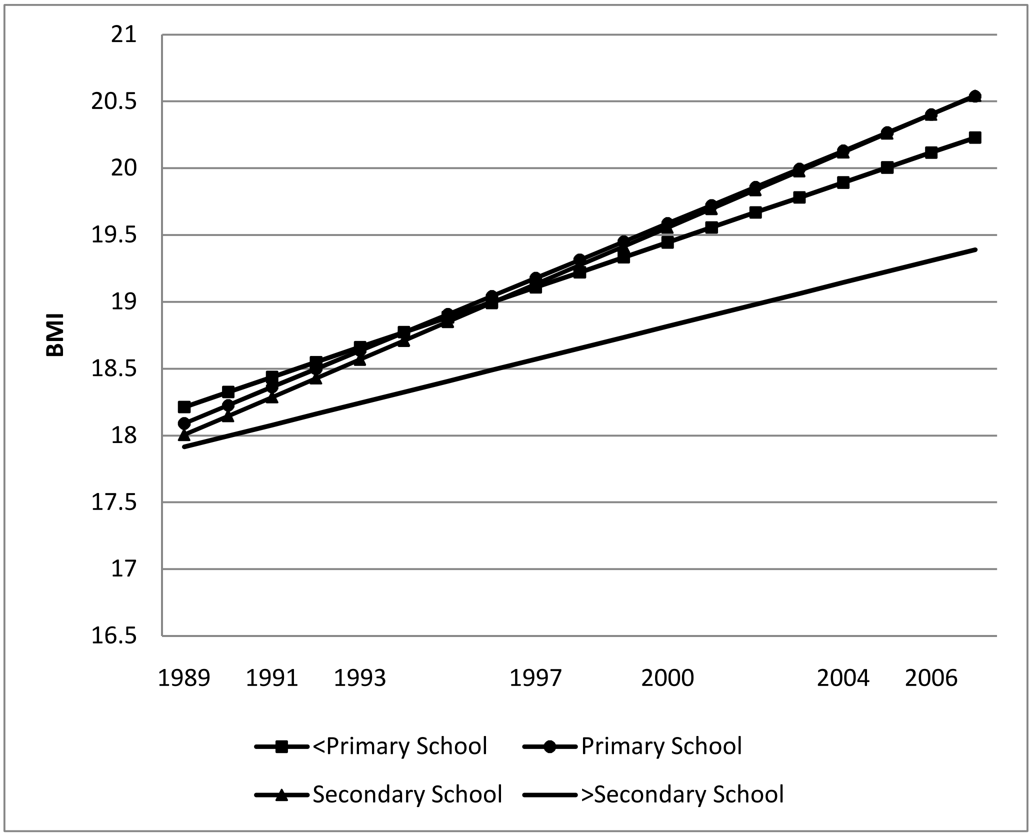
>Secondary School		
Urbanicity+	1.02 (1.00, 1.03)	1.03 (1.01, 1.04)
Mean Urbancity+	0.98 (0.97, 1.00)	1.00 (0.98, 1.02)
Birth Cohort X Urbanicity+	0.99 (0.98, 1.01)	0.98 (0.96, 1.00)
Birth Cohort X Mean Urbanicity+	1.05 (1.02, 1.07)	1.05 (1.03, 1.08)
Person-specific Mean Age+	1.64 (1.27, 2.13)	1.63 (1.47, 1.81)
Person-specific Mean Age Squared+	1.00 (1.00, 1.01)	1.00 (0.99, 1.00)
Birth Cohort X Mean Age+	0.91 (0.55, 1.52)	-
Birth Cohort X Mean Age Squared+	1.00 (1.00, 1.01)	-
Current Smoker	-	0.67 (0.56, 0.80)
	-	-
Intercept	0.02 (0.01, 0.04)	0.002 (0.0007, 0.005)
Number of Observations	23,068	18,693
N	7,314	6,492

*Variable means are the person-specific mean value for these variables over the survey period. The coefficient on the variable for the person-specific mean represents the difference between the between and within effects for each variable. These are included for time-varying variables for which the between and within coefficients were significantly different [86].

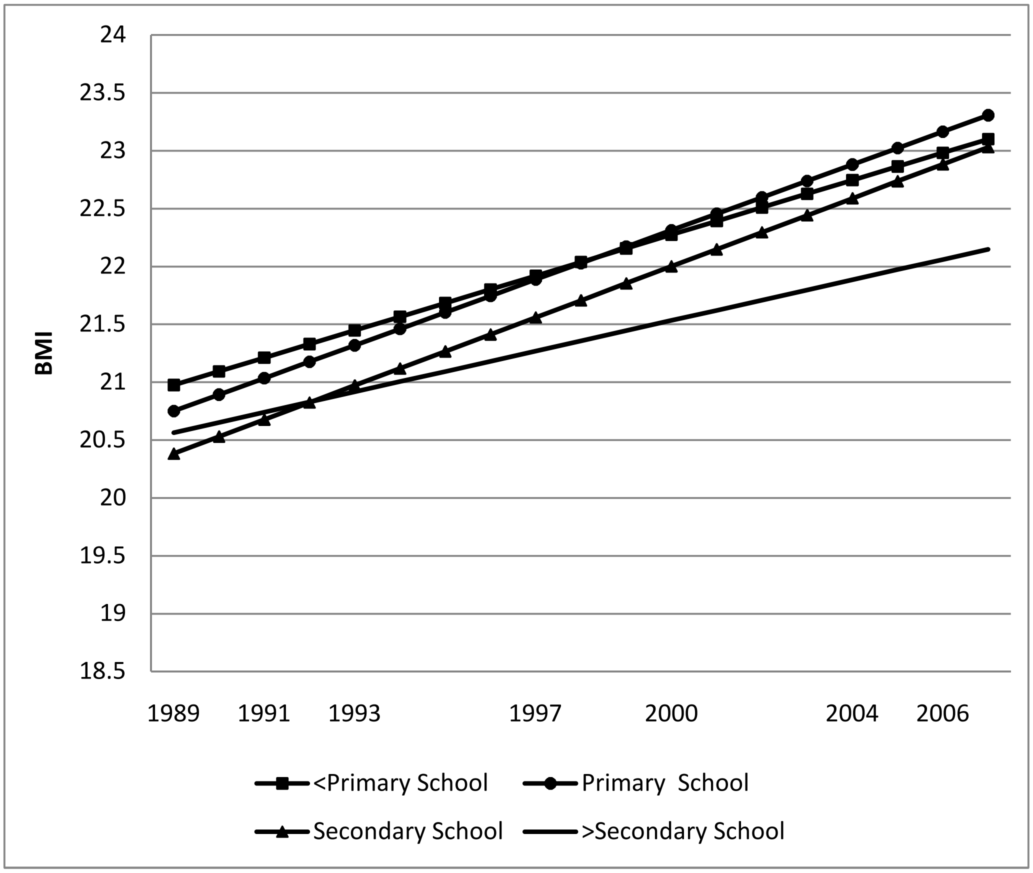
+Urbanicity, mean urbanicity, mean age and mean age squared were mean centered before inclusion in the random effects logistic regression.

Figure 6. Predicted BMI Trajectories for Women (1989-2006), (a) Older Cohort and (b) Younger Birth Cohort

a. Older Birth Cohort (born prior to 1960)

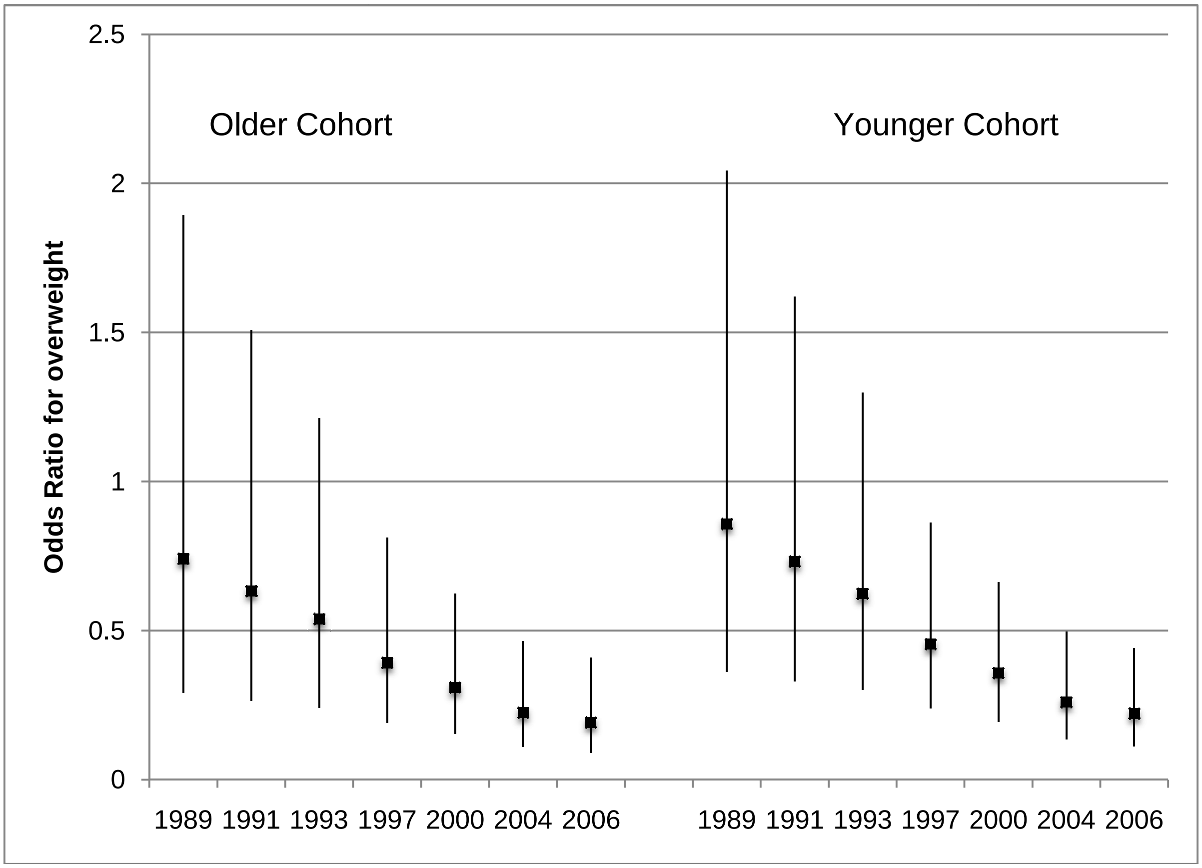


b. Younger Birth Cohort (born in or after 1960)



*Figures displays predicted BMI over survey period based on coefficients from random effects linear model in Table 3 with the following specifications: urbanicity and mean urbanicity level of 53; mean age for older cohort of 54; mean age for younger cohort of 29.

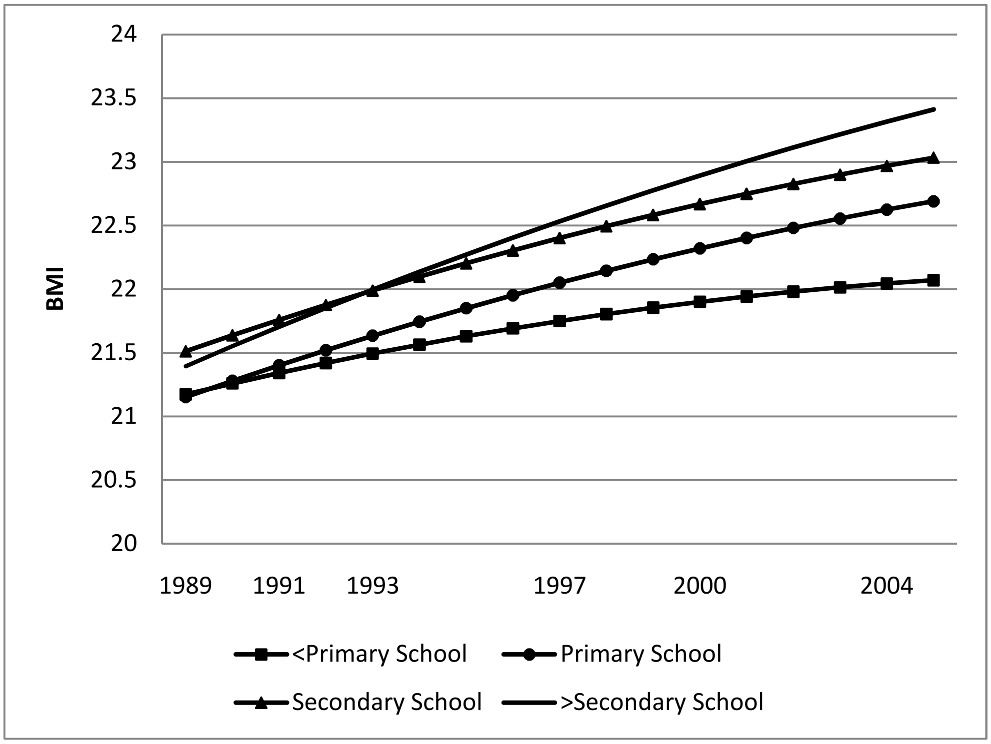
Figure 7. Predicted Odds Ratios for Overweight (BMI≥25) for Highest Education Group Compared Lower Education Group (1989-2006) for Women



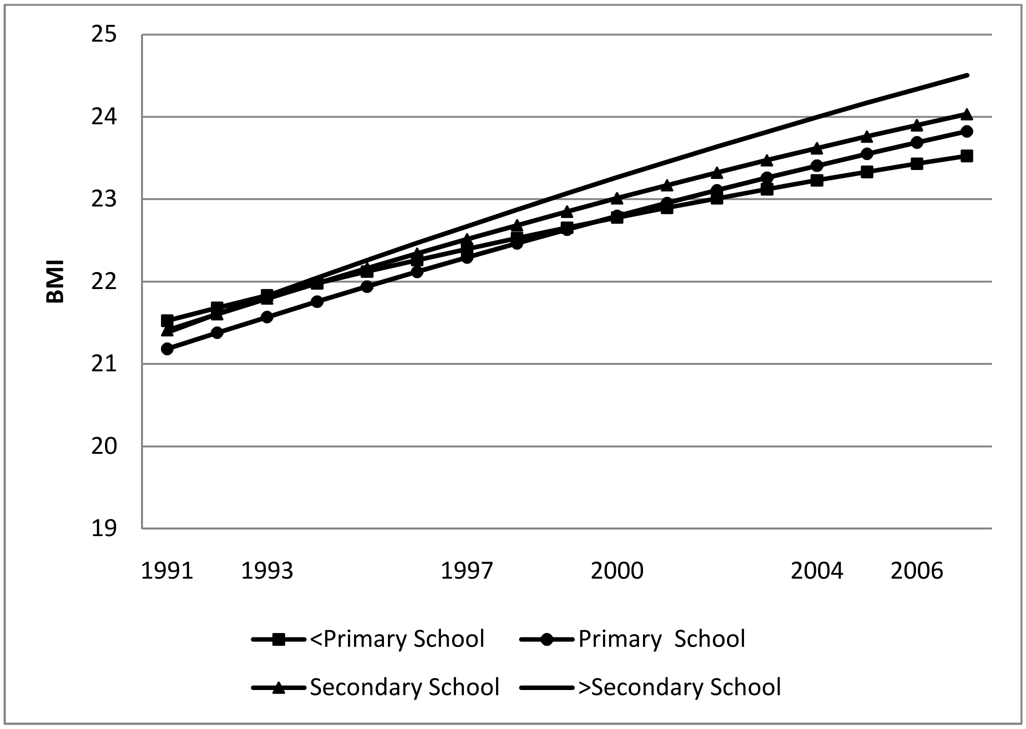
*Figures displays predicted Odds Ratio over survey period based on coefficients from random effects logistic model in Table 4.

Figure 8. Predicted BMI Trajectories for Men (1989-2006), (a) Older and (b) Younger Birth Cohorts

a. Older Birth Cohort (born prior to 1960)

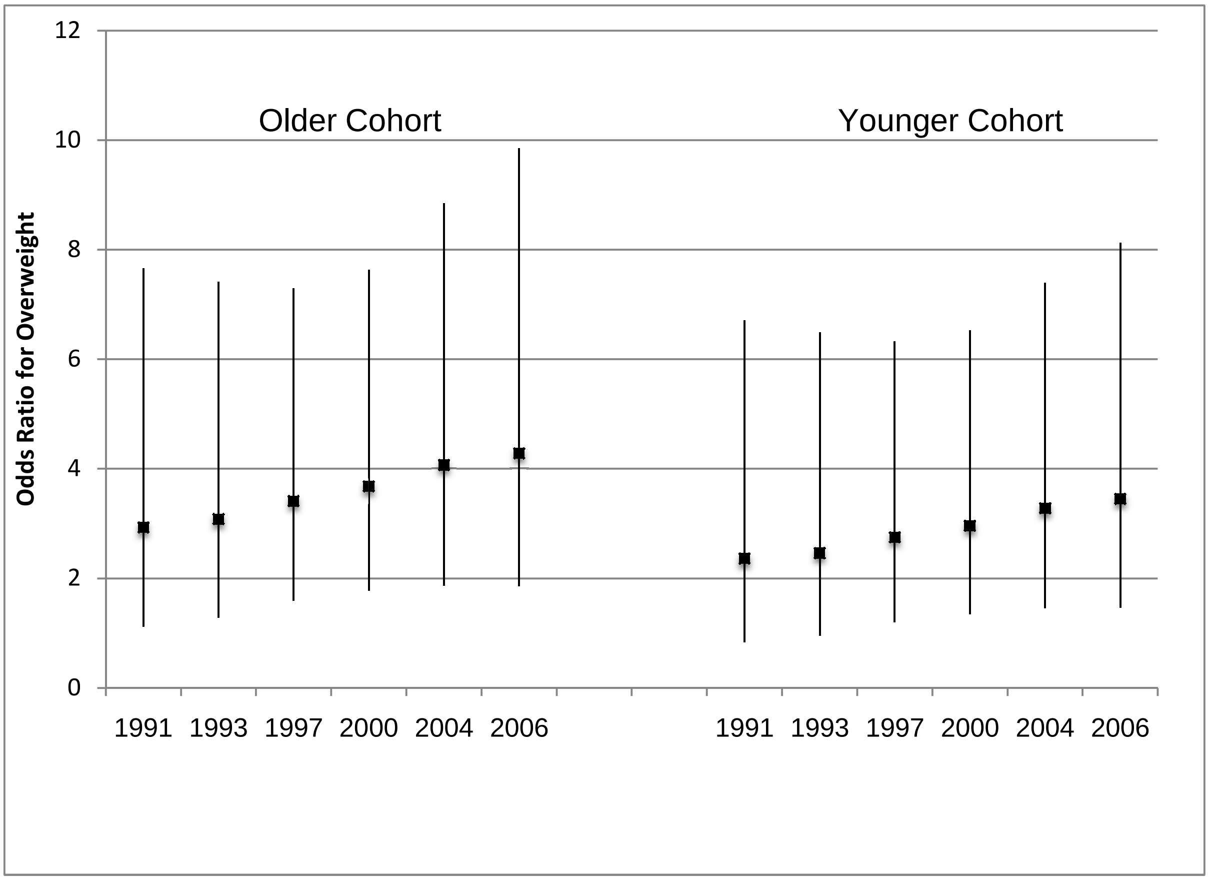


b. Younger Birth Cohort (born in or after 1960)



*Figures displays predicted BMI over survey period based on coefficients from random effects linear model in Table 3 with the following specifications: urbanicity and mean urbanicity level of 53; mean age for older cohort of 54; mean age for younger cohort of 29; nonsmokers.

Figure 9. Predicted Odds Ratios for Overweight (BMI≥25) for Highest Education Group Compared to each Lower Education Group (1989-2006) for Men, (a) Older and (b) Younger Birth Cohorts



*Figures displays predicted Odds Ratio over survey period based on coefficients from random effects logistic model in Table 4.

VIII. SYNTHESIS

A. OVERALL GOALS AND SUMMARY OF KEY RESULTS

This work is motivated by and provides some evidence for one of the major theories in medical sociology and social epidemiology regarding the association between socioeconomic status and health, fundamental cause theory. Fundamental cause theory starts from the observation that low socioeconomic status has been persistently associated with higher levels of disease, throughout time, even as the types of diseases themselves have actually changed. We studied developing countries actively undergoing epidemiologic and nutrition transitions to see whether the risk of overweight conferred by high and low SES is changing and whether the burden of this chronic condition appears to be shifting toward low SES populations in these settings. People with low SES in developing countries are some of the most vulnerable populations worldwide, and empirical evidence regarding changing disease burdens in these populations is necessary to inform public health agencies and policymakers so that interventions can be appropriately tailored for changing needs.

The strongest evidence for socioeconomic status as a persistent and fundamental cause of disease comes from the five countries for which we observed a change in the direction of the relationship between SES and overweight from positive to inverse (Armenia, China, Indonesia, Jordan and Turkey. Weaker, but still consistent, evidence is provided by the growth rates of overweight in the lower SES groups surpassing those in higher SES in 30-50% of the countries studied. If current growth rates were to continue in these countries, they would eventually lead to a higher overweight prevalence in the low SES groups in comparison to high SES groups; however, we do not yet know whether these faster growth rates will continue. Finally, our findings from China, in which we observe a disparity in overweight prevalence emerge during a period of rapid development, whereby low SES women initially have similar mean BMI and prevalence of overweight, but by the end of the survey, they have a significantly higher odds of overweight, provide evidence for a process of what Bruce Link calls “social shaping” of overweight in this context.

Additionally, we sought to identify whether country-level contextual features, such as economic development and income inequality, were salient predictors of disproportionate overweight increases among low SES women. As hypothesized, country-level economic development was positively associated with a greater propensity for disproportionate overweight prevalence increases among the low SES populations compared to high SES populations within countries. Lower income inequality among the most developed countries in our sample was associated with the fastest rates of overweight prevalence growth among low SES populations.

B. SYNTHESIS OF KEY RESULTS

EMERGING TRENDS IN SOCIAL PATTERNING OF OVERWEIGHT IN DEVELOPING COUNTRIES: TESTING THE PREDICTIONS OF THEORY AND EXPERTS

Our study was primarily motivated by fundamental cause theory; however, global health experts from a variety of fields have also predicted that the burden of chronic diseases in lower income countries will soon shift to the poor in these countries [26, 73, 93]. Populations with low SES in developing countries are some of the most vulnerable populations in the world and may be particularly vulnerable to the deleterious potential metabolic consequences of overweight due to inadequate medical coverage of these populations and lack of personal resources to preserve health [93]. Anticipating emerging diseases in these population is therefore of utmost importance. There is a need for empirical evidence demonstrating these trends in order to inform policymakers, heads of state, and bilateral aid agencies of the current and impending risk of chronic diseases [93]. Few previous studies have incorporated either multiple time points or multiple lower income countries [for exceptions see 1, 16, 50, 94] to address these questions. Our study of overweight, a chronic condition and major risk factor for many chronic diseases, fills a gap in this global health literature by empirically testing whether overweight prevalence increases among low SES populations have outpaced those in the higher SES populations among 41 countries in the developing world.

OVERWEIGHT PREVALENCE AND TRENDS IN PREVALENCE BETWEEN LOW AND HIGH SES WOMEN: IS THE DISEASE BURDEN OF OVERWEIGHT SHIFTING TOWARD THOSE IN WITH LOWER SES?

Our analyses of age-standardized, SES-specific overweight prevalence among women with young children reveal that the association between overweight prevalence and SES in developing countries is currently still overwhelmingly positive. In the majority of country-years, using either wealth or education as the indicator of SES, approximately 90% of the estimates displayed a positive relationship between SES and overweight prevalence.

Despite the overwhelmingly positive associations between SES and overweight across country-years, we do find evidence that overweight is increasing at a more rapid rate among low SES populations in 30-50% of the countries studied and that countries with GDPs in the middle to upper-middle range are more likely to display this pattern.

THE DOUBLE-EDGED SWORD OF DEVELOPMENT

The propensity for comparatively faster overweight increases among the lower wealth groups was significantly associated with country-level Gross Domestic Product (GDP) and varied by country-level of income inequality. Specifically, being in the highest country-level GDP tertile with lower income inequality was associated a decrease in the magnitude of inequality overweight levels between SES groups, which was brought about by relatively faster overweight prevalence gains among the lower (versus higher) SES populations.

We speculate that country-level GDP and low income inequality promote exposure to obesogenic features of modern environments for low SES women since women are disproportionately gaining overweight prevalence points in these contexts; however, they also give some suggestion that higher SES women may begin to respond differently to these same environments since the obesity growth rates in these groups are not keeping pace with those in low SES populations. However, to test whether rates in the highest SES populations have actually decelerated in comparison to earlier periods, we would need additional periods of data.

Variance along the spectrum of economic development

The environmental availability of adequate calories to surpass energy needs appears to be a prerequisite for increases in overweight prevalence among the low SES populations, as the very low-income countries still show a predominant trend of higher SES groups gaining disproportionately in overweight prevalence as compared to low SES groups. In these contexts, infectious disease and malnutrition likely still dominate the major causes of morbidity and mortality and low SES is likely a risk factor for these diseases. For example, many of the low-income countries in our study are in Africa, which, as a region, still has a higher percentage of deaths from communicable disease [95].

For countries further along in the epidemiologic transition with chronic diseases occupying a larger share of the burden of morbidity and mortality, we see propensity for overweight prevalence gains to be faster among the low SES populations compared to high SES populations. Our findings with regard to income inequality are surprising, since we expected that lower income inequality might be associated with equivalent rates of increase in overweight between high and low SES populations, speculating that in these contexts, there may be more equitable sharing of resources to prevent overweight. We do find that there is a lower overall inequality in overweight levels, but that the low SES groups are gaining in prevalence at a faster rate than the high SES groups.

It will be interesting to see how this dynamic plays out in the future. Among the developed countries of the world, lower income inequality has been associated with lower inequality in overweight rates. We may see the rate of overweight increase in low SES women begin to slow down as the more income-equitable middle-income countries grapple with increasing overweight prevalence in all populations. Perhaps this currently reflects more equitable access to the obesogenic environmental features, and it’s possible that as overweight becomes more burdensome to lower

SES populations, they will have greater access to medical knowledge to eventually curb this increase as well.

THE LONG VIEW: HOW DOES OVERWEIGHT PREVALENCE BECOME SOCIALLY DIFFERENTIATED OVER TIME IN THE CONTEXT OF RAPID DEVELOPMENT?

We observe the direction of the relationship between SES and overweight change from direct to inverse in five of our study sample countries: Armenia, China, Indonesia, Turkey, Jordan. Using data from China, we sought to investigate whether this finding was robust to longitudinally-collected, within-individual data from the China Health and Nutrition Survey over the same time period. We hypothesized that a social disparity in the relative odds of overweight would have emerged among women since the late 80s in China and we used this as a case study to examine what Bruce Link calls “the social shaping of disease” during rapidly changing conditions. We found significant differences in the BMI and overweight trajectories for women in the lowest education category compared to women in the highest, such that by the end of the survey an SES-based disparity had emerged. Women in the highest education group had approximately a 4.5 times *lower* odds of overweight compared to the lowest education group. For men, the trends were opposite, whereby at the end of the survey, men in the highest education group had approximately 2-4 times *higher* odds of overweight compared to men in the lowest education group.

Potential explanations for our findings have to account for both the male-female difference in the trends among high SES individuals as well as the high-low SES trends among women. Specifically, the ready explanation that relies on exposure to risk factors for obesity, such as sedentary work and lifestyle and energy-dense foods does not seem to offer a great explanation by itself. Specifically, the high income men and women are likely exposed to relatively similar access to energy-dense foods, sedentary occupations and energy-saving modern conveniences, yet high SES women experienced a slowed growth rate while high SES men experienced an increased rate of growth BMI gains odds of overweight. Access to energy-dense foods, sedentary occupations, and labor-saving devices is likely still more limited for the low SES women in comparison to the high SES women in this context. Taken together, the divergent patterns among high income men and women and high versus low SES women seem to implicate other factors motivating the purposeful behavior to curb BMI growth among high SES women. Women with high SES might enact behaviors to limit BMI gains due to either health concerns and health knowledge or to stigma associated with larger BMI. Changing health concerns could prompt changes in women's behavior before men's, but we speculate that stigma around body size might be the initial motivating factor among women in this context. These findings are consistent with, but not definitive proof, of the mechanism suggested by fundamental cause theory: a purposeful application of the resources that accompany social advantage in order to prevent or treat disease or disengage in stigmatized behaviors [7].

C. LIMITATIONS AND STRENGTHS

STUDY SAMPLE

Our sample size is large and the majority of these data come from nationally representative household surveys. Our sample of 41 countries covers approximately one-fourth of all countries in the world. The range of country-level GDP spans from very low income countries to upper middle income; the geographic range of our countries also includes many of the world's regions. We use data from 556,352 women between ages 18 to 49 within these countries and our results should generalize to women with children under age five in our sample countries. The limitations of our sample are that only women with children under five years old had anthropometrics measured at repeated time points in the majority of countries, so our results are not directly generalizable to women without children or women with older children.

REPRESENTATION OF SOCIOECONOMIC STATUS

Socioeconomic status is a complex and multidimensional construct that is not easy to measure perfectly. The majority of the literature regarding socioeconomic status utilizes either occupation, education, income or wealth to represent SES. In this project we used wealth and education separately to represent socioeconomic status. Although it is common to use only one of these indicators to represent SES, as we did, a better representation of SES might create SES categories that combine both wealth and education. This was beyond the scope of the current project, but represents an avenue for future research.

CROSS-COUNTRY COMPARABILITY

Cross-country comparisons offer the unique ability to investigate how large- scale contextual factors may influence a population's health; however, there are also many difficulties inherent in this type of design. First, exposures, outcomes and sampling frame may not be comparable across countries. In our case, reliance on the DHS for the majority of our data, aided in the comparability of these items. These surveys are nationally representative household surveys, in which all women with children under 5 in sampled households had anthropometric measurements taken. Interviewer training is standardized and anthropometrics are measured according to a standard protocol. Questionnaires are also standardized to a large degree, so that education was ascertained in a similar manner in all countries. The assets queried to comprise the wealth index differ slightly based on country-appropriate items [41]. The CHNS is an open cohort study and the IFLS is a longitudinal cohort study. Both are household surveys and used measured anthropometrics taken by standard protocol. They ascertain education and assets in a manner similar to the DHS surveys, and although neither is nationally representative, they both used a sampling design intended to create a sample representative of the area surveyed (9 provinces in China and almost half of all provinces in Indonesia). For the most part, we follow repeated cross-sections in our cross-country analyses, rather than the same populations over time. This is adequate for addressing secular trends in population health across time and place.

In addition to concern over comparable measures between countries, another potential criticism of cross-country comparisons is that the same exposures may have different meaning between countries. We avoid this potential pitfall by getting within-country levels of effect for SES on overweight rather than assuming a homogenous effect for each level of education in our cross-country comparisons.

D. IMPLICATIONS FOR POLICY AND RESEARCH

CHANGING DISEASE BURDEN AMONG POPULATIONS WITH LOW SOCIOECONOMIC STATUS IN DEVELOPING COUNTRIES

Developing countries are home to 80% of the world's population [96] and chronic diseases have recently become a leading cause of death in these contexts [73, 93, 97]. Public health nutrition programs and policies targeted for lower SES populations in developing countries have traditionally focused on treating and preventing malnutrition and oftentimes include supplemental feeding programs. Evidence suggests that malnutrition is still a threat to health in many of these contexts and that low SES populations may be doubly burdened with diseases of under and overnutrition [93]. Just as in the epidemiologic and demographic transitions in general, typically young children are most prone to undernutrition, while nonelderly adults seem to be the population becoming overweight first [58, 98, 99]. We studied overweight in the nonelderly adult population (primarily women). Overweight prevalence increases should be anticipated in the near future in most of the world's populations, including low SES women in lower income countries. Public health programs and clinics that address both the risks of under-nutrition and over-nutrition are urgently needed in order to prevent simply trading diseases of malnutrition for diseases of overweight and obesity.

"HEALTH IN ALL POLICIES"

The persistent relationship between SES and ill-health over time and place has also been recognized by the WHO-endorsed Commission on Social Determinants of Health, which refers to this as the structural factors that produce and reproduce health inequities [100]. The Commission deems "the unequal distribution of health-damaging experiences is not in any sense a natural phenomenon but is the result of a toxic combination of poor social policies and programmes, unfair economic arrangements, and bad politics" [100].

If SES is a "fundamental cause of disease," improving the social and economic conditions of the most disadvantaged populations around the world is essential to improving the health of these populations, and focusing solely on disease intermediary risk factors likely will not prevent this persistent relationship from reappearing as the world faces future epidemiologic and demographic transitions. Improvements in health of all populations, but particularly the most vulnerable, is a primary goal of the WHO; the Commission on Social Determinants of Health has identified the structural causes, the economic and social conditions of disadvantaged populations, as essential targets for intervention if health inequalities are to be decreased in the next generation [100].

Improving access to education, particularly for women, has been an endorsed goal and has been associated with multiple improvements in health outcomes in developing countries [100, 101]. Another prominent example of a policy aimed at improving the economic situation of individuals that has been successful and has resulted in improvements in health is the conditional-cash transfer program, Opportunidades [102]. This model has now been replicated in multiple other countries [103], including the US, in a new program endorsed by Mayor Bloomberg in New York City as a means of incentivizing school attendance among low-income youth [104].

The expansion of the social security pension system in South Africa is an example of a policy aimed at improving economic conditions that turned out to have unexpected positive results on girls' health. Ester Duflo evaluated the social security pension expansion in South Africa and found that even though pensions were distributed to older adults, children's health benefited by the inflow of cash (if the recipient was a grandmother, not a grandfather) [105].

These, of course, are large scale policies/programs that represent collaborations between public health professionals and policy makers, but nevertheless, demonstrate that SES is amenable to intervention and that such interventions can be demonstrated to have fair-reaching effects of human health. Examples such as these, coupled with the recognition that tackling the structural determinants of ill-health will require this type of large-scale intervention in many cases, in part motivates the Adelaide Statement on Health (a joint effort by the WHO and the government of South Austraila) which advocates for “Health in All Policies” [106]. One example of smaller scale economic interventions are microcredit programs which may help families escape the “poverty trap” in low-income countries and have been associated with a variety of improved health outcomes [107]. Microcredit programs work typically by providing money for investment in very small business start up by a community group or for investments in animals which improve a family's security and can generate wealth in the future.

Most of the health outcomes in the above mentioned policy evaluations have been focused on growth and development among children. Increased rates of chronic disease among adults during times of economic development should be anticipated and evaluation of such policies should include implications for chronic, noncommunicable disease in these populations, as well.

E. Future Directions

The Demographic and Health Surveys continue to collect new waves of data in our sample countries and other middle and lower income countries. Future waves of data offer an exciting opportunity to continue to track SES-specific changes in overweight prevalence over time. Future waves of data will enable a stronger test of fundamental cause theory; they will be able to answer the question of whether overweight prevalence levels among the low SES groups actually surpass those of the higher SES groups in many countries over time. Additionally, many of the DHS surveys now measure heights and weights on all women and some are even beginning to include men in these measurements. Future work has the potential to include measurements from these populations and therefore be generalizable to a larger population.

Additionally, detailed data from within singular countries could provide additional means to test the theory that it is a purposeful use of resources by those with high SES that results in lower BMI growth rates or lower overweight prevalence increases in these populations. Surveys of attitudes and behaviors related to body size and health concerns would aid in this investigation.

Additional analyses at the country-level could investigate other country-level factors that have been hypothesized to influence total overweight prevalence as well as the direction of the SES-overweight relationship, such as foreign direct investment, spending on health care and proportion of girls completing primary or secondary education. Additionally, investigating total overweight prevalence as a predictor of the changes in the direction of the SES-overweight relationship would also be a logical next step. Finally, we used only wealth as our indicator of socioeconomic status in these cross-country comparisons. An unexpected, unique, additional set of countries displayed faster overweight prevalence growth rates only when education was used at the indicator of SES. Future research could explore whether there are identifiable country-level characteristics of these countries for which overweight prevalence growth rates are faster for low education groups, but not for low wealth groups.

As mentioned previously, combining our wealth and education measures to create a richer measure of socioeconomic status, might provide a better measure of the construct of SES. The longitudinal data from China also offer the opportunity to observe whether the relationship between SES and overweight will change in the future.

Additional studies could use within country change in GDP over time to more rigorously interrogate GDP as a causal factor in the process of SES-specific overweight prevalence increases. Additionally, using longitudinal data within countries, such as the CHNS, future studies could use within individual changes in education or income/wealth levels or external shocks to income or education to also attempt to investigate SES as an etiologic mechanism in chronic disease promotion or prevention.

Finally, we study overweight as our health outcome of interest, but performing these same analyses with other noncommunicable conditions or diseases, such as hypertension or glucose intolerance, would provide evidence as to whether these same relationship can be seen with multiple health end points.

APPENDIX

Appendix A. Sample sizes and selected mean sample characteristics

Country	Year	Women Interviewed	Eligible Sample†	Full Sample††	Restricted sample+	Age (SD)	BMI (SD)	Parity (SD)	% overweight or obese (SD)	Age-standardized % overweight or obese (SD)	% Urban (SD)	% No School (SD)	% Primary School	% Secondary School (SD)	% Higher than Secondary School (SD)
Armenia	2005	6,566	5,468	5,456	1,433	29.4 (0.2)	24.6 (0.2)	1.9 (0.04)	37.2 (1.8)	45.4 (2.1)	60.4 (2.3)	0.0 (0.0)	0.6 (0.4)	77.9 (1.8)	21.4 (1.8)
Armenia	2000	6,430	5,264	5,263	1,723	30.0 (0.2)	24.6 (0.1)	2.1 (0.04)	38.3 (1.3)	43.8 (1.4)	56.0 (1.9)	0.0 (0.0)	0.3 (0.2)	82.2 (1.1)	17.4 (1.1)
Bangladesh	2007	10,996	9,679	9,660	5,320	28.8 (0.1)	20.4 (0.1)	2.9 (0.04)	10.3 (0.7)	11.5 (0.8)	22.4 (2.2)	31.6 (1.3)	30.5 (0.9)	31.2 (1.1)	6.7 (0.6)
Bangladesh	2004	11,440	9,798	9,794	5,649	28.8 (0.1)	19.9 (0.1)	3.2 (0.04)	7.3 (0.5)	8.1 (0.6)	21.9 (0.8)	42.1 (1.0)	29.0 (0.7)	23.5 (0.8)	5.4 (0.4)

	19		4,35	4,32		26.9	19.3	3.2	4.7	5.3	17.8	46.7	28.1	20.8	4.4
Bangladesh	99	10,544	6	4	4,016	(0.1)	(0.1)	(0.05)	(0.4)	(0.7)	(0.7)	(1.2)	(0.9)	(0.7)	(0.5)
	19		3,81	3,75		26.6	18.9	3.4	2.9	2.7	10.0	55.7	26.9	14.7	2.8
Bangladesh	96	9,127	1	4	3,536	(0.1)	(0.1)	(0.04)	(0.3)	(0.4)	(0.5)	(1.3)	(0.9)	(0.8)	(0.3)
	20		13,3	13,2	10,08	30.0	22.5	3.8	17.4	18.4	37.9	70.4	18.9	10.0	0.7
Benin	06	17,794	11	88	9	(0.1)	(0.1)	(0.04)	(0.6)	(0.6)	(1.0)	(0.8)	(0.5)	(0.4)	(0.1)
	20		4,78	4,78		29.8	22.4	3.8	17.7	19.6	36.7	69.4	19.7	10.4	0.5
Benin	01	6,219	7	7	3,611	(0.1)	(0.1)	(0.06)	(0.9)	(1.1)	(1.1)	(1.3)	(0.9)	(0.7)	(0.1)
	19		2,31	2,29		28.8	21.2	4.2	9.2	11.7	31.8	78.9	15.8	5.1	0.2
Benin	96	5,491	4	0	2,222	(0.1)	(0.1)	(0.06)	(0.7)	(1.1)	(1.5)	(1.2)	(1.0)	(0.5)	(0.1)
	20		13,9	13,9		30.1	25.7	3.4	48.4	50.6	64.8	7.6	53.4	29.0	10.0
Bolivia	03	17,654	74	73	8,142	(0.1)	(0.1)	(0.04)	(1.0)	(1.1)	(0.9)	(0.4)	(0.9)	(0.8)	(0.5)
	19		4,13	4,12		30.0	25.4	3.7	47.4	48.9	63.1	10.6	43.7	35.0	10.7
Bolivia	98	11,187	6	5	3,990	(0.1)	(0.1)	(0.05)	(1.0)	(1.1)	(0.9)	(0.6)	(1.0)	(0.9)	(0.6)
	19		2,34	2,26		28.9	24.3	3.9	34.1	34.9	54.6	13.9	46.2	34.7	5.3
Bolivia	94	8,597	9	5	2,183	(0.2)	(0.1)	(0.07)	(1.2)	(1.7)	(1.5)	(0.9)	(1.4)	(1.3)	(0.6)
Burkina	20	12,477	9,36	9,35	7,737	30.8	21.0	4.1	8.6	8.8	17.0	85.6	8.4	5.6	0.3

Faso	03		0	7		(0.1)	(0.1)	(0.06)	(0.9)	(0.9)	(2.2)	(1.2)	(0.6)	(0.7)	(0.1)
Burkina	19		3,31	3,29		29.8	20.9	4.5	5.6	5.3	11.9	90.8	6.2	2.8	0.2
Faso	98	6,445	4	8	3,170	(0.1)	(0.1)	(0.05)	(0.5)	(0.5)	(0.7)	(0.6)	(0.5)	(0.3)	(0.1)
Burkina	19		3,43	3,40		29.8	21.0	4.5	7.0	7.2	15.8	87.6	9.2	2.9	0.3
Faso	92	6,354	6	8	3,262	(0.2)	(0.1)	(0.05)	(0.4)	(0.5)	(0.9)	(0.9)	(0.7)	(0.3)	(0.1)
	20		6,71	6,71		31.1	21.0	3.0	9.2	10.0	16.9	22.6	58.4	17.8	1.2
Cambodia	05	16,823	6	0	3,649	(0.2)	(0.1)	(0.05)	(0.6)	(0.7)	(0.9)	(1.0)	(1.1)	(1.1)	(0.2)
	20		5,91	5,88		31.2	20.6	3.6	6.1	6.3	16.1	30.4	54.6	14.7	0.3
Cambodia	00	15,351	2	4	3,231	(0.1)	(0.1)	(0.06)	(0.5)	(0.6)	(0.7)	(1.1)	(1.1)	(0.9)	(0.2)
	20		3,92	3,92		29.1	23.6	3.6	28.6	30.3	49.6	25.4	40.3	32.9	1.4
Cameroon	04	10,656	4	4	2,826	(0.2)	(0.1)	(0.07)	(1.0)	(1.1)	(1.5)	(1.3)	(1.1)	(1.1)	(0.3)
	19		1,57	1,57		27.6	22.7	4.0	21.3	21.9	26.3	34.5	39.9	25.2	0.4
Cameroon	98	5,501	6	1	1,498	(0.2)	(0.1)	(0.08)	(1.3)	(2.1)	(1.7)	(2.0)	(2.0)	(1.5)	(0.1)
	19		2,27	2,27		29.7	22.6	3.5	19.4	21.1	37.7	60.0	28.8	10.3	1.0
Cote d'Ivoire	98	3,040	9	8	1,607	(0.2)	(0.1)	(0.10)	(1.3)	(1.6)	(2.5)	(2.4)	(2.1)	(1.0)	(0.2)
	19		2,99	2,98		28.0	22.1	4.2	14.1	16.0	34.6	68.0	23.5	8.3	0.3
Cote d'Ivoire	94	8,099	3	1	2,867	(0.1)	(0.1)	(0.05)	(0.8)	(1.3)	(1.4)	(1.3)	(1.1)	(0.6)	(0.1)

	20		2,84	2,84		29.0	20.8	4.7	7.4	8.7	18.3	77.7	17.8	4.2	0.3
Chad	04	6,085	0	0	2,714	(0.2)	(0.1)	(0.07)	(0.6)	(0.7)	(1.3)	(1.8)	(1.7)	(0.5)	(0.1)
	19		3,59	3,58		28.2	20.5	4.4	5.1	5.2	21.2	79.1	17.8	3.0	0.1
Chad	96	7,454	4	0	3,430	(0.1)	(0.1)	(0.05)	(0.4)	(0.5)	(0.8)	(1.0)	(0.9)	(0.3)	(0.0)
	20		2,46	2,46		37.8	23.1		24.3	19.2	32.7	11.3	17.2	40.1	
China	06	6,746	9	7	NA	(0.2)	(0.1)	NA	(0.9)	(0.8)	(0.9)	(0.6)	(0.8)	(1.0)	31.2
	20		2,59	2,55		37.4	23.1		24.4	19.5	33.5	11.0	22.0	39.1	
China	04	12,725	3	7	NA	(0.2)	(0.1)	NA	(0.8)	(0.8)	(0.9)	(0.6)	(0.8)	(1.0)	27.8
	20		3,19	3,00		36.2	22.8		21.5	18.7	32.5	16.1	21.5	35.6	
China	00	11,784	2	9	NA	(0.2)	(0.1)	NA	(0.7)	(0.7)	(0.9)	(0.7)	(0.7)	(0.9)	26.8
	19		2,95	2,76		35.2	22.4		17.4	15.8	34.0	23.4	22.8	31.1	
China	97	11,720	7	7	NA	(0.2)	(0.1)	NA	(0.7)	(0.7)	(0.9)	(0.8)	(0.8)	(0.9)	22.8
	19		3,00	2,94		34.0	21.9		13.4	12.7	29.8	27.6	22.6	31.3	
China	93	12,459	8	4	NA	(0.2)	(0.1)	NA	(0.6)	(0.6)	(0.8)	(0.8)	(0.8)	(0.9)	18.5
	19		3,23	3,16		33.1	21.8		12.7	12.7	31.1	31.7	21.8	21.8	
China	91	11,206	8	2	NA	(0.2)	(0.1)	NA	(0.6)	(0.6)	(0.8)	(0.8)	(0.7)	(0.7)	16.2
	19		2,69	2,59		31.8	21.8		11.5	11.6	31.8	31.2	22.5	28.2	
China	89	10,854	4	9	NA	(0.1)	(0.1)	NA	(0.6)	(1.0)	(0.9)	(0.9)	(0.8)	(0.9)	18.1

	20		29,9	29,8	14,61	30.2	24.9	2.4	43.2	47.0	74.1	3.5	31.4	49.8	15.3
Colombia	05	41,344	11	95	8	(0.1)	(0.1)	(0.02)	(0.6)	(0.6)	(0.6)	(0.2)	(0.6)	(0.6)	(0.5)
	20		3,15	3,15		28.5	24.7	2.5	41.4	45.3	72.0	3.2	37.3	49.3	10.2
Colombia	00	11,585	8	8	3,091	(0.1)	(0.1)	(0.03)	(0.9)	(1.5)	(1.0)	(0.3)	(1.1)	(1.1)	(0.7)
	19		3,24	3,23		28.6	24.5	2.7	41.0	46.6	67.5	4.7	41.0	46.4	8.0
Colombia	95	11,140	4	8	3,189	(0.1)	(0.1)	(0.04)	(0.9)	(1.3)	(1.0)	(0.4)	(1.0)	(1.0)	(0.6)
Dominican	19		6,46	6,42		29.2	24.4	2.8	39.9	43.5	63.6	7.7	50.5	29.0	12.8
Republic	96	8,422	8	3	3,500	(0.2)	(0.1)	(0.05)	(1.0)	(1.1)	(1.3)	(0.5)	(1.4)	(1.0)	(0.9)
Dominican	19		2,14	6,42		28.0	23.3	3.0	26.3		0.0	0.0	0.0	0.0	0.0
Republic	91	7,318	1	5	2,004	(0.2)	(0.1)	(0.08)	(1.3)		(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	20		17,2	17,2	10,08	30.5	28.9	3.2	74.7	76.1	35.9	34.5	14.1	42.0	9.3
Egypt	05	19,474	99	95	5	(0.0)	(0.0)	(0.01)	(0.1)	(0.1)	(0.3)	(0.2)	(0.1)	(0.2)	(0.0)
	20		8,13	8,13		30.9	27.7	3.3	71.7	72.1	38.2	37.9	14.4	38.9	8.7
Egypt	03	9,159	8	3	4,796	(0.1)	(0.1)	(0.03)	(0.8)	(0.8)	(1.0)	(0.9)	(0.6)	(0.9)	(0.5)
	20		13,9	13,8		30.8	28.4	3.6	72.0	71.8	38.4	43.4	16.2	32.7	7.8
Egypt	00	15,573	07	93	8,215	(0.1)	(0.1)	(0.04)	(0.7)	(0.8)	(1.6)	(1.2)	(0.6)	(1.0)	(0.5)
Egypt	19	14,779	6,72	6,69	6,365	29.7	26.3	3.8	51.9	52.8	41.1	44.3	22.0	28.0	5.6

	95		3	4		(0.1)	(0.1)	(0.05)	(0.9)	(1.0)	(1.1)	(0.9)	(0.7)	(0.8)	(0.4)
	19		4,81	4,81		30.1	26.8	4.1	57.4	56.7	40.2	48.8	25.2	21.5	4.5
Egypt	92	9,864	9	0	4,609	(0.1)	(0.1)	(0.05)	(1.1)	(1.2)	(2.1)	(1.6)	(0.8)	(1.1)	(0.6)
	20		5,25	5,24		29.4	20.2	4.1	3.4	3.6	11.7	73.7	19.2	6.5	0.7
Ethiopia	05	14,070	0	1	3,326	(0.2)	(0.1)	(0.07)	(0.4)	(0.5)	(0.7)	(1.2)	(1.1)	(0.5)	(0.1)
	20		11,7	11,7		29.8	19.9	4.0	2.5	2.5	13.5	79.5	13.6	6.5	0.3
Ethiopia	00	15,367	84	71	7,265	(0.1)	(0.0)	(0.05)	(0.3)	(0.3)	(1.0)	(1.0)	(0.7)	(0.6)	(0.1)
	20		4,31	4,30		30.6	23.1	3.4	24.6	25.2	39.0	35.7	21.1	41.4	1.7
Ghana	03	5,691	1	8	2,826	(1.5)	(0.1)	(0.05)	(1.1)	(1.2)	(1.3)	(1.2)	(0.9)	(1.3)	(0.3)
	19		2,05	2,05		30.1	22.1	3.7	16.2	15.9	26.3	37.4	20.4	41.0	1.2
Ghana	98	4,843	9	0	1,946	(1.7)	(0.1)	(0.05)	(0.9)	(1.1)	(1.1)	(1.3)	(1.0)	(1.4)	(0.3)
	19		1,74	1,74		29.1	21.7	3.7	12.5	12.8	28.7	39.3	54.6	5.2	0.8
Ghana	93	4,562	9	8	1,691	(1.7)	(0.1)	(0.05)	(0.9)	(1.2)	(1.5)	(1.6)	(1.5)	(0.5)	(0.2)
	19		2,32	2,32		29.1	25.1	3.9	44.6	46.9	40.2	30.3	51.2	16.6	1.9
Guatemala	98	6,021	6	2	2,288	(0.2)	(0.2)	(0.12)	(2.2)	(2.1)	(2.9)	(2.2)	(1.9)	(1.9)	(0.6)
	19		4,86	4,86		29.2	24.2	4.2	34.6	36.3	36.5	35.7	48.9	13.2	2.3
Guatemala	95	12,403	4	4	4,778	(0.1)	(0.1)	(0.05)	(0.9)	(1.1)	(1.3)	(1.2)	(1.2)	(1.1)	(0.5)

	20		3,09	3,09		31.0	21.7	4.1	13.2	13.5	27.9	82.5	9.5	7.5	0.5
Guinea	05	7,954	1	1	2,422	(0.2)	(0.1)	(0.07)	(0.8)	(0.8)	(1.3)	(1.0)	(0.7)	(0.7)	(0.1)
	19		3,26	3,23		29.5	21.7	4.3	12.1	12.5	26.2	85.8	7.8	5.0	1.3
Guinea	99	6,753	6	1	3,133	(0.2)	(0.1)	(0.06)	(0.7)	(0.8)	(1.0)	(0.8)	(0.6)	(0.4)	(0.3)
	20		4,12	4,12		29.7	22.5	3.0	22.3	23.2	43.3	29.5	35.8	31.6	3.1
Haiti	05	10,757	2	2	2,492	(0.2)	(0.1)	(0.07)	(1.1)	(1.2)	(1.8)	(1.4)	(1.3)	(1.4)	(0.5)
	20		7,78	7,77		30.2	22.9	3.5	26.2	26.9	39.9	34.6	42.9	21.3	1.1
Haiti	00	10,159	3	5	4,944	(0.2)	(0.2)	(0.10)	(2.3)	(2.2)	(5.5)	(2.3)	(1.5)	(1.5)	(0.2)
	19		1,87	1,86		30.6	21.2	4.1	11.5	11.3	35.0	47.3	39.3	12.6	0.8
Haiti	94	5,356	1	8	1,727	(0.2)	(0.1)	(0.07)	(0.9)	(1.1)	(1.6)	(1.6)	(1.4)	(1.0)	(0.3)
	20	198,75	138,	133,	78,83	32.7	20.5	2.9	11.3	11.1	30.0	36.0	16.8	38.5	8.7
India	05	4	968	694	5	(0.1)	(0.0)	(0.02)	(0.3)	(0.3)	(1.0)	(0.6)	(0.2)	(0.5)	(0.3)
	19		75,6	75,5	40,25	29.1	20.0	3.2	8.7	9.8	23.8	54.9	15.8	21.5	7.8
India	98	90,302	50	37	3	(0.0)	(0.0)	(0.02)	(0.2)	(0.3)	(1.0)	(0.5)	(0.3)	(0.3)	(0.3)
	20		10,3	3,27		25.9	22.9		22.1	30.4		22.0	20.3	36.5	21.1
Indonesia	07	21,737	55	0		(0.1)	(0.2)		(0.7)	(1.3)		(1.2)	(0.9)	(1.1)	(1.0)

	19		6,70	2,14		25.8	21.4		13.1	19.9		41.3	16.4	30.8	11.5
Indonesia	97	7,127	2	7		(0.2)	(0.1)		(0.7)	(1.4)		(1.8)	(1.3)	(1.6)	(1.1)
	20		4,50	4,49		32.2	27.2	4.0	61.6	59.9	84.1	3.2	6.8	61.0	29.0
Jordan	07	10,876	5	9	2,915	(0.2)	(0.2)	(0.07)	(1.4)	(1.5)	(1.9)	(0.5)	(0.7)	(1.4)	(1.5)
	20		4,91	4,90		31.8	27.9	4.3	66.0	65.9	78.3	4.8	9.1	60.8	25.3
Jordan	02	6,006	0	9	3,297	(0.1)	(0.1)	(0.06)	(1.1)	(1.1)	(1.1)	(0.5)	(0.5)	(1.1)	(1.1)
	19		3,08	3,06		30.9	27.3	4.6	62.0	65.0	82.7	6.9	13.0	56.4	23.6
Jordan	97	5,548	3	5	2,930	(0.1)	(0.1)	(0.06)	(1.0)	(1.1)	(0.8)	(0.7)	(0.8)	(1.1)	(1.0)
	19		1,99	1,98		29.8	23.5	2.3	26.0	31.3	46.0	1.0	#VAL	80.9	18.2
Kazakhstan	99	4,800	9	9	674	(0.3)	(0.2)	(0.06)	(2.0)	(2.3)	(3.3)	(0.6)	UE!	(1.7)	(1.5)
	19		3,13	3,13		29.8	24.2	2.4	32.5	38.5	47.4	0.1	0.4	82.5	17.0
Kazakhstan	95	3,771	8	5	1,302	(0.2)	(0.2)	(0.06)	(1.8)	(1.8)	(2.5)	(0.1)	(0.2)	(1.3)	(1.4)
	20		6,22	6,22		29.0	22.5	3.5	21.1	24.2	21.5	13.6	59.4	22.4	4.6
Kenya	03	8,195	7	5	3,986	(0.1)	(0.1)	(0.06)	(0.9)	(1.1)	(1.1)	(1.1)	(1.2)	(0.9)	(0.5)
	19		3,23	3,23		28.4	21.9	3.8	15.0	16.2	19.7	11.2	60.9	25.8	2.1
Kenya	98	7,881	3	3	3,026	(0.2)	(0.1)	(0.06)	(0.8)	(1.1)	(0.9)	(0.8)	(1.3)	(1.1)	(0.3)
Kenya	19	7,540	3,31	3,30	3,143	28.9	22.0	4.3	14.1	15.7	13.2	19.1	56.2	24.2	0.5

	93		8	2		(0.1)	(0.1)	(0.06)	(0.8)	(1.1)	(1.1)	(1.0)	(1.3)	(1.1)	(0.2)
	20		6,38	6,36		30.1	20.6	3.7	6.0	6.3	21.7	25.0	49.4	24.0	1.6
Madagascar	03	7,949	8	2	3,771	(0.2)	(0.1)	(0.08)	(0.5)	(0.5)	(1.2)	(1.9)	(2.0)	(2.0)	(0.3)
	19		2,50	2,50		28.1	20.4	4.3	3.9	4.2	20.0	22.6	55.6	21.2	0.6
Madagascar	97	7,060	8	6	2,419	(0.2)	(0.1)	(0.08)	(0.4)	(0.5)	(1.4)	(1.4)	(1.5)	(1.3)	(0.1)
	20		8,56	8,55		28.7	22.1	3.7	13.3	15.0	15.5	24.9	61.1	13.6	0.4
Malawi	04	11,698	4	7	6,521	(0.1)	(0.1)	(0.04)	(0.6)	(0.7)	(1.8)	(0.9)	(0.9)	(0.9)	(0.1)
	20		10,0	9,95		29.0	22.0	3.9	12.0	12.8	14.6	30.6	59.7	9.7	0.1
Malawi	00	13,220	08	2	7,316	(0.1)	(0.1)	(0.04)	(0.6)	(0.7)	(1.2)	(0.9)	(0.8)	(0.7)	(0.0)
	19		2,26	2,26		29.6	21.6	4.6	9.3	10.0	11.2	53.0	43.6	3.2	0.2
Malawi	92	4,849	9	6	2,100	(0.2)	(0.1)	(0.07)	(0.7)	(0.9)	(0.7)	(1.6)	(1.5)	(0.4)	(0.1)
	20		10,7	10,7		30.0	22.2	4.4	17.4	18.9	31.5	82.3	10.4	6.9	0.4
Mali	06	14,583	26	22	8,476	(0.1)	(0.1)	(0.05)	(0.6)	(0.8)	(1.9)	(0.8)	(0.6)	(0.5)	(0.1)
	20		9,29	9,27		30.2	22.0	4.6	15.0	16.2	27.3	82.1	10.8	6.4	0.8
Mali	01	12,849	2	2	7,396	(0.1)	(0.1)	(0.06)	(0.7)	(0.8)	(1.4)	(0.9)	(0.6)	(0.5)	(0.3)
	19		4,13	4,11		29.0	21.1	4.8	8.9	9.0	26.3	84.5	10.8	4.5	0.2
Mali	95	9,704	8	4	3,970	(0.1)	(0.1)	(0.05)	(0.6)	(0.7)	(1.2)	(0.9)	(0.7)	(0.5)	(0.1)

	20		13,9	13,9		30.9	24.7	2.7	40.6	42.3	53.5	59.0	18.8	18.2	4.0
Morocco	03	16,798	44	43	6,555	(0.1)	(0.1)	(0.04)	(0.8)	(0.8)	(1.1)	(1.0)	(0.6)	(0.7)	(0.3)
	19		2,89	2,86		31.7	24.1	4.5	32.7	32.8	38.6	79.2	11.2	8.2	1.5
Morocco	92	9,256	7	3	2,795	(0.2)	(0.1)	(0.08)	(1.3)	(1.3)	(1.6)	(1.1)	(0.7)	(0.6)	(0.3)
Mozambiqu	20		9,24	9,24		29.5	22.2	3.8	13.9	15.5	34.1	43.7	49.7	6.4	0.2
e	03	12,418	1	0	6,736	(0.1)	(0.1)	(0.04)	(0.6)	(0.7)	(1.3)	(1.3)	(1.0)	(0.6)	(0.1)
Mozambiqu	19		3,13	3,13		27.7	21.5	3.8	9.1	10.3	20.4	41.2	54.8	4.0	0.0
e	97	8,779	2	1	3,012	(0.2)	(0.2)	(0.08)	(1.1)	(1.3)	(2.8)	(2.8)	(2.6)	(1.3)	(0.0)
	20		7,70	7,69		29.8	23.4	2.5	29.3	32.5	42.9	9.2	27.0	58.7	5.1
Namibia	06	9,804	2	5	4,841	(0.1)	(0.1)	(0.04)	(1.0)	(1.1)	(1.4)	(0.6)	(0.8)	(0.9)	(0.6)
	19		2,29	2,21		29.6	22.5	3.7	20.9	22.2	34.6	17.5	47.2	33.4	1.9
Namibia	92	5,421	6	9	2,029	(0.2)	(0.1)	(0.06)	(1.1)	(1.2)	(1.9)	(1.3)	(1.5)	(1.4)	(0.4)
	20		8,67	8,67		29.6	20.4	3.1	7.1	7.8	13.8	60.4	16.7	19.7	3.1
Nepal	06	10,793	7	7	5,003	(0.2)	(0.1)	(0.05)	(0.7)	(0.7)	(1.1)	(1.8)	(1.0)	(1.1)	(0.4)
	20		7,64	7,64		30.2	20.2	3.6	4.7	5.0	7.7	73.9	14.0	11.1	1.1
Nepal	01	8,726	6	4	5,052	(0.1)	(0.1)	(0.06)	(0.5)	(0.6)	(1.3)	(1.5)	(0.7)	(0.9)	(0.2)

	19		3,33	3,33		27.4	19.8	3.6	1.6	1.7	6.5	80.0	10.7	8.1	1.2
Nepal	96	8,429	3	3	3,187	(0.2)	(0.1)	(0.06)	(0.2)	(0.4)	(1.2)	(1.4)	(0.7)	(0.9)	(0.2)
	20		10,1	10,1		29.4	25.8	3.2	50.0	54.3	59.1	17.7	41.7	31.8	8.8
Nicaragua	01	13,060	95	91	6,278	(0.1)	(0.1)	(0.04)	(0.9)	(0.9)	(1.2)	(0.7)	(0.9)	(0.9)	(0.5)
	19		10,3	10,3		29.5	25.0	3.4	42.9	47.0	60.8	18.8	42.2	33.8	5.2
Nicaragua	97	13,634	41	22	6,887	(0.1)	(0.1)	(0.04)	(0.7)	(0.8)	(1.1)	(0.6)	(0.8)	(0.9)	(0.4)
	20		3,40	3,40		30.0	21.6	4.6	13.9	14.9	18.2	85.1	9.7	4.8	0.4
Niger	06	9,223	3	3	2,909	(0.2)	(0.1)	(0.07)	(0.8)	(0.9)	(1.1)	(0.9)	(0.7)	(0.5)	(0.1)
	19		3,26	3,25		28.3	20.8	4.9	7.9	8.3	17.0	87.7	8.7	3.5	0.1
Niger	98	7,577	1	7	3,173	(0.1)	(0.1)	(0.06)	(0.6)	(0.7)	(1.1)	(0.7)	(0.6)	(0.4)	(0.1)
	19		3,20	3,20		28.5	20.8	4.9	8.0	9.3	16.0	90.7	7.2	2.0	0.1
Niger	92	6,503	7	4	3,065	(0.1)	(0.1)	(0.07)	(0.5)	(0.7)	(0.8)	(0.8)	(0.6)	(0.2)	(0.0)
	20		5,66	5,66		29.3	22.5	4.0	20.6	21.9	32.3	46.7	22.3	26.5	4.5
Nigeria	03	7,620	5	4	3,727	(0.2)	(0.2)	(0.08)	(1.5)	(1.4)	(1.8)	(1.9)	(1.0)	(1.4)	(0.6)
	19		2,42	2,11		28.4	22.8	4.0	22.8	22.5	26.8	48.9	24.9	23.0	3.2
Nigeria	99	9,810	1	2	2,038	(0.2)	(0.1)	(0.07)	(1.2)	(1.4)	(2.0)	(1.9)	(1.3)	(1.3)	(0.5)

	20		22,0	2207	12,15	30.3	25.6	2.9	48.9	51.4	63.9	6.7	33.6	40.5	19.3
Peru	00	27,843	78	6	5	(0.1)	(0.1)	(0.03)	(0.6)	(0.7)	(0.7)	(0.3)	(0.7)	(0.7)	(0.7)
	19		10,6	10,6	10,29	29.8	25.1	3.4	45.4	47.2	64.4	8.4	37.1	37.8	16.7
Peru	96	28,951	22	16	1	(0.1)	(0.1)	(0.03)	(0.7)	(0.8)	(0.9)	(0.4)	(0.8)	(0.7)	(0.6)
	19		5,16	5,11		29.7	24.8	3.6	40.4	42.1	65.1	9.5	37.3	37.2	16.0
Peru	92	15,882	6	4	4,986	(0.1)	(0.1)	(0.05)	(0.8)	(1.0)	(1.4)	(0.6)	(0.9)	(0.9)	(0.7)
	20		4,38	4,38		30.6	22.1	3.7	12.0	11.8	16.4	25.6	64.1	9.8	0.4
Rwanda	05	11,321	1	1	2,918	(0.2)	(0.1)	(0.05)	(0.7)	(0.7)	(0.8)	(1.0)	(1.1)	(0.6)	(0.1)
	20		7,70	7,58		30.5	22.3	3.7	13.7	13.5	17.7	32.9	55.8	10.9	0.3
Rwanda	00	10,421	9	4	5,092	(0.1)	(0.1)	(0.05)	(0.6)	(0.6)	(0.9)	(0.9)	(0.9)	(0.7)	(0.1)
	20		3,51	3,45		30.1	22.7	3.3	24.3	27.3	46.3	62.5	24.0	12.3	1.1
Senegal	05	14,602	3	2	2,914	(0.2)	(0.1)	(0.10)	(1.2)	(1.3)	(3.6)	(2.4)	(1.8)	(1.3)	(0.4)
	19		2,90	2,86		29.8	21.9	4.6	16.2	17.6	35.1	80.2	13.7	5.8	0.2
Senegal	92	6,310	2	8	2,804	(0.1)	(0.1)	(0.06)	(0.8)	(0.9)	(1.4)	(1.0)	(0.8)	(0.5)	(0.1)
	20		7,85	7,85		29.3	22.4	3.6	17.2	18.2	25.2	24.9	68.0	5.6	1.5
Tanzania	04	10,329	4	4	5,776	(0.1)	(0.1)	(0.05)	(0.7)	(0.8)	(1.4)	(1.5)	(1.3)	(0.4)	(0.3)
Tanzania	19	8,120	3,79	3,76	3,597	29.1	22.0	4.1	13.3	13.3	20.1	29.4	66.6	3.8	0.1

	96		8	2		(0.1)	(0.1)	(0.05)	(0.7)	(0.7)	(1.3)	(0.9)	(0.9)	(0.4)	(0.1)
	19		4,38	4,36		28.8	21.7	4.2	11.0	11.5	22.0	34.3	62.7	2.8	0.3
Tanzania	92	9,238	3	8	4,128	(0.1)	(0.1)	(0.05)	(0.6)	(0.7)	(3.7)	(1.5)	(1.4)	(0.3)	(0.2)
	20		3,01	3,01		28.7	26.5	2.7	57.1	61.5	69.3	16.8	55.4	22.4	5.5
Turkey	03	8,075	5	4	2,897	(0.1)	(0.1)	(0.05)	(1.3)	(1.5)	(1.1)	(1.2)	(1.4)	(1.1)	(0.5)
	19		2,30	2,30		28.3	26.0	2.8	52.3	56.7	67.0	18.6	58.0	18.8	4.6
Turkey	98	8,576	5	5	2,148	(0.1)	(0.1)	(0.06)	(1.3)	(1.8)	(2.1)	(1.1)	(1.3)	(1.0)	(0.7)
	19		2,40	2,39		28.0	25.8	3.0	50.4	51.6	63.8	26.6	55.0	15.4	3.1
Turkey	93	6,519	2	6	2,222	(0.2)	(0.1)	(0.07)	(1.2)	(2.2)	(1.4)	(1.5)	(1.5)	(0.9)	(0.4)
	20		2,11	2,11		29.8	22.2	4.5	16.4	17.2	14.7	22.1	59.1	15.0	3.7
Uganda	06	8,531	7	7	1,616	(0.2)	(0.1)	(0.08)	(1.2)	(1.3)	(1.9)	(1.5)	(1.7)	(1.3)	(0.6)
	20		4,99	4,98		29.2	21.9	4.3	13.2	13.7	13.2	24.6	59.6	13.3	2.5
Uganda	00	7,246	0	2	3,713	(0.1)	(0.1)	(0.05)	(0.8)	(0.8)	(0.8)	(1.1)	(1.2)	(0.9)	(0.3)
	19		3,14	3,11		27.7	21.5	4.3	8.6	9.4	11.8	32.1	57.3	10.5	0.1
Uganda	95	7,070	5	1	2,968	(0.2)	(0.1)	(0.06)	(0.7)	(0.9)	(0.9)	(1.7)	(1.4)	(0.8)	(0.1)
	20		5,36	5,36		29.4	22.5	3.8	18.8	21.1	37.3	12.3	57.4	26.6	3.6
Zambia	07	7,146	5	4	3,981	(0.1)	(0.1)	(0.05)	(0.7)	(0.8)	(1.3)	(0.7)	(1.2)	(1.0)	(0.6)

	20		5,80	5,80		28.9	21.6	3.8	12.1	14.2	39.1	12.8	58.8	25.7	2.7
Zambia	01	7,658	0	0	4,470	(0.1)	(0.1)	(0.05)	(0.7)	(0.8)	(1.2)	(0.7)	(1.0)	(1.0)	(0.4)
	19		3,80	3,78		28.4	21.9	4.2	13.1	14.8	41.3	13.8	61.9	22.2	2.2
Zambia	96	8,021	6	7	3,558	(0.2)	(0.1)	(0.06)	(0.6)	(0.9)	(1.2)	(1.0)	(1.2)	(1.0)	(0.4)
	19		3,19	3,17		28.4	21.8	4.3	14.1	16.1	48.1	17.3	61.0	19.8	1.9
Zambia	92	7,060	6	4	2,976	(0.1)	(0.1)	(0.06)	(0.8)	(1.0)	(1.5)	(1.2)	(1.2)	(0.9)	(0.3)
	20		7,00	6,98		28.7	23.1	2.7	25.0	28.4	34.6	5.1	34.2	58.3	2.4
Zimbabwe	05	8,907	0	7	4,698	(0.1)	(0.1)	(0.05)	(1.1)	(1.2)	(1.8)	(0.5)	(1.5)	(1.7)	(0.3)
	19		4,32	4,32		28.7	23.6	2.9	27.4	31.9	35.7	6.8	42.5	48.0	2.6
Zimbabwe	99	5,907	4	3	2,911	(0.2)	(0.1)	(0.06)	(1.0)	(1.2)	(1.5)	(0.6)	(1.3)	(1.2)	(0.5)
	19		1,93	1,92		27.9	23.1	3.6	23.0	26.4	25.3	12.6	49.4	36.6	1.4
Zimbabwe	94	6,128	3	6	1,779	(0.2)	(0.1)	(0.07)	(1.1)	(1.9)	(1.1)	(1.1)	(1.3)	(1.4)	(0.4)

†Eligible sample: Women who were nonpregnant, 18-50 years old and had anthropometrics measured.

††Full Sample: Women in eligible sample who had information on all covariates.

+Restricted Sample: Women in eligible sample who has information on all covariates and had a child under 5 years old.

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